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Corporate leverage and currency crises[☆]

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Abstract

Currency crises can arise because it is optimal to bail out financially distressed exporting firms through a currency depreciation. Exporting firms will not undertake profitable investments when high leverage causes debt overhang problems. A currency depreciation increases the profitability of new investments when revenues are foreign-currency denominated and domestic-currency costs are nominally rigid. Ex ante, currency depreciation leads to excessive investment in risky projects even if safer, more valuable projects are available. However, currency depreciation is optimal ex ante if the risky projects have higher expected returns and if firms must rely on debt financing because of underdeveloped equity markets. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

Currency crises have been a frequent phenomenon in recent years. During the past decade, there have been major crises in Europe (the crisis of the Exchange Rate Mechanism), in Latin America (the Tequila crisis), and most recently in Asia. Moreover, these crises are difficult to ascribe solely to incompetent macroeconomic policies. In particular, the Asian currency crisis in 1997–1998 was unexpected and its magnitude a shock. By conventional fiscal measures, the governments of the afflicted countries were not in bad shape at all at the beginning of 1997. Only a couple of years earlier, the very same countries were held as good examples of prudent macroeconomic management by the World Bank. Their budget deficits were not excessive even though the growth of these economies had slowed somewhat during 1996. Current account deficits were large in some countries (Thailand and Malaysia), but in others (Korea and Indonesia) they were very modest. Indeed, Krugman (1999) concludes that there was not a strong case to be made for currency depreciations for macroeconomic reasons. Radelet and Sachs (1998) go even further and blame the magnitude of the crisis on financial panic in the currency markets, aggravated by bad advice from the IMF.

This paper provides a view of currency crises, based on excessive indebtedness and low profitability in the corporate sector, that is applicable to the Asian crisis as well as to some extent to the earlier European and Latin American crises. The argument proposed in this paper is that restoring investment incentives in financially distressed exporting firms through a currency depreciation is optimal *ex post* for an economy. In our model, the economy consists of profit-maximizing exporting firms, whose products are sold in the world markets. These firms can choose either safe or risky business strategies that can be financed either with debt or equity. If the firms choose the risky strategies, they can attain very high profits with some probability. If the chosen strategies fail, the exporting firms can partially recover their losses by investing in profitable new business opportunities. If the firms have been financed with debt, however, they will not undertake the new investments because of debt overhang problems, *i.e.*, because the new investments would only benefit the creditors.

The government would like the new investments to take place, because they would increase the amount of real income for the economy, net of opportunity costs. In our model, the domestic currency is initially pegged to the foreign one. The government can make investments feasible by not defending the currency and thus letting it float. The resulting equilibrium currency depreciation will increase the profitability of new investments when revenues from the new investments are denominated in a foreign currency and when costs denominated in the domestic currency are sticky. If the exporting firms have been financed with equity, the new investment opportunities are feasible and the investments will always take place, and hence there is no need for currency depreciation. However, exporting firms in this model have an incentive to finance their risky projects with debt instead of equity, even if equity financing is readily available, thus forcing a currency depreciation. Moreover, there is no need for a depreciation if the amount of debt can be renegotiated privately between firms

and their creditors, but firms prefer currency depreciation to debt renegotiation because with nominal rigidities in investment costs, the resulting losses from a depreciation are borne by the suppliers of those investments. With private debt renegotiations, the costs are ultimately borne by the firms themselves. Thus, exporting firms have an incentive to precommit not to renegotiate debt levels.

Currency depreciations can be optimal insurance schemes *ex ante* if the risky investments have a higher expected value than the safe ones and if firms are forced to rely on debt financing. Without currency depreciations, equity-constrained firms might have to choose the less profitable safe strategies because of the unavoidable debt overhang problems in risky projects.

Although currency depreciations in this context are always optimal *ex post*, they can be harmful *ex ante* when the safe projects are the more valuable ones. Exporting firms know that the government will not defend the exchange rate if their risky investments have failed, provided that the investments have been financed with debt and there are no debt renegotiations between exporters and their creditors. High leverage without renegotiation leads to a situation in which the exporting companies capture the upside of the investment, but do not suffer from the downside. Therefore, firms make excessive investments in risky projects at the expense of more valuable safe projects.

Moreover, if firms cannot be financed by equity because equity markets are underdeveloped, the extent of the inefficiency could increase. The owners now prefer to engage in risky investments and finance them with debt to a greater extent than with equity financing, because the owners are unable to commit to take the more profitable safer projects even if that would be in their best interest. Equity is the only financing source that provides the owners with the right incentives. Finally, if exporting firms' old debt is denominated in a foreign currency, a larger depreciation is needed to restore incentives to invest. So, somewhat surprisingly, foreign debt only exacerbates the problem. The government would like to commit not to let the currency depreciate, if the safe business strategies are more valuable for the economy as a whole. However, financial markets and exporting firms know that the government will rescue the exporting firms by letting the currency float if need be. Hence the government's wishes to maintain the fixed exchange rate are not credible.

Why did Asia experience a currency crisis? According to our model, the answer is that the countries afflicted were export-oriented countries dominated by large firms with extremely high leverage and low profitability. The recent capital market liberalizations in these countries had resulted in increased foreign-currency borrowing, thus further increasing leverage above already high levels. Moreover, depression in Japan, a strong dollar and a real depreciation of Chinese yuan had severely reduced the profitability of exporting companies. We argue that in the absence of debt renegotiation, the only way out of this debt overhang problem was a currency depreciation.¹

¹Our model also helps to explain some aspects of previous currency crises. A good example is Finland during the European currency crisis in 1991–1993. Finland had pursued an export-led growth strategy not unlike the Asian countries. The exporting firms had high leverage and had invested heavily throughout the 1980s. Moreover, the capital markets had recently been liberalized, and as a result firms had increased

The rest of this paper is organized as follows. Section 2 reviews the related literature. In Section 3 we present the basic framework, in Section 4 we discuss the debt–equity choice when currency depreciations are possible, and in Section 5 we extend the model in several directions. The empirical implications that arise from the model are analyzed in Section 6. Section 7 concludes the paper. All proofs are in the Appendix.

2. Related literature

Our model is indebted to several papers, in the fields of both corporate finance and macroeconomics. The underinvestment problem due to debt overhang was first dealt with by Myers (1977). Jensen and Meckling (1976) show that high levels of debt can lead to overinvestment in risky projects. Especially important to our model is Dewatripont and Maskin (1995), who argue that credit decentralization as a commitment mechanism not to refinance investment projects, when refinancing is optimal *ex post*, discourages managers from undertaking unprofitable risky ones in the first place. This paper is also related to Bolton and Scharfstein (1996), who show that liquidation due to inefficient renegotiation of debt can be beneficial in deterring default.

In the “first generation” of currency crises models developed by Krugman (1979) and Flood and Garber (1984), large budget deficits financed through money creation lead eventually to a decline in currency reserves and to a speculative attack on the currency. In the “second generation” of currency crises models pioneered by Obstfeld (1994), the government has an incentive to devalue the currency because of mounting unemployment. The currency markets understand the government’s incentives, and the resulting attack on the currency increases the incentives of the government to devalue (through higher interest rates), eventually leading to a depreciation.

There are several papers that depart from the traditional macroeconomic reasoning in explaining currency crises. Corsetti et al. (1998a,b, 1999) argue in a view somewhat complementary to ours that creditors’ capital was at least implicitly guaranteed in some Asian countries, if financial difficulties were to arise. This guarantee would naturally lead to overinvestment in risky projects at the expense of

(footnote continued)

their foreign borrowing. The strategy of high leverage and excessive investments would have been risky at best of times, but Finland suffered two major external shocks: the German unification and the collapse of the Soviet Union. The German unification resulted in higher real interest rates and an appreciating Deutsche mark to which the Finnish markka was pegged through the ECU, and the collapse of the Soviet Union meant that Finland lost a major export market. The only way of making further investments feasible was to reduce costs, including the debt level, relative to future cash flows. This was achieved by a currency devaluation. The markka was devalued by 12% in November 1991 and then in the following year the government was forced to let the markka float, resulting in an even bigger depreciation than the year before. For further analysis of the Finnish crisis, see Honkapohja and Koskela (1999), especially for the role that financial liberalization played in the onset of the Finnish crisis.

safer ones. In our model, however, it is the exporting firms' investments that are guaranteed to succeed, not the financiers' returns directly. Chang and Velasco (1998a,b) model a currency crisis in the same way that Diamond and Dybvig (1983) model a bank run. With foreign borrowing and a fixed exchange rate, a run on banks becomes a run on the currency. The currency collapses when the central bank runs out of currency reserves. In Caballero and Krishnamurthy (1999), an outflow of capital can lead to domestic fire sales when a country has a lack of international collateral, thus deepening a capital account crisis to a full financial crisis and rendering these expectations self-fulfilling. Allen and Gale (2000) argue that currency crises can serve as a risk-sharing mechanism between domestic bank depositors and international bond markets. Aghion et al. (2000) and Krugman (1999) also put financial distress at the center of currency crises, but the order of causality is opposite to ours: in these models, shocks or loss of confidence cause a currency depreciation which then causes balance sheet problems for corporations and perhaps depreciations, whereas balance sheet problems cause the depreciation in our model. The reason for this difference is that in those models a depreciation decreases firms' profitability and in our model it increases profitability. Johnson et al. (2000) emphasize problems in corporate governance as an explanation for the Asian crisis and show that a lack of outside investor protection is related to the extent of depreciation in emerging markets.

Gertler (1992) and Lamont (1995) have also studied the macroeconomic consequences of corporate debt overhang. In Gertler (1992), reduced current cash flow caused by adverse productivity shocks leads to a situation in which new investments would benefit mainly debtholders. In Lamont (1995), debt overhang is caused by changes in expectations about future economic conditions.

3. The basic model

The model consists of two periods and two markets: a foreign (world) market and a domestic (home) market. Fig. 1 schematically portrays the timing of the events in the model. At $t = 0$, a representative firm (which could also be a continuum of firms with the same opportunity sets and facing identical shocks) makes both the investment and the financing decisions. The firm produces in the home market, but sells its output in the world markets. The firm's output is the only source of export revenue available to the home market. All agents in our model are risk neutral and the world interest rate r^* is normalized to zero. We assume that the firm is not big enough to affect the level of interest rates nor any other prices, so the firm acts as a price taker in all markets. We assume perfect capital mobility between the world and home markets. The domestic currency is assumed to be pegged to the foreign currency at $t = 0$.

The firm can invest in two projects. Both projects require the same initial investment I_1 denominated in the domestic currency, and the output from both projects is a tradable good that is sold in the foreign market. Prices in the foreign market are denominated in dollars. The exchange rate at $t = 0$ is normalized to be

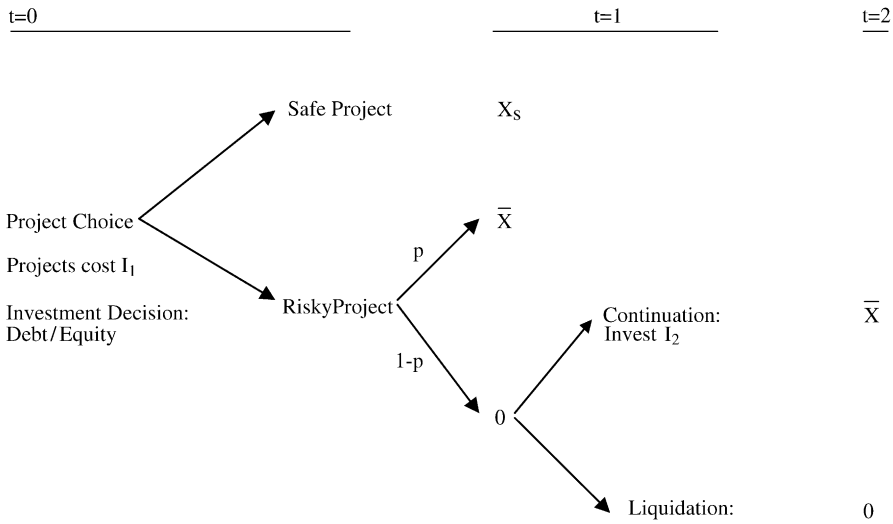


Fig. 1. Timing of the game. The firm can invest in two projects. Both projects require the same initial investment I_1 in the domestic market, and the output is an exportable good that is sold in the foreign market. Prices in the foreign market are denominated in dollars. The exchange rate at $e_0 = 1$ units of domestic currency per dollar. Project S (safe) yields a sure return of X_s dollars at $t = 1$; project R (risky) yields \bar{X} dollars with probability p and zero with probability $1 - p$. However, if the risky project turns bad, the firm can make a continuation decision at $t = 1$, that involves investing I_2 in the domestic market at $t = 1$ and making a sure return of \bar{X} dollars at $t = 2$. Otherwise, the firm is liquidated and the proceeds from liquidation are L , where $L = 0$.

$e_0 = 1$ unit of domestic currency per one dollar. We denote by e the exchange rate prevailing at $t = 1$.

Because of perfect capital mobility and risk neutrality, the uncovered interest rate parity holds:²

$$1 + r = (1 + r^*) \frac{E(e)}{e_0}$$

$$\Rightarrow 1 + r = E(e), \tag{1}$$

where r is the domestic interest rate. The uncovered interest rate parity thus implies that the domestic interest rate is equal to the expected currency depreciation at $t = 1$.

²When the uncovered interest rate parity holds, there are no excess profits to be made for domestic investors, if they want to borrow from domestic market and invest in the foreign market. However, due to the Siegel's paradox (Siegel, 1972), foreign investors can make excess profits by borrowing from the foreign market and investing in the domestic market. This paradox occurs only if domestic investors are interested in returns measured in the domestic currency and foreign investors in returns in the foreign currency. This problem can be avoided by choosing a common numeraire for all investors, or by assuming that purchasing parity holds. In this paper, we apply the first solution (see Siegel, 1975). In our model, the purchasing power parity does not strictly hold, since costs do not adjust immediately to the currency depreciation. We thank Franklin Allen, the referee, for pointing out this problem to us.

Project *S* (safe) yields a sure return of X_s dollars at $t = 1$; project *R* (risky) yields \bar{X} dollars with probability p and zero with probability $1 - p$. However, if the risky project turns bad, the firm could make a continuation decision at $t = 1$ that involves investing I_2 in the domestic market at $t = 1$ and making a sure return of \bar{X} dollars at $t = 2$, where we assume that $\bar{X} - I_2 > 0$, so the investment at $t = 1$ has a positive NPV.³ We assume that the cost of I_2 is set one period before, so that the cost in the domestic currency of I_2 does not change even if there is a depreciation. If the investment does not take place, the firm is liquidated and its assets are sold off. The proceeds from the asset sale are L and those liquidated assets can be used by a new firm. Without loss of generality, we assume that the new firm has access to only zero-NPV projects, so the liquidation value becomes $L = 0$.⁴ We assume that the following holds:

Assumption. $\bar{X} > X_s > I_1 > \bar{X} - I_2 > 0$.

The assumption $\bar{X} - I_2 - I_1 < 0$ guarantees that continuation is not profitable for the shareholders of the firm if debt has been used to finance the initial project and there is no debt renegotiation. However, continuation is preferred to liquidation if the firm is all equity financed or if the amount of debt can be renegotiated.⁵

Either project can be initially financed with debt or equity. If the project is financed with debt, the lender will require a face value for the loan that guarantees a discounted payoff equal to I_1 , the cost of the project. The debt can be either short-term (matures at $t = 1$) or long-term (matures at $t = 2$). Initially we assume that debt is denominated in the local currency, although we will relax that assumption later in the paper and show that currency depreciations become larger and more frequent. If the project is financed with equity and the risky project is taken and fails, the firm's shareholders will optimally choose to make the continuation investment I_2 . The continuation investment can be financed with either debt or equity. If financed with debt, the payoff to the firm's shareholders at $t = 2$ is $\bar{X} - I_2$ (since continuation is

³Denoting the return from the continuation investment by \bar{X} at $t = 2$ is done because of notational simplicity; nothing would change in the analysis if we assumed instead that the return at $t = 2$ would be such that $X_2 \geq \bar{X}$, where X_2 is the return from the continuation investment.

⁴Assuming that the continuation investment has a positive NPV $\bar{X} - I_2 > 0$ and that the liquidation value L is strictly less than the continuation value, but greater than zero, i.e. $\bar{X} - I_2 > L > 0$, does not change any of our qualitative results.

⁵We model the behavior of a single representative firm. However, if applied to a continuum of firms, the assumption that project *R* fails with probability $1 - p$ for all firms implies that negative shocks are perfectly correlated across firms. Harvey and Roper (1999) report that stock market indexes in Asia were dominated by certain industries, which made Asian equity markets vulnerable to common industry-based shocks. Their paper shows a lack of cross-sectional variation in stock returns across firms in a given country. There is additional evidence showing that the shocks suffered by Asian corporations were country-specific and hence not firm-specific. Claessens et al. (1998) blame the large drop in domestic demand for the significant decline in corporate profitability. Corsetti et al. (1998a) mention the following factors that are best viewed as region- or country-specific: the long period of stagnation of the Japanese economy in the 1990s that led to a significant decline in exports in other Asian countries; the sharp appreciation of the U.S. dollar relative to the Japanese yen and the European currencies since the second half of 1995 that has affected currencies pegged to the dollar; and the drop in real estate prices.

riskless, the debt face value is I_2). If financed with equity, the initial shareholders sell a share of the firm equal to $\alpha = I_2/\bar{X}$. The new shareholders thus provide financing and receive $\alpha\bar{X} = I_2$ at $t = 2$; the initial shareholders receive $(1 - \alpha)\bar{X} = \bar{X} - I_2$ at $t = 2$.

Alternatively, if the initial project is financed with equity and fails, continuation can be interpreted as a sale of the firm to new owners, who pay for the company the NPV of the firm's available projects, $\bar{X} - I_2$ at $t = 1$. Equivalently, the new owners receive $\bar{X} - I_2$ at $t = 2$ since, in the absence of currency depreciations, the appropriate interest rate at $t = 1$ is $r_1 = 0$.

The government's objective is to maximize real income for the economy. If project S has been implemented, there is no incentive to let the currency float. Appreciation or depreciation of the currency would not increase the real income X_s available in the economy. The same is true if the risky project has been taken and the return is \bar{X} . If the risky project yields zero, the firm will invest in the new project if the first project has been financed with equity, since $\bar{X} - I_2 > 0$. Since the new investment takes place in any case, there will not be any net gain from a change in the exchange rate. However, to the extent that the project is financed with debt and there is no renegotiation, the government prefers a depreciation if $\bar{X} - I_2 - F < 0$, where F is the face value of the debt used to finance I_1 , and $e\bar{X} - I_2 - F \geq 0$. Without a depreciation the assets of the firm would be sold off and used in a zero-NPV investment, i.e., investing I_2 would yield exactly I_2 . With currency depreciation, the real income available for the economy is \bar{X} instead of I_2 , or the amount of real income those assets would bring in an alternative use. So the real income accruing to the economy is always X_s if the safe project has been chosen. The real income for the economy after a currency depreciation is \bar{X} , but the opportunity cost of a depreciation is the loss of income that assets would be brought in alternative use, I_2 . Since the need of depreciations only arises with probability $1 - p$, the value for the whole economy of choosing the risky project and depreciating the currency is $p\bar{X} + (1 - p)(\bar{X} - I_2)$ in terms of real income, net of opportunity costs. Now let us define \bar{p} such that both S and R have the same value in terms of real income to the economy:

Definition. $\bar{p} = (X_s - \bar{X} + I_2)/I_2$.

It is easy to see that if $p > (<) \bar{p}$, then $p\bar{X} + (1 - p)(\bar{X} - I_2) > (<) X_s$.

After the risky project has failed, the government lets the exchange rate float. The resulting equilibrium exchange rate is such that investors break even in financing the new investment, i.e., the exchange rate e becomes

$$e = \frac{I_2 + F}{\bar{X}} > 1. \quad (2)$$

With this exchange rate, both domestic and foreign investors are willing to finance the continuation investment. If the initial failed investment was financed with short-term debt, then the firm is able to raise new debt financing to pay back the old debt and finance the new investment. If the initial investment was financed with long-term

debt, then the firm will borrow just enough to finance the new investment and the old debt will be paid back from the returns on the new investment.

3.1. The case without currency depreciations

In this section, we assume that depreciations are not possible. This means that the government cannot let the currency depreciate even if it wanted to help the exporting firm because, for example, the country has joined a common currency area (like the Euro-zone) and hence lost its monetary independence. This choice of currency regime is common knowledge, so the firm knows that there is no possibility for a currency depreciation. The purpose of this section is to serve as a benchmark case. Later we will relax this assumption.

Let us define V_i^j as the value of the firm's equity when project i is taken and financed with $j = \{D, E\}$, where $i = \{S, R\}$ and D and E stand respectively for debt and equity. If the firm has only access to equity markets, then clearly the efficient project is always chosen. Suppose instead that the project is entirely financed with debt. Let F^i be the face value of the loan when project $i = \{S, R\}$ is taken. If S is taken, then it has to be that $F^S = I_1$. If the risky project is taken, then $F^R > I_1 > \bar{X} - I_2$ by assumption. Therefore shareholders will prefer to liquidate the firm (debt overhang) even when it is profitable for the firm to continue operations, and F^R satisfies

$$I_1 = pF^R + (1 - p)0 \quad (3)$$

or $F^R = I_1/p$.

Were the project choice observable by the firm's debtholders, the resulting equity value when either project is taken would be $V_S^D = X_s - I_1 = V_S^E$, and $V_R^D = p[\bar{X} - I_1/p] + (1 - p)0 = p\bar{X} - I_1$. Therefore $V_R^D < V_S^D$, and the safe project would always be taken, whenever $p \leq \bar{p}$. At the same time, the firm would be indifferent between debt and equity. For $p > \bar{p}$, the risky project is preferred, and it is financed with equity since $V_R^D < V_R^E = p\bar{X} + (1 - p)(\bar{X} - I_2) - I_1$. Intuitively, the socially optimal project is always taken, but the risky project has to be financed with equity to avoid the debt overhang problem.

Since the project choice is not observable, valuation of the debt contract must take into account the firms's incentives to deviate once financing has been granted. For example, $F^S = I_1$ is the debt's face value if project S is to be taken. However, it is optimal for the firm to promise $F^S = I_1$ and take the risky project instead. In that sense, the pair $\{F^S, S\}$ is not a sequential Nash equilibrium. We prove next that, due to those incentives, equity is in some cases preferred to debt even the safe project is optimal, and that the socially optimal project is always taken in the absence of currency depreciations.

Proposition 1. When currency depreciations are not possible, the firm always chooses the socially optimal project. For $p \geq \bar{p}$, the risky project R is chosen and the project is financed with equity. For $p < \bar{p}$, the safe project S is chosen. If $p \leq (X_s - I_1)/(\bar{X} - I_1) < \bar{p}$, the firm is indifferent between debt and equity and if $\bar{p} > p > (X_s - I_1)/(\bar{X} - I_1)$, S is financed with equity.

The previous results derive from the pervasive effect of the debt overhang problem on the optimal project choice for shareholders. Continuation is optimal from the firm's perspective, but it is only optimal from the shareholders' perspective if the firm is equity financed. For low values of p , the profitability of the risky project is also low and the safe project is clearly preferred. For intermediate values of p , the safe project is still preferred, but if it is financed with debt, shareholders have an incentive to promise a debt repayment I_1 and take the risky project instead. Bondholders are aware of this, but if they require a higher face value, the firm will inconsistently choose the safe project. Therefore, the safe project can only be financed with equity when p is such that $\bar{p} > p > (X_s - I_1)/(\bar{X} - I_1)$. For high values of p , the risky project is chosen and it is financed with equity, since with debt financing the continuation investment cannot be implemented. Note finally that in the absence of currency depreciations, the optimal decision, namely the socially optimal project, is taken.

3.2. Debt renegotiation

In this section we show that financing the risky project with debt, with renegotiation between equityholders and debtholders allowed at time $t = 1$, is exactly equivalent to financing the risky project with equity.

Renegotiating the debt payments when the risky project is taken and fails, but continuation is feasible, is optimal ex post for debtholders as well as for equityholders. Debtholders benefit from the renegotiation since the liquidating proceeds from the firm are zero, while continuation assures them at least a non negative payoff. Equityholders prefer renegotiation because it could make continuation optimal by resolving the debt overhang problem. The distribution of potential gains among the different claimants will depend upon the bargaining power of both parties.

Let δ be the bargaining power of the firm's bondholders, where $\delta \in [0, 1]$, and $\delta = 1$ means that the bondholders can fully extract all possible renegotiation gains. Let F_{REN}^R be the face value of the debt when the risky project is taken and debt is renegotiated at $t = 1$. Since renegotiation is optimal ex post, the face value of the debt will be determined in such a way that

$$I_1 = pF_{\text{REN}}^R + (1 - p)\delta(\bar{X} - I_2) \quad (4)$$

since, with probability $(1 - p)$, the risky project fails and the continuation decision is taken upon renegotiation, so that a proportion δ of the continuation proceeds goes to the firm's bondholders. It implies

$$F_{\text{REN}}^R = \frac{I_1 - (1 - p)\delta(\bar{X} - I_2)}{p} \quad (5)$$

Obviously, the face value of the debt is lower when renegotiation is possible and $\delta > 0$. When $\delta = 0$, debtholders are indifferent between liquidating the firm and allowing for continuation with their claims redeemed. Denoting by $V_{R,\text{REN}}^D$ the value of the firm's equity when the risky project is selected, it is financed with debt, and

renegotiation happens at $t = 1$, we get

$$V_{R,REN}^D = p \left[\bar{X} - \frac{I_1 - (1-p)\delta(\bar{X} - I_2)}{p} \right] + (1-p)(1-\delta)(\bar{X} - I_2). \quad (6)$$

If the continuation decision is ensured by the renegotiation, there is no need for currency depreciations and hence the domestic interest rate equals the foreign interest rate.

Rearranging terms, we get $V_{R,REN}^D = p\bar{X} + (1-p)(\bar{X} - I_2) - I_1 = V_R^E$, that is, the value of the firm's equity when the risky project is financed with equity.

Proposition 2. Debt financing with renegotiation is equivalent to equity financing.

Intuitively, debt renegotiation is a means of increasing the bondholder return if the low state happens, at the expense of their claim when the risky project becomes successful. In the following section we allow for the government to bail out the firm in case the risky project is taken and the firm would otherwise face financial distress.

4. The possibility of currency depreciations and the debt–equity choice

4.1. Allowing for currency depreciations

In this section we relax the assumption that the government credibly commits not to let the currency depreciate. The currency is fixed at $t = 0$, but at $t = 1$, if the risky project has been taken and failed, the government has an incentive to let the currency depreciate, because doing so is optimal ex post for the economy (as shown in Section 3). The choice of currency regime is again common knowledge. In the absence of a commitment mechanism, like the common currency, the firm knows that the government will let the currency depreciate if the risky project fails. This leads to the problem that the firm will prefer the risky investment to the safe one, even if the safe one would be socially more valuable.

Without a depreciation, it is not rational for the firm to undertake the continuation investment I_2 if the risky project has failed and has been financed with debt. With a currency depreciation, however, the situation is different. As long as the exchange rate e at $t = 1$ is such that

$$e\bar{X} - I_2 - F_e^R \geq 0 \quad (7)$$

when the risky investment has failed, it would be optimal for the firm to invest in the second project, where F_e^i is the face value of the debt when depreciations are allowed and project i is taken, $i = \{S, R\}$. It is straightforward to show that $F_e^S = F^S = I_1$. Note that since $\bar{X} - I_2 > 0$, there is no need for a depreciation when the risky project is financed with equity. Additionally, since the firm never defaults when the safe project is taken, the possibility of depreciations is restricted to the case of debt financing of the risky project.

After the risky project fails, the interest rate in the domestic market becomes $r = e - 1$, from Eq. (1). If the risky project succeeds (which happens with probability p), there will be no currency rate changes. Since the currency depreciates with probability $1 - p$ (when the project fails), the discount rate $1 + r$ for the risky project will be

$$\begin{aligned} 1 + r &= \frac{pe_0 + (1 - p)e}{e_0} \\ &= p + (1 - p)e. \end{aligned} \quad (8)$$

The discount rate is known at $t = 0$ and prevails irrespective of whether the project is successful or not. This discount rate makes investors indifferent in expected terms between investing in domestic financial assets or foreign financial assets. If investors buy one unit of riskless asset in the domestic market, next period they will get back $(1 + r) = p + (1 - p)e$ measured in the domestic currency. Instead, if they buy one unit of riskless foreign asset, they will get back $(1 + r^*) = 1$ in dollars. The expected value of one dollar measured in the domestic currency is the amount $p + (1 - p)e$. Hence, the domestic discount rate $1 + r = p + (1 - p)e$ is exactly the rate that makes investors' expected return equal in domestic and foreign markets.

Therefore, if we conjecture that Eq. (7) holds, the expected payoff to debtholders if R is taken and financed with debt will be $(pF_e^R + (1 - p)F_e^R)/(p + (1 - p)e) = F_e^R/(p + (1 - p)e)$, which implies

$$F_e^R = [p + (1 - p)e]I_1. \quad (9)$$

Hence,

$$V_{R,e}^D = \frac{p[\bar{X} - (p + (1 - p)e)I_1] + (1 - p)[e\bar{X} - I_2 - (p + (1 - p)e)I_1]}{p + (1 - p)e} \quad (10)$$

if Eq. (7) holds, that is, if

$$e \geq \frac{I_2 + I_1p}{\bar{X} - (1 - p)I_1} = e^*. \quad (11)$$

Hence, if $e > e^*$, the equity value is $V_{R,e}^D$. Otherwise, liquidation is optimal for the firms' shareholders, there are no depreciations, and $V_R^D = p\bar{X} < V_S^D = V_S^E$ for $p < X_s/\bar{X}$.

Lemma 1. The firm's profits are increasing in the exchange rate e given that the risky project is chosen and a continuation investment is feasible.

There are two effects here: an increase in revenues $e\bar{X}$, and an increase in the discount rate $1 + r = p + (1 - p)e$, and the first effect dominates the second one. Note that the increase in the face value of debt and the increase in the discount rate cancel each other out.

Proposition 3 shows that, under some conditions, it is optimal ex ante for the firm to choose the risky project and finance it with debt, since it is optimal ex post for the

government to let the currency depreciate and increase the profitability of the risky project measured in the domestic currency.

Proposition 3. *There exists $p^* < \bar{p}$ such that, for $p^* \leq p$, the firm chooses project R and finances it with debt. The currency is devalued with probability $1 - p$ and after the depreciation the exchange rate becomes*

$$e^* = \frac{I_2 + I_1 p}{\bar{X} - (1 - p)I_1}. \quad (12)$$

When the success probability p of the risky project R is above a certain threshold, the firm prefers the risky project to the safe project S , even if S is preferred when depreciations are impossible, i.e., when p is such that $\bar{p} > p \geq p^*$. This ex ante choice of an inefficient investment is the cost of depreciations to the economy. The intuition is that the central bank implicitly insures the firm against bad realizations if R is chosen. The firm makes a profit if \bar{X} occurs and breaks even if the low realization occurs. Note also that the creditors are compensated for the risk of depreciation. The losers in this situation are the suppliers of I_2 , since the value of I_2 is now lower measured in dollars. In comparison to the situation in Section 3.1, where investors know they cannot force the government to depreciate, the lack of a commitment mechanism produces undesirable results. The ex post optimality of a currency depreciation in the bad state (with probability $1 - p$) creates the wrong incentives for the firm's shareholders: they select the socially less profitable project and they finance it with debt, which makes continuation infeasible unless the currency is depreciated.

The previous result says that the probability of a currency depreciation is negatively related to the quality of the projects the firm could undertake. If we consider p as a measure of profitability, Proposition 3 implies that currency crises are more likely when the firm's return on investment is low. Harvey and Roper (1999) show that corporate performance indicators (return on equity and return on invested capital) deteriorated throughout Asian markets immediately before the 1997 crisis. Sometimes this decline in performance was quite drastic; for example, the OECD (1999) reports that earnings for Korean computer chip manufacturers declined by 90% in 1996.

Our explanation for currency crises is also consistent with the results in Pomerleano (1998), who finds that in Thailand, the average return on equity declined rapidly from 13% in 1992 to 5% by 1996; similar results are reported for other Asian countries Corsetti et al. (1998a), for instance, report that 20 of the largest 30 conglomerates in Korea displayed in 1996 a return on invested capital below the cost of capital.⁶ Pomerleano (1998) presents some evidence of a dramatic increase in leverage in Asia in the period 1992–1996.⁷ While these papers seem to

⁶Claessens et al. (1998) provide evidence that while in some countries in Asia corporate profitability was indeed low, there were also countries with high corporate profitability, although in most cases performance declined prior to the crisis.

⁷The average debt-to-equity ratio for Hong Kong, Indonesia, South Korea, Malaysia, Philippines, Singapore, and Thailand increased from 48% as of Dec. 31, 1992 to 77% as of Dec. 31, 1996.

suggest that the excessive leverage taken on by corporations in these countries was one of the reasons for the dramatic currency depreciations they suffered, we have just shown how the financial excesses that precede a currency crisis are in fact optimal practices from the corporations' point of view when the exchange rate is fixed but depreciations are possible.

Our model also shows that even if depreciations are optimal ex post (as a means of bailing out exporting firms in financial distress), they are not always desirable ex ante (since they lead to suboptimal projects and excessive risk). The solution is to have a credible commitment mechanism not to let the currency depreciate. There is consensus by now that pegging the exchange rate is not such a mechanism. For instance, Johnson (1999, p. 117), states, "Experience indicates that fixed parties lack credibility in financial markets, particularly where capital controls have been abolished". In light of our model, the government cannot commit ex ante not to devalue the currency because devaluing is clearly optimal ex post, once the risky project has been taken and failed. Only a common currency (where the exchange rate cannot be devalued by the national government) or adoption of another currency can serve as a credible commitment mechanism.⁸

Depreciations in our model are a way to provide firms with contingent insurance. Firms would like to find a way to arrange in advance for debtholders to reduce their claims in bad states of the world, and the government externally implements this contingency by allowing a currency depreciation. Of course, firms can directly contract to do this by allowing renegotiations with pre-existing creditors. However, Propositions 2 and 3 actually show that the firm's equityholders prefer that the government coordinate the reduction in outstanding claims through a depreciation versus a direct renegotiation with the debtholders: equityholders bear the cost of the debt overhang in the case of a renegotiation. However, when the government is forced to let the currency float, the cost of the depreciation is entirely borne by the firm's suppliers.

Finally, our model shows that exporting firms prefer to rely on debt financing rather than equity when the exchange rate is fixed and currency depreciations are possible. Debt financing is preferred even though equity financing would solve the debt overhang problem completely. Why is that? Because the currency depreciation makes the debt riskless and also solves the debt overhang problem, which makes shareholders at least indifferent between debt and equity in present value terms. However, debt financing has one additional benefit: it reduces the discounted value of I_2 (because interest rates increase at $t = 1$ if the risky project is taken), and therefore makes continuation more valuable for the firm than when the firm is financed with equity and currency depreciations do not happen. Formally, we can rewrite the equity value when project R is taken and financed with debt in Eq. (10) as

$$V_{R,e}^D = \bar{X} - I_1 - \frac{(1-p)I_2}{p + (1-p)e}. \quad (13)$$

⁸ Currency boards established in Hong Kong in 1983, Argentina in 1991, Estonia in 1992, Lithuania in 1994, and Bulgaria in 1997 have also been credible commitments against currency depreciations.

The first term in the expression shows that the depreciation does not affect the discounted value of the firm’s revenues from exports. The second term is the discounted value of the debt, which becomes riskless. The third term shows the positive effect of the currency depreciation on the firm’s domestic inputs. It can be seen from Lemma 1 that

$$V_{R,e}^D = \bar{X} - I_1 - \frac{(1-p)I_2}{p+(1-p)e} > p\bar{X} + (1-p)(\bar{X} - I_2) - I_1. \tag{14}$$

In other words, the NPV to shareholders is greater when the risky project is financed with debt than when it is financed with equity.

4.2. Only debt is available

So far we have assumed that investments can be financed with either debt or equity. Next we want to consider the case in which only debt financing is available but debt renegotiations are possible. This situation corresponds to a case in which equity markets are underdeveloped and a proper reorganization mechanism is in place for firms when they are in financial distress. Such a framework is interesting because equity cannot be used as a commitment device to take the safe project, so firms have an incentive to deceive investors, inducing even more risk taking.

A major reason for the underdevelopment of equity markets is a lack of adequate minority shareholder protection (LaPorta et al., 1998). This is the case in most emerging markets. If outside minority shareholders are subject to the opportunism of controlling shareholders, the required return needed to induce these outside investors to finance the investment would be higher than with stringent protection of their rights. Hence, equity financing would be more expensive than debt financing. In this case, we make the assumption that both the risky and safe projects are financed with debt.⁹

If depreciations are not possible and debt cannot be renegotiated, firms might have to forgo profitable but risky investments and accept lower-yielding safe investments instead. The reason is that because of the debt overhang problem, the continuation investment is not feasible anymore. The risky project is chosen only if the NPV of the first investment at $t = 0$, excluding the NPV of the continuation investment, is higher for the risky project than for the safe project.

Proposition 4. Assume that only debt is available for financing the investments, and debt renegotiations and currency depreciations are not possible. Then, for $p \geq p^d > \bar{p}$, where $p^d = X_s/\bar{X}$, the firm chooses the project R. For $p < p^d$, the project S is chosen.

The best investment choice would require that risky investments are taken whenever $p \geq \bar{p}$, but when debt financing is the only source of funds, the risky investment is only chosen if $p \geq p^d > \bar{p}$. This result gives a rationale for efficiency-

⁹ Allowing equity financing, although making it more expensive, would yield qualitatively similar results. We assume debt financing for expositional simplicity.

enhancing depreciations. Currency depreciations could be good for an economy if risky projects are socially desirable and if equity markets are underdeveloped. In this case, if we observe currency crises, they are just a negative realization of an optimal currency policy. However, allowing for private renegotiations of debt between firms and their creditors would also achieve this result.

Next we analyze the case in which currency depreciations and debt renegotiations are possible. Now the firm cannot commit to take the safe project with face value of debt I_1 , even if doing so would be advantageous. The markets know that and charge a higher face value. Consequently, the conditions for choosing the risky project R are easier to fulfill. However, the project choice is still inefficient, even though debt renegotiation is possible, because firm owners prefer a currency depreciation, where the cost of financial distress is externalized, to an internal debt renegotiation.

*Proposition 5. Assume that only debt is available and renegotiation is costless. Then, for $\max[p^{**}, p^{***}] \leq p$, where $p^{**} = (\bar{X}I_1 - \bar{X}^2 + I_1I_2)/I_1I_2 < p^*$, $p^{***} = (X_s - I_1)(I_1 + I_2)/(\bar{X}(\bar{X} - X_s) + (X_s - I_1)(I_1 + I_2)) < p^*$, the firm chooses project R and finances it with debt. The firm's shareholders prefer not to renegotiate the debt, the currency depreciates with probability $1 - p$, and after the depreciation the exchange rate becomes*

$$e^{***} = \frac{I_2 + I_1p}{\bar{X} - (1 - p)I_1}. \quad (15)$$

Note that the exchange rate after depreciation is exactly the same as when the firm is allowed to use equity financing. The only difference is that now the conditions on p are less stringent: the creditors understand that when the firm is borrowing, it might have an incentive to fool the market and choose the risky project instead of the safe project. With debt, the firm cannot commit to take the safe project, whereas equity can serve as a commitment device for that purpose, since after equity financing the firm will always have an incentive to choose the project S .

There is evidence that the countries involved in the Asian crisis of 1997 had prohibitively costly bankruptcy procedures. Radelet and Sachs (1998), for instance, consider the lack of clear bankruptcy laws and workout mechanisms in Asia as a triggering factor in the crisis. Most of the countries involved (with the exception of Hong Kong and Singapore) had antiquated bankruptcy laws that made virtually impossible to force a defaulted debtor into liquidation.¹⁰ Thailand, Indonesia, and South Korea passed new bankruptcy laws only after their currencies collapsed in 1997, a condition imposed by the IMF for the bailouts. Why is it, then, that corporations in East Asia preferred a bailout through a currency depreciation rather

¹⁰ In South Korea, for instance, there was no concept until 1998 of debtor-in-possession financing, which allows distressed companies to reorganize while maintaining control of their assets (*International Herald Tribune*, May 5, 1998, p. 12).

than an informal debt reorganization? If, as in Claessens et al. (1998), corporate debt was mostly bank debt in Asia prior to 1997, explicit workouts could have been possible. However, they did not occur (see Corsetti et al, 1998b). We show in Proposition 5 that even when debt renegotiations are costless, firms prefer currency depreciations because the costs due to inefficiencies can be passed on to the society at large.

Johnson et al. (2000) examine the extent to which corporate governance variables caused the recent Asian crises. They conclude that the level of shareholder protection had an important effect on the extent of depreciations in the crisis. In particular, those countries with lower indexes of minority shareholder rights (La Porta et al., 1998) experienced greater currency depreciations prior to 1996. We have just shown, in line with this piece of evidence, that in the absence of equity financing, some risky projects that would not otherwise be taken are preferred to riskless investments, therefore increasing the likelihood of depreciations and also inducing larger depreciations (the extent of the depreciation is larger for lower p).

5. Extensions

In this section, we extend the basic framework in several directions. First, we allow for the debt to be denominated in a foreign currency and show that the firm could prefer foreign debt to both domestic debt or equity. After that, we consider the situation in which the firm can gamble at $t = 2$ by taking a risky but less valuable project. The firm makes larger profits and suffers an even larger currency depreciation. Finally, we relax the assumption that the cost of I_2 does not adjust at all to the depreciation and show that our analysis still applies but with different parameter values.

5.1. Foreign borrowing

From a general perspective, it is reasonable that an exporting firm will more likely be financed with foreign credit than with domestic credit. One of the most distinctive features of the recent Asian crisis is the foreign debt burden borne by those countries. Pomerleano (1998), for example, shows that 89% of the Indonesian firms' leverage as of September 1997 was denominated in a foreign currency. Additionally, 60% of total liabilities were short-term in Asian countries.

We consider the case in which the investment I_1 is financed with debt denominated in a foreign currency. Thus, if the risky project turns bad and depreciation occurs, the firm needs to pay F_R^D dollars to the foreign lender, or eF_R^D in the domestic currency. The face value of the debt must then satisfy

$$I_1 = \frac{pF_R^D + (1-p)eF_R^D}{p + (1-p)e}$$

$$\Leftrightarrow I_1 = F_R^D. \quad (16)$$

Additionally, the exchange rate in the case of a bad outcome must be such that

$$\begin{aligned} e\bar{X} - I_2 - eF_R^D \\ = e\bar{X} - I_2 - eI_1 \geq 0. \end{aligned} \quad (17)$$

Therefore, after a currency depreciation, the exchange rate e has to satisfy

$$e \geq \frac{I_2}{\bar{X} - I_1} = e^f. \quad (18)$$

We show next that when firms borrow abroad, the risky project is selected even when $p < p^*$, the threshold value in the basic case.

Proposition 6. There exists

$$p^f = \frac{(X_s - I_1)I_2}{(X_s - I_1)I_2 - (X_s - \bar{X})(\bar{X} - I_2)} < p^*$$

such that, for $p^f \leq p$, the firm chooses project R and borrows in a foreign currency. The currency is devalued with probability $1 - p$ and if the low state has occurred, the exchange rate becomes

$$e^f = \frac{I_2}{\bar{X} - I_1}. \quad (19)$$

When foreign credit is available, exporting firms prefer foreign borrowing to equity. The result is larger depreciations, and $e^f > e^*$. Somewhat surprisingly then, borrowing from abroad just exacerbates the problem. In Krugman (1999), foreign borrowing serves to magnify the effect of adverse shocks on real exchange rates. Krugman's view is somewhat similar to ours, where foreign borrowing makes financial distress more costly, but through a currency depreciation the cost is transferred to the rest of the economy. Therefore, firms gain from foreign leverage while they do not bear any of the costs. In fact, the firm will always prefer foreign debt to domestic.

Corollary 1. When the risky project is taken, foreign debt financing is preferred to domestic debt.

One interesting feature of the equilibrium is that the cost of debt in the presence of foreign borrowing is zero, the same as when the safe project is taken. In other words, the risky project becomes safe if it is financed abroad and depreciations are possible. That is a striking feature of our model because it implies that a currency crisis cannot be predicted on the basis of credit spreads. Radelet and Sachs (1998) argue that the Asian crisis was unexpected because lending terms did not tighten in advance of the onset of the crisis. In fact, they note, rating agencies such as Standard & Poor's and Moody's did not change the long-term sovereign debt ratings for the countries in the region (except for the Philippines). To the extent that sovereign debt rates and corporate debt rates are positively correlated, this implies that borrowing costs for

Asian firms remained stable before the crisis started. We have just shown that the expectation of a depreciation leads to an increase in interest rates (as in the Mexican crisis, for example). When exporting firms use domestic borrowing, the cost of debt increases when depreciations are possible; from Eqs. (9) and (12), the cost of debt with domestic borrowing is

$$r_d = p + (1 - p) \frac{I_2 + I_1 p}{\bar{X} - (1 - p)I_1} - 1 = (1 - p) \frac{I_1 + I_2 - \bar{X}}{\bar{X} - (1 - p)I_1} > 0.$$

However, when the firm borrows abroad, the increase in domestic interest rates is offset by the increase in the face value of the foreign debt expressed in the domestic currency, since depreciations are now larger. Hence, the cost of debt remains unchanged for exporting firms in present value terms, and equal to the cost of debt that prevails when depreciations are not possible.

5.2. *The threat of a risky and income-reducing continuation*

In the previous analyses we have assumed that there is only one continuation investment and that it has a positive value to the economy, i.e., $\bar{X} - I_2 > 0$. Now we relax this assumption and show that the existence of a risky, but less valuable, continuation investment leads to larger, more frequent currency depreciations and also larger profits for the firm.

Assume that at $t = 1$, there is a second possible continuation investment that yields $\bar{\bar{X}} > \bar{X}$ with probability s and zero with probability $1 - s$, $s \in (0, 1)$. Further assume that the second investment is worse than selling off the assets of the company in terms of real income accruing to the economy, i.e., $\bar{X} > I_2 > s\bar{\bar{X}}$. If this second investment opportunity exists, the currency has to depreciate more than in the basic case of only one continuation investment. Previously, only $e\bar{X} - I_2 - F_e^R \geq 0$ had to be satisfied in order for the optimal continuation investment to take place. Now the condition for the most valuable continuation investment to be incentive compatible for the firm is more stringent: $e\bar{X} - I_2 - F_e^R \geq s(e\bar{\bar{X}} - I_2 - F_e^R) > 0$. If this condition is not fulfilled, investors are not willing to finance the optimal continuation investment, since the firm would have an incentive to take the more risky, but less valuable, project.

Proposition 7. There exists p^{RC} , where $p^{RC} < p^ < \bar{p}$, such that, for $p^{RC} \leq p$, the firm chooses project R and finances it with debt. The currency is depreciated with probability $1 - p$ and after the depreciation the exchange rate becomes*

$$e^{\bar{RC}} = \frac{I_2 + pI_1}{\bar{X} - (1 - p)I_1 - s(\bar{\bar{X}} - \bar{X})/(1 - s)} > e^*.$$
 (20)

In this situation, the firm makes excessive profits from the continuation investment. Previously, without the threat of wasting money, the condition for the second investment to be feasible was that the shareholders would break even. Now

the shareholders have to be bribed into accepting the more valuable safe project. This means that an even larger depreciation is needed to restore the correct incentives to invest.

5.3. Only partial real depreciation is possible

5.3.1. The case of a partial real depreciation

Previously we assumed that the investment costs I_2 were set one period earlier. Now we relax the assumption that nominal prices are completely rigid. After the depreciation, domestic costs are allowed to increase, but by less than the amount of the depreciation. After the depreciation, the continuation investment can be expressed as $\gamma eI_2 + (1 - \gamma)I_2$. The interpretation of γ is either the proportion of the firm’s costs denominated in foreign currency or else the sensitivity of the firm’s domestic costs to changes in the exchange rate. The case $\gamma = 0$ is the one we consider in the basic model; the case $\gamma = 1$ is considered later.

The condition for the risky project to be taken (and then for depreciations to occur) is

$$X_s - I_1 \leq \frac{p[\bar{X} - (p + e(1 - p))I_1] + (1 - p)[e\bar{X} - \gamma eI_2 - (1 - \gamma)I_2 - (p + e(1 - p))I_1]}{p + e(1 - p)} \tag{21}$$

where $F = (p + e(1 - p))I_1$.

We next prove the existence of a solution in which the risky project is selected.

Proposition 8. In the case of a partial real depreciation, the following hold:

(i) *The risky project is chosen, it is financed with debt, and depreciations occur with probability $(1 - p)$ for $p^{PR} \leq p < \max(\bar{p}, 1 - \gamma)$, where $p^{PR} = p^{PR}(\gamma)$ satisfies*

$$\frac{(1 - \gamma)I_2 + p^{PR}I_1}{\bar{X} - \gamma I_2 - (1 - p^{PR})I_1} = \frac{p^{PR}(\bar{X} - X_s) - (1 - p^{PR})(1 - \gamma)I_2}{(1 - p^{PR})(X_s - \bar{X} + \gamma I_2)} \tag{22}$$

Moreover, p^{PR} is increasing in γ , $p^{PR}(0) = p^$, $p^{PR}(1) = p^R = 1 - (\bar{R} - I_2)(\bar{R} - R_s)/I_1I_2$, and the optimal depreciation satisfies*

$$e^{PR} = \frac{(1 - \gamma)I_2 + pI_1}{\bar{X} - \gamma I_2 - (1 - p)I_1} \tag{23}$$

(ii) *The risky project is taken and it is financed with equity for $\max(\bar{p}, 1 - \gamma) \leq p \leq 1$.*
 (iii) *Otherwise, the safe project is optimal and the firm is indifferent between debt and equity.*

A partial real depreciation happens with probability $(1 - p)$ and induces the firm to take the risky project (debt financed) when $p^{PR} < p < \bar{p}$, that is, when the safe project has a greater NPV. The situation of an undesirable depreciation happens for low levels of γ . Similarly, when the risky project is optimal ($p > \bar{p}$) the firm chooses either debt (after a depreciation) or equity depending on whether p is lower or higher

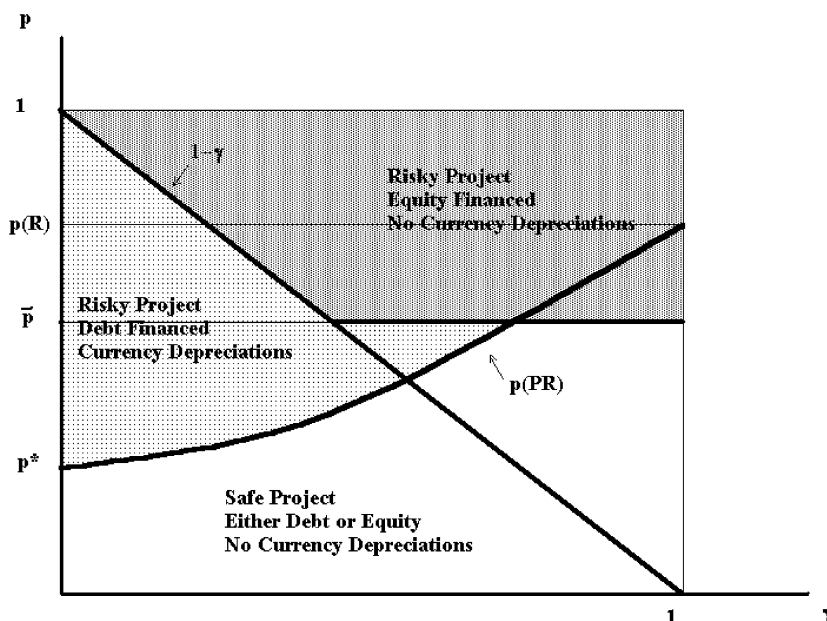


Fig. 2. The case of a partial real devaluation. The graph shows the threshold value $p^{(PR)}$ such that the currency is devalued for $p^{(PR)} < p < \max(\bar{p}, 1 - \gamma)$, the risky project is taken, and it is financed with debt. When $\max(\bar{p}, 1 - \gamma) \leq p \leq 1$, the risky project is optimal, and it is financed with equity. When γ is such that $0 \leq p < \min(\bar{p}^{(PR)}, p)$, the safe project is preferred.

than $1 - \gamma$. Fig. 2 shows that there exists a region of inefficient depreciation: if γ is such that $p^{PR} < \bar{p}$, and $p^{PR} < p < \bar{p}$, the currency is devalued and the risky project is selected, but the safe project is socially preferred. When $\bar{p} < p < 1$, the risky project is selected, being now the socially optimal project. The firm finances the risky project with debt in this case when $\bar{p} < p < 1 - \gamma$, and uses equity otherwise.

Finally, when input prices partially adjust to depreciations, depreciations need to be larger in order for firms to prefer continuation if the low state happens. Therefore, the domestic interest rate is also higher.

Corollary 2. The equilibrium exchange rate e^{PR} that prevails after a depreciation is increasing in γ , the extent to which domestic costs adjust to a depreciation.

The previous result, together with Lemma 1, implies that the firm's profits are a decreasing function of the proportion of I_2 that is denominated in the domestic currency, given that it is optimal for the firm to choose the risky project and finance it with debt. This means that the firm prefers to import a proportion of its investment input. The intuition is exactly the same with foreign borrowing: if a proportion of investment costs are denominated in dollars or otherwise adjust fully to a currency depreciation, a very large depreciation is needed to restore the incentive to take the continuation investment. From Lemma 1, we know that the firm's profits are an

increasing function of e , given that the risky investment is taken and it is financed with debt.

5.3.2. Domestic prices adjust fully to a depreciation

We consider here the case of a firm that will have to pay eI_2 to continue operations at $t = 2$ if the currency is devalued. Domestic costs fully adjust to the depreciation at once and depreciation of the real exchange rate is not possible at all. This is just a special case of the more general situation considered in the previous subsection. The value of the risky project when it is financed with debt becomes

$$V_{R,e}^D = \frac{p[\bar{X} - (p + (1-p)e)I_1] + (1-p)[e(\bar{X} - I_2) - (p + (1-p)e)I_1]}{p + (1-p)e} \quad (24)$$

since the face value of the debt does not change with respect to the original case. In this case depreciations do not happen.

Proposition 9. If domestic costs fully adjust to the depreciation, then the risky project is taken, and it is financed with equity when $p \geq \bar{p}$. Otherwise the firm selects the safe project.

As shown in Fig. 2, increasing γ (reducing partial real depreciation), ceteris paribus, increases the firm's profits to the extent that the firm chooses the risky project and finances it with debt. At some point, profits start declining (whenever γ becomes $\gamma > \min[p^{\text{PR}}(\gamma), 1 - p]$) and the firm prefers equity financing. The socially optimal project is then selected. Proposition 10 describes the particular case of $\gamma = 1$.

5.4. Discussion and limitations

In most cases, countries try to defend their currencies when the pegged exchange rate is experiencing a speculative attack. In our model this does not make sense: currency depreciation is always optimal ex post and a rational government would always abandon the peg without any resistance. This limitation in our model is due to the two-period structure of the model. In a proper multiperiod framework, a government might care about its reputation. It would realize that acting optimally ex post does not always lead to desirable outcomes ex ante. Thus a government could try to foster a tough reputation by not letting its currency depreciate to give exporting companies incentives to invest efficiently in the first place. Our model points out the difficulties of adopting such tough stances.

Moreover, governments usually defend their currencies by raising interest rates. According to our model, this only makes the situation worse for highly leveraged companies. After an increase in interest rates, the debt overhang problem is even more severe for the exporting companies and the afflicted government would have an even greater incentive to let the currency depreciate. Thus, high interest rates imposed by the government would be highly counterproductive. A more efficient way of defending a pegged exchange rate would be to impose restrictions on short-term capital flows.

Currency speculation in our model would have an effect similar to increased interest rates. Assume that there is a positive probability q , $q \in (0, 1)$, of a speculative attack against the currency. A speculative attack could be self-fulfilling in the following way. Suppose that there is no debt overhang problem before the speculative attack, i.e., $\bar{R} - I_2 - F > 0$. With speculation, the new discount rate would be $qe + (1 - q)$, if the attack is expected to be successful. With some parameter values we would indeed get a debt overhang problem, i.e., $(\bar{R} - I_2)/(qe + (1 - q)) - F < 0$, and the speculative attack would succeed, hence justifying the higher discount rate in the first place.

A further limitation in our paper is that we only model the behavior of exporting firms. We could introduce a fully domestic nontradable sector, whose firms would produce intermediate goods for the exporting sector. In our context, that would mean explicitly modeling the firms that produce the investment inputs I_1 and I_2 . Those firms would have their own capital structures. Our results would not change if these firms were financed by equity or domestic credit: a currency depreciation would not create problems for the nontradable sector. However, if these firms used debt denominated in foreign currency, a currency depreciation could create a debt overhang problem for these firms. Our model can be understood as a benchmark case: even if we ignore all the costs that a currency depreciation imposes to the nontradable sector, depreciations can still be very problematic, since they can lead to excessive investments in risky projects.

6. Empirical implications

Our model establishes a causal relation between exchange rate policy and exporting firms' capital structures. We show that if currency depreciations are possible, firms will engage in debt-financed, risky projects that, in case of financial distress, make a currency depreciation optimal ex post for the government. Knowing that, the government would like to commit not to devalue. The model predictions can be summarized as follows:

1. Exporting firms will display increasing leverage prior to currency crises in countries with fixed exchange rates. Leverage increases in our model increase the probability of a depreciation. Note that the causality implied by our model does not imply that leverage increases are always early warnings of currency crises, since the extent of the crisis depends on the riskiness of the projects that are debt-financed. Pomerleano (1998), and Corsetti et al. (1998a) document leverage increases preceding the Asian crisis of 1997.
2. Common currencies and currency boards induce either leverage reductions or a decrease in the riskiness of firms' cash flows. Cross-sectionally, these reductions are larger for export-oriented firms. The previous results imply that exporting firms' betas decrease after the introduction of either the common currency or the currency board.

3. With regard to economies with fixed exchange rate regimes, our model implies that we should observe higher leverage in export industries compared to domestic industries (once other factors such as size and profitability have been controlled for) in small, export-oriented countries. Across countries, we provide an explanation for leverage to be higher in small, export-oriented countries compared to large countries (controlling for industry). For example, we should observe that the Finnish paper and pulp industry displays higher debt levels compared to Canadian or U.S. firms in the same industry. Pomerleano (1998) supports that prediction with a sample of countries that have suffered a currency crisis.
4. Decreases in firm profitability are an early warning of currency problems. Similarly, the model implies that small, export-oriented countries that suffer depreciations display declining profitability prior to the depreciation. This implication is in line with the evidence in Pomerleano (1998) and Harvey and Roper (1999).
5. Underdeveloped equity markets and hence a forced reliance on debt financing increase the probability and magnitude of depreciations. This implication is consistent with the evidence provided by Johnson et al. (2000).
6. If borrowing is in a foreign currency, credit spreads should not increase for exporting companies in the country that is likely to face a currency crisis.
7. The model provides some policy implications, namely that abolishing capital controls (by decreasing the costs of borrowing from abroad) can increase the magnitude and likelihood of depreciations. The reason is that, as shown in Section 5.1, foreign borrowing by large exporting firms induces larger depreciations under fixed exchange rates.¹¹ Corsetti et al. (1998b) discuss the effects of restrictions on short-term inflows on the magnitude of a crisis, and refer to the experiences of Chile, Colombia, and Slovenia in support of our view. However, Krugman (1999) argues that restrictions on foreign-currency debt may not be sufficient if other forms of capital flight are still possible. On the empirical side, Kaminsky and Reinhart (1999) report that banking crises help to predict balance-of-payment crises, and that banking crises are preceded by lending booms fueled by capital inflows and financial liberalization.

7. Conclusions

The countries that have recently experienced currency depreciations have been export-oriented with large exporting firms. This paper provides a framework to analyze the reasons for currency depreciations for such countries. The argument is based on depreciations being optimal *ex post* for the economies in question. After experiencing negative shocks, exporting firms have valuable investment opportu-

¹¹ This implication does not hold if domestic financial markets are not competitive. With noncompetitive domestic financial markets, foreign borrowing could imply a decrease in the real interest rate, and thus the safe project would become relatively more advantageous for the exporting firms.

nities, but they will not invest because of high debt levels. The government can solve these debt overhang problems and make investments feasible, since depreciation of the currency increases the profitability of new investments when revenues are in a foreign currency, and when the costs of the new investment denominated in the domestic currency are sticky. Firms prefer depreciations to private renegotiations of debt, because in depreciations the costs are passed on to other parties. Hence firms have an incentive to commit not to renegotiate their debt levels.

Although currency depreciations are optimal *ex post*, they can have adverse consequences *ex ante* for economies. Exporting firms know that the government will let the currency depreciate if their risky investments fail, provided that the investments have been financed with debt. This leads to high leverage and excessive investment in risky projects at the expense of more valuable and safer projects financed with equity. Knowing this, the government would like to commit not to let the currency depreciate, whenever the costs of a depreciation to the society are greater than the private gains of a depreciation to the exporting firms. We show that the severity of such an inefficiency increases when equity markets are underdeveloped, and when firms borrow abroad. When equity markets are underdeveloped, debt is the only financing source available, and risky investments become preferable from the firm owners' point of view. Foreign borrowing by exporting firms exacerbates the problem, too. If firms' existing debt is denominated in a foreign currency, a larger depreciation is needed to restore incentives to invest. Moreover, when foreign credit is available, firms prefer that to domestic credit.

Letting the currency depreciate is also optimal *ex ante* if risky projects are socially preferred to safe projects, and if the equity markets are underdeveloped and private renegotiations between borrowers and lenders are costly. With underdeveloped equity markets, firms are forced to rely on debt financing. This leads to involuntary debt overhang problems that can be avoided by letting the currency depreciate. Excessive reliance on debt financing could imply that either exporting firms are gambling at the expense of others or that they are severely equity rationed. Thus, for emerging markets, a permanently fixed exchange rate coupled with underdeveloped equity markets would be a dangerous combination in the absence of debt renegotiations. It is then of utmost importance for emerging markets to try to improve the functioning of equity markets through changes in corporate governance and minority shareholder protection. Equally important for emerging markets would be efficient bankruptcy procedures that would allow the renegotiation of debt levels.

Some authors argue (see Giavazzi and Pagano, 1988) that a system like the European Monetary System increases the credibility of governments' policies toward achieving price stability. However, the increased costs of depreciations have not been enough to deter governments from letting their currencies depreciate: the incentives to devalue can be very strong indeed. In our framework, it is not surprising that fixed exchange rate regimes have proved to be so untenable, especially coupled with free capital mobility. If governments of small exporting countries really want to commit not to devalue, then the credible solutions are either to adopt a common currency

like the Euro or to completely dollarize the economy. It has been argued that adopting a common currency can be dangerous because of asymmetric shocks. According to our model, it is because of such shocks that a small country should adopt a common currency. As in all moral hazard problems, providing insurance (through depreciations in our model) increases the need for insurance. The firms' investment strategies are not exogenous. When depreciations are impossible, there will be less need for depreciations.

Appendix

Proof of Proposition 1. Suppose the case with debt financing. If debtholders expect the company to take the safe project, they will offer a debt contract that promises I_1 at $t = 1$. Therefore, the value of the equity with the safe project will be

$$V_S^D = X_s - I_1 = V_S^E,$$

that is, the firm is indifferent between debt and equity. However, the firm could have an incentive to cheat and take the risky project when:

$$V_S^D < V_R^D = p[\bar{X} - I_1].$$

This happens whenever $p > \hat{p} = (X_s - I_1)/(\bar{X} - I_1)$. Note that, since $\bar{X} - I_1 - I_2 < 0$, $\hat{p} < \bar{p}$. Therefore, for $p < \hat{p}$, the firm takes the safe project and it is indifferent between debt and equity. For $p > \hat{p}$, debtholders will be aware of the firm's incentives to cheat and will require a face value I_1/p , in which case the safe project is preferred, since

$$p \left[\bar{X} - \frac{I_1}{p} \right] < X_s - I_1$$

by assumption.

Finally, we have to prove that when the firm is offered the contract I_1/p , it is not willing to cheat and take the safe project. Cheating will never be an equilibrium if the following holds:

$$p \left[\bar{X} - \frac{I_1}{p} \right] > X_s - \frac{I_1}{p}$$

as long as $X_s - I_1/p > 0$, or $p > I_1/X_s$, or if

$$p^2 \bar{X} - p(X_s + I_1) + I_1 > 0.$$

Therefore, the firm will cheat (take the safe project when it is offered I_1/p) for $p_l < p < p_h$, where p_l and p_h are the two roots of the previous square function. It is straightforward to show that $I_1/X_s < p_l$. Hence for $p \in [\hat{p}, \min(p_h, \bar{p})]$, the debt market breaks down: if offered I_1/p (face value corresponding to the risky project) the firm takes the safe project; if offered I_1 (face value corresponding to the safe project) the firm takes the risky project. Hence the project can only be financed with equity. \square

Proof of Proposition 2.

$$V_{R,REN}^D = p \left[\bar{X} - \frac{I_1 - (1-p)\delta(\bar{X} - I_2)}{p} \right] + (1-p)(1-\delta)(\bar{X} - I_2)$$

$$= p\bar{X} + (1-p)(\bar{X} - I_2) - I_1 = V_R^E. \quad \square$$

Proof of Lemma 1. The value of the firm’s equity when the risky project is taken, it is financed with debt, and depreciations can occur is

$$V_{R,e}^D = \frac{p[\bar{X} - (p + (1-p)e)I_1] + (1-p)[e\bar{X} - I_2 - (p + (1-p)e)I_1]}{p + (1-p)e}.$$

Differentiating with respect to e , we obtain

$$\frac{\partial}{\partial e} V_{R,e}^D = \frac{-(1-p)pI_1 + (1-p)(\bar{X} - (1-p)I_1)}{p + (1-p)}$$

$$- \frac{(1-p)[p(\bar{X} - (p + (1-p)e)I_1) + (1-p)(e\bar{X} - I_2 - (p + (1-p)e)I_1)]}{[p + (1-p)e]^2}$$

which equals

$$\frac{\partial}{\partial e} V_{R,e}^D = \frac{(1-p)^2 I_2}{[p + (1-p)e]^2} > 0. \quad \square$$

Proof of Proposition 3. Project R is optimal if $V_{R,e}^D > V_S^E$, that is, if

$$\frac{p[\bar{X} - (p + (1-p)e)I_1] + (1-p)[e\bar{X} - I_2 - (p + (1-p)e)I_1]}{p + (1-p)e} > X_s - I_1,$$

which is equivalent to

$$p\bar{X} + (1-p)[e\bar{X} - I_2] > (p + (1-p)e)X_s. \tag{A.1}$$

Let us define e' from the previous expression as

$$p\bar{X} + (1-p)[e'\bar{X} - I_2] = (p + (1-p)e')X_s.$$

Since $\bar{X} > X_s$, (A.1) holds for $e > e'$. Solving for e' we obtain

$$e' = \frac{p(X_s - \bar{X}) + (1-p)I_2}{(1-p)(\bar{X} - X_s)}. \tag{A.2}$$

Additionally, for R to be an optimal choice, we need (7) to be satisfied, which requires $e > e^*$.

Let us then define p^* as the value of p such that $e^*(p^*) = e'(p^*)$. Hence

$$\frac{p^*(X_s - \bar{X}) + (1-p^*)I_2}{(1-p^*)(\bar{X} - X_s)} = \frac{I_2 + I_1 p^*}{\bar{X} - (1-p^*)I_1}. \tag{A.3}$$

Note that $e'(p)$ is continuous in p for $0 \leq p \leq 1$, $\partial e' / \partial p < 0$, $e'(0) > 0$ and $\lim_{p \rightarrow 1} e' = -\infty$. Additionally, $e^*(p)$ is continuous in p for $0 \leq p \leq 1$, $\partial e^* / \partial p < 0$, $e^*(0) < e'(0)$ and

$e^*(1) > 0$. Hence, $p^* \in [0, 1]$ and $e^*(p) - e'(p) > 0$ for $p > p^*$. Therefore, for $p^* < \bar{p}$, it has to be that $e^*(\bar{p}) - e'(\bar{p}) > 0$. Note that

$$\begin{aligned} e^*(\bar{p}) - e'(\bar{p}) &= \frac{I_2 + I_1 \frac{X_s - \bar{X} + I_2}{I_2}}{\bar{X} - \left(1 - \frac{X_s - \bar{X} + I_2}{I_2}\right) I_1} \\ &= \frac{\frac{X_s - \bar{X} + I_2}{I_2} (X_s - \bar{X}) + \left(1 - \frac{X_s - \bar{X} + I_2}{I_2}\right) I_2}{\left(1 - \frac{X_s - \bar{X} + I_2}{I_2}\right) (\bar{X} - X_s)} \\ &= \frac{I_2 + I_1 \frac{X_s - \bar{X} + I_2}{I_2}}{\bar{X} - \left(1 - \frac{X_s - \bar{X} + I_2}{I_2}\right) I_1} - 1 \end{aligned}$$

using the definition of \bar{p} . This is positive since

$$I_2 + I_1 \frac{X_s - \bar{X} + I_2}{I_2} > \bar{X} - \left(1 - \frac{X_s - \bar{X} + I_2}{I_2}\right) I_1.$$

To see that, note that the last expression is equivalent to

$$\begin{aligned} \frac{I_2(I_1 - \bar{X} + I_2)}{I_2} &> 0 \\ \Leftrightarrow (I_2 - \bar{X} + I_1) &> 0 \end{aligned}$$

by assumption. To ensure continuity, the optimal $e = e^*$.

Next, we need to prove that $F_e^R < \bar{X}$. In equilibrium, for $p^* < p \leq 1$, $F_e^R = [p + (1-p)e^*]I_1$, and substituting the value of e^* from (11), the condition that must be satisfied becomes

$$\bar{X} > \left[p + (1-p) \frac{I_2 + I_1 p}{\bar{X} - (1-p)I_1} \right] I_1$$

or $p > (\bar{X}I_1 - \bar{X}^2 + I_1I_2)/I_1I_2 = p^{**}$. Hence, to prove that in equilibrium, $F_R^D < \bar{X}$, it suffices to prove that $p^{**} < p^*$. A sufficient condition for this is $e^*(p^{**}) - e'(p^{**}) < 0$, where e^* and e' come respectively from (11) and (A.1). Substituting p^{**} into (A.1) yields

$$e'(p^{**}) = \frac{I_2}{\bar{X} - X_s} - \frac{\bar{X} + I_2 - \bar{X}^2/I_1}{\bar{X}^2/I_1 - \bar{X}}.$$

Also

$$\begin{aligned} e^*(p^{**}) &= \frac{I_2 + (\bar{X}I_1 + I_1I_2 - \bar{X}^2)/I_2}{\bar{X} - \bar{X}^2/I_1 - \bar{X}/I_2} \\ &= \frac{I_2^2 + \bar{X}I_1 + I_1I_2 - \bar{X}^2}{\bar{X}(I_2 - \bar{X} + I_1)} \\ &= \frac{\bar{X} + I_2}{\bar{X}}. \end{aligned}$$

Hence,

$$e^*(p^{**}) - e'(p^{**}) = \frac{\bar{X} + I_2}{\bar{X}} - \frac{I_2}{\bar{X} - X_s} + \frac{\bar{X} + I_2 - \bar{X}^2/I_1}{\bar{X}^2/I_1 - \bar{X}}.$$

Rearranging terms yields

$$e^*(p^{**}) - e'(p^{**}) = -\frac{I_2(X_s + I_1)}{(\bar{X} - I_1)(\bar{X} - X_s)} < 0.$$

Finally, we need to prove that $V_{Re}^D > V_R^E$. This derives directly from Lemma 1. \square

Proof of Proposition 4. Assume for now that the following conjecture holds: the face value of debt is I_1 and the firm promises to invest in the safe project S. It is optimal for the firm to cheat if $V_{Re}^D > V_S^D$, that is,

$$\frac{p[\bar{X} - I_1] + (1 - p)[e\bar{X} - I_2 - I_1]}{p + (1 - p)e} > X_s - I_1,$$

which is equivalent to

$$(1 - p)e[\bar{X} + I_1 - X_s] > p(X_s - \bar{X}) + (1 - p)(I_1 + I_2). \tag{A.4}$$

Let us define e'' from the previous expression as

$$(1 - p)e''[\bar{X} + I_1 - X_s] > p(X_s - \bar{X}) + (1 - p)(I_1 + I_2). \tag{A.5}$$

Since $\bar{X} + I_1 - X_s > 0$, (A.5) holds for $e > e''$. Solving for e'' we obtain

$$e'' = \frac{p(X_s - \bar{X}) + (1 - p)(I_1 + I_2)}{(1 - p)(\bar{X} + I_1 - X_s)}. \tag{A.6}$$

With the face value of debt $F = I_1$, the depreciation has to satisfy

$$e\bar{X} - I_1 - I_2 \geq 0,$$

hence the exchange rate after depreciation is

$$e^* = \frac{I_1 + I_2}{\bar{X}}.$$

In order for R to be chosen, we need $e \geq e^* > e''$. Hence

$$\frac{I_1 + I_2}{\bar{X}} > \frac{p(X_s - \bar{X}) + (1-p)(I_1 + I_2)}{(1-p)(\bar{X} + I_1 - X_s)}. \quad (\text{A.7})$$

This is equivalent to

$$p > \frac{(X_s - I_1)(I_1 + I_2)}{\bar{X}(\bar{X} - X_s) + (X_s - I_1)(I_1 + I_2)} = p^{***}.$$

From (A.7), p^{***} satisfies

$$e^*(0) = \frac{I_1 + I_2}{\bar{X}} = \frac{p^{***}(X_s - \bar{X}) + (1-p^{***})(I_1 + I_2)}{(1-p^{***})(\bar{X} + I_1 - X_s)} = \tilde{e}(p^{***}). \quad (\text{A.8})$$

Additionally, and from the previous expression together with (25), clearly $\tilde{e}(p) < e'(p) \forall p \in [0, 1]$. Let \tilde{p} be such that $e'(\tilde{p}) = e^*(0)$. Therefore $e'(\tilde{p}) = e^*(0) > e^*(p^*) = e'(p^*)$ because $e^*(p)$ is decreasing in p from Proposition 3. Hence $\tilde{p} < p^*$ and from (A.8) and the definition of \tilde{p} , $p^{***} < \tilde{p} < p^*$.

From Proposition 3, $p^{**} < p^*$. Hence, the firm will deviate and take the risky project for $\max[p^{**}, p^{***}] \leq p \leq \tilde{p}$, and the face value cannot be I_1 .

We finally need to check that the firm takes the risky project whenever the face value of the debt equals $I_1[p + (1-p)e]$. This is equivalent to

$$\begin{aligned} & \frac{p[\bar{X} - (p + (1-p)e)I_1] + (1-p)[e\bar{X} - I_2 - (p + (1-p)e)I_1]}{p + (1-p)e} \\ & > X_s - (p + (1-p)e)I_1, \end{aligned}$$

or equivalently

$$\frac{p\bar{X} + [(1-p)e\bar{X} - I_2] - (p + (1-p)e)I_1}{p + (1-p)e} > X_s - (p + (1-p)e)I_1.$$

Note that the left-hand side of the previous expression is decreasing in p , and the right-hand side is increasing in p . Therefore, it suffices to show the result for $p = p^*$. For $p = p^*$, and from the definition of (A.1) and (11),

$$\begin{aligned} & \frac{p^*\bar{X} + [(1-p^*)e\bar{X} - I_2] - (p^* + (1-p^*)e)I_1}{p^* + (1-p^*)e} \\ & = X_s - I_1 > X_s - (p^* + (1-p^*)e)I_1. \end{aligned}$$

Therefore, $F_R^D = I_1[p + (1-p)e^*]$ and the optimal depreciation is

$$e^* = \frac{I_2 + I_1 p}{\bar{X} - (1-p)I_1}.$$

Finally, note that the firm will always prefer to force the currency depreciation rather than allowing for debt renegotiation (which, from Proposition 2, is equivalent to equity financing). \square

Proof of Proposition 5. Project R is optimal if $V_{R,e}^{D,f} > V_S^E$, that is, if

$$\frac{p[\bar{X} - I_1] + (1 - p)[e\bar{X} - I_2 - eI_1]}{p + (1 - p)e} > X_s - I_1,$$

which is equivalent to

$$p\bar{X} + (1 - p)[e\bar{X} - I_2] > (p + (1 - p)e)X_s, \tag{A.9}$$

Let us define e' from the previous expression as

$$p\bar{X} + (1 - p)[e'\bar{X} - I_2] = (p + (1 - p)e')X_s.$$

Since $\bar{X} > X_s$, (33) holds for $e > e'$. Solving for e' we obtain

$$e' = \frac{p(X_s - \bar{X}) + (1 - p)I_2}{(1 - p)(\bar{X} - X_s)}. \tag{A.10}$$

In order for R to be the optimal choice, we need $e \geq e^f > e'$. Hence

$$\frac{I_2}{\bar{X} - I_1} > \frac{p(X_s - \bar{X}) + (1 - p)I_2}{(1 - p)(\bar{X} - X_s)},$$

which holds for any p such that

$$p > \frac{(X_s - I_1)I_2}{(X_s - I_1)I_2 - (X_s - \bar{X})(\bar{X} - I_2)} = p^f. \tag{A.11}$$

Now we have to show that $p^f < p^*$. First note that $(I_2 + I_1p)/(\bar{X} - (1 - p)I_1)$ is decreasing in p . Hence, from (A.3),

$$\begin{aligned} & \frac{p^*(X_s - \bar{X}) + (1 - p^*)I_2}{(1 - p^*)(\bar{X} - X_s)} \\ &= \frac{I_2 + I_1p^*}{\bar{X} - (1 - p^*)I_1} < \frac{I_2}{\bar{X} - I_1} = \frac{p^f(X_s - \bar{X}) + (1 - p^f)I_2}{(1 - p^f)(\bar{X} - X_s)} \end{aligned}$$

and, since $(p(X_s - \bar{X}) + (1 - p)I_2)/(1 - p)(\bar{X} - X_s)$ is decreasing in p , it follows that $p^f < p^* < \bar{p}$.

Finally we have to show that the firm prefers foreign borrowing to domestic. Foreign borrowing is optimal if

$$\begin{aligned} & \frac{p[\bar{X} - I_1] + (1 - p)[e^f\bar{X} - I_2 - e^fI_1]}{p + (1 - p)e^f} \\ & > \frac{p[\bar{X} - (p + (1 - p)e)I_1] + (1 - p)[e\bar{X} - I_2 - (p + (1 - p)e)I_1]}{p + (1 - p)e}, \end{aligned}$$

which is equivalent to

$$\frac{p\bar{X} + (1 - p)[e^f\bar{X} - I_2]}{p + (1 - p)e^f} > \frac{p\bar{X} + (1 - p)[e\bar{X} - I_2]}{p + (1 - p)e}.$$

This simplifies to

$$p(1-p)(e^f - e)\bar{X} > p(1-p)(e^f - e)(\bar{X} - I_2),$$

or $\bar{X} > \bar{X} - I_2$.

Proof of Corollary 1. From Proposition 5,

$$V_{R,e^f}^{D,f} = \frac{p[\bar{X} - I_1] + (1-p)[e^f \bar{X} - I_2 - e^f I_1]}{p + (1-p)e^f},$$

where e^f comes from (19). Clearly, $V_{R,e^f}^{D,f}$ is increasing in e^f , since

$$\frac{\partial V_{R,e^f}^{D,f}}{\partial e^f} = \frac{(1-p)e^f[\bar{X} - I_1]}{p + (1-p)e^f} - \frac{(1-p)I_2}{p + (1-p)e^f} > 0.$$

Using $e^f > e^*$ from (11),

$$\begin{aligned} V_{R,e^f}^{D,f} &> V_{R,e}^{D,f} \\ &= \frac{p[\bar{X} - I_1] + (1-p)[e\bar{X} - I_2 - eI_1]}{p + (1-p)e} \\ &= \frac{p[\bar{X} - (p + (1-p)e)I_1] + (1-p)[e\bar{X} - I_2 - (p + (1-p)e)I_1]}{p + (1-p)e} \\ &= V_{R,e}^D. \quad \square \end{aligned}$$

Proof of Proposition 6.

$$V_S^D = X_s - I_1 < V_R^D = p\bar{X} - I_1 \Rightarrow p > \frac{X_s}{\bar{X}}. \quad \square$$

Proof of Proposition 7. The optimal depreciation is in this case

$$e^{RC} = \frac{I_2 + pI_1}{\bar{X} - (1-p)I_1 - s(\bar{\bar{X}} - \bar{X})/(1-s)}.$$

And $e^{***} = e^*$ if $s = 0$.

Differentiating with respect to p ,

$$\begin{aligned} \frac{\partial e^{RC}}{\partial p} &= \frac{I_1[\bar{X} - (1-p)I_1 - s(\bar{\bar{X}} - \bar{X})/(1-s)] - I_1(I_2 + pI_1)}{[\bar{X} - (1-p)I_1 - s(\bar{\bar{X}} - \bar{X})/(1-s)]^2} \\ &= \frac{I_1}{\bar{X} - (1-p)I_1 - s(\bar{\bar{X}} - \bar{X})/(1-s)}(1 - e^{RC}) < 0 \end{aligned}$$

because $e^{RC} > 1$.

Differentiating now with respect to s yields

$$\frac{\partial e^{\text{RC}}}{\partial s} = \frac{((\bar{X} - \bar{X})/(1-s)^2)(I_2 + pI_1)}{[\bar{X} - (1-p)I_1 - s(\bar{X} - \bar{X})/(1-s)]^2} > 0$$

which implies $e^{***} > e^*$.

Finally, let us define p^{RC} as the probability of the risky project succeeding such that

$$\frac{I_2 + p^{\text{RC}}I_1}{\bar{X} - (1-p^{\text{RC}})I_1 - s(\bar{X} - \bar{X})/(1-s)} - \frac{p^{\text{RC}}(X_s - \bar{X}) + (1-p^{\text{RC}})I_2}{(1-p^{\text{RC}})(\bar{X} - X_s)} = 0 \quad (\text{A.12})$$

or $e^{\text{RC}}(p^{\text{RC}}) - e'(p^{\text{RC}}) = 0$, where e' comes from (26).

Therefore, the risky project is taken, it is financed with debt, and the currency is devalued, for $p > p^{\text{RC}}$. Hence, $e^{\text{RC}} - e'$ is increasing in p (using Proposition 3), and increasing in s . Therefore, $p^{\text{RC}} < p^*$. Finally, since $e^{\text{RC}} > e^*$, $e\bar{X} - I_1 - F_e^R > 0$ \square

Proof of Proposition 8. Suppose $X_s - \bar{X} + \gamma I_2 \leq 0$. This implies that $\gamma \leq (\bar{X} - X_s)/I_2$, and the risky project is preferred if

$$e \geq \frac{p(\bar{X} - X_s) - (1-p)(1-\gamma)I_2}{(1-p)(X_s - \bar{X} + \gamma I_2)} = e''.$$

Note that in this case

$$\begin{aligned} & p(\bar{X} - X_s) - (1-p)(1-\gamma)I_2 \\ & \leq p(\bar{X} - X_s) - (1-p)(I_2 - \bar{X} + X_s) \\ & < -(1-p)(\bar{X} - I_2) - (1-p)(I_2 - \bar{X}) = 0 \end{aligned}$$

using the fact that $\gamma \leq (\bar{X} - X_s)/I_2$ and the stated parameter assumption. Therefore $e'' > 0$.

Additionally, the optimal depreciation must satisfy

$$e\bar{X} - \gamma e I_2 - (1-\gamma)I_2 - (p + (1-p)e)I_1 \geq 0,$$

which is equivalent to

$$e \geq \frac{(1-\gamma)I_2 + pI_1}{\bar{X} - \gamma I_2 - (1-p)I_1} = e^{\text{PR}}.$$

Then for R to be preferred with depreciation, it has to be true that $e^{\text{PR}} \geq e''$, which implies

$$\frac{(1-\gamma)I_2 + pI_1}{\bar{X} - \gamma I_2 - (1-p)I_1} \geq \frac{p(\bar{X} - X_s) - (1-p)(1-\gamma)I_2}{(1-p)(X_s - \bar{X} + \gamma I_2)}.$$

Let p^{PR} be such that $e^{\text{PR}}(p^{\text{PR}}) - e'(p^{\text{PR}}) = 0$. Solving for γ as a function of p^{PR} yields

$$\gamma = \frac{I_1 I_2 (1 - p^{\text{PR}})^2 - I_2 X_s (1 - p) + \bar{X} p (\bar{X} - X_s)}{I_2 [X_s - (1 - p) I_1 - p \bar{X}]}$$

And from this expression, $\partial p^{\text{PR}} / \partial \gamma \geq 0, \forall \gamma \in [0, 1]$.

Therefore, for project R to be optimal, it has to be that $p \geq p^{PR}$, from Proposition 3. It is easy to prove that $e^{PR}(p, \gamma) - e'(p, \gamma)$ is decreasing in γ . Besides, it is increasing in p . Hence $\partial p^{PR} / \partial \gamma \geq 0$ which implies $p^{PR} \geq p^*$.

Suppose instead that $X_s - \bar{X} + \gamma I_2 > 0$. This implies that $\gamma > (\bar{X} - X_s) / I_2$, and the risky project is preferred if

$$e < \frac{p(\bar{X} - X_s) - (1 - p)(1 - \gamma)I_2}{(1 - p)(X_s - \bar{X} + \gamma I_2)} = e''.$$

Additionally, the optimal depreciation must satisfy

$$e\bar{X} - \gamma e I_2 - (1 - \gamma)I_2 - (p + (1 - p)e)I_1 \geq 0,$$

which is equivalent to

$$e \geq \frac{(1 - \gamma)I_2 + pI_1}{\bar{X} - \gamma I_2 - (1 - p)I_1} = e^{PR}. \tag{A.13}$$

Then for R to be preferred with depreciation, it has to be true that $e^{PR} < e''$, which implies

$$\frac{(1 - \gamma)I_2 + pI_1}{\bar{X} - \gamma I_2 - (1 - p)I_1} < \frac{p(\bar{X} - X_s) - (1 - p)(1 - \gamma)I_2}{(1 - p)(X_s - \bar{X} + \gamma I_2)}.$$

Let p^{PR} be such that $e^{PR}(p^{PR}) - e'(p^{PR}) = 0$. For project R to be optimal, it has to be that $p \geq p^{PR}$, from Proposition 3. Using $X_s - \bar{X} + \gamma I_2 < 0$, results in $e^{PR}(p) - e'(p)$ decreasing in p , and $\partial p^{PR} / \partial \gamma > 0$. Therefore, the risky project is taken for $p > p^{PR}$.

Finally, we need to check whether $V_{R,e}^D > V_R^E$ in this case. From (21),

$$\begin{aligned} V_{R,e}^D - V_R^E &= \\ & \frac{p[\bar{X} - (p + e^{PR}(1 - p))I_1] + (1 - p)[e^{PR}\bar{X} - \gamma e^{PR}I_2 - (1 - \gamma)I_2 - (p + e^{PR}(1 - p))I_1]}{p + e^{PR}(1 - p)} \\ & \quad - p\bar{X} - (1 - p)(\bar{X} - I_2) + I_1 \\ & = \frac{(1 - \gamma - p)(e^{PR} - 1)(1 - p)}{p + e^{PR}(1 - p)} I_2. \end{aligned}$$

Since the denominator is always positive, and $e^{PR} > 1$, the numerator is positive (negative) when $1 - p - \gamma > (<) '0'$ that is, when $\gamma < 1 - p$. To conclude the proof, it is easy to verify that $p^{PR}(\gamma = 1 - \bar{p}) < \bar{p}$. \square

Proof of Corollary 2. Deriving $V_{R,e}^D$,

$$\left. \frac{\partial V_{R,e}^D}{\partial \gamma} \right|_{e=e^{PR}} = -(1 - p) \frac{[\gamma - (1 - p)]I_2}{[p + (1 - p)e^{PR}]^2} \frac{\partial e^{PR}}{\partial \gamma}$$

which is positive for $\gamma < 1 - p$, since $\partial e^{PR} / \partial \gamma = I_2(I_1 + I_2) / [\bar{X} - \gamma I_2 - (1 - p)I_1]^2 > 0$. From Proposition 8, the risky project is financed with debt whenever $\gamma < 1 - p$. \square

Proof of Proposition 9. Follows directly from Proposition 8. \square

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