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Financial crises and macro-prudential policies

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ABSTRACT

In this paper we study a two-sector production small open economy subject to a collateral constraint in which a financial crisis can arise endogenously and alternate with normal time periods. In this class of models, the scope for policy intervention arises because individual agents do not internalize the effects of their action on a key market price that enters the collateral constraint (i.e. there is a pecuniary externality). Our main result is that the interaction between agents' behavior in crisis and normal times is crucial for the normative implications of this class of models. In contrast to the related literature, we find that in our model economy the social planner borrows more than private agents in normal times (i.e., the economy displays "underborrowing" rather than "overborrowing" in normal times) and yet has a lower probability to enter a financial crisis. While our findings call for both ex-ante and ex-post policy interventions relative to the crisis event, our analysis shows that welfare gains of ex-post policies are much larger than those of ex-ante policies. As a result, adopting only ex ante interventions such as macro-prudential policies or capital controls may be costly in welfare terms. For example, a small macro-prudential tax on debt that lowers the probability of a crisis to zero is welfare-reducing in our model because it also lowers average consumption.

1. Introduction

The long series of financial crises in emerging market economies since the mid-1990s stirred a heated debate on ex post intervention policies that aim at minimizing the cost of a financial crisis when it occurs. The recent sequence of financial crises in advanced economies and the ensuing "great" recession of 2007–2009 have now shifted the focus of the debate toward ex ante prevention policies (the so called macro-prudential policies) that aim at preventing the occurrence of these episodes.

In a series of recent papers, several researchers[1] have advocated the adoption of macro-prudential policies in the form of tax on foreign debt or economy-wide capital controls, relying on the argument that excessive borrowing (i.e., overborrowing) during normal, non-crisis times, exposes the economy to the risk of a sharp reversal in credit flows or a financial crisis. Their analysis is based on a common theoretical framework proposed and extensively investigated by Mendoza (2002, 2010). The main feature of this macroeconomic environment is the presence of an occasionally binding collateral constraint. A desirable feature of this framework is that crisis events (when market access is curtailed) are endogenous and are identified with the situation in which the constraint binds.

In these models the scope for policy intervention follows from a price externality (or pecuniary or credit externality) that arises because agents do not internalize the effect of their individual decisions on a key market price entering the specification of the financial friction—see Arnott et al. (1994) for a discussion. Because of this externality, it has been shown that there is the potential for inefficient borrowing decisions to occur (e.g., Kehoe and Levine, 1993; Fernández-Arias and Lombardo, 1998; Uribe, 2007; Lorenzoni, 2008; Benigno et al., 2009; Korinek, 2010). This potential inefficiency is measured and quantified by comparing the amount that individual agents borrow in the competitive equilibrium (CE) of the economy with the amount that a social planner would choose in an economy subject to the same occasionally binding credit constraint (SP). The difference is that the social planner internalizes the general-equilibrium effects of its borrowing decisions.

The key insight of our analysis is that the behavior of the economy during normal times depends crucially on how the economy is expected to behave during crisis times: thus, ex-ante policies (policy in normal times) depend on ex-post policies (how policy can act in crisis times).[2]

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[1] Bianchi (2011), Bianchi and Mendoza (2010), and Jeanne and Korinek (2011).

[2] Benigno et al. (2009, 2012a) study optimal ex ante and ex post policies under discretion in a similar model environment. Thus, they study how policy affects private sector behavior and vice-versa in this model environment.

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In our framework, a policy that lowers the cost of the crisis not only helps to mitigate its severity, but it also reduces the social value of precautionary saving in tranquil times. Indeed in our economy atomistic agents that do not take into account the general equilibrium implications of their actions, might borrow less than socially efficient rather than more as previously suggested in the literature (i.e. our model economy displays *underborrowing* rather than *overborrowing*).

This insight turns out to be crucial for the normative implications that this class of models delivers. First, differently from related works, we show that there is a clear scope for *both* ex-ante and ex-post policies. Second, in our model, we find that social planner borrows more than in the competitive equilibrium and yet faces a lower probability of a crisis. Third, we find that the welfare gains of ex-post policies are much larger than those from ex-ante ones. This suggests that ex post policies are likely more important than ex ante policies. Last, we show that imposing only macro prudential policies can be welfare reducing in our model. More generally we show that there is a tradeoff between the volatility and the level of consumption in our model. For instance, we show that imposing a small tax on debt in tranquil times could be welfare-reducing: despite driving the crisis probability to zero, this policy is costly in welfare terms because it reduces the average level of consumption.

The key to interpret our results is in the interaction between agents' intertemporal choices and the possibility of allocating resources efficiently in crisis states. Since current saving decisions are affected by expectations about future events, this interaction is critical in normal times when the constraint is not binding but might bind in the future. Indeed, the current marginal value of saving is affected by two forces: the future marginal value of savings and the severity of future crises. The first one is present in endowment and production economies alike: by taking into account the future effect of the pecuniary externality, the social planner values current saving more than private agents and tends to borrow less than them (i.e., because of this effect, the CE tends to display overborrowing relative to the SP allocation). Intuitively, by increasing saving and reducing borrowing the planner reduces the probability of hitting the constraint in the future, other things being equal. The second force is present only in our production economy since it arises from the planner's ability to manipulate the allocation of productive resources across sectors in crisis states: when the constraint binds, the planner allocates resources across sectors so as to increase the key market price that enters the borrowing constraint to relax it. This effect tends to decrease the social value of current savings compared to the private one. Intuitively, a better crisis management makes the crisis less severe and reduces the need to avoid it. The second component is absent in endowment economies since without production there is no possibility of changing the sector allocation of productive resources during a financial crisis. As a result endowment economies imply that crises are efficient events that cannot be ameliorated by policy.

Our welfare analysis also shows the importance of focusing on the effects of this pecuniary externality in production economies. Given an overall welfare gain of moving from the CE to the SP allocation of about 0.12% of permanent consumption, we find that these gains are 25% higher (or 0.15% of permanent consumption), in crisis states that are realized infrequently. Thus, our welfare analysis suggests that intervening in crisis times is more important than intervening in normal times.

The model that we use in this paper is standard, except for the occasionally binding credit constraint. We consider a two-sector (tradable and non-tradable goods) small open economy in which financial markets are not only incomplete but also imperfect, like in Mendoza (2002). The asset menu is restricted to a one-period risk-free bond paying off the exogenously given foreign interest rate. In addition to asset market incompleteness, access to foreign financing is constrained to a fraction of households' total income. Thus, the key market price that enters the specification of the borrowing constraint is the relative price of non-tradable goods.

We differ from similar models in the related literature discussed above mainly in that we use of a production economy. Bianchi (2011) uses an endowment version of our model. He finds that individual agents in the CE borrow more than in the SP (i.e., they overborrow) and advocates the use of a tax on foreign debt or economy-wide capital controls as a way to restore efficiency. Jeanne and Korinek (2011) and Bianchi and Mendoza (2010) analyze models in which the price externality arises because agents fail to internalize the effect of their decisions on an asset price rather than the relative price of non-tradable goods like in our model.[3] Their analysis and policy conclusions are similar to those of Bianchi (2011). All these models are such that ex post interventions policies such as bailouts or any lending of last resort have no significant scope. This is because, by assumption, when the constraint binds, the CE and SP allocations either coincide exactly or do not differ much quantitatively.[4]

The rest of the paper is organized as follows. Section 2 describes the two-sector production model we use and explains the working of the credit externality in this set-up. Section 3 discusses its solution, parametrization and performance. Section 4 compares the CE and the SP equilibria of the baseline model economy we study, discusses the robustness of the main findings of the numerical analysis, and quantifies the welfare gains or costs of debt taxes in this model set-up. Section 5 concludes.

2. Model

The model that we use is a relatively simple, two-sector (tradable and non-tradable) small open economy, in which financial markets are not only incomplete but also imperfect as in Mendoza (2010) and Bianchi (2011), and in which production occurs in both sectors like in Benigno et al. (2009).

2.1. Households

There is a continuum of households $j \in [0,1]$ that maximize the utility function

$$U^j \equiv E_0 \sum_{t=0}^{\infty} \left\{ \beta^t \frac{1}{1-\rho} \left(C_{j,t} - \frac{H_{j,t}^{\delta}}{\delta} \right)^{1-\rho} \right\}, \tag{1}$$

with C_j denoting the individual consumption basket and H_j the individual supply of labor for the tradable and non-tradable sectors ($H_j = H_j^T + H_j^N$). The assumption of perfect substitutability between labor services in the two sectors ensures that there is a unique labor market. For simplicity we omit the j subscript for the remainder of this section, but it is understood that all choices are made at the individual level. The elasticity of labor supply is δ, while ρ is the coefficient of relative risk aversion. In Eq. (1), the preference specification follows from Greenwood et al. (1988).[5]

The consumption basket, C_t, is a composite of tradable and non-tradable goods:

$$C_t \equiv \left[\omega^{\frac{1}{\kappa}} \left(C_t^T \right)^{\frac{\kappa-1}{\kappa}} + (1-\omega)^{\frac{1}{\kappa}} \left(C_t^N \right)^{\frac{\kappa-1}{\kappa}} \right]^{\frac{\kappa}{\kappa-1}}. \tag{2}$$

[3] While Jeanne and Korinek (2011) consider an endowment economy, Bianchi and Mendoza (2010) analyze a production economy. In order to close the gap between the competitive allocation and the social planner's they assume that asset prices coincide in the two allocations.

[4] See Benigno et al. (2011) for a more detailed discussion of the related literature and a quantitative comparison between production and endowment economies. Benigno et al. (2012b) study the interaction between the pecuniary externality and a nominal rigidity in a model with both monetary and macroprudential policies.

[5] In the context of a one-good economy this specification eliminates the wealth effect from the labor supply choice. Here we emphasize that in a multi-good economy, the sectoral allocation of consumption will affect the labor supply decision through relative prices.

The parameter κ is the elasticity of intratemporal substitution between consumption of tradable and nontradable goods, while ω is the relative weight of tradable goods in the consumption basket. We normalize the price of tradable goods to 1. The relative price of the nontradable goods is denoted by P^N. The aggregate price index is then given by

$$P_t = \left[\omega + (1-\omega)\left(P_t^N\right)^{1-\kappa}\right]^{\frac{1}{1-\kappa}},$$

where we note that there is a one-to-one link between the aggregate price index P and the relative price P^N.

Households maximize utility subject to their budget constraint, which is expressed in units of tradable consumption. The constraint each household faces is:

$$C_t^T + P_t^N C_t^N = \pi_t + W_t H_t - B_{t+1} + (1+i)B_t, \tag{3}$$

where W_t is the wage in units of tradable goods, B_{t+1} denotes the net foreign asset position at the end of period t with gross real return $1+i$. Households receive profits, π_t, from owning the representative firm. Their labor income is given by $W_t H_t$.

International financial markets are incomplete, and access to them is imperfect as well. The asset menu includes only a one-period bond denominated in units of tradable consumption. In addition, we assume that the amount that each individual can borrow internationally is limited by a fraction of his current *total* income:

$$B_{t+1} \geq -\frac{1-\phi}{\phi}[\pi_t + W_t H_t]. \tag{4}$$

Note here first that the value of the collateral is endogenous in this model and it depends on the current realization of profit and wage income. The crisis event therefore is endogenous and can be identified with the situation in which the constraint binds in the model. Second, this constraint captures a balance sheet effect (e.g., Krugman, 1999; Aghion et al., 2004) since foreign borrowing is denominated in units of tradables while the income that can be pledged as collateral is generated also in the non-tradable sector.

Like in the related literature, we do not explicitly derive the credit constraint as the outcome of an optimal contract between lenders and borrowers. However, we can interpret the constraint above as the outcome of an interaction between lenders and borrowers in which lenders are not willing to permit borrowing beyond a certain limit. This limit depends on the parameter ϕ that measures the tightness of the borrowing constraint and on current income that could be used as a proxy of future income. Note also that, as emphasized by Arellano and Mendoza (2003), this borrowing constraint shares some features, namely the endogeneity of the risk premium, that would be the outcome of the interaction between a risk-averse borrower and a risk-neutral lender in a contracting framework as in Eaton and Gersovitz (1981).[6] At the empirical level, the specification in terms of current income is consistent with evidence on the determinants of access to credit markets (e.g., Jappelli, 1990) and lending criteria and guidelines used in mortgage and consumer financing.

Households maximize Eq. (1) subject to Eqs. (3) and (4) by choosing C_t^N, C_t^T, B_{t+1}, and H_t. The first-order conditions of this problem are the following:

$$C_T : \left(C_{j,t} - \frac{H_{j,t}^{\delta}}{\delta}\right)^{-\rho} \omega^{\frac{1}{\kappa}}\left(C_t^T\right)^{-\frac{1}{\kappa}} C^{\frac{1}{\kappa}} = \mu_t \tag{5}$$

$$C_N : \left(C_{j,t} - \frac{H_{j,t}^{\delta}}{\delta}\right)^{-\rho} (1-\omega)^{\frac{1}{\kappa}}\left(C_t^N\right)^{-\frac{1}{\kappa}} C^{\frac{1}{\kappa}} = \mu_t P_t^N \tag{6}$$

$$B_{t+1} : \mu_t = \lambda_t + \beta(1+i)E_t[\mu_{t+1}], \tag{7}$$

and

$$H_t : \left(C_{j,t} - \frac{H_{j,t}^{\delta}}{\delta}\right)^{-\rho}\left(H_{j,t}^{\delta-1}\right) = \mu_t W_t + \frac{1-\phi}{\phi} W_t \lambda_t. \tag{8}$$

where μ_t is the multiplier on the period budget constraint and λ_t is the multiplier on the international borrowing constraint. When the credit constraint is binding, the Euler Eq. (7) includes a term ($\lambda_t > 0$) that can be interpreted as a country-specific risk premium on external financing and distorts intertemporal households decisions. Note here that this term can distort households decisions at time t even if the constraint is not binding at time t but there is a positive probability that it binds in period $t+1$. This intertemporal link is embedded in the term $E_t[\mu_{t+1}]$. As a result, the Euler equation implies that current consumption of tradable goods would be lower compared to an economy in which access to foreign borrowing is unconstrained (i.e., precautionary saving would be stronger than in economy without the borrowing constraint).

Looking at the other household first order conditions, we can combine Eqs. (5) and (6) to obtain the intratemporal allocation of consumption, and Eq. (5) with Eq. (8) to obtain the labor supply schedule, respectively:

$$P_t^N = \frac{(1-\omega)^{\frac{1}{\kappa}}\left(C_t^N\right)^{-\frac{1}{\kappa}}}{\omega^{\frac{1}{\kappa}}\left(C_t^T\right)^{-\frac{1}{\kappa}}} \tag{9}$$

$$\left(H_{j,t}^{\delta-1}\right) = \left(\frac{\omega C}{C^T}\right)^{\frac{1}{\kappa}} W_t\left(1 + \frac{1-\phi}{\phi}\frac{\lambda_t}{\mu_t}\right), \tag{10}$$

where

$$\left(\frac{\omega C}{C^T}\right)^{\frac{1}{\kappa}} = (\omega)^{\frac{1}{\kappa-1}}\left(1 + \left(\frac{1-\omega}{\omega}\right)\left(P_t^N\right)^{1-\kappa}\right)^{\frac{1}{\kappa-1}}.$$

When the constraint is binding ($\lambda_t > 0$), the marginal utility of supplying one extra unit of labor is higher, and this helps to relax the constraint: when $\lambda_t > 0$, the labor supply becomes steeper and agents substitute leisure with labor for given wages and prices.

Importantly, like the intertemporal consumption decision, the labor supply is also affected by the possibility that the constraint may be binding in the future. If in period t the constraint is not binding but there is a positive probability that it binds in period $t+1$, we can rewrite Eqs. (7) and (8) as

$$\left(C_{j,t} - \frac{H_{j,t}^{\delta}}{\delta}\right)^{-\rho}\left(H_{j,t}^{\delta-1}\right) = \mu_t W_t,$$

$$\mu_t = \beta(1+i)E_t\left[\lambda_{t+1} + \beta(1+i)E_t[\mu_{t+2}]\right].$$

This shows that the marginal benefit of supplying one extra unit of labor today is higher, the higher is the probability that the constraint will be binding in the future, other things being equal. This effect will induce agents to supply more labor for any given wage, and the labor supply curve to be steeper relative to the case in which there is no credit constraint in the model.

Finally, from Eq. (9), we have that P_t^N will tend to be lower compared to an economy without constraint since the consumption of tradable goods is lower both when the constraint is binding and when is not.

[6] As we discuss in Benigno et al. (2009), a constraint expressed in terms of future income, which could be the outcome of the interaction between lenders and borrowers in a limited commitment environment, would introduce further computational difficulties that we avoid for computational tractability since future consumption choices affect current borrowing decisions.

2.2. Firms

Firms produce tradable and non-tradable goods with a variable labor input and the following decreasing return to scale technologies:

$$Y_t^N = A_t^N H_t^{1-\alpha^N},$$
$$Y_t^T = A_t^T H_t^{1-\alpha^T},$$

where A^N and A^T are the productivity levels, which are assumed to be random variables, in the non-tradable and tradable sectors, respectively. The firm's problem is static and current-period profits (π_t) are:

$$\pi_t = A_t^T \left(H_t^T\right)^{1-\alpha^T} + P_t^N A_t^N \left(H_t^N\right)^{1-\alpha^N} - W_t H_t.$$

The first-order conditions for labor demand in the two sectors are given by:

$$W_t = \left(1-\alpha^N\right) P_t^N A_t^N \left(H_t^N\right)^{-\alpha^N}, \tag{11}$$

$$W_t = \left(1-\alpha^T\right) A_t^T \left(H_t^T\right)^{-\alpha^T}, \tag{12}$$

so that the value of the marginal product of labor equals the wage in units of tradable goods (W_t). By taking the ratio of Eq. (11) over Eq. (12) we obtain:

$$P_t^N = \frac{\left(1-\alpha^T\right) A_t^T \left(H_t^T\right)^{-\alpha^T}}{(1-\alpha^N) A_t^N (H_t^N)^{-\alpha^N}}, \tag{13}$$

from which we note that the relative price of non-tradable goods determines the allocation of labor between the two sectors. For given productivity levels, a fall in P_t^N drives down the marginal product of non-tradables and induces a shift of labor toward the tradable sector.

2.3. Competitive equilibrium

2.3.1. Goods market

To determine the goods market equilibrium, combine the household budget constraint and the firm's profits with the equilibrium condition in the nontradable good market to obtain the current account equation of our small open economy:

$$C_t^T = A_t^T H_t^{1-\alpha^T} - B_{t+1} + (1+i) B_t. \tag{14}$$

The nontradable goods market equilibrium condition implies that

$$C_t^N = Y_t^N = A_t^N \left(H_t^N\right)^{1-\alpha^N}. \tag{15}$$

Finally, using the definitions of firm profits and wages, the credit constraint implies that the amount that the country, as a whole, can borrow is constrained by a fraction of the value of its GDP:

$$B_{t+1} \geq -\frac{1-\phi}{\phi}\left[Y_t^T + P_t^N Y_t^N\right], \tag{16}$$

so that Eqs. (14) and (16) determines the evolution of the foreign borrowing.

2.3.2. Labor market equilibrium and borrowing decisions

The distinguishing and novel feature of our two-sector production economy is an interaction between production, labor and borrowing decisions. This interaction can generate, in equilibrium, stronger precautionary saving than in an endowment economy with the same specification of the household problem. In turn, as we shall see below, this generates the possibility of underborrowing relative to a social planner allocation as opposed to the overborrowing typically found in the related literature.

To analyze this interaction, we can characterize the labor market equilibrium and the sector labor allocation in terms of the following three equilibrium conditions:

$$\left(H_t^{\delta-1}\right) = (\omega)^{\frac{1}{\kappa-1}}\left(1+\left(\frac{1-\omega}{\omega}\right)\left(P_t^N\right)^{1-\kappa}\right)^{\frac{1}{\kappa-1}}\left(1-\alpha^T\right)A_t^T\left(H_t^T\right)^{-\alpha^T}\left(1+\frac{1-\phi}{\phi}\frac{\lambda_t}{\mu_t}\right), \tag{17}$$

$$P_t^N = \frac{\left(1-\alpha^T\right) A_t^T \left(H_t^T\right)^{-\alpha^T}}{(1-\alpha^N) A_t^N (H_t^N)^{-\alpha^N}}, \tag{18}$$

$$P_t^N = \frac{(1-\omega)^{\frac{1}{\kappa}}\left(A_t^N\left(H_t^N\right)^{1-\alpha^N}\right)^{-\frac{1}{\kappa}}}{\omega^{\frac{1}{\kappa}}\left(C_t^T\right)^{-\frac{1}{\kappa}}}, \tag{19}$$

with $H = H^T + H^N$. The first equation is the labor supply schedule with W_t determined by Eq. (12)—note here that the wage falls when tradable labor input increases. The second equation determines the sectoral allocation of labor (the marginal rate of transformation), while the third equation determines the intratemporal consumption allocation (the marginal rate of substitution). When the constraint is not binding (i.e., $\lambda_t = 0$), the system of Eqs. (17)–(19) determines H_t, P_t^N, H_t^N for given C_t^T,[7] productivity levels in the two sectors (A_t^N and A_t^T), and the possibility that the constraint is binding in the future, λ_t.[8]

As we discussed above, and like in an endowment version of our model (see Bianchi (2011) and Korinek (2010)), in our two-sector production economy, lower C_t^T due to a possibly binding borrowing constraint in the future implies a lower P_t^N. However, for given total labor supply, the initial decline in P_t^N induces a shift of labor toward the tradable sector, and hence a fall in production and consumption of non-tradable goods. If goods are complements, as we assume in our calibration, the ensuing decline in non-tradable consumption induces agents to consume even less tradable goods and to save even more compared to the endowment economy, amplifying the initial precautionary saving effect arising from the possibility that the constraint binds or might bind in the future.

We note here that this interaction between consumption and production decisions that occurs when the constraint is not binding, is robust to alternative specification of the borrowing constraint. In fact for the purpose of our argument what we need is that there is a possibility that the constraint will be binding in the future. Indeed, with $\lambda_t = 0$, the labor market equilibrium conditions (17), (18) and (19) are the same if the constraint is specified in terms of land price or asset price (like Jeanne and Korinek, 2011 do) or if there is a working capital constraint like in the model of Bianchi and Mendoza (2010).

2.4. Social planner problem

We now focus on the social planner's problem. The planner chooses the optimal path of C_t^T, C_t^N, B_{t+1}, H_t^T and H_t^N by maximizing Eq. (1) subject to the resource constraints (14) and (15), the international borrowing constraint from an aggregate perspective (Eq. (16)), and the pricing *rule* of the competitive equilibrium allocation (Eq. (9)). The choice of how to determine prices in the social planner problem is an important aspect of the characterization of the social planner problem. By

[7] We can think about this system of equation in the context of a partial equilibrium model of labor/production decisions for given consumption choices.

[8] In Appendix A we determine the sign of the response to total labor supply, the demand of non-tradable and tradable labors and the relative price of non-tradable for a given change in C^T, possibly induced by the expectation that the constraint might bind in the future.

constraining the social planner problem to the pricing rule of the competitive equilibrium we follow the "constrained efficiency" definition of Kehoe and Levine (1993). An alternative would be to use the concept of "conditional efficiency" of Kehoe and Levine (1993). With conditional efficiency the planner problem is constrained by the competitive equilibrium pricing *function* (i.e., $P_t^N = f(B_t, A_t^N, A_t^T)$), in which P_t^N depends on the state variables of the model like in the competitive equilibrium allocation. With conditional efficiency one imposes that equilibrium prices in the competitive and social planner allocation are identical for a given set of exogenous and endogenous states. As we will discuss below this is particularly important in crisis states as it limits the ability of the social planner to relax the constraint.

Thus, we can rewrite Eq. (16) as:

$$B_{t+1} \geq -\frac{1-\phi}{\phi}\left[A_t^T\left(H_t^T\right)^{1-\alpha^T} + \frac{(1-\omega)^{\frac{1}{\kappa}}}{\omega^{\frac{1}{\kappa}}\left(C_t^T\right)^{-\frac{1}{\kappa}}}\left(A_t^N\left(H_t^N\right)^{1-\alpha^N}\right)^{1-\frac{1}{\kappa}}\right], \tag{20}$$

and the first-order conditions for the planner's problem are given by:

$$\begin{aligned} C_T : &\left(C_{j,t} - \frac{H_{j,t}^\delta}{\delta}\right)^{-\rho}\left(\frac{\omega C}{C^T}\right)^{\frac{1}{\kappa}} = \mu_{1,t}^{SP} + \\ &-\frac{\lambda_t^{SP}}{\kappa}\frac{1-\phi}{\phi}\frac{(1-\omega)}{\omega}\left(\frac{(1-\omega)\left(C_t^T\right)}{\omega}\right)^{\frac{1-\kappa}{\kappa}}\left(A_t^N\left(H_t^N\right)^{1-\alpha^N}\right)^{\frac{\kappa-1}{\kappa}}, \end{aligned} \tag{21}$$

$$C_N : \left(C_{j,t} - \frac{H_{j,t}^\delta}{\delta}\right)^{-\rho}(1-\omega)^{\frac{1}{\kappa}}\left(C_t^N\right)^{-\frac{1}{\kappa}}C^{\frac{1}{\kappa}} = \mu_{2,t}^{SP}, \tag{22}$$

$$B_{t+1} : \mu_{1,t}^{SP} = \lambda_t^{SP} + \beta(1+i)E_t\left[\mu_{1,t+1}^{SP}\right], \tag{23}$$

$$\begin{aligned} H_t^T : \left(C_t - \frac{H_t^\delta}{\delta}\right)^{-\rho}\left(H_t^{\delta-1}\right) &= \left(1-\alpha^T\right)\mu_{1,t}^{SP}A_t^T H_t^{-\alpha^T} \\ &+ \frac{1-\phi}{\phi}\lambda_t^{SP}\left(1-\alpha^T\right)A_t^T H_t^{-\alpha^T}, \end{aligned} \tag{24}$$

and

$$\begin{aligned} H_t^N : \left(C_t - \frac{H_t^\delta}{\delta}\right)^{-\rho}\left(H_t^{\delta-1}\right) &= \left(1-\alpha^N\right)\mu_{2,t}^{SP}A_t\left(H_t^N\right)^{-\alpha^N} \\ &+ \frac{1-\phi}{\phi}\lambda_t^{SP}\frac{(1-\omega)^{\frac{1}{\kappa}}}{\omega^{\frac{1}{\kappa}}\left(C_t^T\right)^{-\frac{1}{\kappa}}}\frac{\kappa-1}{\kappa}\left(1-\alpha^N\right) \\ &\times\left(A_t^N\right)^{\frac{\kappa-1}{\kappa}}\left(H_t^N\right)^{\left(1-\alpha^N\right)\frac{\kappa-1}{\kappa}-1}, \end{aligned} \tag{25}$$

where $\mu_{1,t}^{SP}$ is the Lagrange multiplier on Eq. (14), $\mu_{2,t}^{SP}$ is the Lagrange multiplier on Eq. (15) and λ_t^{SP} is the multiplier on Eq. (20).

We now compare FOCs in the CE and the SP. A first difference arises from the term $\mu_{1,t}^{SP}$ in Eq. (21). This equation shows that, in choosing tradable consumption, the planner takes into account the effects that a change in tradable consumption has on the value of the collateral (see also Korinek, 2010 and Bianchi, 2011). This effect is what is usually referred to as the "pecuniary externality" in the related literature and it occurs when the constraint is binding (i.e., $\lambda_t^{SP} > 0$) or, as we noted above, when the constraint is not binding today but there is the possibility that it might bind in the future via $E_t[\mu_{1,t+1}^{SP}]$ in Eq. (23). The Euler equation from the planner perspective, when the constraint is not binding, becomes

$$\mu_{1,t}^{SP} = \beta(1+i)E_t\left[\lambda_{t+1}^{SP} + \beta(1+i)E_t\left[\mu_{1,t+2}^{SP}\right]\right],$$

where $E_t[\mu_{1,t+2}^{SP}]$ is given by Eq. (21) and takes into account the future effect of the pecuniary externality. This effect tends to increase the marginal social value of saving (in the SP allocation) compared to the private value (in the CE allocation).

A second difference arises from the term λ_{t+1}^{SP} in the Euler Eq. (23) and is related to the fact that the behavior of the economy in crisis states in the SP and the CE allocation differs, and hence λ_{t+1}^{SP} may differ from λ_{t+1}^{CE}. If the social planner can alleviate the crisis compared to what happens in the decentralized equilibrium we will have $\lambda_{t+1}^{SP} < \lambda_{t+1}^{CE}$, and this effect would tend to decrease the marginal social value of saving compared to the private one. Thus, the extent to which the decentralized equilibrium might borrow more or less than the socially planned one (generating overborrowing or underborrowing) depends on the relative strength of these two forces.

In the endowment economy case (Bianchi (2011) and Korinek (2010)) we always have $\lambda_{t+1}^{SP} = \lambda_{t+1}^{CE}$ since the social planner cannot improve upon the competitive equilibrium allocation in the crisis state, so only the first effect is present and the decentralized equilibrium always displays overborrowing. In our two-sector production economy, the planner can relax the constraint by increasing the relative price of non-tradable when the constraint binds compared to the competitive equilibrium allocation so that the impact of the crisis is dampened and $\lambda_{t+1}^{SP} < \lambda_{t+1}^{CE}$. As we discuss below, this is achieved by reallocating labor toward the tradable sector for given total labor supply.

It should be stressed here that the relative strength of these two forces depend on the definition of efficiency adopted, and hence on how P_t^N is set in the social planner allocation. Indeed, using the concept of conditional efficiency limits significantly the ability of the social planner to improve upon the competitive allocation in crisis times, since in this case prices would be the same as in the competitive equilibrium allocation for given states. Thus, using the concept of conditional efficiency as opposed to constrained efficiency as we do would dampen the role of the second channel even in a two-sector production economy like ours.[9]

In our production economy, the presence of the occasionally binding borrowing constraint generates additional mechanisms stemming from interaction of consumption and production decisions that ultimately allow the planner to ameliorate the crisis (i.e., $\lambda_{t+1}^{SP} < \lambda_{t+1}^{CE}$). To see these, rewrite the first-order conditions for the labor allocation in the tradable sector as

$$H_t^T : \left(C_t - \frac{H_t^\delta}{\delta}\right)^{-\rho}\left(H_t^{\delta-1}\right) = \left(1-\alpha^T\right)\mu_{1,t}^{SP}A_t^T H_t^{-\alpha^T}\left(1 + \frac{1-\phi}{\phi}\frac{\lambda_t^{SP}}{\mu_{1,t}^{SP}}\right),$$

[9] Note also that, an additional effect would arise in an economy in which an asset price enters the credit constraint (e.g., when the value of an asset serves as collateral rather than income). In this case, because of the forward-looking nature of asset prices, the planner could also take into account the effect of consumption choices on asset prices through their effects on the stochastic discount factor. This effect might induce a higher tradable consumption in the social planner allocation relative to the competitive allocation that goes in the opposite direction of the price externality one. In the case of an asset price-based constraint, therefore, using the concept of conditional efficiency has even stronger implications for the behavior of the economy in the binding region. Indeed, for given states, conditional efficiency would force the social planner allocation to be close to the competitive equilibrium in crisis times, limiting the ability of the social planner to exploit this additional channel in the crisis state. For instance, Bianchi and Mendoza (2010) consider economies in which the borrowing constraint depends on a key asset price and apply the conditional efficiency social planner concept since, for computational reasons, it is difficult to adopt the concept of constrained efficiency. This limits the ability of the social planner to modify the asset price and, as such, the allocation during crisis times compared to the competitive equilibrium allocation.

and rewrite the non tradable labor supply equation (by using Eq. (22) and the equilibrium condition in the non-tradable good market) as

$$H_t^N: \left(C_t - \frac{H_t^{\delta}}{\delta}\right)^{-\rho}\left(H_t^{\delta-1}\right) = \left(1-\alpha^N\right)\mu_{2,t}^{SP}A_t^N\left(H_t^N\right)^{-\alpha^N}$$
$$\left(1+\frac{1-\phi}{\phi}\frac{\lambda_t^{SP}}{\mu_{2,t}^{SP}}\frac{(1-\omega)^{\frac{1}{\kappa}}}{\omega^{\frac{1}{\kappa}}\left(C_t^T\right)^{-\frac{1}{\kappa}}}\frac{\kappa-1}{\kappa}\left(A_t^N\right)^{-\frac{1}{\kappa}}\left(H_t^N\right)^{-\frac{1}{\kappa}\left(1-\alpha^N\right)}\right).$$

These expressions show that, when the constraint is binding, the social marginal utility of supplying one extra unit of *tradable* labor is always positive, while the social marginal value of supplying one extra unit of *non-tradable* labor depends on the degree of substitutability between tradable and non-tradable goods. When goods are substitutes, the planner always supplies one more unit of non-tradable labor, as that helps to relax the constraint. However, when goods are complements, the planner decreases the amount of non-tradable labor supplied at the margin. By altering the sector labor allocation when the constraint binds the planner also alters the consumption choices between tradable and nontradable, and hence P_t^N and saving decisions. In contrast, in an endowment version of our economy, the planner cannot affect P_t^N, and P_t^N must always fall when the constraint binds. In other words, in our production economy, the planner allocates labor across sectors in such a way that P_t^N is relatively higher than in the competitive allocation, and this alleviates the cost of the crisis (i.e., $\lambda_{t+1}^{SP} < \lambda_{t+1}^{CE}$).

A similar set of effects operates also when the constraint is not binding but there is positive probability that it binds. To see this, we can combine Eqs. (25) and (24) to get:

$$\frac{\mu_{2,t}^{SP}}{\mu_{1,t}^{SP}} = \left(\frac{\left(1-\alpha^T\right)A_t^T H_t^{-\alpha^T}}{(1-\alpha^N)A_t^N\left(H_t^N\right)^{-\alpha^N}}\right) \tag{26}$$

and

$$\left(C_t - \frac{H_t^{\delta}}{\delta}\right)^{-\rho}\left(H_t^{\delta-1}\right) = \left(1-\alpha^T\right)\mu_{1,t}^{SP}A_t^T H_t^{-\alpha^T}. \tag{27}$$

Eq. (27) determines total labor supply while Eq. (26) determines the sector allocation of labor in the planner problem. Note now that Eq. (27) is the same expression as in the competitive equilibrium allocation except for ($\mu_{1,t}^{SP}$ versus $\mu_{1,t}^{CE}$). Thus, for a given wage, the labor supply is higher or lower in the social planner allocation relative to the competitive one depending on the comparison between the current marginal utility of tradable in the two allocations ($\mu_{1,t}^{SP}$ versus $\mu_{1,t}^{CE}$).

Eq. (26) is also similar to the corresponding Eq. (10) that holds in the competitive equilibrium allocation except for $\frac{\mu_{2,t}^{SP}}{\mu_{1,t}^{SP}}$. By allocating more labor in the non-tradable sector than in the competitive equilibrium when the constraint is not binding, the planner can increase $\frac{\mu_{2,t}^{SP}}{\mu_{1,t}^{SP}}$, and hence P_t^N, relative to the competitive equilibrium. This shift will increase the production and the consumption of non-tradable goods. When goods are complements, the increase in the consumption of non-tradables will also imply an increase in tradable consumption, hence a decrease in saving and an increase in borrowing in the SP allocation relative to the CE allocation. For given labor supply, this labor reallocation effect, under complementarity in consumption goods, tends to induce underborrowing in the competitive allocation compared to the social planner one.

To summarize, in our production economy, the possibility that the constraint might be binding in the future generates an intertemporal effect, a labor supply effect and a labor-reallocation effect that combined together determine the extent to which the private saving decisions differ from the social ones. The crucial aspect of our analysis is that the planner can reallocate labor across sectors and manipulate P_t^N in the crisis state, making the crisis less costly. In his borrowing decisions in normal times, the planner takes into account the fact that the crisis is less costly and might be induced to borrow more than private agents in the competitive equilibrium allocation (i.e. the economy could display underborrowing).

3. Model solution, parameters, and performance

In this section we describe the global solution methods that we use to compute the competitive and the social planner equilibrium of the model. We then discuss the parameter values chosen and the model's ability to fit the data for a typical emerging market economy like Mexico.

3.1. Solution methods

The competitive equilibrium problem is given by Eqs. (4), (5), (6), (7), (8), (11), (12), (14) and (15) above. The algorithm for the solution of the competitive equilibrium of the model is derived from Baxter (1991) and Coleman (1991), and it involves iterating on the functional equations that characterize a recursive competitive equilibrium in the states (B, A^T). The key step is the transformation of the complementary slackness conditions on the borrowing constraint into a set of nonlinear equations that can be solved using standard solvers (in particular, a modified Powell's method). The key steps are to replace the Lagrange multiplier, λ_t, with the expression $\max\{\lambda_t^*, 0\}^2$ and to replace the complementary slackness conditions:

$$\lambda_t \ge 0,$$
$$B_{t+1} + \frac{1-\varphi}{\varphi}\left(A_t^T\left(H_t^T\right)^{1-\alpha_T} + P_t^N A\left(H_t^N\right)^{1-\alpha_N}\right) \ge 0,$$
$$\lambda_t\left(B_{t+1} + \frac{1-\varphi}{\varphi}\left(A_t^T\left(H_t^T\right)^{1-\alpha_T} + P_t^N A\left(H_t^N\right)^{1-\alpha_N}\right)\right) = 0,$$

with the single nonlinear equation

$$\max\{-\lambda_t^*, 0\}^2 = B_{t+1} + \frac{1-\varphi}{\varphi}\left(A_t^T\left(H_t^T\right)^{1-\alpha_T} + P_t^N A^N\left(H_t^N\right)^{1-\alpha_N}\right).$$

We then guess a function $\mu_{t+1} = G_\mu(B_t, A_t^T)$ and solve for $\{\lambda_t^*, \mu_t, B_{t+1}, C_t^T, C_t^N, H_t^T, H_t^N, P_t^N\}$ at each value of (B_t, A_t^T). This solution is used to update the G_μ function to convergence. Note that if the constraint binds, $\lambda_t^* > 0$ so that $\max\{-\lambda_t^*, 0\}^2 = 0$.[10]

Given the solution for the equilibrium decision rules, we can compute the equilibrium value of lifetime utility by solving the functional equation

$$V\left(B_t, A_t^T\right) = \frac{1}{1-\rho}\left(\left(\omega^{\frac{1}{\kappa}}\left(C_t^T\right)^{\frac{\kappa-1}{\kappa}} + (1-\omega)^{\frac{1}{\kappa}}\left(C_t^N\right)^{\frac{\kappa-1}{\kappa}}\right)^{\frac{\kappa}{\kappa-1}} - \frac{1}{\delta}\left(H_t^T + H_t^N\right)^{\delta}\right)^{1-\rho} + \beta E\left[V\left(B_{t+1}, A_{t+1}^T\right)\middle|A_t^T\right],$$

which defines a contraction mapping and thus has a unique solution.[11]

[10] Note also that $\lambda_t = \max\{\lambda_t^*, 0\}^2 \ge 0$, $\max\{-\lambda_t^*, 0\}^2 \ge 0$, and $\max\{\lambda_t^*, 0\}^2\max\{-\lambda_t^*, 0\}^2 = 0$ so the complementary slackness conditions are satisfied.

[11] This functional equation gives us lifetime utility only in equilibrium. To obtain lifetime utility outside equilibrium, we would need to solve the household problem separating individual debt b from aggregate debt B.

To solve for the social planning equilibrium we set up a standard dynamic programming problem:

$$V^{SP}\left(B_t, A_t^T\right) = \max_{C_t^T, C_t^N, H_t^T, H_t^N, B_{t+1}} \left\{ \begin{array}{l} \frac{1}{1-\rho}\left(\left(\omega^{\frac{1}{\kappa}}\left(C_t^T\right)^{\frac{\kappa-1}{\kappa}} + (1-\omega)^{\frac{1}{\kappa}}\left(C_t^N\right)^{\frac{\kappa-1}{\kappa}}\right)^{\frac{\kappa}{\kappa-1}} - \right. \\ \left. \frac{1}{\delta}\left(H_t^T + H_t^N\right)^{\delta_{1-\rho}} + \beta E\left[V^{SP}\left(B_{t+1}, A_{t+1}^T\right)\middle|A_t^T\right] \right. \end{array} \right\}$$

subject to resource constraints, the borrowing constraint, and the marginal condition that determines P^N:

$$\begin{aligned} C_t^T &= (1+r)B_t + A_t^T\left(H_t^T\right)^{1-\alpha_T} - B_{t+1} \\ C_t^N &= A^N\left(H_t^N\right)^{1-\alpha_N} \\ B_{t+1} &\geq -\frac{1-\varphi}{\varphi}\left(A_t^T\left(H_t^T\right)^{1-\alpha_T} + P_t^N A^N\left(H_t^N\right)^{1-\alpha_N}\right) \\ P_t^N &= \left(\frac{1-\omega}{\omega}\right)^{\frac{1}{\kappa}}\left(\frac{C_t^N}{C_t^T}\right)^{-\frac{1}{\kappa}}. \end{aligned}$$

We approximate the function V^{SP} using cubic splines and solve the maximization using feasible sequential quadratic programming.

Welfare gains and losses are computed as a percent of tradable consumption.[12] Let $V^{SP}(B_t,A_t^T)$ denote lifetime utility in the social planning allocation. We first solve the dynamic functional equation

$$v\left(B_t, A_t^T;\chi\right) = \frac{1}{1-\rho}\left(\left(\omega^{\frac{1}{\kappa}}\left((1+\chi)C_t^T\right)^{\frac{\kappa-1}{\kappa}} + (1-\omega)^{\frac{1}{\kappa}}\left(C_t^N\right)^{\frac{\kappa-1}{\kappa}}\right)^{\frac{\kappa}{\kappa-1}} - \frac{1}{\delta}(H)^{\delta}\right)^{1-\rho} + \beta E\left[v\left(B_{t+1}, \left(A_{t+1}^T\right), \chi\right)\middle|A_t^T\right]$$

where $v(B_t,A_t^T;\chi)$ is the lifetime utility experienced using the competitive equilibrium decision rules with an extra χ percent of tradable consumption given freely to the representative household. This functional equation defines a contraction mapping, so it has a unique solution. From the solution of this problem, we can compute the solution to the nonlinear equation

$$V\left(B_t, A_t^T\right) = v\left(B_t, A_t^T; \chi\left(B_t, A_t^T\right)\right),$$

which yields the percent increase in tradable consumption that renders the representative agent indifferent between the competitive equilibrium and the social planning allocation state-by-state.

3.2. Parameter values

The model is calibrated at quarterly frequency on Mexican data. There are several reasons to focus on Mexico. First Mexico is an advanced emerging market economy whose experience is particularly relevant for the main issue addressed in the paper. Mexico experienced three major episodes of international capital flow reversals since 1980 that are unambiguously regarded as typical examples of sudden stops in capital flows: the first one leading to the 1982 debt crisis; the second one, the well known "Tequila crisis" in 1994–1995; and the third one in 2008–09 during the global financial crisis that led Mexico to seek (or accept) IMF financial assistance. Second, Mexico is a well functioning, relatively large, market-based economy in which production in both the tradable and non-tradable sectors of the economy goes well beyond the extraction of natural resources such as oil or other commodities. Indeed, Mexico is an OECD economy whose experience is relevant also for the advanced economies struggling with financial crises like those in the euro zone. Third and finally, there is a substantial body of previous quantitative work on Mexico, starting from Mendoza (1991), which greatly facilitates the choice of the parameter values of the model. In particular, we choose model parameters following the work of Mendoza (2002, 2010) and Kehoe and Ruhl (2008) to the extent possible, and use available data where necessary to complement or update their choices. In the rest of this section we discuss the parameter values chosen and the model's ability to fit the data.

The specific set of parameter values that we use in our baseline calibration is reported in Table 1. The elasticity of intertemporal substitution is set to standard value of $\rho=2$, like in Mendoza (2002, 2010). We set then the world interest rate to $i=0.01587$, which yields an annual real rate of interest of about 6.5% like in Mendoza (2002): a value that is between the 5% of Kehoe and Ruhl (2008) and the 8.6% of Mendoza (2010).

The elasticity of intratemporal substitution in consumption between tradables and nontradables is an important parameter in the analysis. But there is a good degree of consensus in the literature on its value. We follow Ostry and Reinhart (1992), who estimates a value of $\kappa=0.760$ for developing countries. This is a conservative assumption compared to the value of 0.5 used by Kehoe and Ruhl (2008) that is closer to the one assumed for an advanced, more closed economy like the United States.

Estimates of the wage elasticity of labor supply in Mexico are uncertain at best (Mendoza, 2002, 2010). We set the value of $\delta=1.75$, close to the value of 1.84 adopted by Mendoza (2010). The labor share of income, $(1-\alpha^T)$ and $(1-\alpha^N)$ is set to 0.66 in both tradable and non tradable sectors: a standard value, close to that used by Mendoza (2002), and consistent with empirical evidence on the aggregate share of labor income in GDP in household survey of García-Verdú (2005).

The shock to tradable total factor productivity specified as

$$\log\left(A_t^T\right) = \rho_A \log\left(A_{t-1}^T\right) + \varepsilon_t,$$

where ε_t is an iid $N(0,\sigma_A^2)$ innovation. The parameters of this process are set to $\rho_A=0.537$ and $\sigma_A=0.0134$ which are the first autocorrelation and the standard deviation of aggregate total factor productivity reported by Mendoza (2010). We will show later that this calibration yields an empirically reasonable amount of consumption volatility. Both the average value of A^T and the constant A^N are set to one.

The remaining three model parameters—the share of tradable consumption in the consumption basket (ω), the credit constraint parameter (ϕ), and the discount factor (β)—are set by iterating on a routine that minimizes the sum of squared differences between the moments in the ergodic distribution of the competitive equilibrium of the model and three data targets. The data targets are a C^N/C^T ratio of 1.643, a 35% debt-to-GDP ratio, and an unconditional probability of capital flow reversal of 2% per quarter. The targeted C^N/C^T ratio is the value implied by the following ratios estimated by Mendoza (2002): $Y^T/Y^N=0.648$, $C^T/Y^T=0.665$, and $C^N/Y^N=0.708$.[13] The debt-to-GDP target is Mexico's average net foreign asset to annual GDP ratio, from 1970 to 2008, in an updated version of the Lane and Milesi-Ferretti (2007) data set.

The target for the unconditional probability of capital flow reversal is more difficult to pin down. Despite a significant body of empirical work on identifying sudden stops in emerging markets to describe the macroeconomic dynamics around these events, there is no consensus in the literature on how to define sudden stops empirically, and hence no accepted measure of the unconditional probability of these events. By focusing on Mexico, we can pin down this target simply and unambiguously, measuring it as the relative frequency of Mexico's sudden stops years over the period 1975–2010. This assumes that, as generally accepted, 1982, 1995, and 2009 were sudden stop years for

[12] The rank among allocations would not change if we express welfare gains and losses as a percentage of overall consumption.

[13] Ratios computed with updated data are essentially the same. As we evaluate the model's ability to replicate the 1995 Tequila crisis we use the exact values reported by Mendoza (2002).

Table 1
Model parameters.

Structural parameters	Values
Elasticity of substitution between tradable and non-tradable goods	$\kappa=0.760$
Intertemporal substitution and risk aversion	$\rho=2$
Labor supply elasticity	$\delta=2$
Credit constraint parameter	$\phi=0.415$
Labor share in production	$1-\alpha^T=1-\alpha^N=0.66$
Relative weight of tradable and non-tradable goods	$\omega=0.3526$
Discount factor	$\beta=0.9717$
Exogenous variables	**Values**
World real interest rate	$i=0.01587$
Steady state productivity level	$A^N=A^T=1$
Productivity process	
Persistence	$\rho_{\varepsilon^T}=0.5370$
Volatility	$\sigma_{\varepsilon^T}=0.0134$
Average values in the ergodic distribution	**Values**
Net foreign assets (or minus foreign borrowing)	$B=-0.914$
Quarterly GDP	$Y=0.6486$
Quarterly tradable GDP	$Y^T=0.2544$
Quarterly non-tradable GDP	$Y^N=0.3942$

Mexico. The resulting 2% on a quarterly basis is very close to the 1.9% implied by the empirical analysis of Jeanne and Rancière (2011) over the period 1975–2003, who use an "absolute" definition of sudden stops as current account reversals larger than 5% of GDP. Our choice is also similar to the 2.2% value implied by Calvo et al. (2008) for the period 1990–2004, based on a "relative" definition of sudden stops as current account reversals larger than two standard deviations. The 2% value, however, is at the low-end of the range of values estimated in these studies by pooling data for the whole sample of emerging markets considered.

In order to contrast Mexico data with model outcomes during sudden stop episodes, consistent with both the model and the empirical literature above, we define a sudden stop in the model as an event in which: (a) $\lambda_t>0$ (i.e. the international borrowing constraint is binding) and (b) $(B_{t+1}-B_t)>2\sigma(B_{t+1}-B_t)$ (i.e. the current account or changes in the net foreign asset position in a given period exceed two times its standard deviation). The first criterion is a purely model based definition sudden stop. The second criterion allows us to consider only model events in which there are large current account reversals, in line with the aforementioned empirical literature.[14,15]

With the targets above we obtain $\omega=0.3526$, $\beta=0.9717$, and $\phi=0.415$. The implied value of ω is slightly higher than in Mendoza (2002) and slightly lower than assumed by Kehoe and Ruhl (2008). The implied annual value of β yields an annual discount factor of 0.8915, only slightly lower than in Kehoe and Ruhl (2008).[16] The implied value of ϕ is lower than in Mendoza (2002), who however calibrates it to the deterministic steady state of the model, and there are no standard benchmarks for this model parameter in the literature.

3.3. Empirical performance

The model we use describes Mexico's business cycles and "Tequila's crisis" relatively well. Table 3 compares model-based and data based second moments over the period over the 1993Q1–2007Q4 period. Fig. 1 compares the model and the Mexican data for key variables four quarters before and after 1995Q1.[17] All variables are defined in Table 2.

All data variables are reported in percent deviations from HP filtered trend except the current account, which is reported as a share of GDP. All model variables are reported in percent deviation from ergodic mean except the current account that is reported, as in the data, as a share of GDP. [18] To calculate model moments we simulate the model for 1,000,000 time periods, and retain the final 10,000 simulation periods to calculate moments and identify sudden stop events.

Despite its simplicity, the model describes the data reasonably well except for the behavior of the tradable GDP that is counterfactual because of the labor allocation effect at the sudden stop. As we can see, once we normalize all standard deviations relative to GDP in units of tradable goods (as in Bianchi, 2011), the model roughly matches the ranking of the data volatilities consistent with the results in Mendoza (2002). In particular, the model generates consumption volatility that is almost as high as GDP volatility and a current account that is less volatile than aggregate GDP or its components. The model, however, produces higher relative price volatility and excessively low tradable GDP volatility relative to the data (i.e., relative to GDP volatility).[19] As in the data, all model variables are similarly persistent, but less than in the data (especially for the relative price on non-tradable goods and tradable GDP). All correlations with GDP except the relative price one are also roughly consistent with the data. The correlation between CA and GDP is positive, contrary to what we observe in the data. This is because, as calibrated to Mexican data, the constraint does not alter consumption smoothing enough in the ergodic distribution of the model to generate such a negative correlation.[20] Additionally note that the correlation between CA and net income (defined as GDP minus investment and government expenditure, and hence closer to our model definition) may be either slightly positive or zero in the average emerging market economy (Luo et al., 2012). Furthermore, as is well known (Backus et al., 1993), a model with investment would generate a negative correlation.

Similar strengths and weaknesses emerge by comparing the macroeconomic dynamics around a typical sudden stop event. For this comparison, we focus on the 1995 Tequila crisis, the same episode studied by Kehoe and Ruhl (2008) and Mendoza (2010). Specifically, Fig. 1 compares the model and the Mexican data for key variables four quarters before and after 1995Q1, where the model variables are average across the identified sudden stop episodes, four periods before and four periods after our sudden stop definition is initially met.

As we can see from Fig. 1, the model qualitatively reproduces the large declines in expenditure on consumption and output (both expressed in units of tradable goods), and the relative price of tradable during the 1995 Tequila crisis in Mexico. However, in the model this relative price decline is less persistent than in the data. Similarly, qualitatively, non-tradable output and expenditure on non-tradable consumption measured in units of tradables are described relatively well by the model. The same

[14] The definition of sudden stop typically used in the empirical literature focuses on large capital flows reversals because some smaller ones may be due to terms of trade changes or other factors. Jeanne and Rancière (2011), for instance, exclude commodity importers and oil producers, while Calvo et al. (2008) add other criteria to the second definition we use above.

[15] Note that national accounts data typically have a trend, and hence the empirical literature focuses on changes in the current account, or the first difference of the capital flows. As our model has no trend growth and the data are in percent deviation from HP filter, we focus on the current account rather than its change. We obtain similar results when we define the sudden stop with respect to changes in the current account.

[16] This value is not comparable to the one assumed by Mendoza (2002) as he uses an elastic discount factor specification to obtain a stationary ergodic distribution. In our model, the presence of the borrowing constraint removes the necessity to introduce any device to induce stationarity.

[17] As is evident in the capital flow data (not reported), while capital flows into Mexico started to reverse in the fourth quarter of 1994, they were initially accommodated by a very large decrease in official reserves that eventually led to collapse of the fixed exchange rate regime in December 1994. As a result, the current account started to reverse only in 1995Q1.

[18] We do not HP-filter our simulated data. Because we do not include any features of the data that would generate low-frequency or nonstationary movements, there is no need to remove them.

[19] Note that, using data up to 2007, as we do, the absolute value of consumption volatility in the data is much lower than reported by Mendoza (2002), and hence much closer to GDP volatility.

[20] Bianchi (2011) for instance obtains a negative correlation by calibrating the model to Argentine data with very high shock variance and a low discount factor.

Table 2
Variable definitions.

Variables	Model	Data
GDP	$Y=Y^T+P^NY^N$	NA, production, GDP, 2003 prices
Non-tradable GDP	Y^N	NA, production, GDP, tertiary sectors, 2003 prices
Tradable GDP	Y^T	NA, production, GDP, secondary sectors, 2003 prices
Relative price of nontradable	P^N	Consumer price of services relative to merchandise, index base 2002Q2
Consumption expenditure	$C^T+P^NC^N$	NA, expenditure, private consumption, 1993 prices
Nontradable consumption	$P^NC^N=P^NY^N$	NA, expenditure, services + nationally-produced nondurables, 1993 prices
Tradable consumption	$C^T=(1+i)B+Y^T-B'$	NA, expenditure, imported goods + nationally-produced durables, 1993 prices
Current account	$CA=(B'-B)/Y$	Balance of payment statistics, current account balance to GDP

NA = national accounts.
Data sources:
National accounts are from INEGI, Banco de Información Económica (BIE), http://dgcnesyp.inegi.org.mx/bdiesi/bdie.html.
Consumer price indexes are from Banco de Mexico (Consulta; series SP68277 and SP56335), http://www.banxico.org.mx/sitioingles/polmoneinflacion/estadisticas/cpi/cpi.htm.
Current account and GDP in US dollar are from the IDB Latin Macro Watch (LMW), http://www.iadb.org/Research/LatinMacroWatch/lmw.cfm.

Table 3
Model evaluation: second moments of data and competitive equilibrium.

	Std dev	Std dev relative to GDP		First autocorrelation		Correlation with GDP	
	Data	Data	CE	Data	CE	Data	CE
GDP	2.4%	1.0	1.0	0.8	0.5	1.00	1.00
Nontradable GDP	2.2%	0.9	0.7	0.8	0.5	0.97	0.97
Tradable GDP	3.4%	1.4	0.4	0.8	0.3	0.96	0.91
Consumption	2.6%	1.1	0.9	0.8	0.5	0.91	0.98
Relative price of nontradable	2.5%	1.0	2.9	0.9	0.5	0.26	0.85
Current account (percent of GDP)	2.1%	0.9	0.5	0.8	0.5	−0.61	0.98

lack of persistence characterizes all model variables that generally recover much faster than in the data. We note also that consumption expenditure falls much more than output in our model economy since tradable output increases at the sudden stop. Consistent with the data, tradable GDP also starts to fall sharply before the sudden stops, but it increases during the sudden stop period, counterfactually. As a result, tradable consumption falls much less than non-tradable consumption, while in the data the opposite occurs.

Quantitatively, however, the model produces sudden stop dynamics of an amplitude roughly one order of magnitude smaller than in the data. This dampening occurs for two reasons. First, as we noted above, the model is too simple to provide an accurate quantitative account of the data: in particular, we limit ourselves to only one shock in tradable productivity while other shocks (foreign interest rate shocks or shocks to nontradable productivity) might have contributed to amplifying the dynamic of the economy during a sudden stop. Second, and more importantly, the model counterfactually predicts an increase in total employment at the sudden stop, driven by a sharp increase in labor supply and a fall in the real wage (not reported).

As Kehoe and Ruhl (2008) discuss, there are three ways to generate falling employment in the model: a friction in the labor mobility across sectors, variable capital utilization, and a working capital constraint, but none produces a satisfactory account of labor market dynamics during the Tequila crisis in their model. In addition, in our model they pose additional complications. Imperfect labor mobility and variable capital utilization introduce an additional state variable. But, as we noted earlier, the comparison between the competitive and the social planner allocation that is the focus of the paper constrains the number of endogenous state variables that can feature in our model. A working capital constraint could produce falling output, but is more difficult to justify in contracting terms. In addition while a working capital constraint would generate output falling at the sudden stop, our intuition is that it can increase the gap between social planner and competitive allocation during crisis times so that it would not change our main normative conclusions. For these reasons we prefer to keep the model simple.

4. Inefficient borrowing and macro-prudential policies

In this section we report and discuss a comparison between the competitive equilibrium allocation and the social planner one, based on a full numerical solution of our two-sector production model. In this section, we also discuss the robustness of the analysis to changes in model specification and key parameter values and its implications for the debate on macro-prudential policies.[21]

4.1. Comparing CE and SP allocations

The policy function for foreign borrowing, B_{t+1}, is plotted in Fig. 2, conditional on the worst state of the tradable shock. The decision rules are drawn assuming this shock is received in each period. The continuous line refers to the competitive equilibrium (CE) allocation, while the dotted line refers to the social planner one (SP). The figure shows that there is slight underborrowing when the constraint is not binding and a larger one when the constraint binds—i.e., for each value of the endogenous state B_t, B_{t+1} is smaller in the CE than in the SP throughout the support of the decision rule.[22] This result shows that, in our model, in which there is scope for both ex ante and ex post inefficiency, the latter is quantitatively larger than the former.[23]

This finding is in sharp contrast with the overborrowing results in the related literature—Bianchi (2011), Bianchi and Mendoza (2010) and Jeanne and Korinek (2011). These works have focused only on ex ante inefficiency (i.e., when the constraint does not bind) in models in which ex post efficiency does not arise (Bianchi, 2011) or is limited by construction (Bianchi and Mendoza, 2010 and Jeanne and Korinek, 2011) since prices

[21] The properties of the competitive equilibrium of this economy are well known (see for instance Mendoza, 2002).
[22] We define "overborrowing" as the situation in which a constrained social planner would take on less debt than decentralized agents. Similarly "underborrowing" is defined as the situation in which the social planner takes more debt than decentralized agents. These definitions are consistent with Korinek (2010).
[23] See below for summary statistics on the ergodic distribution of debt in the CE and the SP allocation.

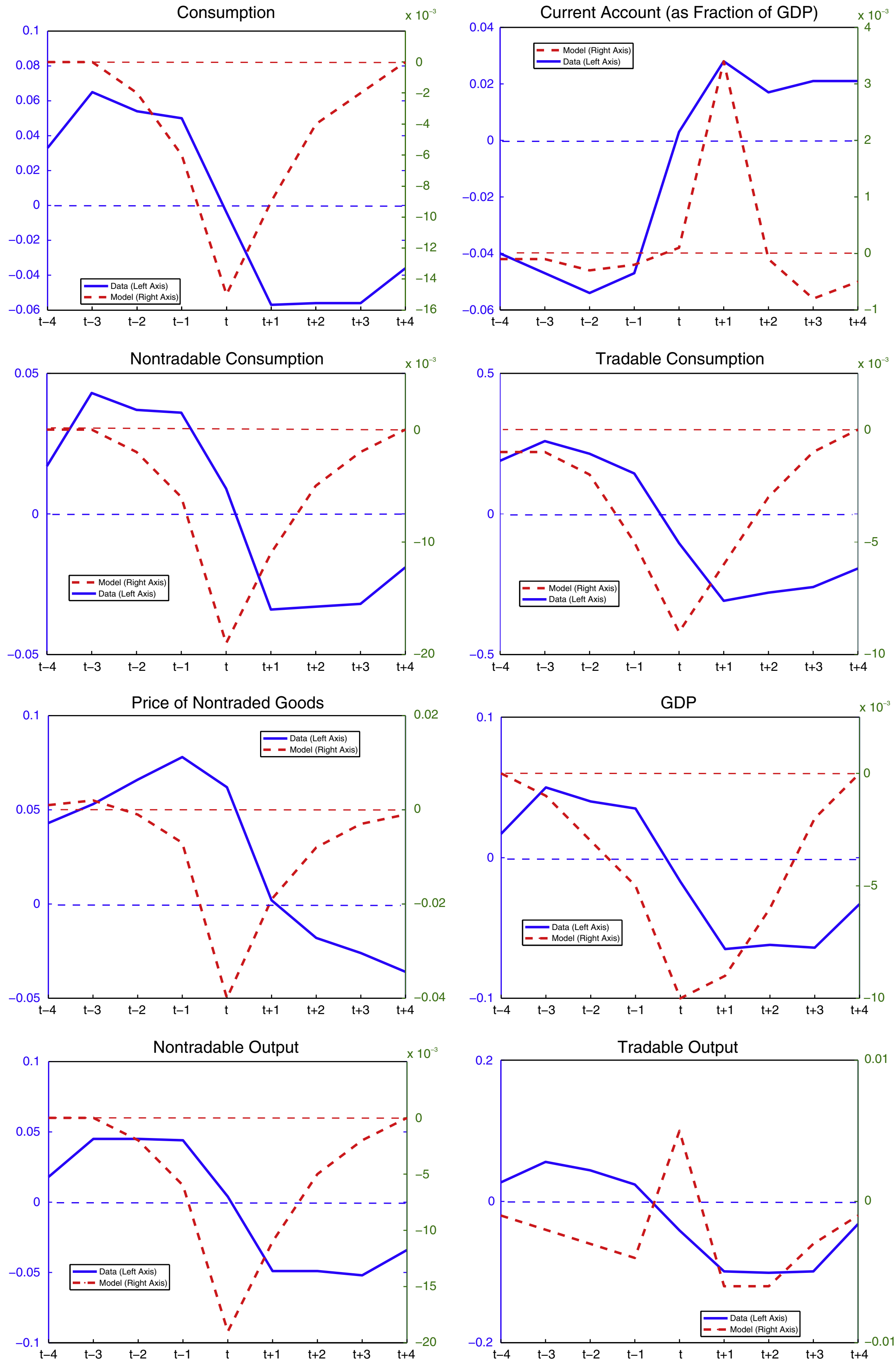

Fig. 1. Event study.

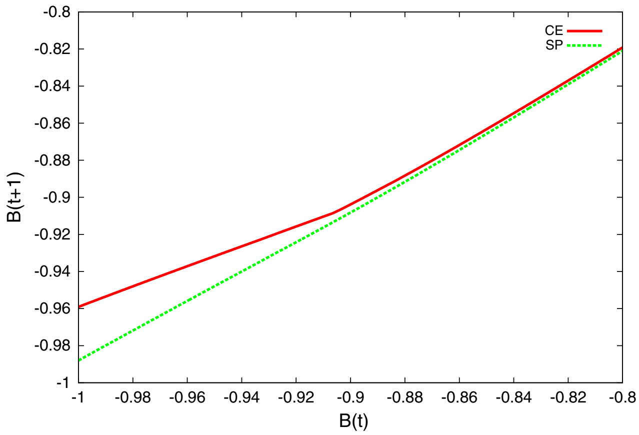

Fig. 2. Decision rule for foreign borrowing.

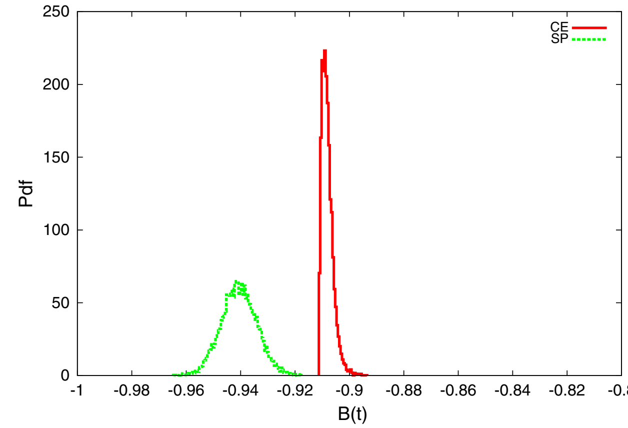

Fig. 3. Ergodic distribution of foreign borrowing.

in the binding region are assumed to be equal in the competitive and social planner allocations. In contrast, Fig. 2 shows that in our model, in which both ex ante and ex post efficiencies can arise, the ex ante inefficiency is not only smaller than the ex post one, but it also of opposite sign. Thus, the planner borrows more than private agents both ex ante and ex post rather than less in our model. Moreover, as we shall see below, higher borrowing in the SP allocation is associated with a lower (rather than higher) probability of hitting the constraint in our model, and hence does not imply higher vulnerability to financial crises.

To quantify these differences, Fig. 3 compares the ergodic distributions of B_t in the CE and the SP allocations. Indeed, the figure shows the "underborrowing" that characterizes our benchmark economy, as the CE distribution is located to the right of the SP one. Nonetheless, *average* debt in the SP in units of tradable consumption is only slightly larger than in the CE (−0.941 and −0.914 in the SP and the CE, respectively), and it is the same as a share of GDP (35% in both the SP and the CE).[24] This is intuitive, as the larger differences between the two allocations are in the constrained part of the distribution support, but that portion is visited infrequently in the stochastic steady state of the model.

Interestingly, despite higher borrowing, the probability of a financial crisis in the SP allocation is lower than in the CE allocation in our model (Table 4). In the benchmark CE allocation, the unconditional probability of a crisis is 2% on a quarterly basis. In the SP allocation, this probability drops to 1.2% per quarter. The intuition is that, by allocating productive resources differently (see below), the social planner increases the value of the collateral through an increase in relative prices and permits more borrowing in response to negative shocks without increasing its probability of meeting the constraint.

The shape of the two distributions is also very different. The shape of the borrowing distribution depends on the location of the intersection between the policy function at different values of the exogenous state and the 45-degree line (not reported), which in turn depends on the shape of policy function itself. In the SP, these intersections occur on a more dispersed portion of the support. As a result, the distribution does not display truncation and appears "unconstrained." In the CE, these intersections are more concentrated to the left of the support, and the distribution appears truncated.

To illustrate the mechanisms underneath our underborrowing result, Figs. 4 and 5 report the policy functions for the other key model variables as a function of the endogenous state, B_t. The policy functions are drawn for the continued realization of the same shock. All variables (B_t, P_t^N, H_t, C_t, H_t^T, H_t^N, C_t^T, and C_t^N) follow a similar pattern in both allocations displaying a kink in correspondence of the level of B_t in which the constraint becomes binding. As the economy moves toward the binding region, agents (and the planner) increase the amount they want to borrow (Fig. 2) and reduce their tradable and non-tradable consumptions (Fig. 5). In this transition, before the constraint binds, the relative price of non-tradables falls in both the competitive and the social planner allocation. Note that the relative price of non-tradable goods in the SP allocation is higher compared to the CE allocation in the non-binding region as the social planner consumes relatively more tradables (i.e., borrows more in equilibrium) in normal times. Since the relative price of non-tradables is lower in the CE allocation compared to the SP one, the sector allocation of labor (see Eq. (13)) is such that, in normal times, in the CE, there is overproduction of tradables and under-production of non-tradables relative to the SP (Fig. 5).

Once the constraint binds we observe two important differences between the CE allocation and the SP one. First, as we already noted, the differences between the decision rules of the CE and the SP are much larger than in "normal times." Second, the SP engineers an increase in P_t^N, accompanied by a decrease in non-tradable production, while in the CE allocation the relative price decreases and non-tradable production rises.

These differences arise because of the way the planner deals with the constraint compared to how private agents do. In our production economy, increasing the value of the collateral in units of tradables could occur by increasing the production of tradables and/or by increasing the value of non-tradable production. As the social planner takes into account the impact of its consumption and production decisions on the relative price of non-tradable goods, it increases the value of collateral by increasing this price (and hence the value of non-tradable production in units of tradable goods) rather than by increasing the amount of non-tradable goods produced. In the SP allocation, a

Table 4
Average foreign borrowing and crisis probability.

Annual average debt in the ergodic distribution	CE	SP
(Percent of annual GDP and in units of tradable consumption)		
Benchmark	35.0 (−0.914)	35.0 (−0.941)
$\kappa = 1.25$	35.0 (−0.909)	35.0 (−0.922)
$\beta = 0.91$	35.0 (−0.960)	35.0 (−1.171)
$\sigma_{\varepsilon^T} = 0.04$	32.0 (−0.878)	33.0 (−0.881)
State-contingent Tobin tax (1% outside sudden stop)	35.0 (−0.892)	na
Crisis probabilities		
(Unconditional, percent per quarter)		
Benchmark	2.00	1.20
$\kappa = 1.25$	2.60	0.35
$\beta = 0.91$	2.05	2.21
$\sigma_{\varepsilon^T} = 0.04$	0.00	0.00
State-contingent debt tax (1% outside sudden stop)	0.00	na

[24] GDP is higher in the SP (0.6674) than in the CE allocation (0.6486).

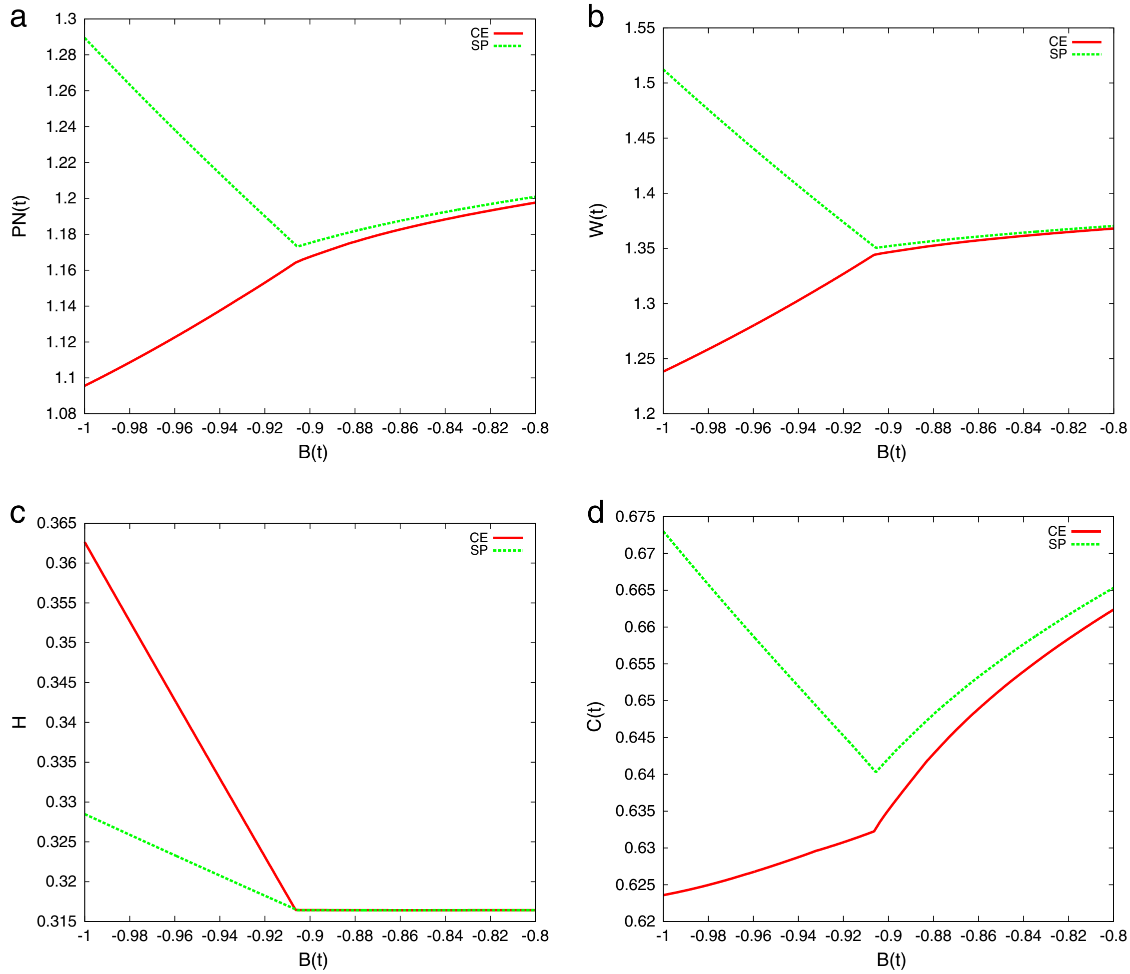

Fig. 4. Decision rules for relative price, wages, labor and consumption.

combination of relatively higher consumption of tradables (i.e., more borrowing) and lower consumption of non-tradables (i.e., by reducing the production of non-tradables) leads to an increase in the relative price. The SP also increases the production of tradable goods but less so than in the CE allocation so that total labor supply rises but less than in the CE allocation. Private agents, on the other hand, tend to increase their borrowing capacity by producing more of both tradables and non-tradables. In doing so they do not internalize the effects of their production decisions on the relative price of non-tradable goods, and in equilibrium we observe a lower relative price that tends to further tighten the constraint.

The key implication of the different ways in which the planner and individuals relax the constraint is captured in Fig. 6, which plots the behavior of the Lagrange multipliers associated with the borrowing constraint (λ_t^{SP} and λ_t^{CE}) and the marginal value of saving (μ_t^{SP} and μ_t^{CE}) in the two allocations. The multipliers on the borrowing constraint, λ_t^{SP} and λ_t^{CE}, are zero in both allocations in normal times, but λ_t^{SP} is always lower than λ_t^{CE} for any given B_t when the constraint binds: thus, a financial crisis is less costly in the SP than in the CE. As we discussed in the previous section, this ex-post difference influences the ex-ante borrowing decisions by agents. In fact we can note that, by ameliorating the severity of the crisis, the social marginal utility of savings, μ_t^{SP} is lower than the private one, μ_t^{CE} for the same given state.

The overall differences in the CE and SP allocations are reflected in the calculation of the welfare gains of moving from the CE to the SP.[25] With higher borrowing and a lower probability of crisis, the SP achieves higher welfare than the CE in our baseline model. The overall welfare cost of inefficient borrowing in our baseline production economy is 0.12% of permanent (tradable) consumption (Table 5). And the welfare gain of moving from the CE to the SP equilibrium in states of the worlds in which the constraint binds is about 25% higher than the overall cost (at 0.15% of permanent tradable consumption) despite the fact that those states are realized very infrequently (2% of the times in the baseline model).

The intuition for this result is that welfare is state dependent in this class of models (see, for instance, Fig. 7 for selected exogenous states). The largest differences in the behavior of these economies arise in the states in which the constraint is binding. And given that the economy spends most of its time outside these states, the overall welfare difference between the two allocations is smaller than the welfare difference in those states. It follows that the welfare difference between the CE and the SP in normal times is much smaller than the overall difference (which includes the binding states).

4.2. Robustness

In this subsection we explore the extent to which the underborrowing result found in our benchmark economy is robust to changes in the model specification and parameter values.

4.2.1. Fixed labor supply

Lets' consider first an alternative model specification, namely the case in which total labor supply is fixed. This case is of interest because

[25] See Section 3 for details on the definitions and computations of these welfare gains and losses.

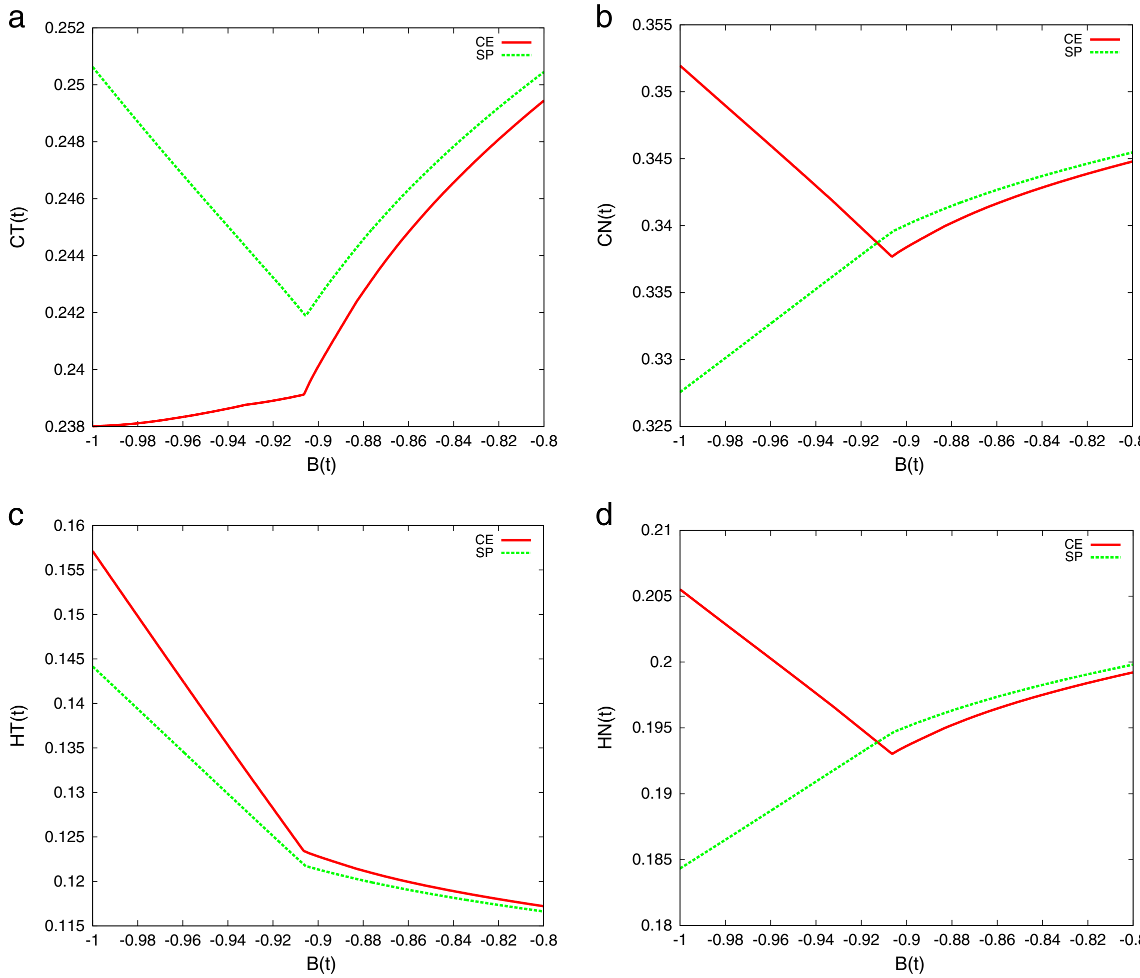

Fig. 5. Decision rules for traded and nontraded consumption and labor.

it shows that, while the labor supply effect is quantitatively important in the CE allocation, it has almost no relevance in the SP allocation. Thus, it shows that the overborrowing result we found is entirely driven by the intra sector allocation of the resources rather than the labor supply effect.

To run this exercise we simply normalize the total labor supply such that $H_t^N + H_t^T = \bar{H}$ and then rerun the experiments discussed above. Fig. 8 reports the results for (B_t, P_t^N, H_t, C_t, H_t^T, H_t^N, C_t^T, and C_t^N). As we can see the behavior of all variables is almost identical in the SP allocation with and without varying labor supply, while the CE allocations are different in the case of fixed labor supply. In particular, our economy not only continues to display underborrowing in both normal and crisis states (see Fig. 8, panel for B_t), but the gaps between CE and SP are much larger with fixed labor supply in crisis states. This implies that our underborrowing result is driven by the intra-sector allocation of labor rather than changes in total labor supply.

4.2.2. Parameter values

Next we explore robustness to changes in key parameter values. We change the parameters that are critical in determining the sign of the inefficient borrowing (as identified by Benigno et al., 2011). We focus on three key parameters: the elasticity of intratemporal substitution that determines the sign of the sector allocation effect, the discount factor that determines the strength of the intertemporal effect, and the variance of the shocks. Fig. 9 reports the decision rule and the ergodic distribution of B_{t+1}. Tables 4 and 5 report the average borrowing, the probability of crisis, along with the welfare gains, respectively, for all cases.[26]

Fig. 9 (Panel b) shows that the results are qualitatively unchanged when we set the elasticity of substitution between tradables and nontradables to 1.25 (i.e., assuming substitutability rather than complementarity between tradable and nontradable goods). Underborrowing though is quantitatively smaller (Table 4). A change in the elasticity of substitution does not affect the marginal utility of tradable consumption, but it has an impact on labor choices through the non-tradable relative price. When the elasticity of substitution increases the change in the relative price in both the CE and SP allocation is smaller for a given change in tradable consumption, and the smaller change in relative prices reduces the labor supply effect in both the CE and SP allocations. In addition, the decrease in non-tradable production and consumption that follows from labor market equilibrium (see Appendix A) is now accompanied by an increase in tradable consumption so that the initial precautionary saving impact on tradable consumption is dampened. With our calibration, the net outcome of these effects is such that underborrowing is smaller compared to the benchmark case in which goods are complements, but it is not eliminated.

Table 5 also shows that, in this case, the probability of sudden stop is higher than in the benchmark case in the CE (2.6%) and much lower in the SP (0.35%): on the one hand, higher substitutability implies that the

[26] In each case, the parameter is changed as reported in Tables 4 and 5, without recalibrating the model.

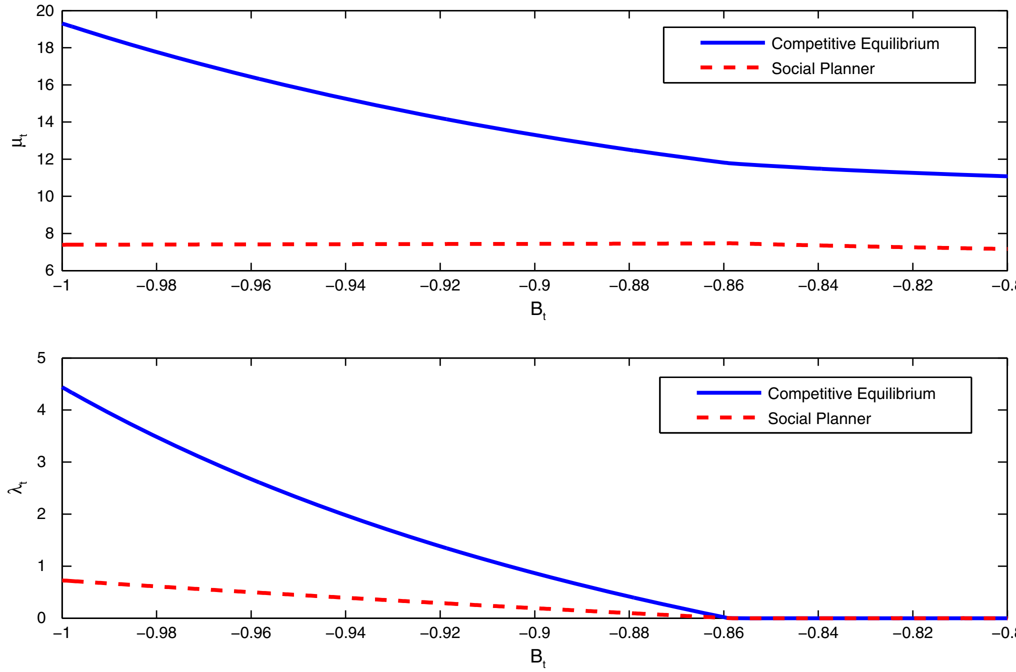

Fig. 6. Multipliers.

relative price drops less than when goods are complements and this helps to relax the constraint. On the other hand, substitutability implies that precautionary saving is reduced and agents borrow more for a given state, increasing the probability of hitting the constraint. In the CE allocation, the second effect dominates the first one, leading to a higher probability of sudden stop. In the SP allocation, instead, the first effect prevails reducing the probability of sudden stop. The welfare gains in moving to the SP allocation are lower in this case (0.0525%, Table 5), since the cost of being in a crisis is smaller in this case.

Underborrowing increases significantly with a lower discount factor. In fact, the ergodic distributions are much further apart than in the baseline case (Fig. 9, Panel c). Lowering the discount factor to 0.91 makes agents more impatient and reduces precautionary saving so that agents borrow more in both the CE and SP allocations. Both the CE and the SP meet the constraint more frequently, but in the SP allocation the unconditional probability of sudden stop is higher than in the CE allocation (from 1.2 in the baseline case to 2.2 with higher discount factor, Table 5). This shows that in the SP allocation it might well happen that the probability of hitting the constraint is higher than in the CE. The reason is that the planner reduces the cost of the crisis so that even if the welfare gains of moving from the CE to the SP remain positive (0.0351 overall, Table 5), they are smaller than in the baseline case.

When we triple the variance of the shocks, underborrowing is strengthened compared to the baseline (Fig. 9, Panel d). Once we increase the variance of the shock by this much, there is such an increase in the precautionary saving in both the CE and the SP that the probability of a sudden stop goes to zero in both allocations. Yet, the shape of the two distributions is different. In the case of the CE, the borrowing distribution is truncated. In the SP is seemingly unconstrained for the reasons explained above. In this case, however, the welfare gain of moving from the CE to the SP is very small, and these gains accrue only in normal times.

Table 5
Welfare gain of moving from the CE to the SP. (In percent of permanent consumption).

	Overall	Crisis states
Benchmark	0.1230	0.1500
$\kappa = 1.25$	0.0525	0.0752
$\beta = 0.91$	0.0351	0.0390
C^T	0.0013	na
State-contingent Tobin tax (1% outside sudden stop)[a]	−0.00024	−0.00035

[a] In this case the welfare gain/loss is relative to the CE.

4.3. Implications for macro-prudential policy

In this subsection we discuss the policy implications of our findings. To summarize them, in the numerical analysis, we have found that underborrowing in normal times is a robust feature of the competitive allocation of our two-sector production model and that it is crucially driven by the planner's possibility to intervene in crisis times. We have also found that the welfare gains of moving from the CE to the SP in crisis states are larger than in tranquil times, and that the same or a higher level of borrowing is not necessarily associated with a higher probability of a financial crisis in the SP allocation relative to the CE allocation.

What are the implications of these results for macro-prudential policy? First, and most importantly, the analysis has shown that the behavior of the economy in normal times depends crucially on how the economy is expected to behave in crisis times. This implies

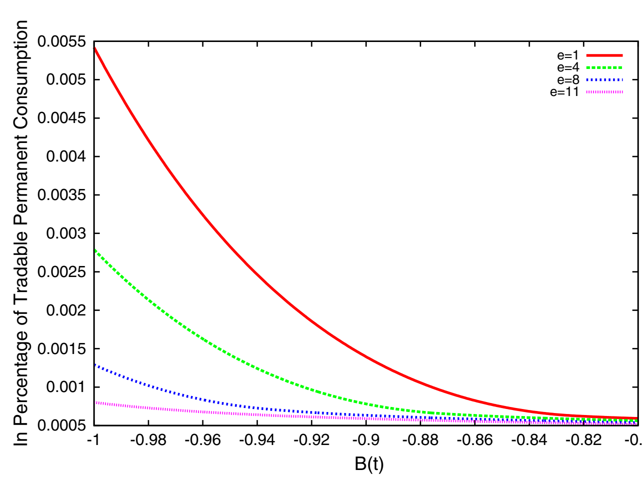

Fig. 7. Welfare by state.

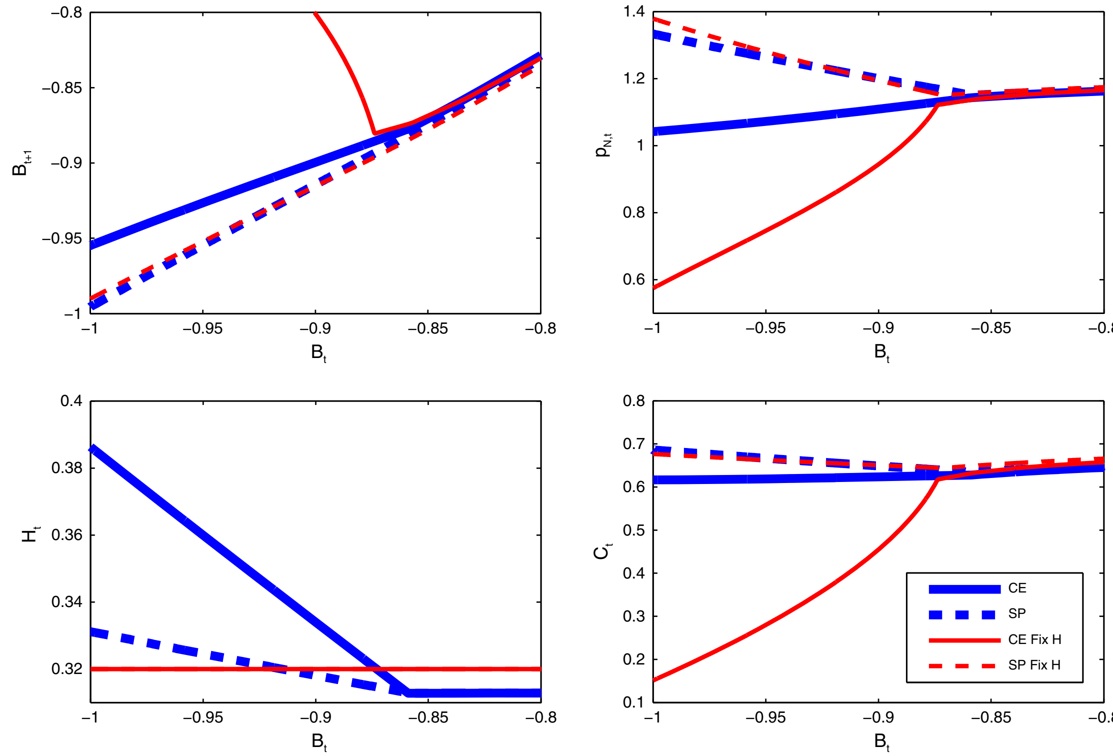

Fig. 8. Fixed labor supply.

that the design of ex-ante policies depends on that of ex-post policies and their characteristics. In particular, in our framework, ex post policies that mitigate the severity of a crisis reduce the social value of precautionary saving in normal times, so that ex-ante policies should be designed to induce more (rather than less) borrowing by private agents.

While our analysis therefore calls for the use of both ex ante and ex post interventions, it has abstracts from implementation issues. Thus, we do not address the question of which specific set of taxes or subsidies could decentralize the SP allocation.[27] In particular, our findings do not imply that a policy maker should subsidize borrowing to restore economic efficiency. In fact our planner allocates productive resources across sectors in both normal and crisis times such that a higher level of borrowing can be sustained safely regardless of how such resource allocation could be decentralized. This highlights that, from a financial stability perspective, how credit flows are allocated is at least as important as how much credit is contracted.

Second, the analysis shows that ex post policies (i.e., policy interventions in crisis states) may be more important than ex ante ones (i.e., policy interventions during tranquil times). Indeed, in our analysis, welfare gains are always significantly higher in crisis states than in other states.

Third, these results illustrate that constrained efficiency can be achieved not only by outright reduction borrowing and the probability of a crisis, as suggested by the existing literature, but also by allocating productive resources more efficiently in both normal and crisis times. In the efficient allocation, relative prices move in such a way that the economy is less vulnerable to the presence of occasionally binding financial frictions. This is because, as we mentioned earlier, our social planner tends to relax the constraint by changing relative prices rather than by changing quantities as individual agents do in the competitive equilibrium. Broadly speaking, this would be consistent with the "old adage" that it is how capital is intermediated and allocated that matters, not how much debt is taken on. After all, the very presence of a financial friction suggests that in a first best world these economies would like to borrow more, not less.[28]

Another way to restate the point above is to note that crises are not completely eliminated by the social planner, and neither the probability of a crisis nor the level of borrowing are good policy objectives. While in general the social planner tends to reduce the unconditional probability of the crisis, there might be cases (for example when agents are impatient) in which the unconditional probability of sudden stop chosen by the social planner is higher than in the competitive equilibrium. More broadly, there is a trade-off between volatility and efficiency in this class of models, and minimizing the probability of the crisis is not necessarily a good criterion to orient policy. In welfare terms, in certain cases, the gains of higher average consumption may outweigh the costs of a more volatile consumption because of the more frequent crises. In these cases, a planner that takes this trade-off into account may allocate resources in such a way as to allow for higher and more volatile consumption to achieve efficiency. It follows that the appropriate policy regime depends on the specific characteristics of the economy.

Fourth, if the design of ex ante policies is sensitive to the structure of the economy, the wrong policy regime might impose costs that exceeds its intended benefits. These costs can be easily quantified in our benchmark economy by imposing a small tax on debt (a capital flow tax or capital control) equal to 1% in tranquil times and zero once the crisis occurs. This simple state-contingent policy rule resembles more specific proposals in terms of macro-prudential policies that have been proposed in the related literature (e.g., Bianchi, 2011, Bianchi and Mendoza, 2010, and Jeanne and Korinek, 2011). Fig. 10 reports the results for this experiment and shows that the desirability of such rules is not robust to the specification of the model. In this case, average borrowing in units of tradable consumption falls to the lowest among all cases

[27] This question is addressed by Benigno et al. (2009, 2012a). They study the welfare properties of discretionary Ramsey optimal policy in a very similar model environment and find that indeed outcomes depend crucially on the number and kind of instruments given to the planner. In particular they find that taxes on consumption (which are interpreted as foreign exchange policy) always dominate taxes on debt (which are interpreted as capital controls) in both endowment and production economies.

[28] See Mendoza (2002) and Benigno et al. (2011) for a quantitative comparison with an unconstrained economy.

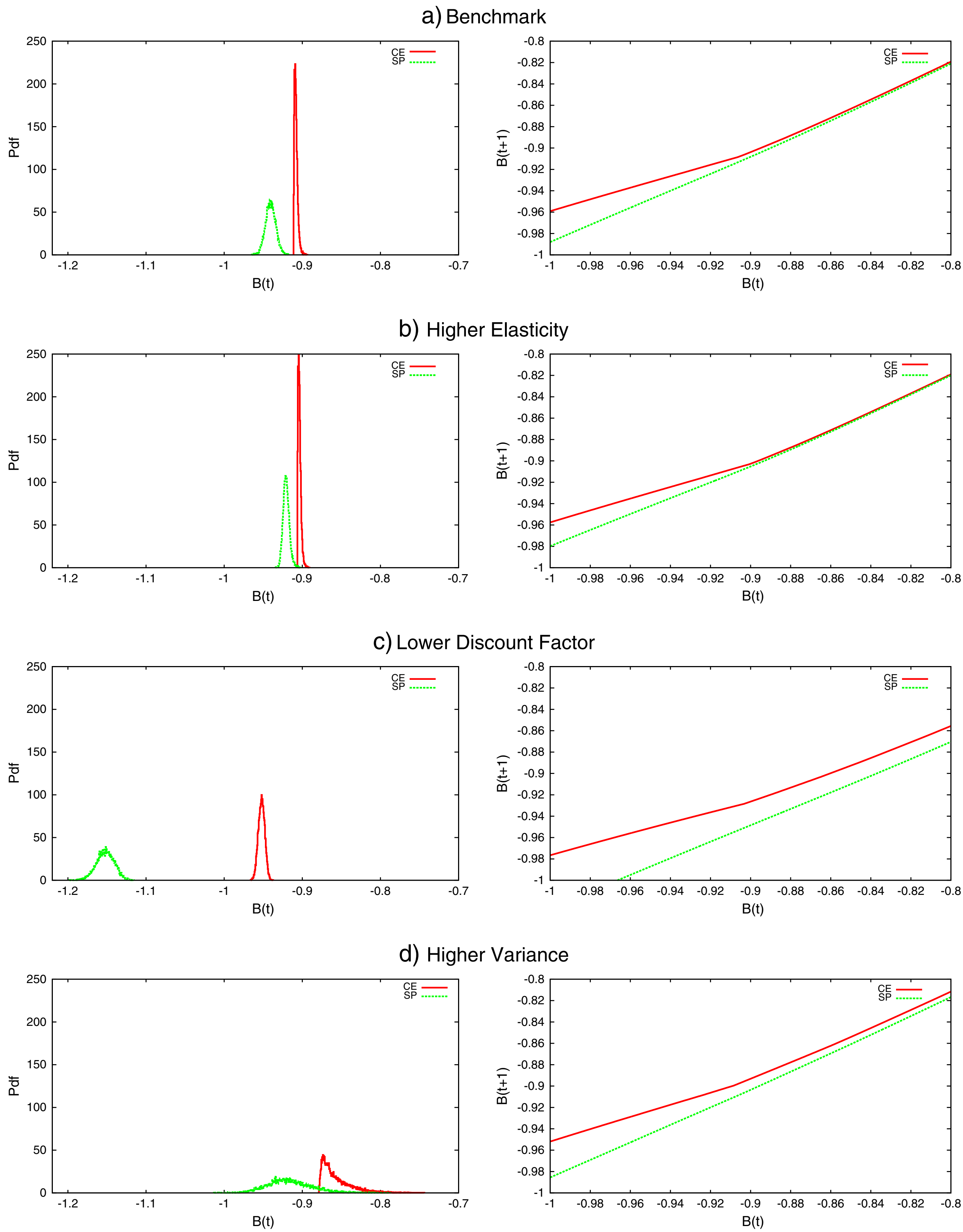

Fig. 9. Robustness.

discussed and the probability of a crisis goes to zero. However, the tax moves the economy further away from the constrained-efficient allocation as evidenced by negative welfare gains in moving from the CE with tax to that without. The tax forces agents to save more, the risk of a crisis disappears, but welfare declines. This implies that the distortion introduced by the policy intervention is more costly in welfare terms than

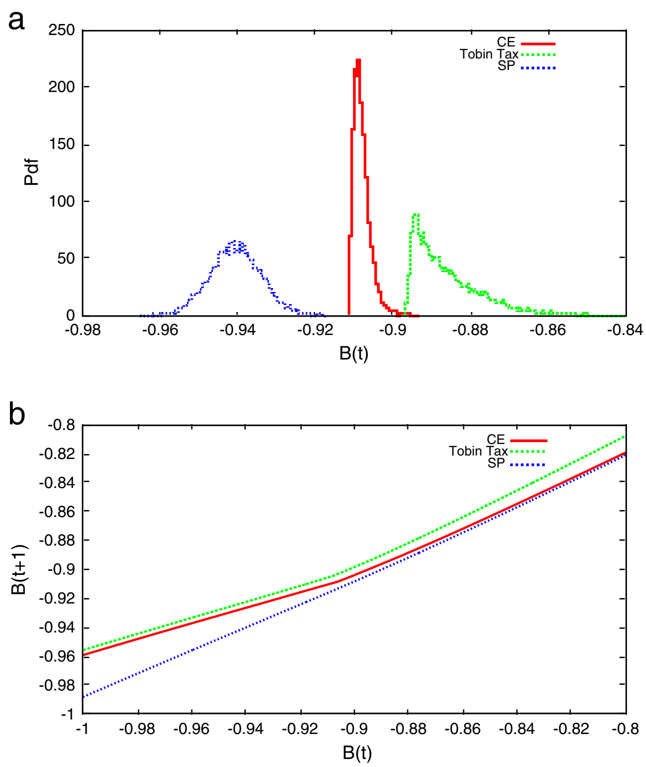

Fig. 10. Debt tax.

the benefit of eliminating the risk of a crisis. It follows that from a policymaker's perspective minimizing the probability of the crisis or targeting any specific level of borrowing is not necessarily good policy targets.

5. Conclusions

In this paper we compared the competitive and the social planner allocations in a two-sector small open production economy with an occasionally binding borrowing constraint in which financial crises are endogenous.

The insight of our work lies in the interaction between agents' behavior in crisis and normal times. We show that the design of macro-prudential policies depends on crisis management policies: by allocating resources efficiently in crisis times, the planner mitigates their severity and reduces the incentive for precautionary savings. In fact, in terms of equilibrium amount of debt, we find that in our model economy the social planner borrows more than private agents in normal times and yet has a lower probability to enter a financial crisis. This highlights that, rom a financial stability perspective, how credit flows are allocated is at least as important as how much credit is contracted. While our analysis shows the need for both ex-ante and ex-post policies, we also find that ex-post policies entails larger welfare gains. Finally, we find that macro-prudential policies alone aimed at reducing the amount of borrowing or the likelihood of a crisis might be counterproductive.

The more general message of our analysis is that macroprudential policy ought to be evaluated in conjunction with crisis management policy and the specific characteristics of the economy, and it is misguided, within this class of models, to associate the use of macroprudential policies with excessive debt (i.e. overborrowing).

A relevant aspect of the analysis that is left for future research is the implementation of the social planner allocation along with the determination of optimal policy when the set of policy tools is restricted. In current ongoing research we are pursuing these avenues (Benigno et al., 2009; 2012a).

Acknowledgments

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Appendix A. Labor market equilibrium in CE allocation

By taking a total differential of the system of Eqs. (17), (18) and (19) we get that

$$sign\left(\frac{dH_t}{dC_t^T}\right) = sign\left(\frac{\alpha^T}{\alpha^N}\frac{1-\alpha^N}{1-\alpha^T} - \frac{Y_t^T}{C_t^T}\right).$$

so that, among other things, the response of total hours worked to a change in precautionary savings depends on labor intensities in the two sector and on whether the country is producing more tradable output than what it consumes during the current period. Moreover it is possible to show that

$$sign\left(\frac{dH^N}{dC^T}\right) = sign\left((\delta-1)\frac{h^T}{\alpha^T} + 1 - \varepsilon_{pn}\right) > 0,$$

where $h^T = \frac{H^T}{H}$ and $h^N = \frac{H^N}{H}$ with

$$\varepsilon_{pn} = \frac{\frac{1-\omega}{\omega}\left(P^N\right)^{1-k}}{1+\frac{1-\omega}{\omega}\left(P^N\right)^{1-k}} < 1$$

so that unambiguously $dH^N/dC^T > 0$. The response of H^T to a change in precautionary savings can then be found using

$$\frac{dH^T}{H^T}\left((\delta-1)h^T + \alpha^T\left(1-\varepsilon_{pn}\right)\right) = -\frac{dH^N}{H^N}\left((\delta-1)h^N + \varepsilon_{pn}\alpha^N\right),$$

which implies that H^T and H^N always move in opposite directions after a change in precautionary savings and so that $dH^T/dC^T < 0$. Finally, $dH^N/dC^T > 0$, $dH^T/dC^T < 0$ implies that $dP^N/dC^T > 0$.

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