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Optimal capital controls and real exchange rate policies: A pecuniary externality perspective ☆

Gianluca Benigno [a,*], Huigang Chen [b], Christopher Otrok [c,d], Alessandro Rebucci [e,f], Eric R. Young [g]

[a] Department of Economics, London School of Economics, London WC2A 2AE, UK
[b] Neustor Inc
[c] University of Missouri, United States
[d] Federal Reserve Bank of St Louis, United States
[e] John Hopkins University Carey Business School, United States
[f] NBER, United States
[g] University of Virginia, United States

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ABSTRACT

A new literature studies the use of capital controls to prevent financial crises. Within this new framework, we show that when exchange rate policy is costless, there is no need for capital controls. However, if exchange rate policy entails efficiency costs, capital controls become part of the optimal policy mix. When exchange rate policy is costly, the optimal mix combines prudential capital controls in tranquil times with policies that limit exchange rate depreciation in crisis times. The optimal mix yields more borrowing, fewer and less severe financial crises, and much higher welfare than with capital controls alone.

1. Introduction

In response to the global financial crisis and its costly aftermath, a new policy paradigm emerged in which old fashioned government policies such as capital controls and other restrictions on credit flows became part of the standard crisis prevention policy toolkit (the so-called macro-prudential policies). A few, large emerging market economies experimented with these tools. And even the traditionally conservative IMF changed its orthodox views on capital controls, advocating the use of such measures when other tools are not available or have run their course of action—see Blanchard and Ostry (2012) and IMF (2012).

☆ This is a substantially revised version of CEP Working Paper No. 1160 and Federal Reserve Bank of St. Louis Working Paper No. 2012-025A, The views expressed in this paper are exclusively those of the authors and not those of the Federal Reserve Bank of St. Louis, the Federal Reserve System, or Neustor Inc. Christopher Otrok currently works as a senior economist for the Council of Economic Advisers (CEA). The CEA disclaims responsibility for any views expressed herein and these views do not necessarily represent the views of the CEA or the United States.

* Corresponding author.
E-mail address: G.Benigno@lse.ac.uk (G. Benigno).

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The key rationale underpinning the use of capital controls is financial stability.[1],[2] The financial stability motive is the focus of the influential contributions of Korinek (2010) and Bianchi (2011).[3] Their analysis is based on variants of a common theoretical framework proposed by Mendoza et al. (2002) and Mendoza (2010). In this framework, the scope for policy intervention arises because of a pecuniary externality stemming from the presence of a key relative price in the collateral constraint faced by private agents. In this environment, prudential interventions (i.e. before a financial crisis occurs) may be desirable because they can make agents internalize the consequences of this externality on their individual decisions. Capital controls in this setting can discourage financial excesses, reduce the amount that agents borrow, thereby lowering the probability of a financial crisis, and hence enhance welfare.

In this paper, we provide an integrated analysis of alternative policy tools that can be interpreted in terms of fiscal, monetary and macroprudential policies using the same model economy studied by Bianchi (2011). A first main finding is that, when financial stability is the sole motive for policy intervention, the optimal policy design aims at supporting the value of the collateral and hence the agents' borrowing capacity during crises times. In this context, policies that support the real exchange rate (or more generally collateral price support policies) during a financial crisis dominates by a large margin prudential controls on capital flows from a welfare point of view. The dominance of price support policies relies, perhaps unrealistically, on the assumption that they are costless to use. Indeed, under the assumption that supporting the value of collateral during crisis times is costly, it becomes optimal to combine price support policies with macroprudential policies such as capital controls.

In our analysis, then, the rationale for macroprudential policies relies on the extent to which price support policies are cost-effective rather than the amount that agents borrow in the unregulated economy during tranquil times. This novel element emphasizes the interaction between ex-ante (normal times) and ex-post (crises times) policy interventions: when price support policy is fully effective in crises times (i.e. it is able to address the pecuniary externality distortion at no other cost) there is no scope for ex-ante policy intervention. However, if the policy is costly in crises times, it is optimal to adopt capital controls during normal times as a way to limit the occurrence of the crises, combined with price support policies in crises times to mitigate their severity. A second main finding is that the optimal combination of ex-ante and ex-post policy interventions achieves welfare gains of 1.10% of tradable consumption relative to the unregulated economy, which is much higher than the typical value found in the literature.

The vehicle to convey our messages is the same model economy used by Bianchi (2011). This is a two-sector (tradables and non-tradables) small open, endowment economy with an occasionally binding international borrowing constraint. Quantitatively, this model has been successful in reproducing the business cycle and the crisis dynamics properties of a typical emerging market economy. In this class of models, a financial crisis event (also labelled a Sudden Stop in capital or credit flows) occurs when the constraint binds. In our model, the value of total current income generated both in the tradable and non-tradeable sectors limits borrowing, denominated in units of tradable consumption. When the borrowing constraint binds, the decline in the relative price of non-tradables generates a balance sheet effect and leads to a Fisherian debt-deflation spiral.

In this economy, there is a well defined scope for government intervention, but there are multiple instruments or tools with which policy could be conducted. The pecuniary externality arises from the fact that individual agents do not internalize the aggregate effect of their borrowing decisions on the relative price of non-tradable goods, which is the price that enters the collateral constraint. There are three types of taxes that can be used to correct it: a tax/subsidy on foreign debt or a tax/subsidy on tradable consumption and a tax/subsidy on non-tradable consumption. The tax on foreign debt is usually interpreted as a capital control, while taxes on either tradable or non-tradable consumption can be interpreted as a real exchange rate interventions because they affect directly the relative price of non-tradables.[4] Our policy analysis considers all three instruments and studies their relative effectiveness in welfare terms. Differently from the existing literature, this paper conducts the policy analysis following a Ramsey optimal taxation approach, assuming that the government budget is always balanced.

The paper first studies the Ramsey problem when capital controls are the only policy tool available, and the government budget constraint is balanced through lump-sum transfers/taxes. Consistent with Bianchi (2011) and Korinek (2010), in this case, the finding is that it is Ramsey optimal to limit the amount that agents borrow in normal times, while no action is needed during crises times. The reason why capital controls are not used by the Ramsey planner in crisis times is that, in this model, they cannot affect the allocation when a crisis occurs (i.e. when the borrowing constraint binds). Thus, in this setting,

[1] Blanchard and Ostry (2012) make explicit reference to the pecuniary externality perspective when motivating the IMF's view on the use of capital controls: "*If there are external effects from foreign borrowing (think of amplified crisis risks for the country, where the risks are not internalized by the borrower), then capital controls can act as Pigouvian taxes and constitute an optimal response at the country level, helping agents to internalize the external effects of their borrowing*".

[2] Historically, as documented by Magud et al. (2011), capital controls have been adopted for fear of capital flows reversal, fear of excessive risk taking, and to contain asset price bubbles. Other traditional reasons include concerns for competitiveness and monetary policy independence—see more on these below.

[3] See also Lorenzoni (2008), Bianchi and Mendoza (2010), Jeanne and Korinek (2012), Jeanne and Korinek (2013) and Benigno et al. (2013).

[4] The interpretation of the relative price of non-tradables as the real exchange rate is standard in the literature. See for instance Bianchi (2011), Caballero and Lorenzoni (2014), Mendoza et al. (2002), Korinek (2010), and Jeanne (2012). Alternatively, the consumption taxes (subsidies) could be interpreted more literally as domestic fiscal policy tools.

when capital controls are the only policy tool available, the best that the government can do is to reduce the probability that a crisis occurs by inducing the private sector to borrow less than in the decentralized equilibrium.

Next, the paper shows that a policy of supporting the real exchange rate during crisis times by relaxing the borrowing constraint when it binds, can achieve a much higher level of welfare. In fact, such a policy can undo the borrowing constraint completely and, as a result, support an equilibrium in which agents behave as if they were in an unconstrained allocation. Importantly, as we shall see, this policy is time-consistent. The policy can be implemented with a subsidy on non-tradable consumption or a tax on tradable consumption. The result hinges on the ability of the Ramsey planner to manipulate the value of collateral with consumption taxes or subsidies that affect the relative price of non-tradable goods without creating any other distortions. Indeed, since these consumption taxes or subsidies are rebated or financed through lump-sum transfers or taxes, they are costless and do not entail further distortions.

Finally the paper shows that, when lump-sum transfers/taxes are no longer available, price support policies during crisis times become costly, and capital controls in normal times complement exchange rate policy in crises times under the optimal policy mix. When ex-post policies are costless they can be used all the way to remove the borrowing constraint, and there is no need to engage in ex-ante policy interventions such as capital controls. But when the use of ex-post policies entails efficiency losses or costs (such as when there are other policy objectives to be traded off for financial stability), then ex-ante policy interventions like prudential capital controls are called for to maximize welfare. Notice that this rationale for the use of ex-ante policy interventions is not related to the amount that agents borrow in the competitive equilibrium of the economy without government intervention. Under the optimal policy with both instruments, there is more borrowing, fewer and less sever crises, and as a result much higher welfare, with gains of 1.10% of tradable consumption relative to the unregulated economy as compared to only .41% with capital controls alone.

The paper relates to a few other recent contributions in the literature on pecuniary externalities which focused both on ex-ante and ex-post policies. Benigno et al. (2013) analyze the extent to which private agents overborrow or underborrow in a production version of our economy. They show that the allocation chosen by a social planner away from the crisis depends on the planner's ability to mitigate a crisis, should one occur. Benigno et al. (2013) do not analyze any implementation issues or optimal policy problems. Jeanne and Korinek (2013) study the time-consistent mix of ex-ante macroprudential regulation and ex-post bailout transfers in a three-period economy in which the relative price that enters the borrowing constraint is an asset price. The presence of the asset price in the policy problem opens the door to a time-consistency issue, which is their main focus and it is not present in our model. Jeanne and Korinek (2013) also study the role of ex-ante and ex-post policies in their model, but they restrict the set of policy tools along two dimensions: first they restrict the use of distortionary taxation to the contingency in which the constraint binds, while we allow the policy maker to choose freely which instrument to use both in normal and crisis times; and second, they do not consider all the possible tools in the context of their model.

Other new theoretical approaches rationalized the use of capital controls. One approach motivates the use of capital controls with the possibility of manipulating the intra or intertemporal terms of trade—conceptually analogous to the use of tariffs to manipulate the goods' terms of trade (Costinot et al., 2014 and De Paoli and Lipinska, 2013). Schmitt-Grohe and Uribe (2015) examine the role of capital controls in an economy with downward nominal wage rigidity and a fixed exchange rate regime. They focus on competitiveness issues and are silent on the financial stability motive we focus on. Farhi and Werning (2012) study capital controls as a way to address the impossibility to simultaneously have an open capital account, a fixed exchange regime, and an independent monetary policy (as known as the "impossible trilemma"). Likewise, Devereux and Yetman (2014) analyze capital controls as a way to restore monetary policy effectiveness when the nominal interest rate reaches the zero lower bound in a global liquidity trap context.

Other approaches have focused on the role of capital controls when there are multiple distortions or objectives. For instance, Brunnermeier and Sannikov (2015) show that restrictions to capital flows can be welfare improving in an economy with multiple goods, incomplete financial markets, and inefficient production, but do not discuss issues of optimal mix between ex-ante and ex-post interventions. Ottonello (2015) studies optimal exchange rate policy with downward nominal wage rigidity, flexible exchange rates, and a borrowing constraint like the one in our model. His analysis focuses on a restricted set of instruments similar to Jeanne and Korinek (2013) and discusses the trade-offs that exchange rate policy faces between competitiveness and financial stability considerations.

More broadly, our paper shares the emphasis on price support policies that limit the depreciation of the real exchange rate during crisis times with the work of Cespedes et al. (2012). They examine the role of other unconventional policy tools such as credit policies and direct interventions in the foreign exchange market, but they do not compute optimal policy and focus on the transmission mechanism of alternative policy tools.[5] In a different framework, Martin and Ventura (2014) also suggest policies that relax the collateral constraint by properly managing the size of "bubbles". More generally, our study of alternative policy tools is related to the work by Correia et al. (2008) in which the role of price stickiness for the design of monetary policy depends on the existence of alternative fiscal policy tools. Finally, in terms of the solution techniques, we apply the same algorithm proposed by Benigno et al. (2012) to solve numerically for the Markov Perfect optimal policy problem in the context of a production version of our economy in which a time-consistency issue arises.

[5] In an optimizing neoclassical framework without credit frictions, Calvo et al. (1995) also analyze the role of real exchange rate targeting as a stabilization policy tool.

The rest of the paper is organized as follows. Section 2 describes the model environment, the scope for government intervention, and the alternative government instruments that we consider. Section 3 studies optimal capital control policy. Section 4 analyzes optimal real exchange rate policy. Section 5 considers the joint use of capital controls and real exchange rate policies when lump-sum transfers/taxes are not available, as well as some robustness exercises. Section 6 relates the main results of the paper to countries's experience with capital controls and price support policies over the past 20 years or so. Section 7 concludes. The numerical solution methods we use as well as other technical material including proofs and extensions are reported in an appendix for online publication, together with the computer code for the implementation of the analysis in the paper (available at the following link: www.people.virginia.edu/~ey2d/capcontrol.zip).

2. The model environment

This section describes our model economy and discusses its key assumptions. It then characterizes the competitive equilibrium of the model. Next it identifies the externality that gives rise to scope for government intervention. And finally, it discusses the alternative government policy instruments analyzed in the rest of the paper.

Consider a small open economy in which there is a continuum of households $j \in [0,1]$ that maximize the utility function

$$U^j \equiv E_0 \sum_{t=0}^{\infty} \left\{ \beta^t u\left(C_t^j\right) \right\}, \tag{1}$$

where C_t^j is the consumption basket for an individual j at time t, and is β the subjective discount factor. E_0 denotes the conditional expectation at time 0. Assume that the period utility function is isoelastic:

$$u\left(C_t^j\right) \equiv \frac{1}{1-\rho}\left(C_t^j\right)^{1-\rho}.$$

The consumption basket, C_t, is a CES aggregate of tradable and non-tradable goods (omitting the subscript j to simplify notation):

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

The parameter κ is the elasticity of intratemporal substitution between consumption of tradable and non-tradable goods, while ω is the relative weight of the two goods in the utility function.

Normalizing the price of tradable goods to 1 and denoting the relative price of the non-tradable goods with P^N, the aggregate price index is given by

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

Note here 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 (expressed in units of tradable consumption) and a borrowing constraint. The asset menu includes only a one-period bond denominated in units of tradable consumption. Each household has two stochastic endowment streams of tradable and non-tradable output, $\{Y_t^T\}$ and $\{Y_t^N\}$. For simplicity, assume that both $\{Y_t^T\}$ and $\{Y_t^N\}$ are Markov processes with finite, strictly positive support. Therefore the current state of the economy can be completely characterized by the triplet $\{B_t, Y_t^T, Y_t^N\}$. Thus, the budget constraint each household faces is

$$C_t^T + P_t^N C_t^N + B_{t+1} = Y_t^T + P_t^N Y_t^N + (1+r)B_t, \tag{3}$$

where B_{t+1} denotes the bond holding at the end of period t, and $(1+r\ )$ is the given world gross interest rate.

Access to international financial markets is not only incomplete but also imperfect in the sense that, by assumption, the amount that each individual can borrow is limited by a multiple of his current total income:

$$B_{t+1} \geq -\frac{1-\phi}{\phi}\left[Y_t^T + P_t^N Y_t^N\right]. \tag{4}$$

One justification of (4) is in terms of liquidity constraints. By this interpretation, lenders require households to finance a fraction ϕ of their current expenses—which include consumption, debt repayments and taxes—out of current income (see Mendoza et al., 2002 for this interpretation):

$$\phi\left(Y_t^T + P_t^N Y_t^N\right) \geq C_t^T + P_t^N C_t^N - (1+r)B_t. \tag{5}$$

In fact, by combining (5) with (3) we obtain (4). Another justification of (4) appeals to an environment in which the borrower engages in fraudulent activities during the period in which the debt is contracted and prevents creditors from seizing any future income—see Bianchi (2011) for this interpretation. Note here that (5) depends on pre-tax income rather than post-tax income. So, in an environment with default, the individual who defaults is left with her/his full tax-obligation.[6]

At the empirical level, as Mendoza et al. (2002) and Bianchi (2011) emphasize, a specification in terms of current income is consistent with evidence on the determinants of access to credit markets, on lending criteria and guidelines used in mortgage and consumer financing (e.g. Jappelli, 1990; Jappelli and Pagano, 1989). The assumption that non-tradable goods can be pledged as collateral is consistent with the evidence reported by Tornell and Westermann (2005) on the use of international credit to finance booms in the non-tradable sector.

The key feature of (4) is that it captures currency mismatches in the balance sheet of the economy—see Krugman (1999). In fact borrowing is denominated in units of tradable consumption, while both the tradable and the non-tradable endowment can be pledged as collateral. Indeed, currency mismatches have been one of the main vulnerability of emerging market economies in the numerous financial crises of the 1990s and the 2000s and continued to be a crucial policy challenge in the post global financial crisis period—see for instance Cespedes et al. (2004), Cespedes et al. (2012), Shin (2013), and Acharya et al. (2015) for a discussion.

From a model perspective, a financial crisis occurs when the constraint binds and the model dynamic changes nonlinearly; an event that is endogenous in the model. Yet the long-run business cycle properties of the economy are only marginally affected by the crises events (Mendoza et al., 2002; Mendoza, 2010). A unique feature of this model environment, therefore, is to nest endogenous financial crisis dynamics triggered by small exogenous disturbances within regular business cycles.

In our small open economy, the motive for borrowing arises from the assumption that $\beta(1+r)<1$ so that agents are impatient compared to foreign lenders. However, we also assume that there is a lower bound on debt strictly greater than the natural debt limit, $\underline{B}>B^n$, such that $B_t \geq \underline{B}$, for all t.[7] This lower bound guarantees that the competitive equilibrium of the economy without government intervention and without the international borrowing constraint (4) is well defined. In particular, it guarantees that there is an ergodic distribution of debt with finite support, and both tradable and non-tradable consumption have a strictly positive lower bound, while the non-tradable price also has finite support with strictly positive lower bound. In order to focus on non-trivial policies, the assumption that the competitive equilibrium allocation always violates the borrowing constraint (4) is also necessary, when $B_t=\underline{B}$, given Y_t^T and Y_t^N.[8]

Note finally that, as the online appendix discusses, our calibration, and in particular the assumption that tradable and non-tradable goods are complement ($\kappa<1$), rules out the possibility of multiple equilibria.

2.1. Competitive equilibrium

The online appendix provides a full characterization of the competitive equilibrium of the economy with the borrowing constraint and no government intervention. In this equilibrium, households maximize (1) subject to (3) and (4) by choosing C_t^N, C_t^T and B_{t+1}. The intratemporal allocation between tradeable and non-tradeable goods is given by

$$\left(\frac{(1-\omega)C_t^T}{\omega\left(C_t^N\right)}\right)^{\frac{1}{\kappa}}=P_t^N. \tag{6}$$

Goods market clearing for tradeable goods yields

$$C_t^T=Y_t^T-B_{t+1}+(1+r)B_t, \tag{7}$$

while for non-tradeable goods it is:

$$C_t^N=Y_t^N. \tag{8}$$

The quantitative properties of this equilibrium are well known (see Mendoza et al., 2002; Bianchi, 2011). Here, it is important to point only out that, as Bianchi (2011) illustrated, this very same model can account well for key business cycles statistics as well as the incidence and severity of financial crises in a typical emerging market economy like Argentina. Throughout the paper, therefore, whenever numerical methods are employed, for illustrative purposes, all parameter values of the model are set exactly like in Bianchi (2011)—and a summary table is reported in the online appendix.

2.1.1. Unconstrained equilibrium

As shown later, two of the government policy instruments that we consider, when used optimally, can completely remove the effects of the constraint (4) and achieve an allocation that is identical to the competitive equilibrium of the model without the borrowing constraint (4). In what follows this allocation is referred to as the "unconstrained equilibrium" (UE) and it is characterized in the online appendix.[9]

[6] See Section 5 for a discussion of what happens when households can default on their tax obligation as well, and the borrowing constraint depends on post-tax income.

[7] If C^T and C^N are strong substitutes, this constraint may bind; since the evidence is that C^T and C^N are complements, this possibility is remote.

[8] This restriction amounts to a lower bound on ϕ.

[9] The existence of a lower bound on debt which is strictly greater than the natural debt limit guarantees that the competitive allocation without borrowing constraint has an ergodic distribution of debt with finite support under the assumption that $\beta(1+r)<1$.

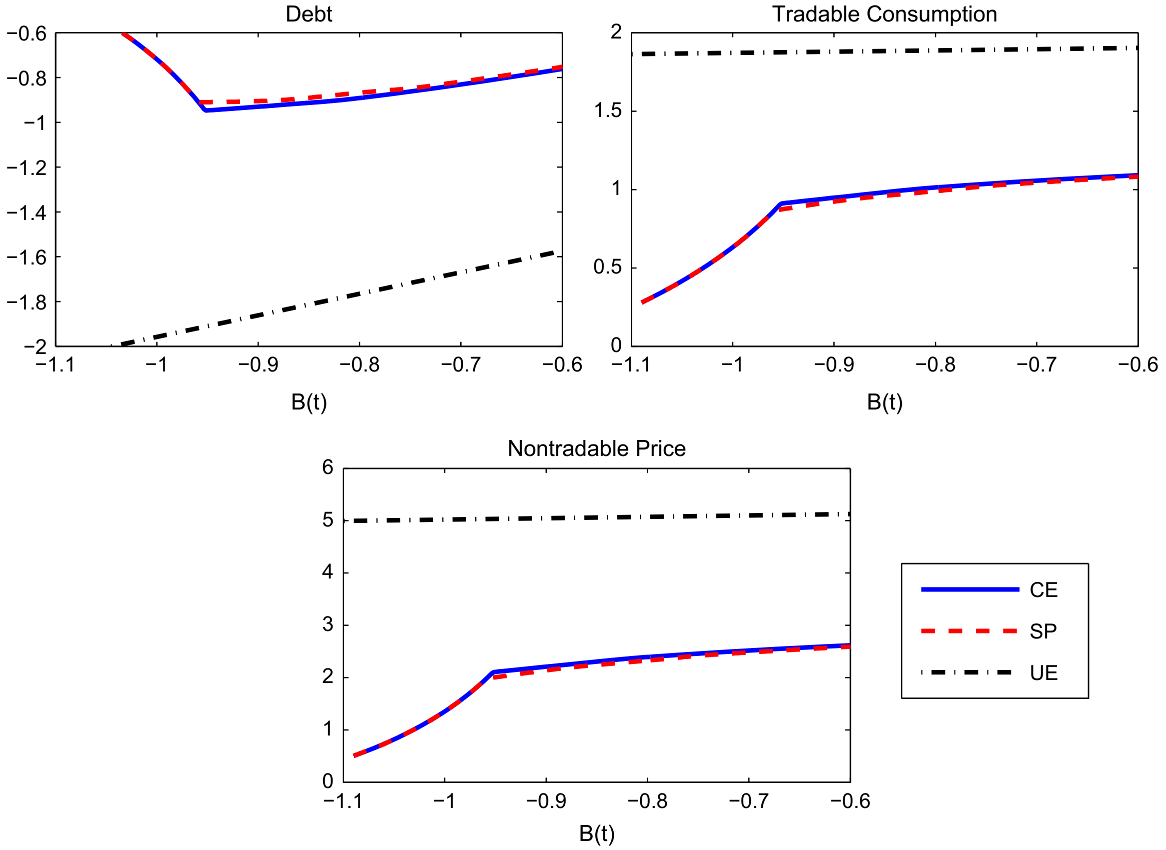

Fig. 1. Alternative allocations: decision rules. *Notes*: CE denotes the competitive equilibrium allocation; SP the social planner allocation; UE the unconstrained equilibrium. The figure plots the equilibrium decision rules or policy functions of the endogenous variables conditional on one-standard deviation shocks. Borrowing decreases from left to right on the *x*-axis.

In the deterministic steady state of the model, since agents are impatient, the allocation will tend to converge towards the natural debt limit.[10] In our stochastic economy, agents engage in precautionary saving so that the probability of hitting the natural debt limit is zero.

Also note that the unconstrained equilibrium characterizes an allocation in which financial markets are incomplete so that there are inefficient variations in consumption due to the lack of state contingent debt. For completeness, the online appendix describes the first best allocation in which agents in the small open economy have access to state contingent securities and compare it with the unconstrained allocation.

2.2. *Pecuniary externality*

In order to understand the rationale for policy intervention in our model, we first follow the recent literature—e.g., Lorenzoni (2008); Korinek (2010) and Bianchi (2011)—and focus on a benevolent social planner problem with restricted planning abilities. The rest of the paper then focuses on Ramsey optimal policy. In particular, start by assuming that the social planner can directly choose the level of debt subject to the credit constraint while allowing goods markets to clear competitively. Unlike the representative agent in the competitive equilibrium of the model, the social planner internalizes the effects of his/her borrowing decisions on the equilibrium relative price of non-tradables. This is relevant in our set up because, when the constraint binds, the agents' borrowing capacity depends on the value of the collateral, which in turn is determined endogenously by the equilibrium relative price of non-tradables.

2.2.1. *Social planning problem*

Specifically, the social planner maximizes (1) subject to the same borrowing constraint (4) that private agents face and the market clearing conditions for tradables and non-tradable goods (7) and (8). In specifying this problem, the equilibrium

[10] In our model, this level equals (minus) the annuity value of the lowest tradable endowment value.

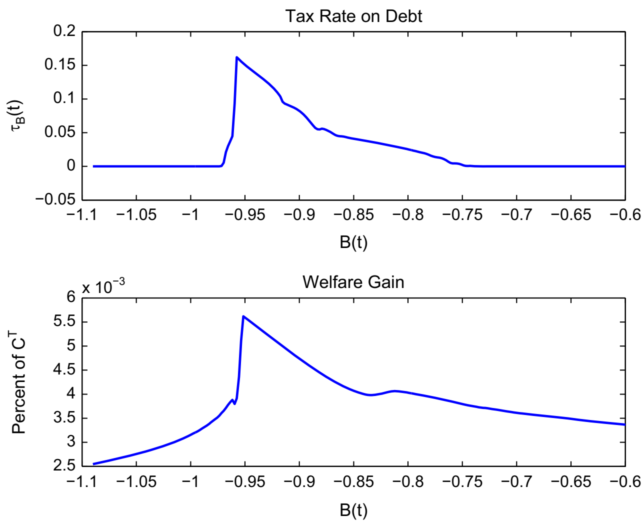

Fig. 2. Optimal capital control policy. *Notes*: The figure plots the optimal debt tax rate and the associated welfare gain relative to the competitive equilibrium conditional on one-standard deviation shocks. Borrowing decreases from left to right on the *x*-axis.

price of non-tradables is determined competitively according to the pricing rule (6). This condition also serves as a constraint on the planning problem to eliminate P_t^N from the borrowing constraint.[11]

Fig. 1 illustrates graphically the consequences of the presence of the borrowing constraint by comparing the policy functions of the endogenous variables (C_t^T, B_{t+1}, P_t^N) for a negative one-standard deviation shock.[12] Consider the three allocations we defined above: the competitive equilibrium (CE) with borrowing constraint, the social planner (SP) problem and the unconstrained equilibrium (UE).[13]

Fig. 1 shows the difference between the policy functions of the constrained (CE and SP) on the one hand and the unconstrained (UE) equilibrium allocations on the other. In particular, the UE allocation features a much higher level of tradable consumption and debt, as well as a higher relative price of non-tradable goods, compared to the CE and SP allocations. In the absence of the borrowing constraint, agents can borrow freely from international capital markets to smooth consumption for any given stock of existing debt. In contrast, the CE and SP allocations are relatively close: they diverge only slightly in the region in which the constraint is not binding, but it is expected to bind in the future; otherwise they coincide exactly, including particularly in the region in which the constraint binds.

In the CE and the SP allocations, in the region in which the constraint binds (i.e., when there is a financial crisis in our model), both consumption of tradables and the relative price of non-tradables fall sharply.[14] This decline is the consequence of the so-called "Fisherian deflation" or fire sale mechanism emphasized in the financial crisis literature. When borrowing is constrained, consumption is lower relative to the desired amount in the unconstrained equilibrium. Lower tradable consumption is accompanied by a decline in relative price of non-tradables, which in turn reduces the value of collateral, tightening borrowing capacity and reducing tradable consumption further, a feedback loop that results in an even lower relative price of non-tradables and tradable consumption.

As emphasized by Lorenzoni (2008), Korinek (2010) and Bianchi (2011), when the constraint does not bind (i.e. in normal times), but it is expected to bind in the future with some positive probability, agents in the competitive equilibrium consume more than in the social planner allocation. As the appendix shows, this difference arises because individual agents do not take into account the additional benefit of reducing consumption today, which in turn represents the marginal benefit of consuming more when the constraint binds in the future.

Note however that, in this endowment economy, for a given state $\left\{B_t, Y_t^N, Y_t^T\right\}$ in which the constraint binds, the CE and the SP allocations coincide. For a given amount of existing debt, tradable consumption will be the same in the two allocations since it is constrained by the borrowing limit. The equilibrium relative price of non-tradables is also equalized, since the consumption of non-tradables is pinned down by its endowment.[15]

[11] This formulation is usually referred to as "constrained-efficient" planning problem in the literature. A second possibility, sometimes referred to as the "conditionally-efficient" problem, is to determine this relative price by imposing as a constraint on the problem the competitive equilibrium *policy function* (in our case $P_t^N = f^{CE}(B_t, Y_t^N, Y_t^T)$). In our endowment economy, however, these two definitions give exactly the same result and do not affect the normative analysis. See Kehoe and Levine (1993) and Lorenzoni (2008) for more details and a discussion.

[12] A policy function is the nonlinear equilibrium relation between the endogenous variables of the model and its exogenous and endogenous states (in our case, the triplet $\left(\left\{B_t, Y_t^N, Y_t^T\right\}\right)$.

[13] Complete solutions for these allocations have to be computed numerically with the global solution methods that the online appendix describes.

[14] In the figure, the binding region starts in correspondence to the kink in the policy functions.

[15] Recall that the relative price of non-tradables is proportional to the ratio of tradable over non-tradable consumption.

Table 1
Ergodic averages.

	Debt to income (%)	Prob. of crisis (%)	Welfare gain (%)
CE	−29.2	6.7	NA
SP	−28.4	1.2	0.41
UE	NA	0.0	33.8
OP	−30.5	4.9	1.10

Notes: CE denotes the competitive equilibrium allocation; SP the social planner allocation; UE the unconstrained equilibrium; OP the optimal policy equilibrium with both debt tax and non-tradable consumption tax. The table reports ergodic means (in percent). Welfare gains are relative to the CE and are measured in unit of tradable consumption.

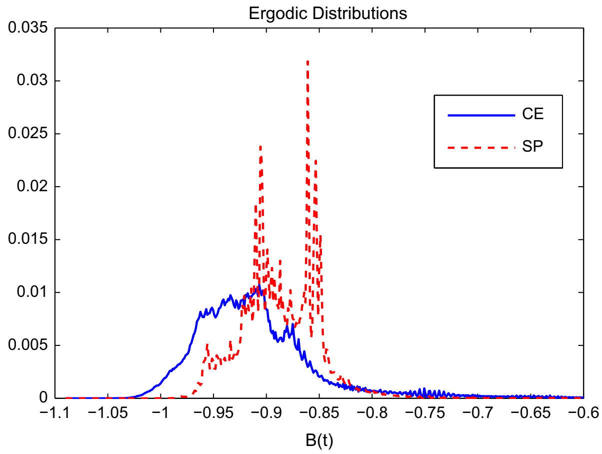

Fig. 3. Optimal capital control policy. *Notes*: The figure plots the ergodic distribution of debt in units of tradable consumption in the competitive equilibrium (CE) and the social planner allocations (SP). Borrowing decreases from left to right on the *x*-axis.

2.3. Alternative policy instruments

While there is a well defined scope for government intervention, in this economy, there is a variety of instruments or tools with which policy could be conducted. In fact, there are at least three types of taxes that can be used: a tax/subsidy on debt, a tax/subsidy on tradable consumption and a tax/subsidy on non-tradable consumption. Our policy analysis considers all of them, studying their relative effectiveness in welfare terms if used one at the time as well as their joint use.[16]

The policy analysis is conducted as a Ramsey optimal taxation exercise, assuming that the government budget is always balanced. Thus, for given policy instrument(s), the Ramsey planner maximizes the representative household's utility function, subject to the resources constraints and the first order conditions of its maximization problem.

Tax on debt: The first policy tool that we examine is a tax τ_t^B (<0) or a subsidy (>0) on one-period debt issued at time t, B_{t+1}. This instrument is usually referred to as a capital control.[17] With lump-sum transfers/taxation, the government budget constraint is:

$$T_t = \tau_t^B B_{t+1}, \tag{9}$$

where T_t denotes the lump sum transfer or tax. In this case, the household's budget constraint in the competitive equilibrium of the model becomes

$$C_t^T + P_t^N C_t^N = Y_t^T + P_t^N Y_t^N + T_t - B_{t+1}\left(1+\tau_t^B\right) + (1+r)B_t, \tag{10}$$

while the liquidity constraint becomes

$$\phi\left(Y_t^T + P_t^N Y_t^N\right) \geq C_t^T + P_t^N C_t^N - (1+r)B_t + T_t. \tag{11}$$

Combining these three constraints gives rise to the same international borrowing constraint as before, so that access to international financial market continues to be constrained by (4).

[16] Note that any given allocation could possibly be implemented by different tax instruments. This indeterminacy in the tax instruments depends on the fact that there are two decision margins but we are considering three possible policy tools—see also Costinot et al. (2014) on this.

[17] One of the best known cases of a use of such a tool is the Brazilian IOF tax. See Pereira and Harris (2012) for a detailed account of this actively researched country case.

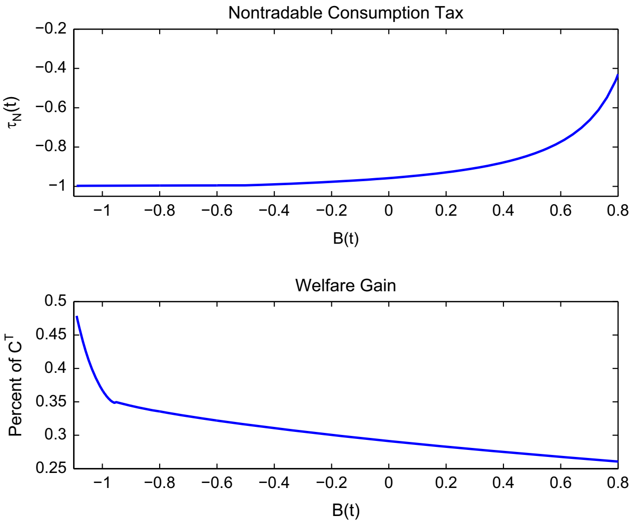

Fig. 4. Optimal exchange rate policy. *Notes*: The figure plots the optimal non-tradable consumption tax rate and the associated welfare gain relative to the competitive equilibrium conditional on one-standard deviation shocks. Borrowing decreases from left to right on the *x*-axis.

Taxes on consumption: The other two policy tools are consumption taxes on non-tradable and on tradable goods. Both policy tools influence directly Eq. (6) and affect the relative price of non-tradable goods, P_t^N, which in the context of our economy is a proxy for the real exchange rate—see for example Mendoza et al. (2002), Caballero and Lorenzoni (2014), Korinek (2010), Bianchi (2011), Jeanne (2012), and Schmitt-Grohe and Uribe (2015) for the same interpretation. For this reason, in what follows, these two tools are referred to as "real exchange rate policy" or "exchange rate policy" for brevity. Alternatively these taxes can be also interpreted as fiscal devaluation/revaluation when monetary policy tools are not available (i.e. in a fixed exchange rate regime or in a currency union).

With a tax on non-tradable consumption, $(1+\tau_t^N)$, the household's budget constraint becomes

$$C_t^T + P_t^N\left(1+\tau_t^N\right)C_t^N = Y_t^T + P_t^N Y_t^N + T_t - B_{t+1} + (1+r)B_t, \tag{12}$$

where $\tau_t^N > (<)0$ is now a tax (or a subsidy) on non-tradable consumption and $T_t > (<)0$ is a government lump-sum transfer (or tax). As in the case of capital controls, the government budget balances period by period:

$$T_t = \tau_t^N P_t^N C_t^N. \tag{13}$$

In this case, the liquidity constraint becomes

$$\phi\left(Y_t^T + P_t^N Y_t^N\right) \geq C_t^T + \left(1+\tau_t^N\right)P_t^N C_t^N - (1+r)B_t + T_t, \tag{14}$$

which combined with the individual and the government budget constraints above determines the same international borrowing constraint as before (4).

With a tax on tradable consumption, $(1+\tau_t^T)$, the household now faces the following budget constraint:

$$\left(1+\tau_t^T\right)C_t^T + P_t^T C_t^N = Y_t^T + P_t^N Y_t^N + T_t - B_{t+1} + (1+r)B_t. \tag{15}$$

The government budget constraint continues to balance period by period:

$$T_t = \tau_t^T C_t^T, \tag{16}$$

and the borrowing constraint remains as in (4).

3. Optimal capital controls

This section studies the optimal Ramsey problem when the policy tool is τ_t^B. The Ramsey problem for τ_t^B is to choose a competitive equilibrium that maximizes (1). More formally:

Definition 1. For a given $\{B_0\}$ and assuming that $\{Y_t^T\}$ and $\{Y_t^N\}$ are Markov processes with finite, strictly positive support, the Ramsey problem for τ_t^B is to choose a competitive equilibrium that maximizes

$$U^j \equiv E_0 \sum_{t=0}^{\infty} \left\{\beta^t u(C_t)\right\},$$

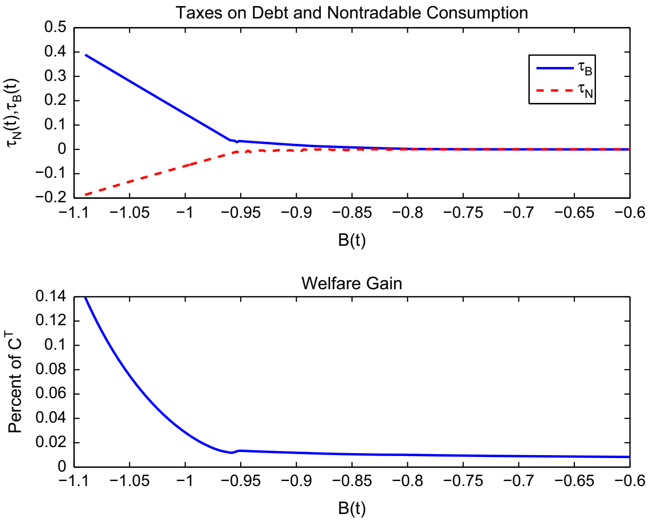

Fig. 5. Optimal capital control and exchange rate policy. *Notes*: The figure plots the optimal debt and non-tradable consumption tax rates and the associated welfare gain relative to the competitive equilibrium, conditional on one-standard deviation shocks. Borrowing decreases from left to right on the *x*-axis.

subject to the resource constraints (7) and (8), the government budget constraint (9), the borrowing constraint

$$B_{t+1} \geq -\frac{1-\phi}{\phi}\left[Y_t^T + P_t^N Y_t^N\right], \tag{17}$$

and the first order conditions of the household,

$$u'(C_t)C_{C^T}(1+\tau^B) = \lambda_t + \beta(1+r)E_t\left[u'(C_{t+1})C_{C^T}\right], \tag{18}$$

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

The following proposition that qualifies the main result of Bianchi (2011) can now be stated:

Proposition 1. *In an economy defined by (1), (4), (12) and (9) with a tax on τ_t^B as the government instrument, the Ramsey optimal policy with τ^Bas instrument replicates the social planner allocation (SP). Moreover the optimal policy is time-consistent.*

Proof. See online appendix.

A few remarks are in order here. As discussed by Bianchi (2011) and noted in the previous section, when the constraint binds (i.e. $\lambda_t^{SP} > 0$), the social planner allocation coincides with the competitive equilibrium allocation, and therefore it is optimal to set $\tau_t^B = 0$. When the constraint does not bind, but can bind with positive probability in the next period (i.e. $\lambda_t^{SP} = 0$, but $E_t[\lambda_{t+1}^{SP}\Sigma_{t+1}^{SP}] > 0$ in Eq. (44) in the online appendix), the optimal state contingent τ_t^B is a tax on borrowing ($\tau_t^B < 0$). Thus, it is optimal to engage in a policy intervention even when the constraint does not bind but might bind in the future. In this sense the optimal policy is "prudential" or "precautionary" in nature. Intuitively, since τ_t^B is impotent during the crisis, the best thing that policy can do, conditional on having only the tax on debt as instrument, is to reduce the probability that a crisis occurs by limiting the amount that agents borrow in equilibrium (i.e. by taxing B_{t+1}). Note also that, in the region in which the constraint binds ($\lambda_t > 0$), any value of τ_t^B can implement the social planner allocation.[18]

Fig. 2 plots the policy function of τ_t^B, for a negative one-standard deviation shock, that solves the optimal policy problem above and replicates the SP allocation, as well as the welfare gains for τ_t^B as a function of current bond holdings. Fig. 3 reports the ergodic distributions of debt in the CE and the SP allocations. Table 1 reports the ergodic mean of debt as a share of (annual) income in units of tradable consumption, the unconditional probability of a financial crisis in the model, as well as the average welfare gain associated with this policy instrument relative to the CE.[19]

[18] This is true as long as τ^B is less than $\overline{\tau}^B$, i.e. the maximum value of the tax rate consistent with the constraint being binding.
[19] See the appendix on the solution method for the SP allocation and the computation of the welfare gains.

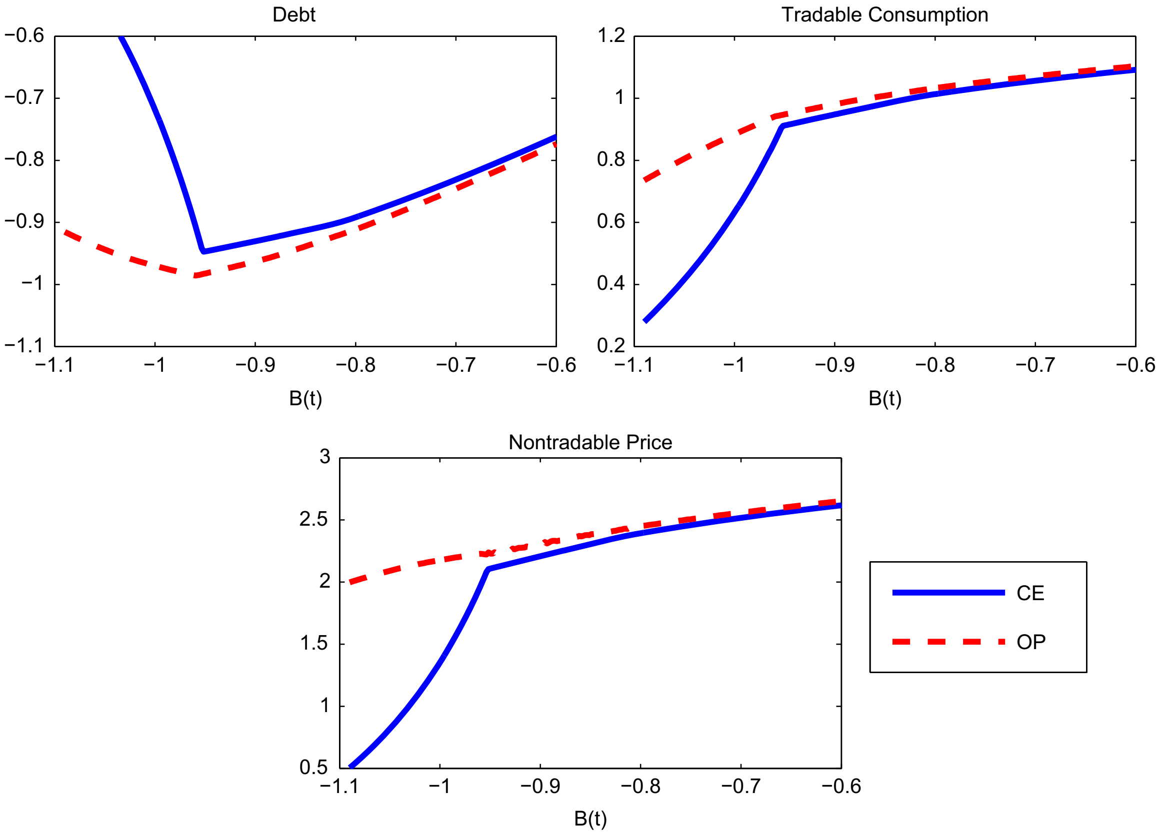

Fig. 6. Optimal capital control and exchange rate policy: decision rules. *Notes*: CE denotes the competitive equilibrium allocation; OP the optimal policy equilibrium with both debt tax and non-tradable consumption tax. The figure plots the equilibrium decision rules of the endogenous variables plotted conditional on one-standard deviation shocks. Borrowing decreases from left to right on the *x*-axis.

When the economy approaches the binding region, the tax rate goes to zero; before the crisis hits, the higher is the probability that the constraint binds, the higher is the tax on borrowing. Looking at the welfare gains it is evident that they also peak when the constraint binds, but revert to zero slower than the tax rate. The welfare gains of optimal capital controls persist past the level of debt at which the constraint binds because entering a crisis with less debt makes the crisis relatively less costly (see Fig. 8 and its discussion on this latter point). As Fig. 3 and Table 1 illustrate, the policy intervention reduces the debt/income ratio and the likelihood of a financial crisis. This implies that the economy, on average, will borrow less under the optimal capital control policy than in the competitive equilibrium, but will experience fewer and less severe financial crises (Table 1 and Fig. 8).

4. Optimal exchange rate policy

Let us now focus on use of consumption taxes financed with lump-sum taxation discussed above. Specifically, consider first the non-tradable consumption tax, as the online appendix shows that the tax on tradable consumption can achieve the same results when used optimally. We refer to this policy tool as “costless exchange rate policy” because it can be implemented without incurring in any efficiency cost associated with its financing. Section 5 discusses the case of distortionary financing.

4.1. Non-tradable tax

Like before, define first the Ramsey problem when τ_t^N is the policy instrument.

Definition 2. For a given $\{B_0\}$ and assuming that $\{Y_t^T\}$ and $\{Y_t^N\}$ are Markov processes with finite, strictly positive support, the Ramsey problem for τ_t^N as instrument is to choose a competitive equilibrium that maximizes

$$U^j \equiv E_0 \sum_{t=0}^{\infty} \left\{ \beta^t u(C_j) \right\},$$

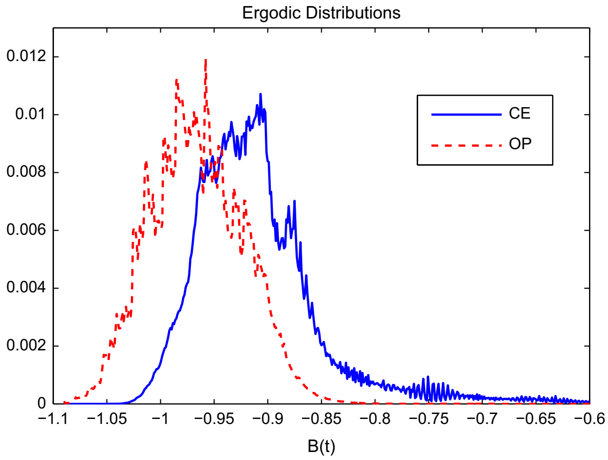

Fig. 7. Optimal capital control and exchange rate policy. *Notes*: The figure plots the ergodic distribution of debt in units of tradable consumption in the competitive equilibrium (CE) and the optimal policy equilibrium with both debt tax and non-tradable consumption tax (OP). Borrowing decreases from left to right on the *x*-axis.

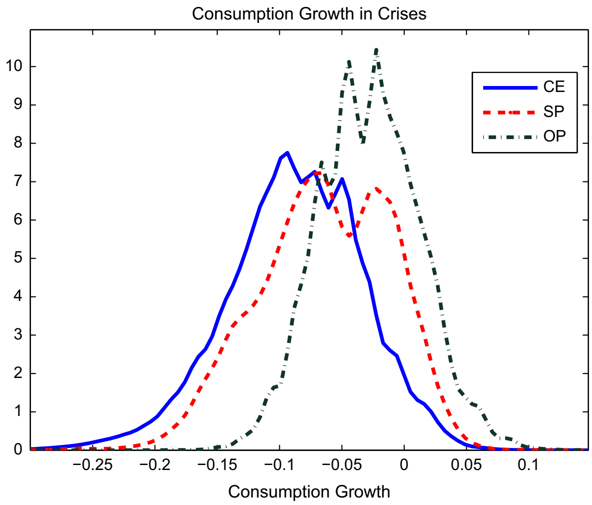

Fig. 8. Comparing Policy Regimes. Notes: CE denotes the competitive equilibrium allocation; SP the social planner allocation; OP the optimal policy equilibrium with both debt tax and non-tradable consumption tax. The figure plots the ergodic distribution of consumption growth in the period after the constraint was binding. Borrowing decreases from left to right on the *x*-axis.

subject to the resource constraints (7) and (8), the government budget constraint (13), the borrowing constraint

$$B_{t+1} \geq -\frac{1-\phi}{\phi}\left[Y_t^T + P_t^N Y_t^N\right]. \tag{20}$$

and the first order conditions of the household

$$u'(C_t)C_{C^T} = \lambda_t + \beta(1+r)E_t\left[u'(C_{t+1})C_{C^T}\right], \tag{21}$$

$$\frac{(1-\omega)^{\frac{1}{\kappa}}\left(C_t^N\right)^{-\frac{1}{\kappa}}}{\omega^{\frac{1}{\kappa}}\left(C_t^T\right)^{-\frac{1}{\kappa}}} = P_t^N\left(1+\tau_t^N\right). \tag{22}$$

It is important to point out that the non-tradable consumption tax directly affects the relative price of non-tradables (i.e. the real exchange rate). Note also that, in normal times and in the unconstrained equilibrium, the determination of the consumption of tradable and non-tradable goods is independent from P_t^N. Therefore, τ_t^N is neutral when the constraint does not bind. In fact, the Euler equation and the goods market equilibrium conditions are all that is needed to determine consumption of tradables and non-tradables when the constraint does not bind. In contrast, when the constraint binds, τ_t^N is no longer neutral because changes in P_t^N affect the value of the collateral, and hence the consumption of tradable goods.

The next proposition says that, when used optimally, this policy instrument can achieve the unconstrained allocation (i.e., it assures that the borrowing constraint is never strictly binding in the equilibrium of our economy so that $\lambda_t = 0$ for all t). To characterize the solution of this Ramsey problem, one can follow the same two steps of the previous proposition. Thus, first characterize a policy rule for τ_t^N that decentralizes the unconstrained competitive equilibrium. Then show that this equilibrium is the one that solves the Ramsey problem above.

Proposition 2. *In an economy defined by (1), (4), (12) and (13) with a tax on non-tradable consumption τ_t^N as the government instrument, there exists a policy for τ_t^N that decentralizes the unconstrained allocation. This policy is Ramsey optimal and time-consistent.*

Proof. See online appendix.

Several remarks are also in order here. The proposition above implies that exchange rate policy always dominates capital control policy in welfare terms. Under this policy, it is possible to undo the constraint completely and replicate the unconstrained equilibrium. In contrast, capital controls can only limit (by reducing the probability of hitting the constraint) the distortionary effects of the pecuniary externality associated with the constraint, but not the constraint itself. As we can see from Table 1, these welfare differences can be quantitatively very large.

How does exchange rate policy work? The intuition for the result is that (22) directly links the tax rate to the relative price of non-tradables. When the borrowing constraint does not bind, the policy tool is neutral in the sense that it affects P_t^N, but not the consumption allocation. In contrast, when the constraint binds, the tax is no longer neutral and can be used to affect the value of collateral in the borrowing constraint, and hence also tradable consumption. By subsidizing the consumption of non-tradable goods, the policy increases its relative price. Crucially, when the constraint binds, a higher relative price increases the value of collateral and avoids the debt-deflation mechanism that would otherwise ensue.[20]

In equilibrium, agents anticipate that this policy will undo the constraint when it binds and will behave as if the constraint does not exist (i.e. like in the unconstrained allocation). As we can see from Fig. 1, for a given endowment of non-tradable goods, the unconstrained allocation (UE) entails a much higher price of non-tradables and consumption of tradable goods during tranquil times than in the two constrained allocations (the CE and SP). Eventually (i.e. in finite time) our economy will hit the borrowing constraint because agents are relatively impatient. When that happens, under the optimal policy, τ^N will be set so that the multiplier on the constraint is zero (i.e. the constraint is just binding).

Notice here that the policy function for τ^N is time-consistent, and hence promising to eliminate the borrowing constraint by supporting the relative price of non-tradable whenever the constraint binds is fully credible in equilibrium.

This optimal policy can also be implemented with a fixed tax rate. Since any policy schedule $\tau_t^N \in (-1, \hat{\tau}_t^N]$ can achieve the unconstrained allocation, for any $\hat{\tau}_t^N$ that undoes the borrowing constraint, there also exists a fixed subsidy $\tau_{fix}^N \in (-1, \hat{\tau}_t^N]$ that replicates such allocation. This consideration is important because it simplifies the practical implementation of the policy. Indeed, for a given exogenous state $\{Y_t^T, Y_t^N\}$ with finite support, it is possible to determine the corresponding fixed subsidy for which the constraint does not bind. The fixed level of τ_{fix}^N will be such that $\tau_{fix}^N \in (-1, \hat{\tau}_{t,\min}^N]$, where $\hat{\tau}_{t,\min}^N$ is the lowest value of the subsidy given the finite support of the exogenous states.

Welfare gains from this policy tool are two orders of magnitude higher than the gains from implementing the SP allocations in Table 1. Fig. 4 plots the implied optimal τ^N as a function of current debt position and the associated welfare gains for a negative one-standard deviation shock. The implied subsidy and the welfare gains associated with it increase with the level of debt. As Fig. 4 illustrates, this optimal policy subsidizes non-tradable consumption, limiting the downward pressure on the relative price of non-tradable goods. As a result, agents can borrow and consume much more in both good and bad times. In this case, however, the probability of a crisis is zero, despite the fact that borrowing and consumption are much higher than in the CE or the SP (Table 1).

Note here that, for our calibration (which is the same as in Bianchi (2011)), agents are very impatient and the incentive to borrow dominates the precautionary motive that tends to contain their borrowing. The relative strength of this "impatience" effect implies that even when the initial net foreign assets position is positive, agents will borrow up to the borrowing limit, so that a tax subsidy on non-tradable consumption is needed to relax the credit constraint. As the current debt position worsens, the state contingent tax subsidy becomes bigger, tending towards the lower bound of -1.

To quantify what a more realistic policy can achieve in welfare terms, consider the case of a fix, 10 percent non-tradable subsidy. Such intervention yields an average relative price of on non-tradables that is approximately 10 percent less depreciated than in the competitive equilibrium, with an average welfare gain of 0.4 percent of permanent consumption. This is about the same as the gain attained with the optimal capital control policy, which nonetheless is a state contingent tax schedule (Table 1).

[20] For this reason, in broader terms, we can interpret this policy also as a collateral price support policy, aimed at putting a floor under asset price valuations during a financial crisis. In the specific case of our model, it takes the form of a fiscal intervention aimed at supporting the relative price of non-tradeable that enters the borrowing constraint.

4.2. Tradable tax

This section highlights the differences between the working of the tax on non-tradable and the one on tradable consumption, as the appendix shows that they achieve the same allocation and welfare gains.

The tax on tradable consumption τ_t^T affects not only the intratemporal relative price, but also the intertemporal allocation of resources through the Euler equation. Despite this difference, it is possible to find a policy for τ_t^T that replicates the unconstrained allocation, like in the case of the non-tradable consumption tax τ_t^N. The difference between the two policies is that the subsidy on non-tradable consumption requires financing through lump sum taxes, while the revenues from the tax on tradables will be rebated as lump sum transfers to private agents. From a practical standpoint, this is important though, as fiscal space is typically limited in the midst of a financial crisis.

Indeed, both policy tools (τ_t^T and τ_t^N) could be interpreted more strictly in terms of fiscal policy actions or more broadly as policy aimed at targeting the real exchange rate. In a way, the latter interpretation is related to the recent literature that proposes to manipulate the real exchange rate through the use of fiscal tools—see for instance Lipinska and Von Thadden (2009), Franco (2011) and Farhi et al. (2013). The difference is that here we want to limit the depreciation of the real exchange rate for financial stability purposes, while in the literature on fiscal devaluation the idea is to engineer a devaluation to gain competitiveness.

5. Optimal capital controls and exchange rate policy with distortionary financing

The previous section showed that exchange rate policy dominates capital control policy in welfare terms when it can be implemented in a costless manner—i.e., by using lump-sum transfers to finance the non-tradable subsidy, and hence without introducing any additional distortion. The key point is that, in a debt-deflation environment, optimal policy aims at relaxing the collateral constraint. In particular, optimal policy aims at supporting the relative price that influences the borrowing constraint and, in principle, can undo the effects of a binding constraint completely. The result however hinges on the ability of the Ramsey planner to manipulate the price of collateral without costs, because our instruments operate in the context of a balanced budget in which lump sum transfers or taxes are available.

This section departs from this key assumption and considers an environment in which lump-sum transfers/taxes are not available, the government budget balances with distortionary financing, and it is costly to manipulate the price of the collateral with consumption taxes. As Section 6 discusses further, the distortionary financing cost introduced can be interpreted more broadly as representing another friction in the economy, a second objective of exchange rate policy, or any situation in which managing the real exchange rate during a financial crisis is difficult. For this reason we label these set of interventions “costly exchange rate policy”.[21]

Given the structure of our endowment economy, there are two possibilities for the government budget constraint. In the first one, the set of taxes is arbitrarily restricted to τ_t^B and τ_t^N. In the second one, all the tax instruments discussed thus far, τ_t^B, τ_t^N, and τ_t^T can be used. So let us look at each of them in turn.

5.1. Two policy instruments

In the first case, the government budget constraint becomes:

$$\tau_t^B B_{t+1} = \tau_t^N P_t^N C_t^N, \tag{23}$$

with the tax on borrowing financing the subsidy on non-tradable goods or, alternatively, the subsidy rebating the revenue from taxing debt. The following definition states the corresponding Ramsey problem.

Definition 3. For a given $\{B_0\}$ and assuming that $\{Y_t^T\}$ and $\{Y_t^N\}$ are Markov processes with finite, strictly positive support, the Ramsey problem for τ_t^N and τ_t^B when (23) holds is to choose a competitive equilibrium that maximizes

$$U^j \equiv E_0 \sum_{t=0}^{\infty} \left\{ \beta^t u\left(C_t^j\right) \right\},$$

subject to (7) and (8) and (20), and the first order conditions of the households

$$u'(C_t)C_{C^T}(1+\tau_t^B) = \lambda_t + \beta(1+r)E_t\left[u'(C_{t+1})C_{C^T}\right], \tag{24}$$

[21] In a model with heterogenous agents, lump-sum instruments will have distributional implications. Here we abstract from these issues, but still consider an environment in which lump sum instruments are not available.

$$\frac{(1-\omega)^{\frac{1}{\kappa}}\left(C_t^N\right)^{-\frac{1}{\kappa}}}{\omega^{\frac{1}{\kappa}}\left(C_t^T\right)^{-\frac{1}{\kappa}}}=P_t^N\left(1+\tau_t^N\right). \tag{25}$$

There is no analytical solution for this problem, so one has to relay on numerical methods. To do so, note first that, given our chosen instruments (i.e. τ_t^N and τ_t^B), the problem is time consistent.[22] Next, We use the computational algorithm that exploits the Markov-Perfect nature of the equilibrium, proposed by Benigno et al. (2012) and summarized in the appendix. Note that, for comparison purposes, the economy continues to be calibrated exactly as in Bianchi (2011). The rest of this section reports and discusses only the actual solution.

Fig. 5 plots the policy function under the optimal policy for τ_t^N and τ_t^B and the associated welfare gains in terms of tradeable consumption as a function of current bond holdings for a negative one-standard deviation shock. Fig. 6 describes the policy function for B_{t+1}, C_t^T and P_t^N under the optimal policy (OP, dashed line) and the competitive allocation (CE, solid line). Fig. 7 reports the ergodic distribution of debt. In order to assess the severity of the crisis, Fig. 8 also reports the ergodic distribution of total consumption growth in unit of tradable consumption during crisis times (i.e., the change in consumption from $t-1$ to t, given that the economy is in a financial crisis in period t). For this purpose, a crisis is identified, as in Bianchi (2011), by a constraint that binds strictly and a debt reduction larger than one-standard deviation. In these plots, the constraint binds at a level of debt of about -0.95, where the policy rules display a kink.

As Fig. 5 shows, when exchange rate policy is costly, there is scope for both ex-post and ex-ante interventions. During crises times, like before, the optimal policy requires subsidies to non-tradable consumption to limit the depreciation of the relative price of non-tradable goods. This is now financed by a tax on the amount that agents borrow. During normal times, the optimal policy requires capital controls whose revenues are rebated in the form of subsidies to non-tradable consumption.

The optimal policy mix depends crucially on the interaction between ex-ante and ex-post interventions. In the context of our simple economy, this interaction is affected by the way the policy interventions are financed. When financing of ex-post intervention is not costly (i.e. there are lump-sum taxes) policies aimed at supporting the market price of collateral are fully effective and can achieve the unconstrained allocation. In contrast, when financing of ex-post intervention is distortive, preventing excessive depreciation of the real exchange rate becomes costly, and the optimal policy weights the marginal benefit of relaxing the borrowing constraint with the distortion introduced by capital controls. Indeed, when the constraint binds, the tax on debt affects C_{t+1} through (24). Since the ex-post policy becomes costly, it is no longer fully effective in addressing the pecuniary externality, and it becomes optimal to intervene during normal times to reduce the probability of meeting the borrowing constraint. Consistent with this, a comparison of Figs. 2 and 5 shows that the optimal tax rate on debt, in the region where the constraint is not binding, is now much smaller than the case in which capital control is the only government instrument.

There are three other features of the optimal policy that are noteworthy. First, when the constraint is not binding, while the tax on the amount that agents borrow affects their borrowing decision, the subsidy to non-tradable consumption is neutral and is equivalent to a lump-sum transfer. On the other hand, when the constraint binds, both instruments affect the real allocation.

Second, in this more general set up, like in the case of costless exchange rate policy, there continues to be more borrowing and consumption than in the competitive equilibrium despite the fact that the economy experiences fewer and less severe crises (see Table 1 and Fig. 8). The Ramsey planner achieves this by choosing a different allocation of consumption, with relatively more consumption of tradable goods compared to the competitive equilibrium allocation. As a consequence, the welfare gains of this optimal policy mix are more than twice as large as those in which only capital controls are used, and continue to be larger the more indebted is the economy (see Fig. 5 and Table 1). This is consistent with the old adage that where borrowing is allocated is at least as important as how much borrowing takes place.

Third and finally, agents borrow more than in the competitive equilibrium allocation during normal times even though optimal policy requires a tax on the amount agents borrow (Figs. 6 and 7). Intuitively, on the one hand, agents want to borrow less because their borrowing is taxed; on the other hand, they are willing to borrow more since crises events are mitigated (only in part in this case) by policy intervention (see Fig. 8 and Table 1, respectively). Indeed, the real exchange rate depreciates less during crises times compared to the competitive equilibrium allocation and allows agents to consume more (Fig. 6). In this setting, therefore, the rationale for capital controls is not related to the amount that agents borrow in the unregulated economy, the so-called "overborrowing" on which the existing literature focused on, but rather to the relative (in)effectiveness of the ex-post intervention.

[22] To see this, note that the problem above can be reduced to a static one by considering the restricted case in which the Ramsey planner maximizes agents' utility subject to (7), (8), (20) and (25). One can then solve for the allocations, the multiplier on the credit constraint and the relative price. Next, use (23) and (24) to retrieve the path of taxes. The online appendix also provides an alternative proof based on the equivalence between the commitment and the time-consistent solution of the problem above.

5.2. Three policy instruments

Consider now the second possibility in which all available distortionary taxes can be combined to balance the budget:

$$\tau_t^B B_{t+1} = \tau_t^N P_t^N C_t^N + \tau_t^T C_t^T. \tag{26}$$

In this situation, it is possible to show analytically that there is a combination of the three tools that can achieve the unconstrained allocation even if there are no lump-sum transfers/taxes. In the appendix, we prove that we can always combine the triplet of policy tools (τ_t^N, τ_t^T, τ_t^B) to undo the international borrowing constraint.

The policy implication of this last exercise echoes what was emphasized earlier: the set of instruments and their relative effectiveness is crucial for the optimal policy design. The third instrument addresses the distortion introduced by the second one in crisis times. Intuitively, it is possible to use the tax on tradable goods to undo the efficiency losses caused by the use of tax on borrowing when policy aims at supporting the real exchange rate. This is consistent with the notion that with enough instruments we can always undo a friction—cfr. Correia et al. (2008). In our specific context, this implies that the challenge for the policy maker is to identify the particular combination of instruments that are most effective in addressing the pecuniary externality and its interaction with the others relevant frictions in the economy.

5.3. Extensions

Our analysis shows that, in economies with occasionally binding collateral constraints, it is optimal to design policies aimed at relaxing the constraint when it binds, and the desirability of policies aimed at preventing crisis depends on the cost-effectiveness of such crisis resolution interventions. Here we want to discuss some extensions of the basic framework and show that the main messages of our optimal policy analysis are robust in this model environment.

Imperfect exchange rate intervention: Consider first a more realistic case of costly (or less than fully effective) ex-post intervention, which we label "imperfect exchange rate intervention," for example, because it is not feasible to perfectly control the real exchange rate during the financial crisis. In practice, this might be due to imperfect credibility or because of limited availability of foreign exchange reserves needed to support the nominal exchange rate, as we discuss in Section 6.

To model this idea (fully developed in the appendix), assume that when it is not feasible to implement the desired level of the subsidy τ^N, τ^N must be set to zero. The appendix shows that under this policy it is not always possible to relax the collateral constraint, so that it becomes optimal to intervene ex-ante, from a Ramsey planner perspective, like in the case of distortionary financing discussed above. Intuitively, when exchange rate intervention is imperfect, crises become more costly events, and it is desirable to tax borrowing in normal times to limit the probability that a crisis occurs.

Borrowing constraint with post-tax income: A second extension is a situation in which the borrowing constraint depends on post-tax income as follows:

$$B_{t+1} \geq -\frac{1-\phi}{\phi}\left[Y_t^T + P_t^N Y_t^N - T_t\right]. \tag{27}$$

The appendix shows that, under this assumption, changes in τ^N financed through T_t, will not relax the borrowing constraint[23]. Despite this, it is possible to show that the general principle of optimal policy design in this class of models that we stressed above continues to hold, but may require the use of different policy tools. In fact, in this specific case, the policy maker would need to use the tax on borrowing, τ^B, along with lump-sum transfers/taxes to relax the constraint. When (27) holds and binds, the Ramsey planner can increase the value of the collateral by transferring resources to the household via T_t, at the a cost of higher τ^B. Indeed, the appendix shows that this case is isomorphic to the one in which the borrowing constraint depends on pre-tax income, and the available policy tools are τ^N and τ^B. The only difference is that the borrowing constraint is now relaxed through T_t rather than by engineering an increase P_t^N.

Production: Lastly, note that in a production economy there would be multiple margins on which the pecuniary externality can distort decisions—see for instance the economy analyzed by Benigno et al. (2012, 2013). In this case, Benigno et al. (2012) show that exchange rate policy alone via τ^N cannot remove the borrowing constraint or even achieve the SP allocation of that economy. For example, the optimal policy for τ^N alone, in that more general setting, is a tax in normal times and a subsidy in crisis times. The policy, therefore, has both a crisis prevention element aimed at containing the frequency of financial crises, and a crisis resolution element aimed at mitigating their effect by relaxing the constraint when they do occur. To achieve the SP allocation of that economy or to remove the borrowing constraint altogether, however, would require the use of multiple tools. Indeed, in that model environment, collateral price support policies induce distortions in the allocation of labor between tradeable and non-tradeable production that requires the use of an offsetting policy tool to fully restore efficiency or contain the cost of trying to remove the constraint.

[23] This can be seen by combining (27) with the government budget constraint $T_t = \tau_t^N P_t^N C_t^N$.

6. Discussion

Our model is useful to discuss exchange rate policy in the real world, and the implied "optimal" policies are consistent with the experience of emerging market economies over the past 20 years or so.

A first implication of our analysis is on the role of collateral price support policies when they can be implemented in a costless manner. In the context of the model, these policies take the form of a fiscal subsidy to the consumption of non-tradable goods, financed in a lump sum manner. This contains the fall of the relative price of non-tradable (or the depreciation of the real exchange rate in our model) that typically occurs during a sudden stop of capital inflows. If such a policy is feasible, our analysis shows that, not only it contains the crisis when one occurs, but it also eliminates the scope for any prudential measure such as capital controls. This is because the intervention can removes the borrowing constraint altogether, which is the only source of inefficiency in our model economy. Of course, in reality, there are other distortions, possibly leading to different conclusions as it is discussed below.

Which polices in the real world can support the real exchange rate and how costly are they to implement? In practice, the real exchange rate is typically supported by defending the nominal exchange rate by selling previously accumulated foreign exchange reserves. And while accumulating or borrowing foreign exchange reserves is costly, drawing them down at any particular point in time is costless.

For example, during the global financial crisis, Brazil and Mexico faced a sudden stop in private capital inflows following the Lehmann's collapse in September 2008. The Brazilian Real depreciated by more than 20 percent in a month against the US dollar, and the central bank intervened heavily to defend it as predicted by our model. As Mesquita and Toros (2010) emphasize, the main motivation for this intervention was the vulnerability of the non-financial corporate sector to the depreciation of the Real because of their exposure in the derivative market to US dollar swaps (proxied in our model with borrowing in units of tradable consumption). A similar experience was shared by Mexico when large corporate entities were also exposed to foreign currency derivatives at the time of Lehmann's collapse. In their account of the Mexican experience, Cespedes et al. (2012) emphasize how the response of the policy authorities consisted in foreign exchange market intervention with the objective to limit the depreciation of the Mexican Peso in the face of currency mismatches in the corporate sector balance sheet.

More broadly, in the context of the recent US and European financial crises, the prescription of our model can be interpreted as interventions that avoid the collapse of asset prices when a crisis occurs. In this sense, our results not only rationalizes the need to set a floor under the exchange rate as in the emerging market crises of the 1990s and the 2000s, but also the non-conventional policies of purchasing risky assets to contain "fire sales" and the asset deflation spirals that characterized the United States and European crises.[24]

Official reserves however are always limited, and this limited availability exposes countries to costly speculative attacks. Many emerging market countries learned this lesson the hard way in the 1990s and the 2000s as speculative attacks on limited pools of foreign exchange reserves broke many pegs: Mexico in 1994, Thailand in 1997, South Korea and Indonesia in 1998, Russia in 1998, Brazil in 1999, Argentina in 2001, Uruguay in 2002, etc. Once out of reserves, these countries had to borrow foreign currency from the IMF under tight macroeconomic adjustment programs to contain the initial devaluations. Indeed, as predicted by our model, supporting the exchange rate was a crucial component of all adjustment programs supported by the IMF in Indonesia, South Korea, and Brazil during the period 1997–1999 (IMF Independent Evaluation Office, 2003). These adjustment programs turned out to be economically and politically very costly. As a result, after these crises, countries started to accumulate very large pools of official reserves to deploy in support of the exchange rate in the case of sudden halt in capital inflows as they did during the global financial crisis.[25] But even when accomplished gradually rather than borrowing from the IMF, reserve accumulation is costly. Countries must save in a precautionary manner in a riskless asset while continuing to borrow in risky instruments as long as they are in a net debtor position. So there is a carry cost, or premium for holding reserves.

Perhaps even more importantly, exchange rate policy also has other objectives than that of maintaining financial stability by mitigating the effects of currency mismatches. Exchange rate policy is typically tasked to also address competitiveness issues and to contribute to macroeconomic stability by helping to manage inflation. In our model, financial stability is the only policy objective, as there are no other frictions justifying intervening in the economy for macroeconomic stabilization or competitiveness reasons.

If we were to introduce other frictions and hence policy objectives, a trade off would emerge similar to the one we studied in the previous section by assuming distortionary financing of exchange rate policy or imperfect exchange rate interventions. One example is a government that targets the real exchange rate by manipulating the nominal parity in the presence of both a borrowing constraint like ours and a nominal rigidity. In this case, the advantage of keeping the exchange rate relatively appreciated is to support the agents' borrowing capacity. The disadvantage would be to cause unemployment

[24] It is possible to show that the small open economy studied here is isomorphic to an environment in which domestic banks intermediate foreign saving and households borrow using a domestic asset as collateral. In that context, optimal ex-post policy, when warranted, supports domestic asset prices. See Bianchi (2011) and Cesa-Bianchi and Rebucci (2016) for more discussion of that set up.

[25] Emerging markets official reserves (excluding gold) increased from about one trillion US dollar in 2000 to over 6 trillions in 2012 according to IMF IFS data (or about a third of world GDP valued at current US dollars). While this spectacular accumulation of reserve assets cannot be explained entirely by prudential or precautionary motives, most empirical studies concur that precautionary saving is the most important determinant of this process.

in response to shocks. Our distortionary cost captures the essence of costly ex-post interventions in the presence of other distortions or government objectives.[26]

Indeed, the second main policy implication of our analysis is that, if financial crises cannot be contained or mitigated without incurring significant costs, or there are additional distortions to consider associated with their resolution, a policy of crisis prevention becomes part of the optimal policy mix, such as for instance using capital controls in a countercyclical manner. However, when both ex-ante and ex- post interventions are used jointly under the optimal policy mix, the level of the tax on borrowing is much lower than when the capital control is used as the only instrument (cf. Figs. 2 and 5).

This latter result is consistent with available empirical evidence on the use of capital controls. As Fernandez et al. (2015) pointed out, if countries were to use capital controls in a prudential manner as implied by Proposition 1, we should observe active use of countercyclical capital controls. However, when Fernandez et al. (2015) looked at a large number of countries over the period 1995–2011, they found that capital controls are virtually flat during episodes of boom and bust in output or the current account.

In summary, we conclude from this review of country experiences over the past 20 years or so that, while the mechanics of optimal policies implied by our model are different than those typically implemented in the around the world, the general principle followed by these policies is very much consistent with them. The policies implied by our analysis are also consistent with the available empirical evidence on the use of capital controls, in stark contrast to those implied by the existing literature.

7. Conclusion

In response to the recent global financial crisis, a new policy paradigm emerged in which old fashioned forms of government interventions such as capital controls and other quantitative restrictions on credit flows—the so called macro-prudential policies—have become part of the standard policy toolkit. Arguably, macro-prudential policies are desirable because they can help prevent financial crises that otherwise would be too costly to endure or contain with only ex-post interventions.

In this paper we study the optimal policy mix of ex-post, crisis management policy tools and ex-ante, crisis prevention policy tools. We first show that when the Ramsey planner can choose among different policy tools, ex-post collateral price support policies dominate prudential policy measures in welfare terms by a very large margin. This dominance is conditional on the extent to which price support policies do not entail efficiency losses. Indeed, when collateral price support policies can be used without costs, there is no need for macro prudential policies. In contrast, when crisis management policies are not fully effective because they are costly to implement, ex-ante policies such as capital controls can be rationalized as a complement to collateral price support policies that limit the occurrence of crises. The joint use of ex-ante and ex-post policies achieves a welfare gain of more than 1 percent of permanent consumption in our model; a gain that is twice as large as the welfare gain of using only capital controls.

Our analysis is conducted in the context of a relatively simple quantitative model, but in reality the trade-offs that policymakers face are richer that the ones implied by our framework. For instance, there are benefits from a more depreciated exchange rate in terms of the classical expenditure switching effect of the exchange rate that are not incorporated into our analysis. To an extent, our model can be interpreted as one in which balance-sheet considerations dominate other exchange rate policy motives, but we acknowledge that a richer model would be needed to quantify these issues. We regard the study of optimal monetary and macro-prudential policy in a quantitative model in which pecuniary externalities interact with nominal rigidities as an area of fruitful future research.

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[26] Ottonello (2015) studies optimal exchange rate policy in such a set up and illustrates the trade off between increasing agents' borrowing capacity (dubbed credit access policy) and unemployment.

Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jmoneco.2016.10.004.

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