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Ex-ante implications of sovereign default

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ABSTRACT

I study how the possibility of default on external debts affects other capital allocation decisions in a small open economy. In the model, default has an option value derived from the randomization over ex-post default regimes, which depends on country-specific productivity shocks. This feature of default reduces incentives for ex-ante diversification, which would reduce exposure to the productivity shock. As a result, if the economys debt to capital ratio is allowed to cross a fixed threshold (identified in the model), the unique equilibrium exhibits an allocation of capital that is less productive in expectation and more volatile than in a benchmark model without default. The model therefore captures a number of salient features of emerging and less developed countries, where low levels of international risk-sharing have gone hand-in-hand with frequent and recurring default events.

1. Introduction

Sovereign defaults are a recurring feature of many less developed and emerging countries (henceforth LDECs). There have been more than 100 default events in LDECs over the past 40 years (1970–2010). Moreover, a number of countries have defaulted more than once in this period. For example, Argentina, Brazil, Myanmar and Sri Lanka each defaulted thrice between 1980 and 2002 alone (see Hatchondo et al. (2007) for the date and frequency of sovereign defaults in LDECs). The empirical regularity of default in many LDECs suggests that default is not always a reaction to unanticipated, adverse economic conditions, but may sometimes reflect a conscious policy choice (Reinhart and Rogoff, 2004).[1] If default is an instrument of policy it can have feedback effects on other capital allocation decisions.

In this paper, I propose a simple open economy model to study the implications of sovereign defaults on ex-ante and ex-post capital allocation decisions. I introduce the possibility of default into an otherwise standard model of international risk-sharing. A small open economy makes capital allocation decisions both before and after the realization of a productivity shock. Ex-ante to the shock, the country decides how much to borrow from international lenders subject to a borrowing constraint. The country can invest capital either domestically or in a perfectly negatively correlated foreign sector. I assume that the representative consumer is risk-averse and so, without default, the optimal capital allocation uses the foreign sector to fully diversify against productivity shocks. To study how default impacts incentives for international diversification, I introduce the possibility of default on debt after the realization of the productivity shock, where default triggers a simple punishment mechanism that forces the country to utilize a strictly dominated (traditional) sector.

The option to default changes substantively the optimal allocation of capital both ex-ante and ex-post. Specifically, there are now two regimes. If access to capital markets is limited by a tight borrowing constraint, default is never realized in equilibrium (because of the punishment mechanism) and the ex-ante capital allocation is the same as without default. However, if the country has sufficient access to capital markets, the country borrows more, does not diversify risks and defaults on debt when it realizes a low productivity shock. This second regime has two consequences: relative to the benchmark model without default (1) the expected productivity of capital decreases because capital is allocated to the less productive traditional sector when default occurs, and

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[1] For example, Reinhart and Rogoff (2004) argue that while default events can be detached from fundamentals by well-known coordination problems (currency crises, bank runs, sudden stops, etc.), the "serial default" observed in some emerging economies is much more systematic and that "sovereign defaults tend to recur like clockwork in some countries, while being entirely absent in others" (Reinhart and Rogoff, 2004).

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(2) the variance of productivity increases because the country does not use the foreign sector to diversify against productivity shocks. As a result, the expected returns decrease while the volatility increases. Surprisingly, both effects occur in equilibrium despite the fact that the country has to pay a premium to compensate international lenders for the default-risk.[2]

There is a simple underlying intuition for the trade-off between ex-ante diversification and the ex-post decision about default. Intuitively, default can be viewed as an alternative insurance mechanism for an agent that faces a bad productivity shock. In the event of an incomplete market, default provides an additional asset to the agent. As discussed in Dubey et al. (2005), agents may use default as an alternative way to insure themselves when a bad productivity shock is realized. Default may be more fitting to the needs of the agent depending on the realization of the shock. Like Dubey et al. (2005), in the current paper, an agent that borrows too much of debt finds it optimal to choose default when faced with a bad productivity shock.[3] The basic idea in the current paper is that there is a trade-off between diversification mechanism (through ex-ante capital allocation in a perfectly negatively correlated production process in the foreign sector) and ex-post default on external debt. International diversification provides a hedge against country-specific productivity shocks. On the other hand, the option value of default is related to a randomization over different *ex-post* regimes, where default is optimal when productivity is low and not optimal when productivity is high. Since diversification reduces exposure to productivity shocks, it curtails randomization and decreases the option value of default. As a result, the optimal allocation depends on a trade-off between the insurance value of diversification and the option value of default, which are in conflict with each other. It is most beneficial for the agent to default on the external debt in a bad state if the agent has not utilized ex-ante diversification. The larger the external debt to capital ratio, the more important the option value of default becomes. As a result, there is a threshold effect in terms of the borrowing constraint leading to two regimes (Regime I is with full diversification and no default while Regime II is with no diversification and default in low state only).

The results of the model provide some basic insights into trade-offs facing LDECs as they become more integrated into international capital markets. Capital market integration provides opportunities for diversification, which can reduce exposure to country-specific productivity shocks (resulting into "income risk-sharing"). However, a large literature has shown that risk-sharing has not increased in LDECs as would have been anticipated by standard models of international market integration (see for e.g., Kose et al., 2009; Flood et al., 2009; Yeyati and Williams, 2011). One reason may be that capital market integration has gone hand-in-hand with a large increase in sovereign debt, and a concomitant increase in default incentives. The model in this paper provides a simple theoretical mechanism consistent with this idea, and therefore complements the growing empirical literature on risk-sharing and default in LDECs.

The model and analysis in this paper therefore represent an application of the theory on limited enforcement and default risk (e.g., Kehoe and Levine, 1993; Dubey et al., 2005), and collateralized debt and bankruptcy (e.g., Chatterjee et al., 2007; Geanakoplos and Zame, 2013), to an open economy setting, where I show how default affects incentives for risk-sharing. I discuss the related literature in detail in the next section, Section 2. In the subsequent section, I present the two-period model of a small open economy with a single representative agent, and study efficient allocations as the solution to a planner's problem. The basic set-up of the model is simple in order to highlight the key interaction between diversification decisions ex-ante to a shock, and the value of ex-post default options. The analysis of the model proceeds in two steps. I first introduce the model without default in Section 3 and analyze capital allocation decisions in this benchmark case. I then introduce default with a risk premium to the benchmark set up in Section 4 and present the main result, which shows how default with risk premium affects ex-ante capital allocation decisions. Section 5 concludes. Proofs of results are given in a separate Appendix.

2. Related literature

The current paper is related to a wide literature on limited enforcement of contracts and default-risk. The theory of limited enforcement without default is discussed in Kehoe and Levine (1993); Kocherlakota (1996) and Alvarez and Jermann (2000), while for limited enforcement with default see Zame (1993) and Dubey et al. (2005). The first set of studies assumes a complete set of contingent assets to search for allocations that are efficient subject to limitations on enforceability of contracts. However, in these models, unlike in the present paper, default never actually happens in equilibrium and the market structure they consider may therefore miss salient features of those LDECs which have regularly witnessed default in the recent past.

The second set of studies assumes incomplete markets where default can occur in equilibrium with a positive probability. In particular, Arellano (2008); Aguiar and Gopinath (2006) and Bai and Zhang (2012), present models of emerging economies in which there are equilibrium default events. However, their analysis is restricted to international financial market transactions of non-contingent bonds only. The point of distinction of the current paper from this previous literature is the emphasis in this paper on the role of the interaction of ex-post default risk with ex-ante allocation of capital in contingent assets for diversification purposes.

The paper also builds on a literature on bankruptcy and default, which assumes incomplete markets with a requirement of collateral for borrowing, for example, Zame (1993); Tarun (2003) and Geanakoplos and Zame (2013). In this literature, default can also occur in equilibrium with a positive probability. In particular, Geanakoplos and Zame (2013) extend an otherwise standard intertemporal general equilibrium model by incorporating collateral requirements, possibility of default and durable assets. They show that collateral requirement affect allocations, prices, market structure and the efficiency of the market outcomes. In particular, they show that collateral requirements that lead to default ex-post can be efficient ex-ante in comparison to collateral requirements that do not lead to default.

The collateral requirement to secure the borrowing in this literature provides a pecuniary penalty of default in the form of forfeiture of collateral in the event of default. Another version of forfeiture that incorporates some exemption where fraction of income of the defaulter is not garnished is modeled in Araujo et al. (2002). The basic idea behind forfeiture in general is that a potential defaulter is exposed to seizure of collateral or some other claims. The framework in the current paper does not explicitly model the collateral requirements but the opportunity to invest in the foreign sector provides similar exposure to claims of the borrower which can be seized in the event of default.

In addition, the risk premium modeled in the current paper is motivated by Chatterjee et al. (2007) where credit suppliers can link the price of the loans made out to the households based on the type of household as well as the credit levels. This means that

[2] Borrowers pay a premium as a compensation to international lender for assuming the default risk. This premium is paid by the borrowers indirectly in the form of a lower price for domestically issued bonds.

[3] As it will be clear from the main result, the equilibrium with default in our setting is therefore related to Dubey et al. (2005)'s Example 2 which illustrates that despite having receipts on hand to fulfill the promise of repayment to lenders, the borrower defaults if they realize a bad state of the economy and therefore such a default can be classified as a strategic default.

the default option results into discontinuous wealth distribution in terms of wages and capital rent (in steady state). Furthermore, they show that the households with high earnings (beyond a certain high threshold) are better off not defaulting and saving while the households with lower earnings (below a certain low threshold) are better off repaying their debt and borrowing. In between these thresholds is the regime where the households end up defaulting.

In this paper, I adapt the punishments and risk premium modeled in the aforementioned literature, and apply the set up in the context of an open economy framework. In the open economy framework, it is then possible to capture the implication of recurrent sovereign defaults in developing and emerging economies on ex-ante and ex-post capital allocation decisions and international risk-sharing.

As a result, the analysis in this paper is also related to a large literature on home-bias in consumption and equities.[4] A lack of consumption risk-sharing can be viewed as a reflection of a consumption home-bias, while a lack of international capital diversification is related to an equity-home bias. Sorensen et al. (2007) provide empirical evidence that both biases are closely linked, at least in industrialized countries. Lewis (1999) discusses both home-biases, the relationship between them, and various explanations proposed in the literature. Most theoretical explanations depend on market imperfections or the presence of non-tradable goods. The idea that a consumption home-bias can be related to domestic control over *ex-post* policy responses such as default decisions is a feature of the current paper that adds to this literature.

The results of the paper also add to a literature that has pointed to possible unintended consequences of international integration of economies. For example, Newbery and Stiglitz (1984) study a a standard competitive international trade framework with incomplete risk markets. They show that the free trade of goods is Pareto inferior to autarky. The underlying mechanism at work in their model is that free trade not only changes the distribution of risk among producers and consumers, but also affects the capital allocation decisions of the producers (through a price feedback effect). The present model has similar implications for integration of capital markets (as opposed to good markets). The borrowing constraint can be viewed as a measure of the degree of integration. While higher borrowing constraint eases access to international capital for the home country, and allows international investors to exploit higher returns in the emerging economy, the resulting higher debt to capital ratio in the home country increases incentives for default. The result is that the country may end up using capital in a way that is less productive (in expectation) and more volatile (because of the trade-off between default option values and diversification). Accounting for a default option therefore reduces substantially the possible gains to increased capital market integration.

3. Benchmark model

I first introduce a model of a small open economy without default, which will serve as benchmark for the analysis of default in the next section Section 4.

3.1. Domestic economy

There are two time periods ($t = 1, 2$) and a single representative agent. The agent maximizes time separable expected utility with discount factor $\beta > 0$ and constant relative risk aversion felicity function on consumption $u : \mathbb{R}_+ \to \mathbb{R}$, with $u(c) = c^{1-\gamma}/(1-\gamma)$. The coefficient of risk-aversion is denoted by γ where $0 < \gamma < 1$. The restriction $0 < \gamma < 1$ implies that preferences are strictly increasing and that the representative agent is strictly risk-averse.

Capital is the only input to production, and all technologies are linear. In period 1 there is a traditional sector with production function $f(K) = AK$, where $A > 0$ is productivity parameter. The agent has an initial capital stock $\overline{K} > 0$ to use for production in period 1. The output from period 1 production can be consumed in period 1, $c_1 \geqslant 0$, or carried forward as capital for period 2 production, $K_1 \geqslant 0$. In period 2 the same traditional sector is available again, but there is also a modern sector. I interpret the modern sector as reflecting an integration in international goods markets which allows the country to specialize. Specialization increases productivity (see Assumption (A1.2) below), but also exposes the domestic economy to additional volatility from external shocks. Specifically, I assume that there are two equally likely states, a high state H and a low state L. The production function in the modern sector is $f(K) = a_H K$ in the H state and $f(K) = a_L K$ in the L state, where $a_H > a_L > 0$.[5] The variability in the productivity of the modern sector can be interpreted directly as a productivity shock, or could reflect changes in the value-product of output which will be sold on the international market.[6]

The shock to modern sector productivity is realized after period 1 decisions, and before capital allocation decisions (and default decisions in the model presented in Section 4) are made in period 2. As a result, in period 2, the agent must decide how much of domestic capital to allocate to each of the sectors in each of the states. Denote by $K_2^T \in \mathbb{R}_+^2$ and $K_2^M \in \mathbb{R}_+^2$ the state-contingent allocations of capital to the traditional sector and modern sectors in period 2, respectively. Due to the productivity shock, period 2 consumption is also state-contingent and denoted by $c_2 \in \mathbb{R}_+^2$.[7]

3.2. International capital markets

There are two interactions in the international capital markets. First, the agent can borrow capital from risk-neutral international lenders in period 1, denoted by $D_1 \in \mathbb{R}$.[8] In the benchmark model there is no default, and so we can assume that capital must be repaid in period 2 at a fixed rate of interest $r \geqslant 0$, which the small open economy takes as given. We assume that the economy is LDEC and offers excess returns, reflected in the assumption that expected productivity in the modern sector $\mu = (1/2)a_H + (1/2)a_L$ exceeds $(1 + r)$

[4] The consumption home-bias refers to the empirical observation that equality of consumption growth rates – an implication of the basic common priors, Arrow-Debreu complete markets model – is rejected by the data (e.g., Backus et al., 1992). Equity home-bias refers to the empirical observation that the proportion of foreign assets held by domestic investors is too small relative to the predictions of standard portfolio theory (e.g., Levy and Sarnat, 1970; French and Poterba, 1991).

[5] The important parts of the distributional assumption on shocks are symmetry and a compact support. The assumption that there are two equally likely states of the world is otherwise not critical to the analysis. It is possible, for example, to extend the model by allowing for a continuous and uniformly distributed shock, but at considerable cost in terms of notation and complexity of the solution. With a continuous distribution, threshold values appear as endogenous limits on an integral, and it is easier therefore to gain clear insights from the model with a discrete distribution. The symmetry assumption has substantive content as well. Later when we add a foreign sector to the model, shocks that are not symmetric around their mean imply that either the foreign or domestic economy is inherently more productive and would therefore induce an incentive for cross-border capital flows that is not related to risk-sharing.

[6] The advantage of specialization in sectors where a country has comparative advantages goes back to the classical Ricardo and Hecksher-Ohlin-Mundell trade models (see, e.g., Dornbusch et al., 1977). The trade-off between the productivity gains from specialization and the increased vulnerability to external shocks is established theoretically in Easterly et al. (2000), and verified empirically for emerging economies in Kose et al. (2006).

[7] K_2^{MH} and K_2^{ML} denote capital allocated domestically in the modern sector in state H and state L, respectively. K_2^{TH} and K_2^{TL} denote capital allocated domestically in the traditional sector in state H and state L, respectively. c_2^H and c_2^L denote period 2 consumption in the H and L states, respectively.

[8] In principle, the agent can also lend capital on the international capital market, but under the basic assumptions of the model (presented in Section 3.3) this will never be optimal.

(implied by Assumption (A1.3) below). Without further restrictions, this assumption would imply that it is optimal to borrow an infinite amount of capital in period 1. I therefore assume a simple borrowing constraint:

$$D_1 \leqslant \bar{\omega} K_1, \tag{1}$$

where $\bar{\omega}$ is the borrowing constraint. The borrowing constraint $\bar{\omega}$ can be interpreted as a measure of capital market integration and is the central parameter used for comparative statics since it limits the debt to capital ratio the agent can hold going into period 2 (where default decisions will be made in Section 4). I assume throughout that $\bar{\omega} \leqslant a_L/(1+r)$, which ensures that the agent is always able to repay sovereign debts in period 2 (and so default, if it occurs, is voluntary).[9]

In addition to access to non-contingent bonds, international capital markets also allow for foreign direct and equity investments that can be used specifically to diversify and hedge against country-specific productivity shocks. Here, the potential for risk-sharing is modeled by allowing the country to invest a fraction of its accumulated capital abroad, prior to the realization of productivity shock in the modern sector. Capital outflows are invested in a foreign, modern sector which is assumed to have perfectly negatively correlated productivity shocks in relation to the modern sector at home. This means that the country can, in principle, fully diversify against the productivity shock $a_s \in \{a_L, a_H\}$ in the modern sector through international diversification of capital. Denote the fraction of capital invested at home by $\theta_1 \in [0, 1]$, and the fraction invested in the foreign sector by $(1 - \theta_1)$.[10]

Two implications of the assumptions on technologies at home and abroad are worth emphasizing. First, since production shocks in the modern sector at home and abroad are perfectly negatively correlated, the country can perfectly diversify production risks by choosing $\theta_1 = 1/2$. Hence, when the representative agent is risk-averse, there are maximal insurance gains from risk-sharing.[11] On the other hand, since technologies have constant returns to scale in all sectors (home and abroad) and both states are equally likely, there are no benefits from investment in the foreign sector other than for risk-sharing purposes. A risk neutral agent would be indifferent between investments in either sector. Hence, the focus of the analysis is purely on foreign investments for the purpose of risk-sharing.

3.3. Productivity assumptions

The following assumption captures key relationships between the various parameters of the model presented in this section. Denote the random productivity in the modern sector in period 2 by a.

Assumption 1. The following relationships exist between the productivity parameters in the modern sector, traditional sector and the interest rate.

(A1.1) $0 < \overline{K}, 0 < \bar{\omega} \leqslant \frac{a_L}{1+r}$.
(A1.2) $0 < A < a_L < a_H$.
(A1.3) $1 + r < \frac{a_H}{2}$.

The first assumption, (A1.1), lists the exogenous variables where $\overline{K}$ is the initial endowment of capital and $\bar{\omega}$ is the exogenous borrowing constraint. The upper bound of $\bar{\omega}$ ensures that the borrower is able to repay the debt and therefore any default in equilibrium is voluntary.[12]

The second assumption, (A1.2) simply states that the modern sector dominates the traditional sector. With a weak inequality this assumption is without loss of generality since the capital allocation decision between modern and foreign sectors is made *ex-post*, and if $A > a_L$ the economy could simply utilize the traditional sector in state L (in which case A essentially replaces a_L). The assumption of a strict inequality is only required to ensure uniqueness of results and is otherwise not essential. As such, this is an innocuous assumption.

The third assumption (A1.3) simply states that the gross returns on capital in the high state are twice as high as the international cost of capital. This assumption also implies that $\mu > (1 + r)$ which is empirically relevant for LDECs as in general, the expected productivity of capital in these economies is higher than the international cost of capital. The fact that there has traditionally been a considerably greater flow of capital into these economies as a group than out of these economies, suggests that this assumption finds empirical support. It is important to note that the quantitative requirement for Assumption (A1.3) comes from the assumption that the probability of a low state is 0.5 (and even then it is sufficient but not necessary to ensure that the country will borrow when it must pay a risk-premium for default). Since, in the analysis, the probability of a low state corresponds to the probability of default, the high requirement on the rate of return in the open economy relative to the world at large is dictated by the high probability of default. This high default probability is maintained for simplicity and greater clarity of the analysis, because it helps to remove investment incentives from the *ex-ante* capital allocation decision and thereby helps to focus the analysis on diversification and risk sharing. The assumption is not essential to the intuition behind the trade-off between *ex-ante* diversification and default options in general.[13]

3.4. Efficient allocations

Fig. 1 gives a timeline summarizing the decision problem of the planner in the benchmark case. Recall that in period 1 the planner makes a borrowing/lending decision (D_1), a capital accumulation decision (K_1), and an *ex-ante* capital allocation decision between

[9] The borrowing constraint has a number of implications for the analysis. First, it ensures the existence of an equilibrium in the current linear technology set-up. Second, it ties the borrowing of the country directly to its capital accumulation decision. Together with the multiplicative separability of the CRRA utility, this allows for a complete separation of capital accumulation and default decisions in the proof of the main proposition, Proposition 2, for the model with default (in Section 4). Third, the borrowing constraint acts as a simple parameter for comparative statics which will be used in the model with default to distinguish between regimes in which default does and does not occur.

[10] In reality, investments in the foreign sector might generally be accompanied by a counter-flow of investments into the domestic, modern sector from abroad. It is notationally simpler and without loss of generality to suppress these counter-flows since they do not have welfare implications for the domestic consumer. It is important only to highlight that foreign investment into the domestic economy are not subject to default or repossession, at least not to the advantage of the domestic consumers.

[11] While the possibility of perfect risk-sharing through foreign investment is an extreme assumption, the main result of the following section will show that even then, default may lead to imperfect risk-sharing.

[12] Note that the restriction on $\bar{\omega}$ implies that default – when it occurs – is always voluntary since net output (after paying debt obligations) in period 2 is always at least equal to

$$a_L K_1 - (1+r)\bar{\omega} K_1 = K_1(a_L - (1+r)\bar{\omega}) \geqslant 0 \Longleftrightarrow \bar{\omega} \leqslant a_L/(1+r). \tag{2}$$

[13] With the conditions in part (A1.2), the model in this section simply illustrates that if the return on capital is sufficiently high for LDECs to borrow despite credit-risk premia, the trade-off between diversification and default remains. Qualitatively, this does not require any change in the structure of the model, and the quantitative requirement (what constitutes a "sufficiently" high rate of return in the high state) is dictated here by other assumptions that simplify the analysis and interpretation but are not germane to the central argument. Since LDECs have witnessed large inflows of debt over the past 20–30 years despite paying substantial credit-risk premia, the key motivation for the assumption lies in its implications for borrowing behavior and these clearly find considerable empirical support.

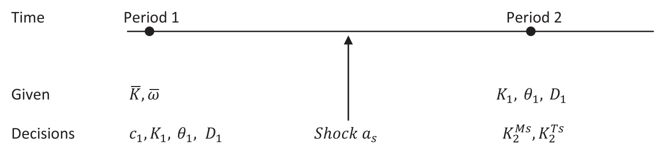


Fig. 1. Problem 1: Timeline.

the home and foreign sectors (θ_1 and $(1-\theta_1)$, respectively). In period 2 the planner then makes a decision regarding an *ex-post* capital allocation decision between the modern and traditional sectors (K_2^M and K_2^T). The exogenous parameters of the model are the productivity parameters A, a_L, a_H, the interest rate r, the initial capital stock $\overline{K}$ and the borrowing constraint $\bar{\omega}$.

The objectives and constraints of the representative agent can be summarized by the following optimization problem:

Problem 1.

$$\max_{\{(c_1,K_1)\geqslant 0, D_1,\theta_1\in[0,1]\}, c_2, K_2^M, K_2^T} \quad u(c_1) + \beta\left[\frac{1}{2}u(c_2^H) + \frac{1}{2}u(c_2^L)\right]$$

$$\text{s.t.} \quad c_1 \leqslant A\overline{K} + D_1 - K_1$$

$$c_2^s \leqslant \left[a_s K_2^{Ms} + AK_2^{Ts}\right] + (2\mu - a_s)(1-\theta_1)K_1 - (1+r)D_1$$

$$K_2^{Ms} + K_2^{Ts} \leqslant \theta_1 K_1$$

$$D_1 \leqslant \bar{\omega} K_1$$

Definition 1. (Efficient Allocation) Given parameter values for $(\overline{K}, \bar{\omega}, A, a_H, a_L, r, \beta)$, an allocation $(c_1, K_1, \theta_1, D_1, c_2, K_2^M, K_2^T)$ is *efficient* if it solves Problem (1).

3.5. Risk-sharing without default

Diversification (through θ_1) allows the agent to hedge against the productivity shock in the modern sector, and therefore leads to risk-sharing. The following proposition establishes that the agent will make full use of international risk-sharing when there is no option to default.

Proposition 1. *Under Assumption 1, a unique efficient allocation exists. Moreover, if $(c_1^*, K_1^*, D_1^*,\ \theta_1^*, c_2^*, K_2^{M*}, K_2^{T*})$ is efficient, then $D_1^* = \bar{\omega}K_1^*, K_2^{T*} = 0, \theta_1^* = (1/2)$, domestic output in state H is higher than in state L but $c_2^H = c_2^L$.*

Proof. The proof is given in the Appendix. □

Proposition 1 illustrates that when the country is able to share risks, it will fully diversify income and thereby fully insure against output shocks. To see that the country achieves full diversification, note that the Proposition establishes that the country produces only in the modern sector in period 2, and that in period 1 it allocates one half of its capital each to the home and foreign sectors. As a result, while domestic output remains volatile (subject to the shock in the modern sector), domestic consumption is constant. Moreover, the uniqueness of the efficient allocations establishes that the introduction of international risk-sharing opportunities leads to a strict *ex-ante* welfare gain as compared to the case when there is no option to diversify. In addition, the borrowing constraint binds as with international risk-sharing, despite risky borrowing as $r > a_L - 1$, there is a risk-free return on capital $\mu - 1$ and under Assumption 1 the country will therefore exhaust the borrowing constraint. By providing insurance against the productivity shock in the more productive modern sector, international risk-sharing therefore also potentially increases investment.

4. Model with default

I now allow for the country to make a discrete decision in period 2 about whether to service or default on its debt obligations from the previous period. I also introduce an additional assumption, Assumption 2, that relates the default punishment mechanisms to the technological productivity parameters. All other features of the environment are as in the previous model, and Assumption 1 is maintained throughout.

Default decisions are made after the realization of the productivity shock, and before period 2 capital allocations. The default decision is denoted $\lambda_2 \in \{0,1\}^2$, where $\lambda_2^s = 1$ means that the country services its debts in state $s \in L, H$, while $\lambda_2^s = 0$ means that it defaults. Hence, if the open economy has a debt stock of D_1 from period 1 and chooses $\lambda_2^s = 1$ it must repay $(1+r)D_1$ in state s. If the country chooses $\lambda_2^s = 0$ it defaults on $(1+r)D_1$ and faces default penalties (discussed below).

4.1. Risk-premium

Intuitively, the default option becomes more valuable as the agent's stock of debt in period 2 increases. But it is clear that if international lenders had rational expectations regarding the default decisions of the borrower country, they would accept default risk only if they are compensated with an appropriate risk-premium. I therefore augment the benchmark model to allow for a risk-premium to be paid to international investors in the presence of a default option. Specifically, I assume that the country can borrow by selling bonds to international investors, and then impose a no-arbitrage condition on the price of bonds to account for the possibility of default. I then look for an allocation and a bond price such that (1) the open economy makes optimal choices given the borrowing constraint and bond price, and (2) given the default decisions of the borrower country, international investors are indifferent between the purchase of bonds or the use of international capital markets at the given rate of interest r (the no-arbitrage condition).

I assume that the number of international investors is large relative to the size of the open economy, and that international investors are well diversified so that they behave in a risk-neutral manner in their lending decisions. Lenders can either buy bonds from the open economy at a price $P \geqslant 0$, or invest money in the international capital markets and obtain a risk-free rate of interest r. International lenders can condition their choices on the price of bonds issued by the small open economy, the initial capital stock $\overline{K}$, as well as the borrowing constraint $\bar{\omega}$. Note that the borrowing constraint and the initial capital stock are both observable at the time the country issues bonds, so the basic assumption here is one of common knowledge regarding basic economic primitives. The bond prices should then satisfy the following no-arbitrage condition.

$$P(1+r) = \frac{1}{2}(1+r)\lambda_2^H + \frac{1}{2}(1+r)\lambda_2^L \tag{3}$$

To motivate the no-arbitrage condition, suppose that the price of a bond issued by the borrower country is P. An international investor then has two choices in period 1: (1) The investor can lend P units of period 1 capital to the international market, for which they will obtain a return of $P(1+r)$ in period 2. Alternatively, (2) the lender can buy 1 bond from the open economy and obtain a return of $(1+r)$ in each state in which the country services debts, and 0 in each state in which the borrower country defaults. Hence, the lender's returns depend on the borrower country's default decisions. This feature of the model is in the spirit of Chatterjee et al. (2007)'s model where the price of the loan made out to the household is linked to the type of household and the level of credit borrowed by the household.

With a large number of investors, the no-arbitrage condition is required to ensure that the supply for bonds equals the demand for bonds. If investors preferred bonds to investments in the capital market, demand would be infinite and therefore exceed supply. If investors preferred investments in the capital market to the purchase of bonds, demand would be zero and any positive bond issue would lead to excess supply. Although, I do not model the dynamics of price adjustment explicitly, the no-arbitrage condition can be interpreted as a market clearing condition that determines the bond price given rational expectations about default behavior. The possible outcomes for a risk-neutral international lender are summarized in Table 1.

Since the initial capital stock $\overline{K}$ and the borrowing constraint $\bar{\omega}$ are known, international investors can correctly predict the default behavior of the open economy. The no-arbitrage condition therefore requires that for any borrowing constraint and bond price P, the optimal default decision of the open economy equates the return identified in the corresponding row from Table (1) with the risk-free return in international markets $P(1+r)$. So, for example, if the borrowing constraint and bond price leads the country to assume a level of debt to capital at which it will default in neither state, then it must be that the price of the bond solves

$$P(1+r) = (1+r) \tag{4}$$
$$\Rightarrow \quad P = 1 \tag{5}$$

If the borrowing constraint and price of the bond lead the country to default in exactly one state of the world, then in the equilibrium it must be that the bond price solves

$$P(1+r) = \frac{1}{2}(1+r) \tag{6}$$
$$\Rightarrow \quad P = \frac{1}{2} \tag{7}$$

Finally, no-arbitrage rules out the possibility of a strictly positive price of bonds when the borrower country defaults on bonds in both states of the world (since if the country defaults in both states of the world, the no-arbitrage condition implies that the price of bonds will be zero).

4.2. Default punishments

Some explicit punishment for default is necessary. Suppose the country could sell bonds at some price P in period 1. If there was no punishment for default, it would always be optimal to pursue the optimal plan from the benchmark model and then default on debts in both states in period 2. The no-arbitrage condition would then imply a zero price for bonds $P = 0$, so that de facto there is no international borrowing at all. It is therefore in the borrower countries own interest to have some default punishments that make repayment of bonds in at least some states optimal, so that a commitment to repay debts with positive probability is dynamically consistent.

In much of the existing literature, exclusion from future borrowing is the primary default punishment (e.g., Aguiar and Gopinath, 2006; Bai and Zhang, 2012; Cuadra and Sapriza, 2008; Lizarazo et al., 2009; Yue, 2010). Of course, exclusion from future borrowing is not a suitable punishment in a two period model. Moreover, Bulow and Rogoff (1989) argue that exclusion from future borrowing is in general not sufficient to prevent default and therefore not sufficient to provide access to international capital for LDECs. Empirical evidence also suggests that exclusion either does not occur in practice or is only very short-term (see, for e.g., Beers and Bhatia, 1999). Bulow and Rogoff (1989) suggest that other direct punishment mechanisms are required and state that: "Our analysis establishes rather general conditions under which small countries *cannot* establish a reputation for repayment. If these conditions are met empirically, then loans to LDECs are possible only if creditors have either political rights which enable them to threaten the debtor's interests outside its borrowing relationship, or legal rights. Legal rights might include the ability to impede a country's trade, or to seize it financial assets abroad." I capture both of the direct mechanisms suggested by Bulow and Rogoff (1989) by assuming that there are two punishments for default.

Table 1
No-arbitrage condition.

Lender's options	Invest	Return
Lend on the international market	P	$P(1+r)$
Lend to country that never defaults	P	$(1+r)$
Lend to country that defaults in one state only	P	$\frac{1}{2}(1+r) + \frac{1}{2}0 = \frac{1}{2}(1+r)$
Lend to a country that always defaults	P	0

First, I allow for a country that defaults on debts to be punished in terms of trade sanctions. Specifically, I assume that in period 2 the country looses access to the modern sector. If the country defaults, trade sanctions are imposed and it is not able to participate in international trade, and therefore cannot trade the output from production in the modern sector (which is specialized to international trade). Hence, a defaulting country is forced to produce using the traditional sector. This impediment to trade represents a default punishment because, by assumption, productivity in the modern sector dominates productivity in the traditional sector in both states of the world. It also captures, in a stylized way, the empirical observation that productivity – especially in exporting sectors – usually falls dramatically after default events.[14] Second, if the country defaults, I assume that all capital invested abroad is repossessed (i.e., returns on that capital do not accrue to the defaulting country).

Unlike Dubey et al. (2005), these penalties of default are pecuniary in nature. There is a material loss associated with the option to default. In particular, the first punishment (seizure/forfeiture of foreign assets) can be viewed as losing collateral in the event of default (where collateral is analogous to the investments made in foreign sector in period 1 for diversification purposes). This punishment is motivated by the literature on bankruptcy and default with collateralized and uncollateralized borrowing (e.g., Araujo et al., 2002; Tarun, 2003; Chatterjee et al., 2007; Geanakoplos and Zame, 2013). The second punishment (trade sanctions) reduces the return on capital if the economy defaults. This punishment is also modeled in preceding literature such as Kehoe and Levine (1993) and Tarun (2003). The underlined idea of this punishment is that since in both states of the world the modern sector performs better than the traditional sector (i.e., $a_s > A$), losing access to the modern sector results in a reduction of the return on capital by $a_s - A$ which is the difference between the state dependent return on capital from the modern sector and the return on capital from the traditional sector.

As a result of these default punishments, the borrower country faces the following trade-off: if it defaults it saves on the payment of debts and therefore retains a higher quantity of capital to use in domestic production. However, default also leads to repossession of foreign assets and trade restrictions which reduce the marginal return per unit of capital employed domestically.

It is the combination of the two default punishments (namely the trade sanction and seizure of foreign held capital) that is central to the analysis. The trade sanction is of greater importance in equilibrium, but if only trade sanctions are present there is a strong

[14] Martinez and Sandleris (2011) presents empirical evidence that sovereign defaults are associated with a decline in trade and productivity.

incentive for capital flight. Specifically, the agent can borrow on international capital markets and invest all capital in the foreign sector ($\theta_1 = 0$), then trade sanction is completely ineffective. The seizure of foreign held capital functions primarily to limit this option. The seizure of foreign capital never actually occurs on the equilibrium path. If seizure of capital was the only punishment, there would be a natural incentive to default first and foremost after the realization of a high productivity shock (when the foreign shock is low and so foreign held capital is less productive). The trade sanction counteracts this incentive because it affects the value of domestic capital in both states, and therefore affects the value of domestically held capital relatively more in the high state (when the domestic modern sector is most productive, and the loss of being forced into the traditional sector is therefore greatest).

4.3. Productivity assumptions

In addition to Assumption 1, the model with default introduces an additional assumption motivated by the default punishments.

Assumption 2. The following relationships exist between the productivity parameters in the modern sector and the traditional sector:

(A2) $(a_H - a_L)/2 < A < a_H - a_L$.

This additional inequality, (A2), puts a lower bound and an upper bound on the severity of punishments. This assumption can be interpreted as imposing an intermediate default punishments (see e.g., Dubey et al., 2005). Unlike Dubey et al. (2005), we exogenously impose these default punishments. The recent economic history of LDECs has numerous examples of external debt defaults (or substantial restructuring or renegotiation of debts) which, almost without exception, were precipitated by large negative output shocks. In the context of the model, A should be interpreted as the productivity in the open economy following this type of default event. The inequality $(a_H - a_L) < 2A$ puts an upper bound on how large the variation in productivity in the modern sector can be, relative to the output in a default event. The inequality $(a_H - a_L) > A$ puts a lower bound on the variation between the productivity realizations in the modern sector relative to the productivity in the default event.

4.4. Risk-adjusted equilibrium

A timeline summarizing the order in which decisions are made is given in Fig. 2.

For a given price of bonds $P \geqslant 0$, the representative agent now faces a more extensive optimization problem which includes the option to default on debts in period 2 (and the resulting default punishments):

Problem 2.

$$\max_{\{(c_1,K_1)\geqslant 0, D_1, \theta_1\in[0,1]\}, c_2^s, K_2^{Ms}, K_2^{Ts}} \quad u(c_1) + \beta\left[\frac{1}{2}u(c_2^H) + \frac{1}{2}u(c_2^L)\right]$$
$$\text{s.t.} \quad c_1 \leqslant A\overline{K} + PD_1 - K_1$$
$$c_2^s \leqslant \left[\lambda_2^s a_s K_2^{Ms} + AK_2^{Ts}\right] + \lambda_2^s(2\mu - a_s)(1-\theta_1)K_1 - \lambda_2^s(1+r)D_1$$
$$K_2^{Ms} + K_2^{Ts} \leqslant \theta_1 K_1$$
$$D_1 \leqslant \bar{\omega}K_1$$

When we compare Problem 1 and Problem 2, three main differences are evident: first the default decision denoted by λ_2^s is introduced, second the default punishments for default are included, and finally, the price of bonds P is introduced to allow for risk-premium to compensate investors for default risk. The solution concept

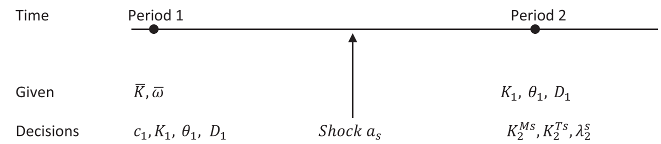


Fig. 2. Problem 2: Timeline.

for the analysis is a *risk-adjusted equilibrium*, which closes the model by adding the no-arbitrage condition to determine the price of bonds.

Definition 2. (Risk-Adjusted Equilibrium) For a given set of parameters $(a_H, a_L, A, r, \beta, \overline{K}, \bar{\omega})$, an allocation $(c_1, K_1, D_1, \theta_1, \lambda_2, c_2, K_2^M, K_2^T)$ and a bond price P constitute a *Risk-Adjusted Equilibrium* (henceforth RAE) if $\left(c_1, K_1, D_1, \theta_1, \lambda_2, c_2, K_2^M, K_2^T\right)$ solves Problem 2 and the no-arbitrage condition

$$P(1+r) = \frac{1}{2}(1+r)\lambda_2^H + \frac{1}{2}(1+r)\lambda_2^L \tag{8}$$

is satisfied.

The main result characterizes RAE of the model, and illustrates the interaction between *ex-ante* risk-sharing decisions and *ex-post* default decisions. Specifically, the characterization identifies two different regime types. In *Regime I* the country fully diversifies against productivity shocks ($\theta_1 = 1/2$), the country does not default on debt in either state ($\lambda_2 = (1,1)$), and the price of bonds equals 1 ($P = 1$). Regime I is therefore essentially identical to the solution in the benchmark model without default. However, for a sufficiently high borrowing constraint, there is an alternative regime, *Regime II*, in which the country does not utilize the possibility for international diversification at all ($\theta_1 = 1$), the country defaults in the low state and repays debts in the high state ($\lambda_2 = (1,0)$), and the risk of default is reflected in a price of bonds $P = 1/2$.

Proposition 2. *Suppose that Assumptions 1 and 2 are satisfied, then there exists a threshold value of the borrowing constraint* $\omega^* \in \left(0, \frac{a_L}{1+r}\right)$ *such that:*

1. *For any* $\bar{\omega} < \omega^*$ *there exists a unique Risk-Adjusted Equilibrium with an allocation* $K_1^* > 0$, $D_1^* = \bar{\omega}\bar{K}_1{}^*, \theta_1^* = 1/2$, $\lambda_2^* = (1,1), K_2^{M*} = ((1/2)K_1^*, (1/2)K_1^*), K_2^{T*} = (0,0)$ *and a price* $P = 1$. *Call this Regime I.*
2. *For any* $\bar{\omega} > \omega^*$ *there exists a unique Risk-Adjusted Equilibrium with an allocation* $K_1^* > 0$, $D_1^* = \bar{\omega}K_1^*, \theta_1^* = 1$, $\lambda_2^* = (1,0), K_2^{M*} = (K_1^*, 0)$, $K_2^{T*} = (0, K_1^*)$ *and a price* $P = 1/2$. *Call this Regime II.*
3. *For* $\bar{\omega} = \omega^*$, *there are exactly two Risk-Adjusted Equilibria, one in Regime I and one in Regime II.*

Proof. The proof is given in the Appendix. □

Fig. 3 illustrates value functions corresponding to three cases: Case 1 (bold line) captures full diversification and no default in both states, Case 2 (dotted line) captures no diversification and default in low state only and Case 3 (starred line) captures no diversification and default always. When $\bar{\omega} < \omega^*$, Case 1 dominates Case 2 and Case 3 and results into Regime I. When $\omega^* < \bar{\omega} \leqslant \frac{a_L}{1+r}$, Case 2 dominates Case 1 and Case 3 and results into Regime II. These regimes (Regime I and Regime II) are illustrated in the Figure.[15]

[15] Note that Case 3 is not relevant to our discussion as Assumption (A1.1) restricts $\bar{\omega} \leqslant \frac{a_L}{1+r}$.

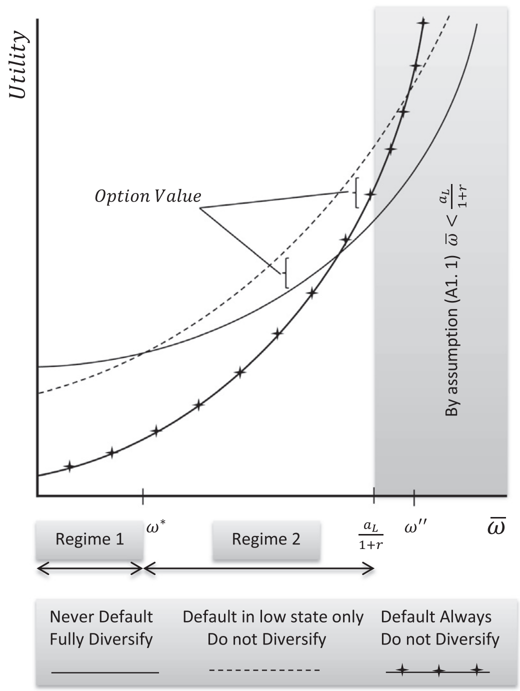


Fig. 3. Illustration of Proposition 2. Fig. 3 exhibits Proposition 2 by illustrating the value functions corresponding to three cases: Case 1 (bold line) captures full diversification and no default in both states, Case 2 (dotted line) captures no diversification and default in low state only and Case 3 (starred line) captures no diversification and default always. The first equilibria is captured in the Figure as Regime I where the agent fully diversifies and does not default in either states (Case 1 dominates). The second equilbria is captured in the Figure as Regime II where the agent does not diversify and defaults in the low state but not defaults in the high state (Case 2 dominates).

The interesting feature of Proposition 2 is the existence of Regime II and the existence of Regime II is closely tied to the intuition of the trade-off between the *ex-ante* diversification and the option-value of default. This intuition is illustrated in Fig. 4 which illustrates value functions in a situation with no diversification in Panel 4.1 and full diversification in Panel 4.2. The three cases in the illustration are as follows: (1) never default, (2) default in low state only and (3) default always. The comparison between the two panels show that diversification and option value of default are in conflict with each other. Option value of default is maximized when there is an exposure to risk (i.e., with no diversification) while diversification removes this exposure to risk and hence curtails the option value of default. Regime II exactly avails this option value of default (due to the exposure to the productivity shocks) and defaulting only in the low state.

There are two welfare implications of the introduction of a default option. First, for $\bar{\omega} = \omega^* + \epsilon$ for $\epsilon > 0$ but sufficiently small, the agent would strictly prefer Regime I (with full insurance against the productivity shock and a higher price of bonds $P = 1$). However, it is simply not possible to commit to not default, despite the severe default penalties. The option value of default is simply too high, and so the only RAE is in Regime II. As a result, when $\bar{\omega}$ goes above ω^*, the RAE is in Regime II even though this is welfare decreasing for the representative agent.

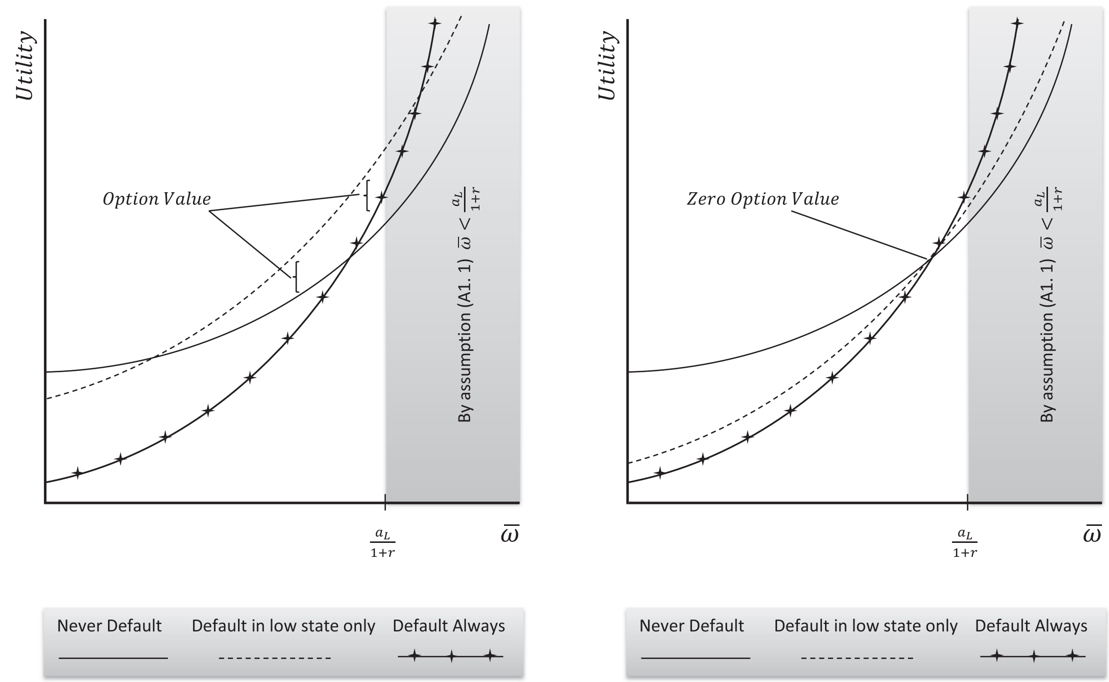
Second, in Regime II there is an inferior allocation of capital. One could easily re-cast the analysis in a two-country model, with another country that is identical except that the productivity shock is perfectly negatively correlated. For $\bar{\omega} < \omega^*$ the two countries would then fully share productivity risks, not default and receive a price of bonds $P = 1$ (Regime I). However, for $\bar{\omega} > \omega^*$, the countries would not share productivity risks, default in their own L state respectively, and each receive a price $P = 1/2$ for their bonds (Regime II). Again, that Regime II is realized in a RAE for $\bar{\omega}$ sufficiently high is a result of the inability to commit not to default, given the option value that default provides. However, the result is that the return on capital in one country is always a_H and in the other country would be A (because the country defaults and is forced to use the traditional sector). If the countries could commit not to default, then both countries could share risks and produce in the modern sector. One would then always have return on capital of a_H and the other a_L. Since, by Assumption (A1.2), $a_L > A$, Regime II therefore results in a lower overall return on capital from the two economies combined. The default option therefore implies a worse allocation of capital in the two small open economies. In addition to this worse allocation of capital, both countries in Regime II experience volatile consumption, while if they could commit to not default, they would achieve constant consumption across the two states in period 2. Since representative agents are risk-averse, this volatility is a further source of inefficiency.

5. Conclusion

The process of integrating LDECs into international capital markets has not always been smooth. The potential risk-sharing benefits of direct and equity investments which were supposed to decouple domestic income from idiosyncratic output shocks have not been fully realized. Default events on external and sovereign debts remain a recurring feature. Both of these aspects have been studied independently of each other in a large open economy literature. In this paper, I propose a model to look at both aspects together in an open economy framework. The model adapts the theory on collateralized household borrowing (e.g., Geanakoplos and Zame, 2013) and unsecured credit (e.g., Chatterjee et al., 2007), to an open economy framework. In such a framework, it is then possible to study the implications of sovereign default on capital allocation and risk sharing decisions.

Specifically, the model in this paper studies a small open economy that has *ex-ante* opportunities to hedge against idiosyncratic output shocks by allocating a fraction of its capital to a negatively correlated foreign sector, a borrowing decision, and an *ex-post* policy decision about default on external debts. The model highlights a general trade-off between risk-sharing and the option value of default. Risk-sharing reduces exposure to productivity shocks, but default options are valuable precisely when there is an exposure to shocks (so that default can be tailored ex-post to shock outcomes). In an equilibrium that accounts for the risk-premium that must be paid to international lenders facing default risks, the model generates a simple threshold in terms of the debt to capital ratio. When borrowing conditions are tight, so that the debt to capital ratio is low, the country optimally diversifies against all risks, never defaults, and achieves a high price of bonds. However, if borrowing conditions are more generous, so that the debt to capital ratio that can be achieved is higher, the country optimally gambles on high productivity and uses default as an insurance mechanism in case of bad productivity shocks.

The previous literature on sovereign default such as Arellano (2008); Aguiar and Gopinath (2006) and Bai and Zhang (2012) restrict the transactions in international market to non-contingent bonds only. These ex-post instruments to delink consumption growth from output growth are generally regarded as ineffective, due to the cyclicality of external debt borrowing (Kose et al. (2007)). In addition, many economies are now increasingly utilizing foreign direct investments and equities as an alternative means to delink consumption growth from output growth (Schmitz, 2012). The current paper contributes to this set of literature by emphasizing the role of the interaction of ex-post default risk with ex-ante allocation of capital in contingent assets which is increasingly



4.1: No Diversification   4.2: Diversification

Fig. 4. Trade-off between Diversification and the Option-Value of Default. Fig. 4.1 illustrates the option value of default in the situation with no diversification (Fig. 4.1 and full diversification (Fig. 4.2. The option value of default is related to the randomization over different *ex-post* default decisions (and implicitly on the default punishments). In particular, default in low state and not default in high state is optimal in the case where agent does not diversify the risk. This is the main reason behind the existence of Regime II in Proposition 2 and illustration in Fig. 3. This regime disappears with full diversification as it is illustrated in Fig. 4.2.

available in emerging economies as an alternative means for diversification purposes.

A number of theoretical predictions from the model can be used to understand salient features of the process of capital market integration experienced by LDECs. If a country gains greater access to international capital markets for non-contingent bonds (measured by a simple borrowing constraint in the model), the equilibrium of the model sees the country eschew ex-ante risk-sharing opportunities and enter a default regime, where it services debts when output shocks are good and defaults when output shocks are bad. The result is an unnecessarily high volatility of domestic consumption, an overall worse return on capital, and a concomitant decrease in welfare. All these features occur in equilibrium with compensation for international investors who bear default risks, and despite the fact that access to international capital markets has actually increased. This suggests that allowing LDECs to accumulate an excess debt to capital ratio without appropriate institutions to curtail default incentives, may substantially inhibit other potential gains of capital market integration, such as a more efficient allocation of capital or risk-sharing against idiosyncratic productivity shocks.

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Appendix

Proof of Proposition 1. First I establish a number of necessary conditions for a solution to Problem 1. Suppose that $\left(K_1^*, D_1^*, K_2^{M*}, K_2^{T*}, \theta_1^*\right)$ is a solution to the optimization problem of the borrower country. By backward induction, start in period 2 with a fixed $(K_1^*, D_1^*, \theta_1^*)$. Then by Assumption (A1.2), $a_s \in \{a_H, a_L\} > A$, then it must be that $K_2^{T*} = (0,0)$ and $K_2^{M*} = (K_1^*, K_1^*)$. As a result, $(K_1^*, D_1^*, \theta_1^*)$ must solve the following simplified optimization problem:

$$\max_{\{K_1 \geqslant 0, D_1, \theta_1 \in [0,1]\}} u(A\overline{K} + D_1 - K_1) + \frac{\beta}{2}[u(a_H\theta_1K_1 + (2\mu - a_H)(1-\theta_1)K_1 - (1+r)D_1) + u(a_L\theta_1K_1 + (2\mu - a_L)(1-\theta_1)K_1 - (1+r)D_1)]$$
$$s.t \;\; D_1 \leqslant \bar{\omega}K_1 \tag{9}$$

Next show that the country will fully diversify against its domestic productivity shock. The optimality of $\theta_1^* = 1/2$ follows directly from the concavity of u. Define

$$A := \theta_1\left[(a_H - a_L)K_1^* + a_LK_1^* - (1+r)D_1^*\right] + (1-\theta_1)\left[a_LK_1^* - (1+r)D_1^*\right] \tag{10}$$
$$B := \theta_1\left[(a_L - a_H)K_1^* + a_HK_1^* - (1+r)D_1^*\right] + (1-\theta_1)\left[a_HK_1^* - (1+r)D_1^*\right] \tag{11}$$

For an arbitrary $\theta_1 \in [0,1]$ note that period 2 expected utility is given by $(1/2)u(A) + (1/2)u(B)$, while expected utility for $\theta = 1/2$ is given by $u[(A+B)/2]$. Since u is concave

$$u\left(\frac{A+B}{2}\right) \geqslant \frac{1}{2}u(A) + \frac{1}{2}u(B) \tag{12}$$

and the inequality is strict whenever $K_1^* > 0$. It follows that the optimal $\theta_1^* = 1/2$.

Now using that $K_2^{T*} = (0,0), K_2^{M*} = (K_1^*, K_1^*)$ and $\theta_1^* = \frac{1}{2}$, it follows that K_1^* and D_1^* must solve the following optimization problem:

$$\max_{\{K_1 \geqslant 0, D_1\}} \;\; u(A\overline{K} + D_1 - K_1) + \beta[u(\mu K_1 - (1+r)D_1)$$
$$s.t \;\; D_1 \leqslant \bar{\omega}K_1 \tag{13}$$

We next observe that in any solution to Problem 13, $K_1^* > 0$. For sake of contradiction, suppose this is not the case and that $K_1 = 0$ at a solution. Then by the constraint $c_2 \geqslant 0$ this implies $D_1^* \leqslant 0$. Suppose first that there is any feasible plan with $D_1 = 0$, then

$c_2 = 0$ and for $\epsilon > 0$ and sufficiently small $K_1 = \epsilon$ is feasible. Moreover, by the Inada condition on u ($\lim_{c\to 0} u'(c) = \infty$), for ϵ sufficiently small, $K_1 = \epsilon$ strictly dominates $K_1 = 0$. Hence, $K_1 = 0$ and $D_1 = 0$ is strictly dominated by a plan with $K_1 > 0$ and $D_1 \leqslant 0$.

Now suppose $K_1 = 0$ and $D_1 < 0$ but feasible, with corresponding $c_1 \geqslant 0$. Then consider the alternative plan $(\widehat{K}_1, \widehat{D}_1, \hat{c}_1) = (-D_1, 0, c_1)$. This plan is feasible since (K_1, D_1, c_1) is feasible since $\mu > (1+r)$, this plan strictly dominates (K_1, D_1) because it leads to strictly greater c_2 in both states. Hence, $K_1 = 0$ is always strictly dominated by a plan with $K_1 > 0$.

Next show that at a solution the borrowing constraint must bind at a solution to Problem 13. Specifically, suppose that we have a solution with $K_1^* > 0$, then we argue that $D_1 < \bar{\omega} K_1^*$ is strictly dominated by $\widehat{D}_1 = \bar{\omega} K_1^*$. To see this, suppose that there is a feasible plan with $D_1 = \bar{\omega} K_1^* - \epsilon$ for some $\epsilon > 0$ and period 1 consumption of $c_1 \geqslant 0$. Then the plan $(\widehat{K}_1, \widehat{D}_1, \hat{c}_1) = (K_1 + \epsilon, D_1 + \epsilon, c_1)$ is feasible. Since c_1 remains unchanged period 1 utility remains unchanged. However, c_2 increases by $(\mu - (1+r))\epsilon > 0$ (implied by Assumption (A1.2)). Hence, for $K_1^* > 0, D_1 < \bar{\omega} K_1^*$ is strictly dominated by $\widehat{D}_1 = \bar{\omega} K_1^*$.

Now, using that at a solution $K_2^{T*} = (0,0), K_2^{M*} = (K_1^*, K_1^*), \theta_1^* = \frac{1}{2}$, $K_1^* > 0$ and $D_1^* = \bar{\omega} K_1^*$, we can determine the optimal K_1^* by solving the following simplified problem.

$$\max_{K_1 > 0} u(A\overline{K} - (1-\bar{\omega})K_1) + \beta u((\mu - \bar{\omega}(1+r))K_1) \tag{14}$$

With a solution of K_1^* from this problem, we have a solution to the optimization Problem 1 (given in the text). It therefore remains to show that there exists a unique $K_1^* > 0$ that solves Problem 14. It is straightforward to verify that the objective function in Problem 14 is continuously differentiable and strictly concave, and so the following first order condition is necessary and sufficient for a solution to Problem 14:

$$\begin{aligned} f(K_1) :&= \beta(\mu - \bar{\omega}(1+r))u'((\mu - \bar{\omega}(1+r))K_1) \\ &\quad - (1-\bar{\omega})u'(A\overline{K} - (1-\bar{\omega})K_1) = 0 \end{aligned} \tag{15}$$

Now note that,

$$\begin{aligned} f'(K_1) &= \beta \underbrace{u''(\mu K_1 - (1+r)\bar{\omega} K_1)}_{<0 \text{ by concavity}} \underbrace{(\mu - (1+r)\bar{\omega})^2}_{>0} \\ &\quad + \underbrace{(1-\bar{\omega})^2}_{>0} \underbrace{u''(A\overline{K} - (1-\bar{\omega})K_1)}_{<0 \text{ by concavity}} < 0 \end{aligned} \tag{16}$$

$$\lim_{K_1 \to 0} f(K_1) > 0 \tag{17}$$

$$\lim_{K_1 \to \frac{A\overline{K}}{1-\bar{\omega}}} f(K_1) < 0. \tag{18}$$

Hence, by the intermediate value theorem, there exists a unique $K_1^* > 0$ that solves (16). Since the FOC are both necessary and sufficient, it follows that $K_1^* > 0$, $D_1^* = \bar{\omega} K_1^*, \theta_1^* = (1/2)$, $K_2^{T*} = (0,0)$ and $K_2^{M*} = (K_1^*, K_1^*)$ is the unique efficient allocation. □

Proof of Proposition 2. We first consider the optimization problem for the borrower country given a price for bonds $P = 1$. In this case, the borrower country faces the following optimization problem:

$$\begin{aligned} v(\overline{K}, \bar{\omega}) &= \max_{\{(c_1, K_1) \geqslant 0, D_1, \theta_1 \in [0,1]\}, c_2^s, K_2^{Ms}, K_2^{Ts}} u(c_1) \\ &\quad + \frac{\beta}{2}\left[u(c_2^H(K_1, \theta_1, D_1)) + u(c_2^L(K_1, \theta_1, D_1))\right] \\ \text{s.t.} \quad c_1 &\leqslant A\overline{K} + D_1 - K_1 \\ c_2^s &\leqslant \left[\lambda_2^s a_s K_2^{Ms} + A K_2^{Ts}\right] + \lambda_2^s (2\mu - a_s)(1-\theta_1)K_1 - \lambda_2^s (1+r) D_1 \\ K_2^{Ms} + K_2^{Ts} &\leqslant \theta_1 K_1 \\ D_1 &\leqslant \bar{\omega} K_1 \end{aligned} \tag{19}$$

In period 2 there are four possible default choices. By Assumption (A1.2) $a_H > a_L > A$ each default choice immediately determines an optimal period 2 capital allocation. Hence, there are four possible optimal plans in period 2:

1. $\lambda_2 = (1,1), K_2^M = (K_1, K_1), K_2^T = (0,0)$;
2. $\lambda_2 = (0,0), K_2^M = (0,0), K_2^T = (K_1, K_1)$;
3. $\lambda_2 = (1,0), K_2^M = (K_1, 0), K_2^T = (0, K_1)$;
4. $\lambda_2 = (0,1), K_2^M = (0, K_1), K_2^T = (K_1, 0)$.

We next study the optimal period 1 decision corresponding to each of the four cases.

Begin with case (1). Since $P = 1$ and $\lambda_2 = (1,1)$ this case is essentially identical to the optimization problem (Problem 1) in Proposition 1. We therefore have that for any $(\overline{K}, \bar{\omega})$ there exists a $K_1^1 > 0$ such that $K_1^* = K_1^1, D_1^* = \bar{\omega} K_1^1, \theta_1 = (1/2)$ are the optimal period 1 choices.

Now consider case (2). In this case $\theta_1 = 1$ clearly dominates any $\theta_1 < 1$ (since in state H it is optimal to have $\theta_1 = 1$ because the home country has a higher return on capital, and in state L it is optimal to have $\theta_1 = 1$ because of the default punishment), and dominates strictly if $K_1 > 0$. We can use the same argument used in the proof of Proposition 1 to show that $K_1 > 0$ strictly dominates $K_1 = 0$. Moreover, using $\theta_1 = 1$, the constraint $D_1 = \bar{\omega} K_1$ clearly binds. It then follows as for Case (1) that there exists $K_1^2 > 0$ such that $K_1^* = K_1^2, D_1^* = \bar{\omega} K_1^2, \theta_1 = 1$ are the optimal period 1 choices.

Now consider case (3). Again, $\theta_1 = 1$ clearly dominates any $\theta_1 < 1$ (due to the default punishment), and dominates strictly if $K_1 > 0$. It again follows as in the proof of Proposition 1 that $K_1 > 0$ strictly dominates $K_1 = 0$. Moreover, the constraint $D_1 = \bar{\omega} K_1$ must bind (since the constraint binds in case (1) where in state H and L, the return on capital is μ, and here the return on capital is $a_H > \mu$ in state H and in state L there is a default). It then follows as for Case (1) that there exists $K_1^3 > 0$ such that $K_1^* = K_1^3, D_1 = \bar{\omega} K_1^3, \theta_1 = 1$ are the optimal period 1 choices.

Finally, consider case (4). Fix any $\theta_1 \in [0,1]$ and observe that by the same arguments as in the proof of Proposition 1 it again follows that $K_1 > 0$, and the constraint $D_1 = \bar{\omega} K_1$ binds. Now observe that in period 1, for any $K_1 > 0$ and $D_1 = \bar{\omega} K_1$ the expected period 2 utility under case (4) is

$$\frac{1}{2} u([A\theta_1]K_1) + \frac{1}{2} u(([a_L \theta_1 + a_H(1-\theta_1)] - (1+r)\bar{\omega})K_1) \tag{20}$$

For $\theta_1 = 1$, the expected period 2 utility under case (3) is

$$\frac{1}{2} u(AK_1) + \frac{1}{2} u([a_H - (1+r)\bar{\omega}]K_1) \tag{21}$$

Clearly, for any $\theta_1 \in [0,1]$ the expected utility in (20) is dominated by the expected utility in (21), and dominated strictly whenever $K_1 > 0$. Hence, case (4) will not affect period 1 decisions.

We are therefore left with three cases, each of which directly determines an optimal θ_1 decision, and in each of which $K_1 > 0$ and the borrowing constraint binds.

We next determine which case dominates from a period 1 perspective. For this, we use the fact that utility is multiplicatively separable, so that each case corresponds to a unique optimal choice of θ_1 independently of K_1. This allows us to compare the respective expected period 2 utilities only in terms of parameters. Corresponding to each of the three remaining cases and for any $K_1 > 0$, these are therefore:

$$\text{Case1}: \ u((\mu - (1+r)\bar{\omega})u(K_1) \tag{22}$$

$$\text{Case2}: \ u(A)u(K_1) \tag{23}$$

$$\text{Case3}: \ \left[\frac{1}{2} u(a_H - (1+r)\bar{\omega}) + \frac{1}{2} u(A)\right] u(K_1) \tag{24}$$

We now compare these three expected utilities to determine values of $\bar{\omega}$ at which each one of the cases dominates.

- Case 1 < Case 2: By the assumption that u is strictly increasing, this holds if and only if

$$A > \mu - (1+r)\bar{\omega} \quad (25)$$

$$\iff \quad \bar{\omega} > \frac{\mu - A}{1+r} =: \omega' \quad (26)$$

- Case 3 < Case 2: By the assumption that u is strictly increasing, this holds if and only if

$$A > a_H - (1+r)\bar{\omega} \quad (27)$$

$$\iff \quad \bar{\omega} > \frac{a_H - A}{1+r} =: \omega'' \quad (28)$$

- Case 1 > Case 3: It is not possible to get a closed form solution, but we show that a unique ω^* exist between 0 and ω' such that Case 1 > Case 3 if and only if $\bar{\omega} < \omega^*$. Define $f(\omega)$ as:

$$f(\omega) = u(\mu - (1+r)\omega) - \frac{1}{2}u(a_H - (1+r)\omega) - \frac{1}{2}u(A) \quad (29)$$

First observe that

$$\frac{\partial f(\omega)}{\partial \omega} = -(1+r)u'(\mu - (1+r)\bar{\omega}) - \frac{1}{2}(-(1+r))u'(a_H - (1+r)\bar{\omega}) \quad (30)$$

$$= \underbrace{-(1+r)}_{<0} \underbrace{\left[u'(\mu - (1+r)\bar{\omega}) - \frac{1}{2}u'(a_H - (1+r)\bar{\omega})\right]}_{>0} \quad (31)$$

$$< 0 \quad (32)$$

Now note that

$$f(0) = u(\mu) - \frac{1}{2}u(a_H) - \frac{1}{2}u(A) \quad (33)$$

By strict concavity of u,

$$u(\mu) > \frac{1}{2}u(a_H) + \frac{1}{2}u(a_L) \quad (34)$$

$$> \frac{1}{2}u(a_H) + \frac{1}{2}u(A) \quad (35)$$

Hence, $f(0) > 0$. Next note that

$$f\left(\frac{\mu - A}{1+r}\right) = u(A) - \frac{1}{2}u(a_H - (\mu - A)) - \frac{1}{2}u(A) \quad (36)$$

$$= \frac{1}{2}[u(A) - u(A + (a_H - \mu))] \quad (37)$$

Since $a_H > \mu$ and u is strictly increasing, it follows that $f((\mu - A)/(1+r)) < 0$. Hence, by the continuity of u, there exists a unique $\omega^* \in (0, \omega')$ such that $f(\omega) > 0$ if and only if $\omega < \omega'$ and $f(\omega) = 0$ if and only if $\omega = \omega'$.
- Now make two observations:
  - We have $\omega', \omega'', \omega^*$ such that $0 < \omega^* < \omega' < \omega''$. Also, for $\bar{\omega} \in [0, \omega^*)$ Case 1 strictly dominates Case 2 and Case 3; for $\bar{\omega} = \omega^*$ Case 1 and Case 3 lead to the same expected utility and both dominate Case 2.
  - Assumption (A2) implies that $\omega' < \frac{a_L}{1+r} < \omega''$. Also, for $\bar{\omega} \in (\omega^*, \frac{a_L}{1+r}]$ Case 3 strictly dominates Case 1 and Case 3.

We can now complete the proof of Proposition 2 by establishing a number of claims.

Claim 1.

When $\bar{\omega} < \omega^*$ there exists a unique RAE, and it is of Regime I.

Proof. Suppose that the price for bonds is $P = 1$. By the arguments at the beginning of the proof, an optimal solution to the borrower countries optimization problem (if it exists) occurs under Case (1). Assumption (A1.3) implies that $\mu > (1+r)$ and it therefore follows exactly as in the proof of Proposition 1 that there exist a unique $K_1^* > 0$, such that $(K_1^*, D_1^* = \bar{\omega}K_1^*, \theta_1^* = 1/2, \lambda_2^* = (1,1), K_2^{M*} = ((1/2)K_1^*, (1/2)K_1^*), K_2^{T*} = (0,0))$ is the unique optimal plan for the borrower country. Moreover, given $\lambda_2^* = (1,1)$ the no arbitrage condition implies that $P = 1$. Hence, this is a Regime I Risk-Adjusted Equilibrium.

Now note that for any $P \geqslant 0$ the borrowing constraint implies that it is never optimal for the borrower country to default, since the period 2 constraint is identical to the period 2 constraint in Problem 1 (in the text), and with a debt to capital ratio $D_1/K_1 < \omega^*$ it follows from the proof of Proposition 1 that default in period 2 is never optimal. As a result, an optimal plan for the borrower country always involves $\lambda_2 = (1,1)$. Hence, any price $P \neq 1$ can not occur in a risk adjusted equilibrium. Hence the Regime I RAE is unique. □

Claim 2. *When $\bar{\omega} > \omega^*$ there is a unique RAE, and it is of Regime II.*

Proof. First consider the optimization problem of the borrower country if the price of bonds $P = 1/2$.

To show that the borrowing constraint will bind at an optimal plan, first consider the case when the default decision in period 2 is $\lambda_2 = (1,0)$. Suppose for sake of contradiction that $(c_1, K_1, D_1) \geqslant 0$ is part of a feasible plan in which $D_1 = \bar{\omega}K_1 - \epsilon$ for some $\epsilon > 0$ (hence, the borrowing constraint does not bind). Consider an alternative plan in which period 1 choices have changed to $(\hat{c}_1, \widehat{K}_1, \widehat{D}_1) = (c_1, K_1 + (\epsilon/2), D_1 + \epsilon)$. Note that at a price of $P = 1/2$ this plan is feasible because the plan (c_1, K_1, D_1) was feasible by assumption. Under the new plan consumption in period 1 is unchanged and the change in period 2 consumption in state H is $(a_H(\epsilon/2) - (1+r)\epsilon)$. By Assumption (A1.3), $a_H > 2(1+r)$ and therefore the last term is strictly positive. The change in period 2 consumption in state L is $A(\epsilon/2) > 0$. Hence, expected utility under the plan $(\hat{c}_1, \widehat{K}_1, \widehat{D}_1)$ is strictly greater because u is strictly increasing.

By an analogous argument, the borrowing constraint binds when the default decision in period 2 is $\lambda_2 = (1,1)$.

When the default decision is $\lambda = (0,0)$ the borrowing constraint necessarily binds, since additional borrowing can always be used to increase period 1 utility without any decrease in period 2 utility (due to default).

The borrowing constraint therefore binds for all relevant (i.e., not always dominated) period 2 default decisions, and the borrowing constraint must therefore bind at an optimal plan.

However, since the period 2 problem itself does not depend on the price of bonds (P), it follows from the arguments regarding Problem 19 that when the borrowing constraint binds and $\bar{\omega} \in \left(\omega^*, \frac{a_L}{1+r}\right]$, there exists a unique $K_1^* > 0$ such that the unique optimal plan of the borrower country is $(K_1^*, D_1^* = \bar{\omega}K_1^*, \theta_1^* = 1, \lambda_2^* = (1,0), K_2^{M*} = (K_1^*, 0), K_2^{T*} = (0, K_1^*))$. Also, given $\lambda_2^* = (1,0)$ the no arbitrage condition implies that $P = 1/2$. Hence, for $\bar{\omega} \in \left(\omega^*, \frac{a_L}{1+r}\right]$, this is a Regime II risk adjusted equilibrium.

To show uniqueness of the RAE found above for $\bar{\omega} \in \left(\omega^*, \frac{a_L}{1+r}\right]$, first suppose that $P > 1/2$. Then it is clear that at any optimal plan the borrowing constraint binds and therefore $\lambda_2 = (1,0)$. It then follows that P is not consistent with the no arbitrage condition. Now suppose that $P < 1/2$. This can be consistent with the no arbitrage condition only if $P = 0$ and $\lambda_2 = (0,0)$. If $P = 0$ there is no benefit of borrowing and so no benefit of defaulting on debts. The borrower country should therefore not borrow and fully diversify by choosing $\theta_1 = 1/2$ following the argument of Proposition 1. However, if the $\theta_1 = 1/2$ and $D_1 = 0$, there is clearly a cost of default. Hence, $\lambda_2 = (1,1)$ is optimal. Hence, $P = 0$ and $\lambda_2 = (0,0)$

cannot be a RAE. It follows that $P = 1/2$ is the unique price at which there exists a RAE when $\bar{\omega} \in \left(\omega^*, \frac{a_L}{1+r}\right]$, and so the Regime II RAE is unique. $\square$

Claim 3. *When $\bar{\omega} = \omega^*$ there are two RAE, one of Regime I and one of Regime II*

Proof. In the arguments regarding Problem 19, when $\bar{\omega} = \omega^*$, the period 2 utility of Case (1) is equal to the period 2 utility of Case (3). Now if $P = 1$, then following the proof of Claim 1 there is a solution to the optimization problem of the borrower country with $\lambda_2 = (1,1)$. When $\lambda_2 = (1,1), P = 1$ satisfies the no-arbitrage condition, and so there is a RAE of Regime I. If $P = 1/2$, then following the proof of Claim 2 there is a solution to the optimization problem of the borrower country with $\lambda_2 = (1,0)$. When $\lambda_2 = (1,0)$, $P = 1/2$ satisfies the no-arbitrage condition, and so there is a RAE of Regime II.

To show that there are no other RAE, consider the case when $P = 1$ and suppose that $\lambda_2 \neq (1,1)$. Then P does not satisfy the no-arbitrage condition. If $P = 1/2$ and $\lambda_2 \neq (1,0)$, then the no-arbitrage condition implies that $\lambda_2 = (0,1)$. But the arguments regarding Problem 19 show that this is not a solution to the borrower countries period 2 problem when $\bar{\omega} = \omega^*$. The only other possibility is $P = 0$ and $\lambda_2 = (0,0)$, but this is not a RAE by the same arguments as at the end of Claim 2. Hence, the Regime I and Regime II RAE are the only RAE when $\bar{\omega} = \omega^*$. $\square$

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