Currency Crises and the ADR Shadow Exchange Rate

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Abstract

Empirical evidence suggests that asset prices have a considerable predictive power over currency crises. In this paper, I develop an analytical model that shows that prices of cross-listed assets, issued in the domestic country and traded both on the domestic and a foreign market, can be used to compute the shadow exchange rate and forecast devaluations. Among cross-listed assets, I focus on the behavior of American Depositary Receipts (ADRs). The paper extends the literature of currency crises and speculative attacks by allowing trading in two different markets. The cross-listed asset provides an alternative technology to the investor to acquire dollars. Arbitrage implies that the shadow exchange rate should be equal to the official exchange rate. In line with the empirical evidence, the model predicts there is an anticipatory deviation from this law of one price prior to currency crises.

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1 Introduction

Currency crises are associated with large output declines and fiscal costs from higher debt levels, increasing country risk premium, lower tax revenues and higher expenditures stemming from corporate and banking sector rescues and bail-outs. Critically, currency crises affect external financing conditions for local corporations, who borrow to pay for inputs (such as wages and foreign inputs), which eventually reduce its output. Although some of these effects might be partially off-set by better conditions on the exporting sector, it is clear that currency crises are also associated with high uncertainty.

In the proximity of currency crises, countries are usually subject to massive fluctuation in asset prices, as they experience sudden reversal of capital flows. Kaminsky and Reinhart [1999] show for a large sample of currency crises, the stock market collapses the year before the crises. However, the literature on forecasting currency crises avoids providing more precise predictions on the timing and magnitude of the crises. This paper uses market data to improve the predictive power of these episodes, relative to the variables proposed by the first generation model of currency crises. The challenge to identify the currency crises risk from other factors affecting the asset prices, is solved using cross-listing assets.

The contribution of this paper is to develop a theoretical model that captures the behavior of asset prices during currency crises and shed some light over the potential predictive power of asset prices. This paper focus on recent episodes of currency crises. The paper provides further evidence on the anatomy of currency crises by analyzing the behavior of cross-listing asset. American Depositary Receipts (ADRs), as tool to measure investors expectations with respect to the exchange rate, provide a way to assess the currency crises risk. Arbitrage between the price differential of the ADR and its corresponding underlying imposes that the law of one price (LooP) should hold. The LooP, in turn, establishes that the price of both securities should be proportional to the prevailing exchange rate. The model implies that in anticipation of the crisis, the LooP ceases to hold due to informational and market frictions.

The increasing uncertainty prior to currency crises is not captured in the first generation models of currency crises. According to this view, there is no role for speculation as the crises are solely caused by inconsistent monetary policies. Inflationary pressures tied up with a fixed exchange rates lead to a reduction in the demand for real balances and to a corresponding fall of the foreign reserves at the central bank. The currency crisis takes place when international reserves fall below a critical threshold. The central bank devalues the domestic currency and a perfectly anticipated attack depletes the central bank's reserves. However, the predictability of the attack implies that neither the exchange rate nor the asset prices can display discrete changes, in contrast with the empirical evidence.

Figures (1-2) illustrate the evolution of the stock exchange index and the official exchange rate around the currency crises in Argentina and Thailand. The figures show a steady decline in the stock

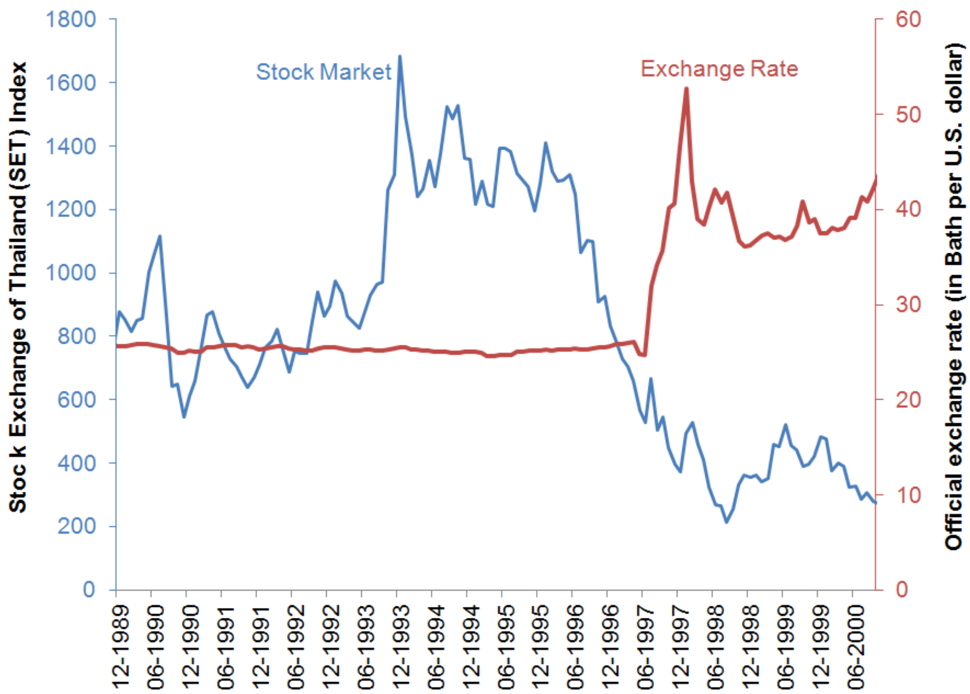

Figure 1: **Thailand.** Stock market index (SETI) and official exchange rate. Note: This figure shows the Stock Exchange of Thailand and the official exchange rate for Thailand from December 1989 to December 2000. In July 1997, the Bank of Thailand devalued the currency 40% during the first month, while the SETI has been falling for the previous 2 year. Source: Bloomberg.

market in anticipation to the collapse of the exchange rate regime. For the case of Thailand, the stock market dropped for more than 12 consecutive months before the Bank of Thailand abandoned the exchange rate regime. Despite that the market aggregates disperse information in the economy, the fact the stock market is affected by different risks highlights its weakness in predicting currency crises.

In Argentina the evidence is even more contradicting since the stock market increased before the collapse of the currency peg. In this case, the traditional view, that considers that investors unfold their positions in domestic currency before the outbreak of the crisis, is challenged. This paper analyzes the dynamics of the asset prices conditioned on whether the stocks are cross-listed, as suggested by Auguste, Dominguez, Kamil, and Tesar [2006]. They observe the trading volume in cross-listed stocks in Argentina during the financial crisis of 2001 increased dramatically.

Obstfeld [1996] and Eichengreen, Rose, and Wyplosz. [1995] early pointed out the counter-factual implication of the first generation view. The authors present evidence that the exchange rate regime is not obviously unsustainable in the sense the first generation models imply prior to the crises[1]. In this way, the second generation models of currency crises better capture the unpredictability of crises. Uncertainty over the outcome of the coordination game (whether the

[1] In particular, Obstfeld [1996] shows that for the case of the European Monetary Union during 1992-94, in countries such as France, Belgium or Denmark did not display signs of weak fundamentals.

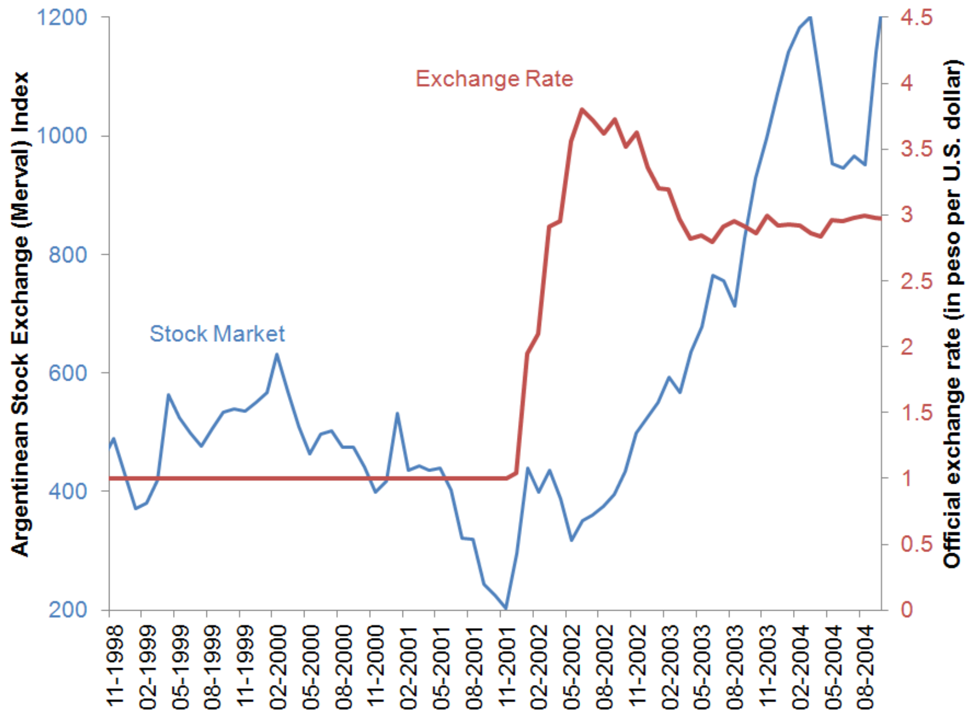

Figure 2: **Argentina.** Stock market index (Merval) and official exchange rate. Note: This figure shows the evolution of the Merval and the official exchange rate for Argentina from November 1998 to September 2004. In December 2001, the Central Bank of Argentina devalued the currency initially by 45%, while the Merval simultaneously increased. Source: Bloomberg.

speculative attack is successful) creates a coordination problem and allows for multiple equilibria. Self-fulfilling expectations affect the actions of the central bank who passively observes the run on the peg.

Despite the fact that multiplicity appears to close the gap between the theory and the empirical evidence, extensions by Morris and Shin [1998] show that the existence of multiple equilibria may not be robust to the inclusion of information asymmetries. In particular, when assuming heterogeneously informed agents, it is enough that the precision of the idiosyncratic private signals is high enough to prevent coordination failures. In this case, the equilibrium is characterized by unique monotone strategies.

Recent literature on currency crises has extended the work of Morris and Shin [1998] to incorporate financial prices as endogenous sources information into the coordination game. In line with the literature on noisy rational expectations, asset prices aggregate initially dispersed private information. In particular, Hellwig, Mukherji, and Tsyvinski [2006][2] and Angeletos and Werning [2006] suggest different frameworks in which uniqueness is preserved under similar conditions to

[2] Hellwig, Mukherji, and Tsyvinski [2006] assume first an elastic bond supply which conflicts with the inferring of information from the asset prices, generating a backward bending bond demand and multiple market clearing interest rates. However, they also show that if the domestic bond supply is inelastic and/or shocks are large, the information content of interest rates is reduced and there is a unique equilibrium.

that of the original work of Morris and Shin [1998]: the precision of private information is relatively higher (to that of the pubic signal), preventing the failure of coordination. Note that most of the related studies assume uncertainty with respect to the strength/willingness of the central bank to sustain the currency peg.

This paper proposes two extensions to the second generation models of currency crises. First, I replace the main source of uncertainty from the balance sheet of the central bank to the performance of the domestic asset. Investors are asymmetrically informed about its asset payoffs. In this way, the model resembles more closely to sudden reversal of capital flows observed in the recent episodes in East Asia (1997-98) and Russia (1998) for example. An investor unfolds her positions denominated in domestic currency as her expectation about the dividends of domestic assets deteriorates. Simultaneously, she turns into alternative hard-currency investments. When a sufficiently large measure of investors go to the central bank to exchange domestic currency, foreign reserves at the central bank drop (below some commonly known threshold determined by the central bank, as in Obstfeld [1986]), and a devaluation takes place. Asset prices in the model also play a dual role, affecting the payoffs of the domestic asset and aggregating disperse private information.

Second, I expand the model to introduce cross-listing assets. Cross-listing assets play an important role in the global economy. On the one hand, they allow companies to access financing opportunities with greater liquidity and transparency. On the other hand, provide international investors with accessible tools to obtain greater diversification. Among the cross-listing instruments[3], I concentrate on American Depositary Receipts (ADRs). As discussed by Bailey, Chan, and Chung [2000], ADRs account for most of the trading of cross-listed assets. ADRs are dollar-denominated claims, priced in the U.S. market, of shares of the (underlying) domestic stock on which the ADR is written. Since the ADR can be converted into shares of underlying at any point in time, both securities are nearly perfect substitutes. By comparing the prices of the ADR and the corresponding underlying, I am able to obtain a measure of the exchange rate investors expect, in the event of a currency crisis. I define the ratio of the prices as the ADR shadow exchange rate.

In a frictionless and financially integrated economy, arbitrage enforces the law of one price between both securities. This law stipulates that if two assets have the same payoffs, then they most have the same price (see Cochrane [2005] p. 61). The only difference between both securities is the currency they are denominated, which I consider it to be initially fixed. Once this is accounted, the relative price of the underlying to the ADR should be proportion to the prevailing exchange rate in the domestic economy (measuring pesos to dollars). Empirical evidence rejects this results during periods of capital controls or in anticipation of a currency crises.

Although there are many impediments to arbitrage, given its observability and measurability, market frictions stand out in the literature. Most studies focus on the role of market friction, such

[3]Non-U.S. firms list shares in U.S. markets in several different ways: New York or Global registered shares, American Depositary Receipts, or even direct listings ordinary shares of the domestic market. These instruments differ in term of their fungibility (or, exchangeability) between the underlying stock and the cross-listed ones, affecting the investors ability to arbitrage away cross-border differences.

as transactions costs and controls on capital flows, as the drivers of the (persistent) wedge between prices of the ADR and the underlying. However, as I point out below, market frictions are unable to explain the dynamic behavior of the wedge at the verge of the crises.

Main mechanism. Consider an investor holding a position in domestic currency in a country with fragile fundamentals that could be subject to a currency crisis. Given that the domestic asset is cross-listed, the investor has access to two alternative technologies to acquire dollars. The first one is going to the central bank. The second one is making a cross-market transaction: purchasing the underlying, converting it into ADR, and selling those shares in the foreign market. An investor who doesn't have a strong view that there will be a devaluation, considers the cross-market transaction a better option because is *(i)* reversible (the investor can convert back the ADR into shares of the underlying) and *(ii)* the investor benefits from observing new information enclosed in the ADR price. When the economy is closer to the tipping point of fundamentals (beyond which there is a devaluation), the investor put higher value to underlying asset, avoiding to exchange her position to hard currency.

The goal of the paper is to show that despite the fact the capital controls create a observable friction that affects arbitrage, they fail to replicate the anticipating behavior of the prices of cross-listing assets to currency crises. The valuation of the underlying asset increases relative to the exchange-rate-adjusted price of the ADR prior to the devaluation. We propose an information friction in the context global games, as the main mechanism the explains the behavior. The value of the underlying asset derives from the expected dividend payments plus the option to wait holding while the stock to get more information, helping assert whether a devaluation takes place or not.

2 An Introduction to ADRs

Almost all non-U.S. companies that list their shares on U.S. exchanges use American Depositary Receipts (ADRs) as one of the main instruments. ADRs were initially developed to provide U.S. investors with accessible instruments to better diversify their portfolios. The issuance of an ADR requires a U.S. depositary banks to purchase shares of the underlying stock and place them on its account at the custodian bank in the local country. A broker can also initiate the creation of ADRs by following the same procedure, and placing the share of underlying on the depositary bank's account at the custodian bank. Cancellations or redemptions of ADRs simply require reversing the process. These are the step are to convert an underlying into its corresponding ADR, and vice-versa. Each ADR represents a specific number of underlying shares issued in a domestic market. ADRs have several advantages over other cross-listing shares (dollar-denominated, U.S. clearance and settlement), but are not fully fungible[4]. Moreover, as Gagnon and Karolyi [2010] points out, the convertibility is definitively not seamlessly, since it requires many intermediaries and usually takes 1 to 2 business days to be completed.

From the perspective of the firms, issuing ADRs allows access to a broader and more liquid investor base as well as it gives the opportunity to raise new capital. However, non-U.S. companies are required to comply with the U.S. Securities and Exchange Commission (SEC) requirements: filing a registration statement and furnish an annual report with a reconciliation of financial accounts. In this way, U.S. investors find more transparent conditions for investing in firms overseas.

Moreover, the convertibility feature of ADRs allows computing a measure of the ADR shadow exchange rate, as the ratio of the price of the underlying stock (denominated in domestic currency) to the price of the ADR (denominated in dollars). The ADR shadow exchange rate is a measure of the exchange rate investors expect after a potential currency crisis and is able to predict the post-devaluation official exchange rate.

As early noted by Alexander, Eun, and Janakiramanan [1987], cross-listing securities can be used to surpass barriers on capital flows such capital controls. In this way, ADRs provide an alternative technology to acquire dollars in the domestic country (other than going to directly to the central bank). The cross-market transaction requires *(i)* purchasing the underlying stock in the domestic markets (denominated in domestic currency), *(ii)* converting the underlying into (corresponding number of shares of) ADRs, and finally *(iii)* selling the ADRs (denominated in dollars) in the U.S. exchange. The returns on the cross-market transaction are restricted by arbitrage, with respect to returns on dollars at the central bank.

Models without information frictions find limitation in assessing the ADR shadow exchange rate. Consider first the case with perfect information. I focus on an investor trying to profit from an arbitrage opportunity between both technologies (for purchasing dollars). Assume the initial exchange rate is 1. The (gross) returns on the cross-market transaction (CMT) and the dollar investment are

$$\text{Returns on the CMT: } \frac{e\tilde{p}}{p} \qquad \text{Returns on dollars: } e \tag{1}$$

where e denotes the future exchange rate in terms of domestic currency to US dollars, p is the price of the underlying stock (denominated in pesos), and $\tilde{p}$ represents the price of the ADR (denominated in dollars). No arbitrage implies that the return from both investments should be equal,

$$\text{No arbitrage} \qquad \Rightarrow \qquad \frac{p}{\tilde{p}} = 1 \tag{2}$$

[4]For a definition a full fungibility see Gagnon and Karolyi [2010]. Briefly, full fungibility requires among other conditions that both claims are identical and there are no legal restrictions on cross-border ownership and trading.

which represents the law of one price in this model[5].

This article also consider the effect of the introduction of capital controls in a step towards restoring independent monetary policy with a fixed exchange rate regime[6]. Raising the Tobin-tax on capital outflows will reduces the opportunity cost of holding the domestic asset and thus reduce the dollar demand. This seems like a natural way to think about interest rate policy in the context of currency crises since, in practice, the policy makers' rationale for imposing capital controls is to increase the attractiveness of domestic currency–denominated assets while maintaining the fixed exchange rate and the level of international reserves untouched.

Consider now the case where capital controls are in place. For simplicity, I model controls on capital outflows as a Tobin-tax proportional to the level of exchange rate. Denote the level of capital controls by τ. The taxes affects sudden dollar withdraws from the central bank. In this case, the price of a dollar at the central bank increases to $(1+\tau)$ and the return is reduced by the same factor. Since the ADR conversion provides a legal option to surpass the controls, the returns on the cross-market transaction are unaffected. The no arbitrage condition in this case is

$$\text{No arbitrage (under capital controls)} \qquad \Rightarrow \qquad \frac{p}{\tilde{p}} = (1+\tau) \tag{3}$$

One of the empirical regularities found in the literature is the persistent relative discount (premium) taken on ADR after the introduction of controls capital on outflows (inflows). Melvin [2003], Auguste, Dominguez, Kamil, and Tesar [2006] and Levy Yeyati, Schmukler, and Van Horen [2009] study the behavior the cross-listing securities during episodes with capital controls. They propose this market friction as the mechanism that limits arbitrage and prevents the law of one price from holding.

Pasquariello [2008] empirically shows that the law of one price ceases to hold in proximity to financial crises. In particular, finds that between ADR returns and the dollar returns of their perfect substitutes weakened considerably (by 54% on average).

From equation (3) it is clear that capital controls introduce a constant wedge from the law of one price without market frictions, represented in equation (2). Assume that the no arbitrage condition fails, and discrepancies between the price of the underlying and the price of the ADR adjusted by the exchange rate persist. In order to study the deviations from the law of one price, I define a market measure of the expected exchange rate. The ADR shadow exchange rate s_t the price ratio of both securities:

[5] With common knowledge:

- If $p/\tilde{p} > (1+\tau)$, no agent demand dollars $\rightarrow$ No Devaluation.
- If $p/\tilde{p} < (1+\tau)$, agents do not use cross-listing assets.
- If $p/\tilde{p} = (1+\tau)$, agents are indifferent between both technologies.

[6] According to the Mundell's trilemma, a country cannot simultaneously maintain a fixed exchange rate and an independent monetary policy, in a context of free capital flows.

$$s = \frac{p}{\tilde{p}} \tag{4}$$

The ADR shadow exchange rate represents a measured of the implied exchange rate discounted by ADR investors. It is clear that capital controls only create a constant wedge between the price of both securities[7], an a persistent deviation of the ADR shadow exchange rate from the official exchange rate[8].

3 Empirical evidence

Figure (3) below displays the ADR shadow exchange rate and the official exchange rate in Malaysia during a period of high stress on the ringgit currency, exacerbated by the Asian crises. The dashed line represents the official exchange rate between domestic currency and U.S. dollars. In September 1998, the exchange rate regime changed from a floating to a fixed exchange rate. The solid line represents the ADR shadow exchange rate measured according to (4). The Malaysian government imposed capital controls and pegged the ringgit on September 1998 in order to attenuate the effects of the Asian crisis. After the first imposition of capital controls, the ADR shadow exchange rate increased without any simultaneous change of the official exchange, as predicted by equation (3). As external conditions improved and the pressure on the central bank diminished and capital controls were reduced, the ADR shadow exchange rate converged to the peg rate.

Figure (4) displays the ADR shadow exchange rate and the official exchange rate for Venezuela during the Mexican crisis. The Venezuelan government introduced capital controls in late June 1994, adopting a fixed exchange rate after a crawling peg regime. The Venezuelan central bank introduced a program to recapitalized troubled banks, trying to deal with the banking crises, which resulted in increasing inflationary pressures stemmed from the money supply increased. The ADR shadow exchange rate shows investor's higher devaluation expectations. In early 1995, ADR investors anticipated a devaluation from 170 VEB/USD to 320 VEB/USD. Expectation were not met, and the central bank was able to cope with the speculative attack. However, on December 1995 as the ADR shadow exchange rate overpass the psychological 300 VEB/USD upper bound, the attack becomes stronger and the central bank is unable to maintain the currency peg. One week late the fixed exchange rate was realignment to 290 VEB/USD. On April 1996, the capital controls were lifted. The currency was allowed to float, and it depreciated to 470 VEB/USD representing a realignment of more than 70%. The devaluation was forecasted by ADR investors.

Figure (5) displays the ADR shadow exchange rate and the official exchange rate during the financial in Argentina in 2001. After the hyperinflation episode in 1989, Argentina adopted a fixed

[7]This analysis abstracs from the signalling component of the government actions which might trigger a sudden change in the investor's beliefs.

[8]Auguste, Dominguez, Kamil, and Tesar [2006], Levy Yeyati, Schmukler, and Van Horen [2009], Eichler, Karmann, and Maltritz [2009] among others find that controls on capital outflows lead to a higher ADR shadow exchange rate than the official: controls lead to a price premium of the underlying over the ADR stock.

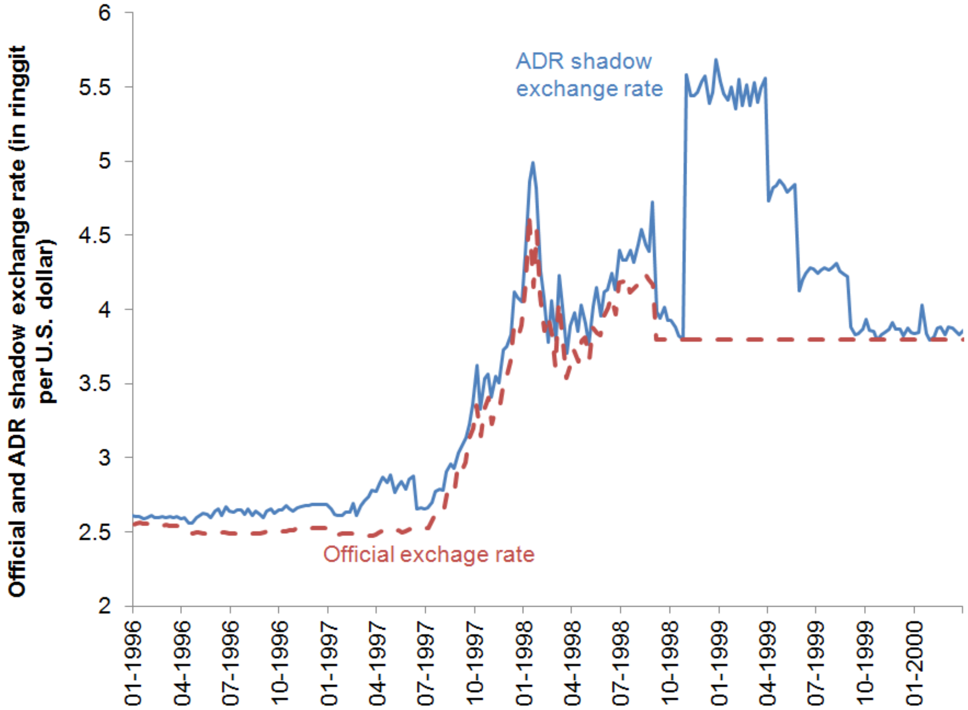

Figure 3: ADR shadow exchange rate and official exchange rate Malaysia 1995–2000. Note: This figure shows the ADR shadow exchange rate and the official exchange rate for Malaysia. Capital control were imposed from September 1998 to August 1999. The ADR shadow exchange rate is calculated according to equation (4). ADR stocks/underlyings data is from the following stocks: Genting Malaysia Berhad, Kuala Lumpur Kepong, Lion Industries, MBf Holdings and Silverstone. Source: Datastream.

exchange rate that peg the peso one to one to the dollar. During the Mexican crisis, the Argentinean central bank was able to maintain the exchange rate despite of the pressures from sudden capital reversals. In the early 20001, the incapacity of policy makers to use the exchange rate as a buffer to accommodate with the worsening external shocks, exacerbated the misalignment of the nominal exchange rate.Capital controls were introduced on December 2001 to November 2002 as a measure to rescue the currency peg. Before the introduction of capital controls the ADR shadow exchange rate reflected devaluation expectations. The peg finally collapsed on January 2002 generating a devaluation of 40% that was expected by ADR investors who set the ADR shadow exchange rate at around 1.5 ARS/USD in the week preceding the devaluation.

Figure (6) illustrate the ADR shadow exchange rate and the official exchange rate during the financial in Argentina for the recent past. After the collapse of the currency board in 2002, the central bank adopted a crawling peg exchange rate. With the objective to reduce the exchange rate volatility, the government set a path for the exchange rate with a constant depreciation rate. Since early 2011, the external conditions continuously deteriorated increasing expectation of a devaluation. The government imposed capital controls, restricting investors access for foreign exchange. The investors use the ADRs in order to acquire dollars.

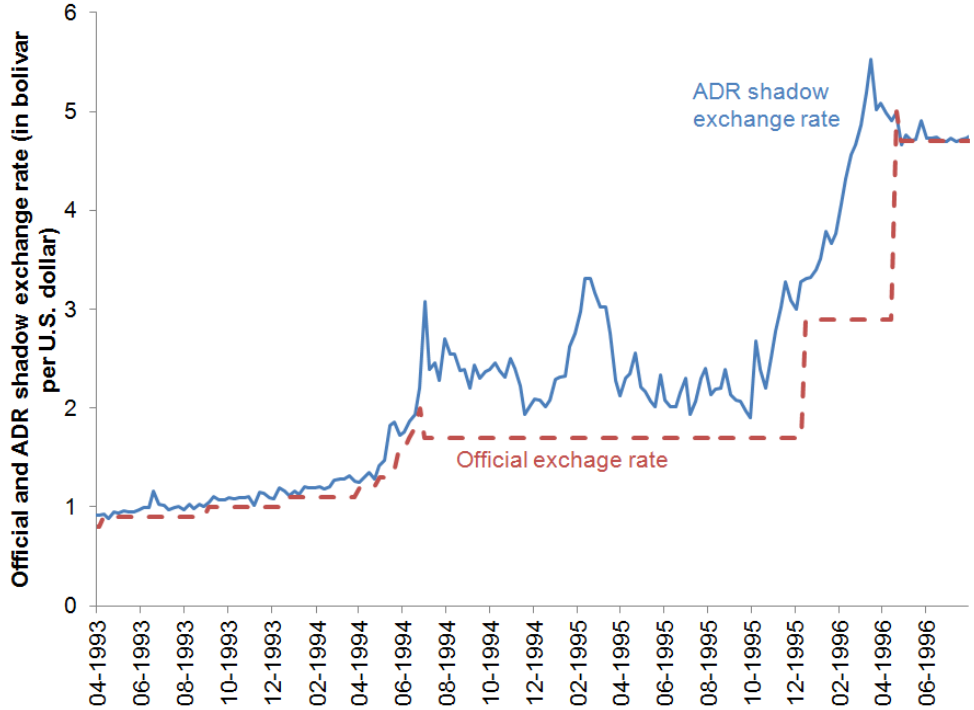

Figure 4: ADR shadow exchange rate and official exchange rate Venezuela 1993–1997. Note: This figure shows the ADR shadow exchange rate and the official exchange rate for Venezuela during the capital control period from June 28, 1994 to April 19, 1996. On December 12, 1995 the exchange rate was realigned from 170 bolivar/dollar to 290 bolivar/dollar. On April 22, 1996, the peg collapsed. The ADR shadow exchange rate is calculated according to Eq. (4).

Figures (4-5) suggest that the ADR shadow exchange rate anticipates to the collapse of the fixed exchange rate regime. This is the center of the paper. This anticipatory deviation from the law of one price requires that the domestic asset becomes more valuable than the ADR adjusted by the prevailing exchange rate. Recall that both securities are claims on the same stream of cash-flows (differentiated only by the currency of denomination). This pre-crisis dynamic of the ADR shadow exchange rate will not be captured in a model with perfect information as displayed by equation (3).

In order to understand the deviation of from the law of one price, note that the underlying asset is not only valuable for the domestic investor for the cash-flow stream, but also for its capacity for eventually convert it for the ADR to acquire dollars. For the domestic investor the option of waiting in order to observe more information becomes increasingly important when he is uncertain whether a devaluation will take place or not. In this way, the price of the underlying risky asset can be decomposed into the expected dividend and the value of the option to convert it into ADRs.

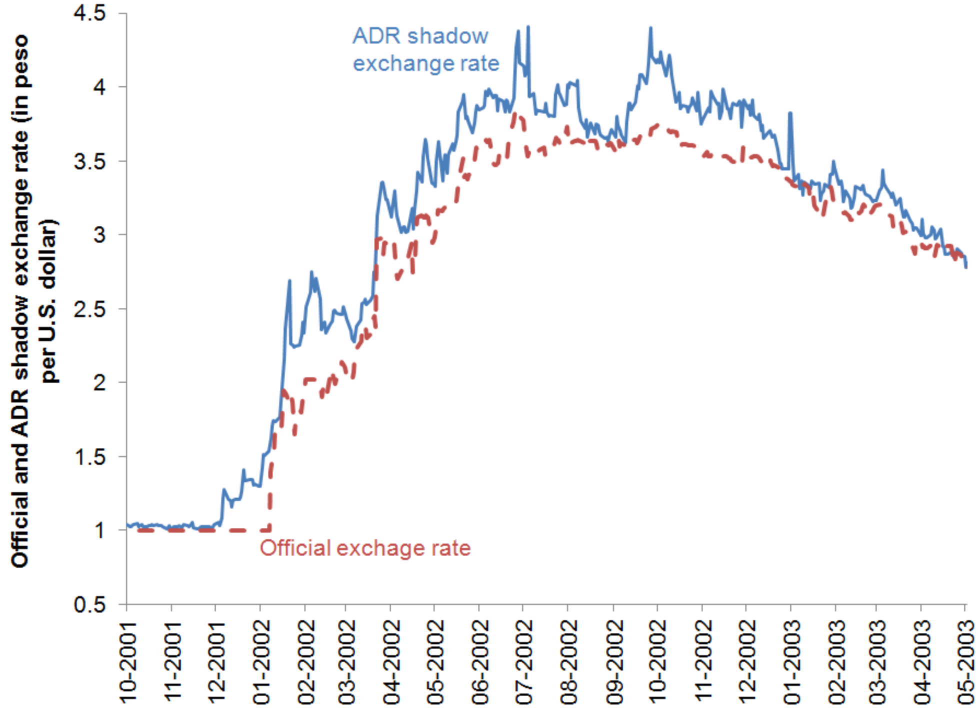

Figure 5: ADR shadow exchange rate and official exchange rate Argentina 2001–2002. Note: This figure shows the ADR shadow exchange rate and the official exchange rate for Argentina around the currency crises. On December 6, 2001 the exchange rate was realigned from 1 peso/dollar to 1.2 peso/dollar. For the next 3 year, the exchange rate fluctuated around 3.8 and 4.2 peso/dollar. The ADR shadow exchange rate is calculated according to Eq. (4).

4 Literature Review

This paper is related to several strands in the literature. It fits within the second generation models of currency attacks that considers heterogenous beliefs, going back to Morris and Shin [1998]. It is more closely related to Angeletos and Werning [2006] and Hellwig, Mukherji, and Tsyvinski [2006] models of speculative attacks that focus on the role of markets in providing useful information about the economic fundamentals. The main difference with these papers is that I allow investors to trade cross-listing asset, being able to use the cross-market transaction as an alternative technology to acquire dollars.

First generation models of currency crises view successful attacks as episodes in which agents to simultaneously run on the foreign reserves of the central bank (as in Krugman [1979] and Flood and Garber [1984]). Assuming common knowledge the devaluation outcome is perfectly anticipated implying that the exchange rate and the asset prices cannot display discrete changes. Obstfeld [1996] and Morris and Shin [1998] show the implication of the model in the absence of the common knowledge assumption. Agent's actions display strategic complementarities since the attack from some speculators increases the probability of a successful attack, increasing the incentive of others to attack.

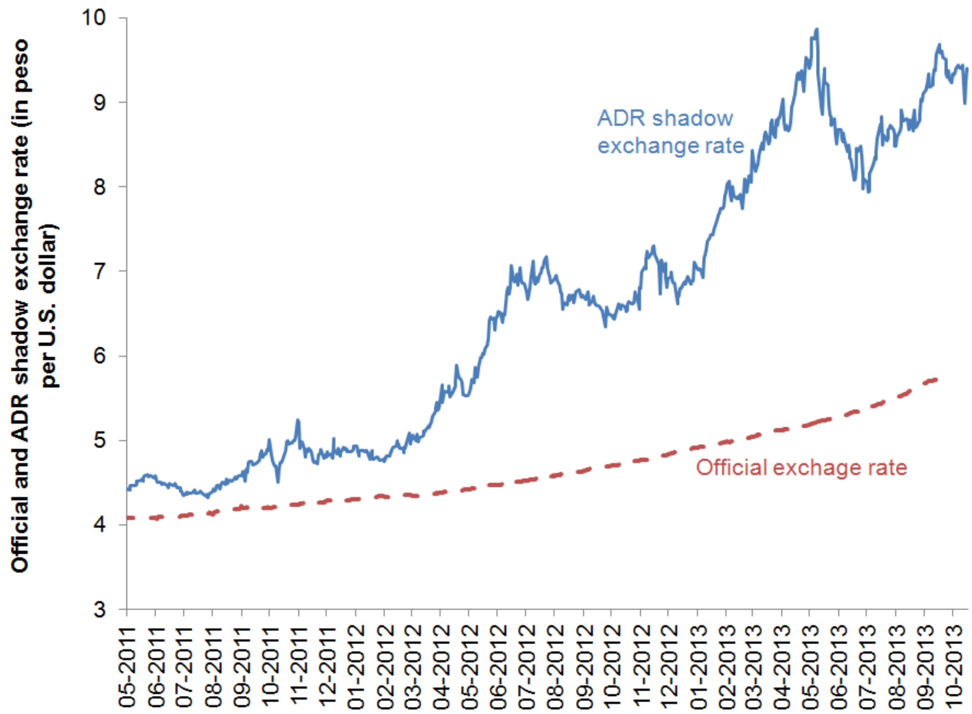

Figure 6: **Official and Shadow Exchange Rate.** The shadow exchange rate and official exchange rate Argentina 2008–2013. Note: This figure shows the ADR shadow exchange rate and the official exchange rate for Argentina during the capital control period from December 2012 to May 2013.

The literature on speculative attacks and currency crises has assumed as the main source of uncertainty the characteristics of the central bank. Morris and Shin [1998] and Goldstein, Ozdenoren, and Yuan [2011] assume that agents are uncertain about the strength of the central bank to confront an speculative attack or the value of maintaining the currency peg. Hellwig, Mukherji, and Tsyvinski [2006] who assumes uncertainty over the highest tolerable level of interest rates for the central bank, in line with Obstfeld [1986]. This assumption might contradict empirical evidence that suggests that along the course of the currency run, the central bank and the news industry do not passively sits as foreign reserves dwindle. Moreover, at times when the odds of a currency run increases, the newspaper's coverage on the central bank account's peaks, increasing the amount and the precision of the public information available. This in turn makes it harder to achieve the uniqueness result that emerges in models on global games. One example is Angeletos and Werning [2006], who introduce exogenous and endogenous public information in a model of speculative attacks. Uniqueness is attained as long as the precision of the private signals exceed some increasing function of the public signal (agents based their decision more heavily in their own private signal).

Among others, Drazen [2000] and Krugman [2000] suggest that the outcome of the speculative attack is not necessarily related to the reserves. This paper differs from most of the studies mentioned above, by assuming the main source of uncertainty is the fundamentals that drives the performance of local asset. In this direction, the model focus on the behavior of asset prices in an environment that allows for speculative attacks.

In terms of the role of the government, Lahiri and Vegh [2003] and Flood and Jeanne [2005] study the ability of the interest rate to delay the balance of payment crises. Goldstein, Ozdenoren, and Yuan [2011] and Kurlat [2013] analyze the feedback effects from the market to policy decisions. The main results are non-monotonic optimal policy functions.

There is an extensive empirical literature that studies the role of financial crises in assessing the impact on the efficiency and integration of financial markets. According to Bailey, Chan, and Chung [2000], ADRs account for most of the equity trading across borders. The relevance of foreign investors is studied in Bailey, Chan, and Chung [2000], suggesting that foreign traders activity is consistent with "noise trader".

Doidge, Karolyi, and Stulz [2004] show that firms listed in the U.S. have a Tobin's q ratio that exceeds by 16.5% the q ratio of firms from the same country that are not listed in the U.S. Auguste, Dominguez, Kamil, and Tesar [2006] observe a dramatic change in the trading volume in cross-listed shares in Argentina during the financial crisis of 2001. They show that although the aggregate trading volume of the local stock exchange (Merval) steadily declines, cross-listed stocks trading volume jumps dramatically at the time of the financial crises, from representing roughly 40 percent of the total volume to over 80 percent.

Karolyi and Stulz [2003] and Gagnon and Karolyi [2010] find that home bias tends to increase local influences on asset prices. They find that local market portfolios, in general, explain better the cross-sectional variation in expected returns for local stocks, though they also find that equity flows and cross-country correlations increase global influences on asset prices.

Empirical literature has also focus on the role of ADSs in global financial integration (see, for example, Melvin [2003], Auguste, Dominguez, Kamil, and Tesar [2006] and Levy Yeyati, Schmukler, and Van Horen [2009]). My paper develops a theoretical framework that studies the effects of financial crises and the ADR pricing. Empirical studies suggest that the returns on U.S. ADRs are negatively affected by currency crises (Kim, Szakmary, and Mathur [2000]; Bin, Blenman, and Chen [2004], Pasquariello [2008]), but more crucially, display a persistent violation of the law of one price between an ADR and its underlying stock.

Levy Yeyati, Schmukler, and Van Horen [2009] show that capital controls can be easily evaded, and they do affect financial integration as measure by the cross-market premium. Controls on capital inflows put downward pressure on domestic markets relative to international ones, generating a negative premium. The opposite happens with controls on capital outflows.

Levy Yeyati, Schmukler, and Van Horen [2004] argue that the most liquid stocks, which are also cross-listed, had the largest increase in price during the financial crises in Argentina. They show that while liquidity played a role in explaining Argentine stock returns, a dummy variable for ADR shares is significant and positive even after controlling for liquidity. Cross-listed assets display a particular behavior during financial crises that can help to predict the proximity of the outbreak.

Eichler, Karmann, and Maltritz [2009] show there is a strong link between ADR shadow exchange rate and currency crisis, as ADR investors discount higher currency crisis risks from a deterioration of fundamentals such as a fall in commodity prices, a depreciation in the trading partners' currencies, an increase in the sovereign yield spreads, or interest rate spreads widen. They suggest that ADR spreads reflect investors' expectations of a devaluation, and represent the mean exchange rate investors expect following a currency crisis or a realignment.

The rest of the paper is organized as follows. In section 5 I present the setup of the model. In section 6 I solve the benchmark model when investors do not have access to a cross-listing asset. I consider the model with common knowledge, and latter assume information asymmetries. In section 7 I allow investor to trade a cross-listed asset and contrast the empirical implications with the previous section. Finally, in section 8 I present some final remarks.

5 Model

There are four periods, $t \in \{0, 1, 2, 3\}$, and two countries: home and foreign. To fix ideas, one may think of the home country as a small developing economy and the foreign country as a financially developed country. There are two consumption goods: domestic currency and foreign currency. I refer to the home country's currency as the peso and the foreign country's currency as the dollar. Initially, the home country is subject to a currency peg. There is also a (domestic) risky asset and the corresponding ADR. I shall refer to the (domestic) risky asset interchangeably as the underlying asset or simply the risky asset, as opposed to the ADR which has only that nomenclature.

The domestic risky asset is traded in the domestic asset market, and pays dividends denominated in pesos at $t = 3$. The domestic asset market clearing price p, is denominated in pesos. The ADR is traded in the foreign market, and pays dividends denominated in dollars at $t = 3$. The market clearing price in the foreign market of the ADR, $\tilde{p}$, is denominated in dollars. Both assets are in zero net supply. Both prices are perfectly observable by all the agents.

Asset markets are segmented. Assets in the domestic market are traded in peses, while those in the foreign market are traded in dollars. At $t = 0$, only the domestic asset market opens, while at $t = 1$, only the foreign asset markets open. The time in between both trading session accounts for the delay in the ADR conversion (the time it takes to a domestic investor to exchange the shares of domestic risky asset into ADRs)[9]. The government of the home country imposed capital controls, in an attempt to defend the peg against a speculative attack. I assume that the reduced ability to repatriate profits for foreign investors, distorted by the controls on capital outflows, effectively reduce capital inflows at $t = 0$.

The economy is populated by a measure-one continuum of domestic investors, uniformly dis-

[9] Most cross-market transactions are completed after 1 to 2 business days. Only settled shares might be converted. In terms of intermediation, the CMT requires to deposit the shares in the account of the custodian bank, and for the depositary bank to issue new shares.

tributed in the unit interval and indexed by $i \in [0, 1]$, a stochastic measure of noise traders in the domestic market, a representative foreign investor, denoted by f, and the central bank (CB) of the home country.

Timing of the game. At $t = 0$, the domestic market opens. The domestic investor makes her portfolio decision and trades with the noise trader. At $t = 1$, the foreign market opens, where the domestic and foreign investor trade shares of ADRs. At $t = 2$, the central bank determines whether the regime status is maintained or abandoned. Finally, at $t = 3$, all assets pay off and investors consume.

5.1 Assets

Four assets are traded in the economy: pesos, dollars, the (domestic) risky asset, and the ADR. Without loss of generality, I assume there are no other intrinsic dollar-denominated asset. I fix net return on pesos equal to 0, which is equivalent to assuming that the domestic nominal interest rates is 0. The domestic risky asset pays off a stochastic dividend given by θ units of pesos, at $t = 3$. The risky asset is denominated in pesos, and the market price p is perfectly observable to all agents.

The ADR represents claims on the same dividends as the domestic asset, but adjusts it by the prevailing exchange rate at $t = 2$, after the decision of the CB. For simplicity, I assume each ADR represents 1 unit of the underlying (the conversion rate is 1)[10]. Denote e_t the exchange rate, defined as units of pesos per dollar, at period t. I normalize the initial exchange rate to $e_0 = 1$. The ADR pays θ/e_2 units of dollars at $t = 3$. The foreign market price, $\tilde{p}$, is denominated in dollars and also perfectly observable.

Each investor is endowed with the technology to convert shares of the domestic asset into shares of ADR. Therefore, the investor holding a share of the underlying at $t = 0$ is able to convert it into a share of ADR, and vice verse. The conversion process takes 1 period.

Each investor can get dollars by going to the CB, to exchange her pesos. The exchange rate might change only once, at $t = 2$, when the CB decides whether to sustain the currency peg, and the domestic currency could be subject to a devaluation. Initially, the exchange rate is fixed, $e_0 = e_1 = 1$. At $t = 2$, if there is no devaluation, the exchange rate remains unchanged. Otherwise, if there is a devaluation the exchange rate drops to $E > 1$, units of pesos for the dollar. In the benchmark model, E is assumed exogenous and commonly known. For $t \geq 2$, the exchange remains constant: $e_2 = e_3$, as described by equation (5).

[10]Each share of ADR might represent a bundle of shares of the underlying domestic risky asset. The number of shares each ADR represents determines the conversion ratio, which is fixed at the time of the initial listing. The ADR bundles several shares in order to avoid the price of the ADR from falling below some minimum value required by the NYSE for being listed.

$$e_2 = \begin{cases} E & \text{if Attack is successful: Devaluation} \\ \\ 1 & \text{if Attack fails: No Devaluation} \end{cases} \quad (5)$$

The return on the dollar investment is given by the devaluation rate. The devaluation, in turn, depends on whether the attack is successful.

Let $\tau \geq 0$ capture the Tobin-like tax on capital outflows, introduced by the government of the home country. In the current framework, I abstract from the government's problem, and assume τ as exogenous. The optimal taxation of capital outflows problem under a signalling framework is studied by Angeletos, Hellwig, and Pavan [2006]. Capital controls increase the price of dollars at the CB in the home country, to $(1 + \tau)$.

Table (1) summarizes the net payoffs of the different investments[11]. The left column conditions payoffs on a failing attack, while the right column displays the payoffs for the opposite case. The top section of the table refers to the investment opportunities in the domestic market, and payoffs are denominated in pesos. The bottom section presents the payoffs for the investment opportunities in the foreign market, denominated in dollars.

Table 1: Net payoffs

	Devaluation	No Devaluation
Domestic Market (in pesos)		
Pesos	0	0
Risky Asset	$\theta - p$	$\theta - p$
Dollar	$E - 1 - \tau$	$-\tau$
Foreign Market (in dollars)		
ADR	$\theta/E - \tilde{p}$	$\theta - \tilde{p}$
Dollar	0	0

Discussion. First, I describe the payoffs of the investment opportunities in the domestic market. Note that without capital controls ($\tau = 0$), pesos are weakly dominated by dollars. In this case, the investor's decision becomes binomial, between the domestic risky asset and dollars. The net

[11] Table (2), in the appendix, displays the matrix of gross payoffs.

payoff of the domestic asset is, conditional on p, independent of the regime status. However, the price of the underlying is endogenous and, in equilibrium, fluctuates with the regime status. In particular, p is determined by the market clearing condition in the domestic market, and is such that the marginal investor is indifferent between investing in the risky asset or the alternatives.

The domestic investor converts dollars back at $t = 2$ in order to consume pesos. The net payoff of the dollar investment is $e_2 - (1 + \tau)$. I assume capital controls as such that $E - 1 - \tau > 0$. If there is no devaluation, the payoff of dollars is negative, equal to $-\tau$. In this case, the risky asset becomes relatively more attractive. In equilibrium, the asset price increases such that only a fraction of the investors demand the risky asset. On the other hand, if there is a devaluation, the dollar investment becomes relative more attractive and the asset price decreases.

Therefore, the price of the domestic asset fluctuates with the CB's decision, which is ultimately be determined by the fundamentals of the model, the realization of the dividend payment and the measure of noise traders.

Investors in the foreign market bear the exchange rate risk. If there is no devaluation, the gross payoff of the ADR is given by θ, equal to that of the domestic asset. On the other hand, if there is a devaluation, the ADR gross payoff is $\theta/E < \theta$. In this case, the ADR becomes relatively less attractive within the options in the foreign market. In equilibrium, the ADR price decreases in order to leave the marginal trader indifferent.

5.2 Players

Domestic Investors. Each domestic investor is initially endowed with one unit of pesos[12]. The domestic investor has risk-neutral preferences over her consumption at $t = 3$. For simplicity, I assume that the investor only values pesos.[13]. Denote the information set of investor i at $t = 0$ by $\mathcal{I}_{0i}$, and that for $t = 1$ by $\mathcal{I}_{1i}$.

At $t = 0$ the domestic investor trades in the domestic market, and at $t = 1$ she trades in the foreign market. In particular, if the domestic investor is holding the underlying, she can convert the shares into ADRs. Once in the foreign market, she has the option to keep the ADR shares and receive the dollar-denominated payoffs, given by θ/e_2 units of dollars, or, alternatively, she can sell them in the foreign market for $\tilde{p}$ dollars. In either case, at $t = 2$ the domestic investor exchanges the dollar position back into pesos, to consume pesos.

The domestic investor maximizes the expected final wealth, denominated in pesos, subject to her budget constraint and her information set, by choosing at $t = 0$ to hold pesos, acquire the risky asset at the prevailing market price p, or go to the CB to exchange her endowment for dollars, at a price $(1 + \tau)$. At $t = 1$, she rebalances her portfolio by choosing to either keep or sell the ADR

[12]This assumption helps to focus on the case of sudden capital reversals (or sudden stops), which is the center of this model.

[13]Generalizations of this assumption, when the domestic investor consumes a basket of domestic and foreign currency, does not change the qualitative results.

shares.

Equation (6) represents the domestic investor's budget constraint at $t = 0$, in terms of pesos. The investor's individual demands for the risky asset, dollars and pesos are denoted by $\{a, d, m\}$, respectively. Note that, in line with Hellwig, Mukherji, and Tsyvinski [2006], the investor simultaneously chooses the optimal portfolio and whether to attack the currency peg. Attacking requires unfolding a position in pesos, and taking a dollar position. An individual attack is represented by $d > 0$. When the investor purchases shares of underlying, she is indeed sustaining currency peg.

$$1 \geq ap + d(1 + \tau) + m \tag{6}$$

At $t = 1$, the domestic market is closed and the domestic investor holding pesos has no option but to keep them. I guess (and verify below) that the domestic investor holding dollars at $t = 0$, does not unfolds this position until $t = 3$. The domestic investor holding the domestic asset at $t = 0$, faces the decision to convert those shares into ADRs or not. Without loss of generality, I assume the domestic investor always converts the shares of domestic asset.

Let κ denote the proportion of ADR shares, the domestic investor keeps, and $1-\kappa$ the proportion of ADR shares she supplies in the foreign market, at $t = 1$. Let w^a represent the continuation value for the domestic investors holding shares of the domestic asset, at $t = 1$. Formally, at $t = 1$, investor i chooses κ_i to maximize the expected peso-denominated return.

$$w^a = \max_{\kappa_i \in [0,1]} \mathbb{E}\left[e_2 \left(\kappa_i \frac{\theta}{e_2} + (1 - \kappa_i)\tilde{p}\right) \mid \mathcal{I}_{1i}\right] \tag{7}$$

where $\mathbb{E}[\cdot \mid \mathcal{I}_{1i}]$ denotes the conditional expectation with respect to the information set of investor i, at $t = 1$. Given the investor's risk neutrality, the solution to problem (7) is a corner solution, $\kappa \in \{0, 1\}$.

Let $w(e_2, \theta)$ denote the investor's final wealth denominated in pesos, for a given realization of the exchange rate e_2 and the dividend payoff θ. The domestic investor is indifferent between converting her dollar position into pesos at any date $t \geq 1$. I assume she unfolds her position at $t = 2$. According to table (1), $w(e_2, \theta)$ is given by

$$w(e_2, \theta) = aw^a + de_2 + m \tag{8}$$

The investor i's maximization problem at $t = 0$ is given by

$$\begin{cases} \max\limits_{\{a_i, d_i, m_i\}} & \mathbb{E}[w(\theta, e_2) \mid \mathcal{I}_{0i}] \\ s.t. & 1 \geq a_i p + d_i(1 + \tau) + m_i \\ & a_i, d_i, m_i \geq 0 \end{cases} \tag{9}$$

where $\mathbb{E}[\cdot \mid \mathcal{I}_{0i}]$ denotes the conditional expectation with respect to the information set of investor i, at $t = 0$.

The aggregate demand for dollar at $t = 0$, denoted by D, is computed by integrating individual demands. In the same way, I define the aggregate demand for domestic assets, A, and for pesos M. The aggregate supply of ADR in the foreign market, denoted by K, is given by the integral of individual supplies.

$$A = \int_0^1 a_i di, \qquad D = \int_0^1 d_i di, , \qquad M = \int_0^1 m_i di, \qquad K = \int_0^1 \kappa_i a_i di \tag{10}$$

Foreign investor. The representative foreign investor is initially endowed with dollars. The foreign investor also has risk-neutral preferences, but only values dollars at $t = 3$. The controls on capital outflows, effectively prevents the foreign investor from moving resources into the home country. Therefore, the foreign investor moves only at $t = 1$[14]. Denote the information set of the foreign investor by $\tilde{\mathcal{I}}$.

The foreign investor maximizes his expected dollar-denominated final wealth, by investing in ADRs or staying in dollars. The foreign investors cannot short-sell any of the asset neither. Let $\tilde{/}w(e_2, \theta)$ denote the expected final wealth of the foreign investor, denominated in dollars, conditional on the realization of the exchange rate e_2, and dividends of the domestic asset, θ.

$$\tilde{w}(e_2, \theta) = \tilde{a}(\theta/e_2 - \tilde{p}) \tag{11}$$

Formally, the maximization problem solved by each investor f at $t = 1$, requires the investor to submit a demand for ADRs, denoted by $\tilde{a}$, conditional on his information set, and

$$\begin{cases} \max\limits_{\tilde{a}} & \mathbb{E}[\tilde{w}(\theta, e_2) \mid \tilde{\mathcal{I}}] \\ s.t. & \tilde{a} \geq 0 \end{cases} \tag{12}$$

Noise traders. At $t = 0$, a stochastic measure of noise traders supplies shares of the risky asset. In line with Grossman and Stiglitz [1980], noise traders prevent the domestic asset price from perfectly revealing the realization of the fundamentals, condensed in the aggregate demand for assets. The measure of noise traders is assumed to be inelastic with respect to p, and takes the form $\Phi(u)$, following Albagli, Hellwig, and Tsyvinski [2013], where $\Phi(\cdot)$ represents the CDF of the normal distribution, and u is normally distributed, independent of θ, according to

$$u \sim N(0, \sigma_u^2) \tag{13}$$

For tractability reasons, I assume each noise trader supplies shares of the risky asset worth 1 peso. Under this assumption, each investor on the demand side of the risky asset mirrors each noise

[14]Extending the model by allowing the foreign investor also to move at $t = 0$, does not affect the qualitative results.

trader, both trading shares worth 1 peso. This assumption allows for a linear closed form solution and satisfies sufficient conditions for a unique equilibrium.

The aggregate stochastic risky asset supply is given by

$$S(p, u) = \frac{\Phi(u)}{p} \tag{14}$$

Central bank. At $t = 2$, the central bank observes the size of the attack, D, and determines whether to maintain the regime. Following Krugman [1979], Flood and Garber [1984] and Obstfeld [1986][15], the CB's decision solely depends on the loss of foreign reserves. The stock of foreign reserves available is initially fixed.

Denote the stock of foreign reserves held by the CB by TR and the maximum tolerable loss of reserves by the CB by R. The maximum tolerable loss of reserves R might be the total reserves TR or that level minus the interest payments on external debt. I focus in the case of an exogenously given level of R, commonly known. R represents the strength of the CB to support the peg. The literature on speculative attacks usually assumes the strength of the CB to be the main source of uncertainty in the economy. This model focus instead in the case where agents perfectly observe the balance sheet of the CB. This is a realistic assumption since at stress time for the CB, there is a wide news coverage on CB's accounts, which seems to be known by the relevant agents in the economy.

The CB simply manages the balance sheet, and is forced to abandon the peg if and only if

$$D > R \tag{15}$$

The regime's change requires a large mass of investors simultaneously attacking. The investors' actions are strategic complements. It pays to attack the regime if and only if the regime collapses and, in turn, the regime collapses if and only if the measure of agents attacking is sufficiently large. Therefore, the investor purchases dollars only if she believes others are also attacking, which happens when the expected return of the risky asset is low.

Equation (5), that describes the determination of e_2, highlights the coordination motive present in the model. The payoff of the dollar investment can be rewritten as $\mathbb{1}_{\{D>R\}}(E-1)-\tau$, where $\mathbb{1}_{\{D>R\}}$ is an indicator function that equals 1 if there is a devaluation. The payoff of dollars is increasing in the mass of investors attacking the regime, D.

Discussion. Short-selling constraints bound the size of the attack, D. From equation (6), the individual dollar demand is bounded by $d \in [0, \frac{1}{(1+\tau)}]$. Therefore, the aggregate demand for dollars is also bounded by $D \in [0, \frac{1}{(1+\tau)}]$.

[15] Other authors have focus on the case where the CB is concerned by the high domestic interest rates, such as Obstfeld [1996], Lahiri and Vegh [2003] and Flood and Jeanne [2005]

According to equation (15), there are at least two intervals for R that uniquely determined the outcome of the game, even with perfect information, when multiplicity seems to be more prominent in the literature. First, if $R \leq 0$ the regime collapses with certainty, and the payoffs are reflected in the left column of table (1). Second, if $R > 1/(1+\tau)$, higher than the upper bound of D, the regime survives with certainty, independently of the outcome of the coordination game. In this case, dollars are dominated by pesos.

These two sets are also described by the literature with unique equilibria in the coordination game, and for that reason are not at the center of the studies. Following the literature, I consider level of foreign reserves such that $R \in (0, 1/(1+\tau)]$. If the foreign reserves lie within this interval, the CB is vulnerable to a large demand of dollars, and to a speculative attack.

5.2.1 Information

In the beginning of the game, nature draws θ from a given distribution. I assume θ is log-normally distributed according to the following relationship,

$$\log(\theta) = \vartheta \tag{16}$$

where ϑ is drawn from a normal distribution with mean $-\frac{1}{2}\sigma_\vartheta^2$ and variance σ_ϑ^2.

$$\vartheta \sim \mathcal{N}(-\frac{1}{2}\sigma_\vartheta^2, \sigma_\vartheta^2) \tag{17}$$

The realization of ϑ, and those of θ, remains unobserved to the agents, up to $t = 2$ when payoffs are observed. Normality makes the analysis tractable.

Investors have imperfect and asymmetric about ϑ. Before choosing the asset allocation, each investor i observes an idiosyncratic private signal about ϑ, denoted by x_i. Conditional on ϑ, the private signals are independent, and identically distributed according to a normal distribution[16] with mean ϑ and variance σ_x^2,

$$x_i \sim \mathcal{N}(\vartheta, \sigma_x^2) \tag{18}$$

The information set of the investor i at $t = 0$ is given by $\mathcal{I}_{0i} \equiv \{x_i, p\}$, while her information set at $t = 1$ is given by $\mathcal{I}_{1i} \equiv \{x_i, p, \tilde{p}\}$.

The foreign investor observes his own private signal denoted by $\tilde{x}$, independent of $\{x_i\}_{i\in[0,1]}$, distributed according to a normal distribution with mean ϑ and variance σ_x^2,

$$\tilde{x} \sim \mathcal{N}(\vartheta, \sigma_{\tilde{x}}^2) \tag{19}$$

The information set of the investor f at $t = 1$ is given by $\tilde{\mathcal{I}} \equiv \{\tilde{x}, p, \tilde{p}\}$.

[16] Alternatively, it can be consider that $x_i = \vartheta + \sigma_x \xi_i$, where $\xi \sim \mathcal{N}(0, 1)$ independent of ϑ, and independently distributed across agents.

Following Grossman and Stiglitz [1980], disperse information is aggregated through prices. Each investor is able to extract an endogenous public signal about ϑ from the market prices p and $\tilde{p}$. The public signals are denoted by z and $\tilde{z}$, respectively. I guess (and then verify) that public signals are a monotonically related to the corresponding market price.

In particular, z and $\tilde{z}$ are centered around ϑ, with variance σ_z^2, conditional on ϑ[17],

$$z \sim \mathcal{N}(\vartheta, \sigma_z^2), \qquad \tilde{z} \sim \mathcal{N}(\vartheta, \sigma_z^2) \tag{21}$$

In terms of information, p is observationally equivalent z, and I shall use them interchangeably when referring to the information set of investors.

The presence of z in the investor's information set requires that *(i)* the public signal can be perfectly inferred from p, and *(ii)* investors understand that p reveals z, as in the rational expectation literature. For notational purposes, denote the precision of private and public information by $\alpha_x = \sigma_x^{-2}$ and $\alpha_z = \sigma_z^{-2}$, respectively.

Finally, let $\mu(x, p)$ denote the posterior cdf of ϑ, conditional on observing signal x and market price p.

$$\mu(x, z) = \Phi\left(\sqrt{\alpha_\vartheta + \alpha_x + \alpha_z}\left(\vartheta - \frac{-1/2 + \alpha_x x + \alpha_z z}{\alpha_\vartheta + \alpha_x + \alpha_z}\right)\right) \tag{22}$$

Analogously, let $\mu(x, p, \tilde{p})$ denote the posterior cdf of ϑ, conditional on observing signal x and market prices p and $\tilde{p}$.

$$\mu(x, z, \tilde{z}) = \Phi\left(\sqrt{\alpha_\vartheta + \alpha_x + \alpha_z + \alpha_{\tilde{z}}}\left(\vartheta - \frac{-1/2 + \alpha_x x + \alpha_z z + \alpha_{\tilde{z}}\tilde{z}}{\alpha_\vartheta + \alpha_x + \alpha_z + \alpha_{\tilde{z}}}\right)\right) \tag{23}$$

Discussion. Investors are risk-neutral, and only cares about the first moment of θ. The investor's i conditional expectation about θ is given by,

$$\begin{aligned}\mathbb{E}[\theta \mid x_i, z] = \mathbb{E}[\exp(\vartheta) \mid x_i, z] &= \exp\left(\mathbb{E}[\vartheta \mid x_i, z] + \frac{1}{2}Var[\vartheta \mid x_i, z]\right) \\ &= \exp\left(\frac{\alpha_x x_i + \alpha_z z}{\alpha_\vartheta + \alpha_x + \alpha_z}\right)\end{aligned} \tag{24}$$

where $\alpha_x/(\alpha_\vartheta + \alpha_x + \alpha_z)$ and $\alpha_z/(\alpha_\vartheta + \alpha_x + \alpha_z)$ are the relative precision of the private and public signals, and $(\alpha_\vartheta + \alpha_x + \alpha_z)^{-1}$ is the overall precision of information.

Note equations (22-23) that posterior beliefs $\mu(x, p)$ and $\mu(x, p, \tilde{p})$ are first-order stochastically (FOS) increasing in x. Moreover, beliefs are FOS increasing with respect to p, as long as z and p are

[17] Again, it can be consider that

$$z = \vartheta + \sigma_z \epsilon \tag{20}$$

where $\epsilon \sim \mathcal{N}(0, 1)$ is the noise of the public signal, independent of both θ (and ξ).

monotonically related. Moreover, from equation (24), the conditional expectation of θ, $\mathbb{E}[\theta \mid x, p]$, is also increasing in x, and p.

6 Benchmark: No Cross-listed Asset

Before introducing a cross-listed asset (ADR) in the next section, I provide a comprehensive analysis for the backbone of the stylized model featuring only the domestic risky asset and a dollar investment. This simplified model resembles coordination problems such as capital flows reversals from a developing country during sudden stops episodes.

The mechanism is as follows. Initially, the exchange rate is fixed. Consider an investor with an initial investment position on domestic assets, equities issued by domestic firms. I highlight two reasons for the investor to unfold this position. Either if the investor's beliefs about the performance of the domestic assets deteriorate or if the beliefs about aggregate capital outflows increase. In both cases, the investor sells the domestic assets for domestic currency and exchange it for dollars at the CB. Investors simultaneously moving away from the domestic economy put pressure on the CB. If the capital flow reversal is large enough, there is a devaluation.

I proceed in two steps: first, I examine equilibrium outcomes with common knowledge; then, I examine the model with privately informed traders. By comparing the two environments, I assess the role of the information structure and determine to what extent the insights of the common knowledge environment extends to the game with private information.

6.1 The sequence of events:

At the beginning of the game, nature draws θ according to equation (16), which remains unknown to the agents. The CB commits to intervene/defend the peg at the cost of losing reserves R. In this benchmark, the foreign market remains closed. For this reason, the foreign investor does not participate, and the timeline shortens to only 3 period.

- At $t = 0$: The domestic market opens. Investor i observes the private signal x_i, and chooses her portfolio of pesos, risky asset and dollars.
- At $t = 1$: The CB determines whether the regime collapses, which happens if and only if $D \geq R$.
- At $t = 2$: Asset payoffs are realized and investors consume.

6.2 Equilibrium

I now formally define an equilibrium for the benchmark setting. Let $\{a(x,p), d(x,p), m(x,p)\}$ denote the demands for risky asset, dollars and pesos. Individual demands are mappings from signal-price pairs (x,p) into bounded asset holdings: $a(x,p) : \mathbb{R}^2_+ \to [0, \frac{1}{p}]$, $d(x,p) : \mathbb{R}^2_+ \to [0, \frac{1}{(1+\tau)}]$, and $m(x,p) : \mathbb{R}_+^2 \to [0,1]$. Let $D(\theta,p) : \mathbb{R}_+^2 \to [0, \frac{1}{(1+\tau)}]$ represent the size of the aggregate attack, for a given fundamental θ and market price p. $A(\theta,p) : \mathbb{R}_+^2 \to [0, \frac{1}{p}]$ and $M(\theta,p) : \mathbb{R}_+^2 \to [0, \frac{1}{1}]$ represent the aggregate demands of the risky asset and pesos, respectively. The risky asset market price function is given by $p(\theta,u) : \mathbb{R}_+^2 \to \mathbb{R}_+$ for each realization of θ and u. Finally, let $\mu(x,p)$: $\mathbb{R}_+^2 \to [0,1]$ denote the posterior cdf of ϑ, conditional on observing signal x and market price p.

Definition 1 *An equilibrium consists of investor's strategies $\{a(x,p), d(x,p), m(x,p)\}$, aggregate asset demands $\{A(\theta,p), D(\theta,p), M(\theta,p)\}$, a price function $p(\theta,u)$, and posterior beliefs $\mu(x,p)$, such that, (i) $\{a(x,p), d(x,p), m(x,p)\}$ solves the program (9) given the asset price $p(\theta,u)$ and beliefs $\mu(x,p)$, (ii) aggregate demands aggregate individual's according to (10), (iii) the price function $p(\theta,u)$ is such that the asset market clears for all (θ,u), (iv) the regime changes if and only it $D(\theta,p) > R$, and (v) $\mu(x,p)$ satisfies the Bayes' rule given by (22), whenever is possible.*

6.2.1 Equilibrium Characterization

First, I consider the optimal investment decision of the domestic investor. I impose $\kappa = 1$ (since the foreign market is closed) and the continuation value of holding the domestic asset boils down to $w^a = \theta$. The expected final wealth is then given by

$$\mathbb{E}[w(e_2,\theta) \mid x,p] = a\mathbb{E}[\theta \mid x,p] + d\mathbb{E}[e_1 \mid x,p] + m \tag{25}$$

Imposing the budget constraint, the program (9) can be rewritten as follows.

$$\max_{a,d} \quad pa\mathbb{E}[\frac{\theta}{p} - 1 \mid x,p] + (1+\tau)d\mathbb{E}[\frac{e_1}{(1+\tau)} - 1 \mid x,p] + 1 \tag{26}$$

where $\mathbb{E}[\frac{\theta}{p} - 1 \mid x,p]$ captures the conditional expected excess return of the risky asset (over pesos), and $\mathbb{E}[\frac{e_1}{(1+\tau)} - 1 \mid x,p]$ the the conditional expected excess return of dollars. The (gross) return on pesos is 1. Given that investors are risk-neutral, there is no diversification and the investor allocates her entire endowment in the asset with the highest conditional expected return.

The conditional expected (gross) return on the risky asset, $\mathbb{E}[\theta \mid x,p]/p$, is monotonically increasing in x according to equation (24). Given the market price p, the investor who observes a higher realization of the private signal is relatively more inclined to invest in the risky asset. In line with rational expectations models, the market price has a dual functions: market clearing and information aggregation. In this model, higher realizations of p reduce the expected return on the risky asset through the market clearing channel, but also provide a positive (noisy) signal to the investor which increases the expected return.

Let $\pi(x,p)$ denote the probability of a devaluation, conditional on observing a private signal x, and the market price p. The conditional expected (gross) return on the dollar investment is

$$\mathbb{E}[e_1 \mid x,p]/(1+\tau) = \pi(x,p)(E-1) + 1 \tag{27}$$

If $\mathbb{E}[\theta \mid x,p]/p > \max\{1, \pi(x,p)(E-1)+1\}$, pesos and dollars are strictly dominated by the risky asset, to the investor who observes a private signal x and the market price p. In this case, the investor allocates her endowment into the risky asset, being able to acquire up to $a(x,p) = 1/p$, while $d(x,p) = m(x,p) = 0$. The investor's optimal risky asset demand is given by

$$a(x,p) = \begin{cases} \frac{1}{p} & \text{if } \frac{\mathbb{E}[\theta|x,p]}{p} > \max\{1, \frac{\mathbb{E}[e_1|x,p]}{(1+\tau)}\} \\ \in \left[0, \frac{1}{p}\right] & \text{if } \frac{\mathbb{E}[\theta|x,p]}{p} = \max\{1, \frac{\mathbb{E}[e_1|x,p]}{(1+\tau)}\} \\ 0 & \text{otherwise} \end{cases} \tag{28}$$

If $\pi(x,p)(E-1)+1 > \max\{1, \mathbb{E}[\theta \mid x,p]/p\}$, pesos and the risky asset are strictly dominated by dollars. In this case, the investor demands up to $d(x,p) = 1/(1+\tau)$ dollars, whereas $a = m = 0$. The investor's optimal dollar demand is given by

$$d(x,p) = \begin{cases} \frac{1}{(1+\tau)} & \text{if } \frac{\mathbb{E}[e_1|x,p]}{(1+\tau)} > \max\{1, \frac{\mathbb{E}[\theta|x,p]}{p}\} \\ \in \left[0, \frac{1}{(1+\tau)}\right] & \text{if } \frac{\mathbb{E}[e_1|x,p]}{(1+\tau)} = \max\{1, \frac{\mathbb{E}[\theta|x,p]}{p}\} \\ 0 & \text{otherwise} \end{cases} \tag{29}$$

Aggregate demands are computed as the expectation of the individual demands, conditional on the true realization of θ. In this way, aggregate demands also equal to the measure of investors demanding each particular asset times the upper bound of the asset demand. The asset's aggregate demands are given below.

$$\text{Risky Asset:} \qquad A(\theta,p) = \mathbb{E}[a(x,p) \mid \theta] = \int_0^1 a(x,p) d\Phi\left(\sqrt{\alpha_x}(x-\vartheta)\right) \tag{30}$$

$$\text{Dollars:} \qquad D(\theta,p) = \mathbb{E}[d(x,p) \mid \theta] = \int_0^1 d(x,p) d\Phi\left(\sqrt{\alpha_x}(x-\vartheta)\right) \tag{31}$$

$$\text{Pesos:} \qquad M(\theta,p) = \mathbb{E}[m(x,p) \mid \theta] = \int_0^1 m(x,p) d\Phi\left(\sqrt{\alpha_x}(x-\vartheta)\right) \tag{32}$$

The aggregate budget constraint, displayed in equation (33), is obtained by integrating investors' budget constraints.

$$1 = A(\theta,p)p + D(\theta,p)(1+t) + M \tag{33}$$

Note that, there is a devaluation as long as the demand for peso-denominated asset is sufficiently low.

$$D > R \qquad \Rightarrow \qquad 1-(1+\tau)R > pA(\theta,p) + M \tag{34}$$

The CB is the only to have access to the technology to convert pesos into dollars, and absorbs the excess supply of pesos in the money market. The market-clearing condition is

$$A(\theta, p) = \frac{\Phi(u)}{p} \qquad \Rightarrow \qquad \frac{1}{p}\int_0^1 \mathbb{1}_{a(x,p)>0} d\Phi(\sqrt{\alpha_x}(x-\theta) = \frac{\Phi(u)}{p} \tag{35}$$

where $\mathbb{1}_{a(x,p)>0}$ is an indicator function that takes value 1 if $a(x,p) > 0$. Equation (35) requires that the measure of investors demanding the risky asset equals the stochastic measure of noise traders, and highlights the importance of the functional form of the supply of risky asset, in terms of tractability. Equation (35) also stresses the dependance of the price function on the two sources of noise in the model, $p(\theta, u)$. The effect of the market price p is capture in $a(x,p)$.

6.3 Common knowledge benchmark

Assume first that θ is common knowledge, but investors are still uncertain about the realization of u, and therefore about the aggregate demand for dollars $D(\theta, p)$. In this case, multiplicity arises from the coordination failure, similar to Obstfeld [1996]. Each investor forms higher order beliefs in the coordination game which ultimately allows for self-fulfilling equilibria. The result is supported by the fact that the price of dollars is initially fixed (the CB provides a perfectly elastic supply dollars at price $(1+\tau)$).

Introducing the risky asset market, into the Morris and Shin [1998] framework, helps to avoid multiplicity even in the case of common knowledge, as long as the aggregate asset supply is sufficiently inelastic. Each investor forms beliefs about u, using the private signal x and market price p, which is the only source uncertainty. The market price works as a coordination device, providing a noisy signal about u.

Under common knowledge, the individual and aggregate risky asset demand coincide. The (gross) return on the risky asset is known, and is given by θ/p. The return on the dollar, however, still depends on the regime status, as described in table (1). If there is a devaluation, the (gross) return on dollars is $E/(1+\tau)$. If there is no devaluation, the (gross) return is $(1+\tau)^{-1}$.

In order to describe the equilibrium, first consider the case the investor knows there is a devaluation. In this case, pesos are strictly dominated, implying that $m = M = 0$. According to equation (34), this event requires: $pA < 1-(1+\tau)R$. Recall that pA represents the measure of investors investing in the risky asset. The marginal investor's first order condition requires her to be indifferent between acquiring the risky asset and dollars. Therefore, the market price is $p = \theta(1+\tau)/E$. On the other hand, if $Ap > 1-(1+\tau)R$ there is no devaluation. In this case, dollars are dominated, hence $d = D = 0$. The indifference condition between acquiring the risky asset and pesos has to be satisfied. The market price then only reflects the value of the dividend payment: $p = \theta$.

The equilibrium market clearing condition is $A(\theta, p) = S(u, p)$, which is equivalent to $pA(\theta, p) = \Phi(u)$. The equilibrium is entirely determined by the realization of u. Note that the perfectly inelastic supply is a sufficient (but not necessary) condition for uniqueness. In the extension, I relax this assumption to study the necessary conditions for uniqueness.

For simplicity, I choose the market clearing price when the supply of risky assets is either 0 or

1, consistent with the equilibrium. These events happen with 0 probability, and are not the source of multiplicity in the model. The equilibrium price function is given by,

$$p(\theta, u) = \begin{cases} \frac{\theta(1+\tau)}{E} & \text{if} \quad 0 \leq \Phi(u) < 1 - R(1+\tau) \\ \theta & \text{if} \quad 1 - R(1+\tau) \leq \Phi(u) \leq 1 \end{cases} \tag{36}$$

The individual's and aggregate risky asset demand is displayed in the equation (37) below.

$$A(\theta, p) = a(\theta, p) = \begin{cases} \frac{1}{p} & \text{if} \quad \theta > p \\ \in \frac{1}{p}\left[1 - (1+\tau)R, 1\right] & \text{if} \quad \frac{\theta}{p} = 1 \\ \in \frac{1}{p}\left[0, 1 - (1+\tau)R\right] & \text{if} \quad \frac{\theta}{p} = \frac{E}{1+\tau} \\ 0 & \text{otherwise} \end{cases} \tag{37}$$

The following lemma characterizes the posterior beliefs. Proofs are provided in the appendix.

Lemma 2 *Under common knowledge, in equilibrium the market price p reveals information about the measure of noise traders, u. Let $\pi(p)$ denote the probability of devaluation conditional on the market price p.*

$$\pi(p) = \begin{cases} 0 & \text{if} \quad p = \theta \\ 1 & \text{if} \quad p = \frac{\theta(1+\tau)}{E} \end{cases} \tag{38}$$

Moreover, p perfectly coordinates the investors.

Figure (7) graphically represents the market for the risky asset. The blue line depicts the measure of investors demanding the risky asset, captured by $p \times A(\theta, p)$, at different prices. If $pA(\theta, p) < 1 - (1+\tau)R$, the demand for dollar is high enough to generate a successful attack. In this case, $p = \theta(1+\tau)/E$ leaves the investor indifferent between both the risky asset and dollars. Analogously, if $pA(\theta, p) > 1 - (1+\tau)R$ there is no devaluation, and $p = \theta$ satisfies the indifference condition. The green lines represent two possible realizations of the measure of noise traders, $\Phi(u)$. Conditional on the realization of θ, a small measure of noise traders represents increases the probability of a devaluation, by lowering the liquidity of the asset.

The following proposition establishes the existence of a unique equilibrium under common knowledge.

Proposition 3 *Under perfect information about θ, there is a unique equilibrium in which, $p(\theta, u)$ is given by (36), and the investor's individual strategies and aggregate demands are given by (37).*

The next corollary investigates the effects of capital controls on the equilibrium under perfect information about θ. Capital controls distort the domestic price of dollars, and therefore the indifference condition for the marginal investor that prices the risky asset, as displayed in equation (36). Abstracting from the signalling problem, capital controls effectively reduce the unconditional

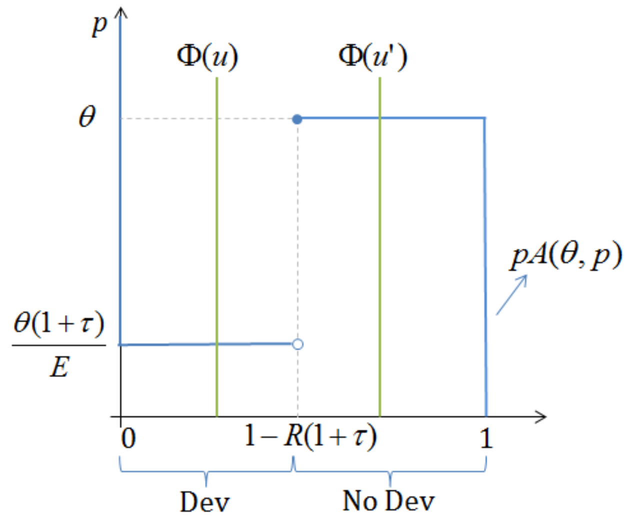

Figure 7: **Asset market:** clearing market condition $A(\theta,p) = S(u,p)$.

probability of a devaluation[18] denoted by π, given by

$$\pi \equiv \Pr(\text{Devaluation}) = \Pr(\quad 1 - R(1+\tau) > \Phi(u)) \tag{39}$$

which is monotonically increasing in τ. As mentioned above, given that there is no uncertainty over the θ , the regime is determined by the realization of the measure of noise traders $\Phi(u)$.

Corollary 4 *Under perfect information about θ, the probability of a devaluation is monotonically decreasing on the level of capital controls τ. Moreover, higher capital controls increase the overvaluation of the risky asset measure by $p - \theta$.*

6.4 Asymmetric information

In the analysis of the model under asymmetric information, I focus on monotone equilibria, defined as perfect Bayesian equilibria such that an investor attacks if and only if her private signal x is below some threshold $\underline{x}(z)$, where the information that is conveyed by p can be characterized by a sufficient statistic z. The equilibrium market price function p depends on z, not separately on θ and u. Lower realizations of θ increase the probability of a devaluation, since this implies that a larger mass of investors receive signals below $\underline{x}(z)$. Analogously, an investor purchases the risky asset if and only if her private signal x is above some other threshold $\overline{x}(z)$. In equilibrium, these thresholds satisfy $\underline{x}(z) \leq \overline{x}(z)$. An investor who observes a private signal x such that $x \in [\underline{x}(z), \overline{x}(z)]$, remains put in pesos. Both thresholds are identical across all investors.

The aggregate size of the attack is $D(\theta,p) = \Pr(x \leq \underline{x}(z) \mid \theta)$. According to equation (31), is given by

[18] This corollary abstracts from the signaling problem of the government when establishing this capital controls. This signaling problem is further studied in Angeletos, Hellwig, and Pavan [2006] and Filippini [2013].

$$D(\theta, p) = \int_{-\infty}^{\underline{x}(z)} \frac{1}{(1+\tau)} d\Phi(\sqrt{\alpha_x}(x - \vartheta)) = \frac{1}{(1+\tau)} \Phi(\sqrt{\alpha_x}(\underline{x}(z) - \vartheta)) \tag{40}$$

which is monotonically decreasing in θ, with $\lim_{\theta \to -\infty} D(\theta, p) = 1$ and $\lim_{\theta \to \infty} D(\theta, p) = 0$. Therefore, there exists a unique threshold $\theta^*(z)$ such that

$$D(\theta^*(z), p) = R \tag{41}$$

Then, there is a devaluation if and only if θ is below threshold $\theta^*(z)$. Define $\vartheta^*(z) \equiv \exp(\theta^*(z))$. The investor's posterior belief of a devaluation is given by $\pi(x, p) = \Pr(\vartheta \leq \vartheta^*(z) \mid x, p)$. Under the normality assumptions,

$$\pi(x, p) = \Phi\left(\sqrt{\alpha_x + \alpha_z + \alpha_\vartheta}\left(\vartheta^*(z) - \frac{-1/2 + \alpha_x x + \alpha_z z}{\alpha_\vartheta + \alpha_x + \alpha_z}\right)\right) \tag{42}$$

which is monotonically decreasing in x, with $\lim_{x \to -\infty} \pi(x, p) = 1$ and $\lim_{x \to \infty} \pi(x, p) = 0$. Also higher realizations of z are associated with higher beliefs about ϑ (asset prices work through the information aggregating channel - as long as z and p are monotonically related) and lowers probabilities of a devaluation.

Lemma 5 *The posterior belief of a devaluation, of the investor who receives a private signal x, and observes a market price p, is given by $\pi(x, p)$, according to equation (42), and is monotonically decreasing in x and z.*

Given the previous result, $\mathbb{E}[e_1 \mid x, p]$ monotonically decreasing in x. Recall that $\mathbb{E}[\theta \mid x, p]$ is monotonically increasing in x. Then, for a given p, there exists a unique marginal investor who is indifferent between acquiring dollars, or the alternatives. This marginal investor is characterize by her private signal, denoted by $\underline{x}(z)$. The threshold $\underline{x}(z)$ satisfies the following condition,

$$\frac{\mathbb{E}[e_1 \mid \underline{x}(z), p]}{(1+\tau)} = \frac{\pi(\underline{x}(z), p)E + (1 - \pi(\underline{x}(z), p))}{(1+\tau)} = \max\{1, \frac{\mathbb{E}[\theta \mid \underline{x}(z), p]}{p}\} \tag{43}$$

where the maximum operator contains the conditional expected return of the risky asset and peso investment, for the marginal investor who observes her private signal $\underline{x}(z)$ and the market price p. Conditional on p, investors who receive a signal $x < \underline{x}(z)$, strictly prefer dollars to the alternatives.

In the same way, there exists a unique marginal investor who is indifferent between purchasing the risky asset or the alternatives. Denote by $\overline{x}(z)$ the private signal of this marginal investor. $\overline{x}(z)$ satisfies the following condition,

$$\frac{\mathbb{E}[\theta \mid \overline{x}(z), p]}{p} = \max\{1, \frac{\mathbb{E}[e_1 \mid \overline{x}, p]}{(1+\tau)}\} \tag{44}$$

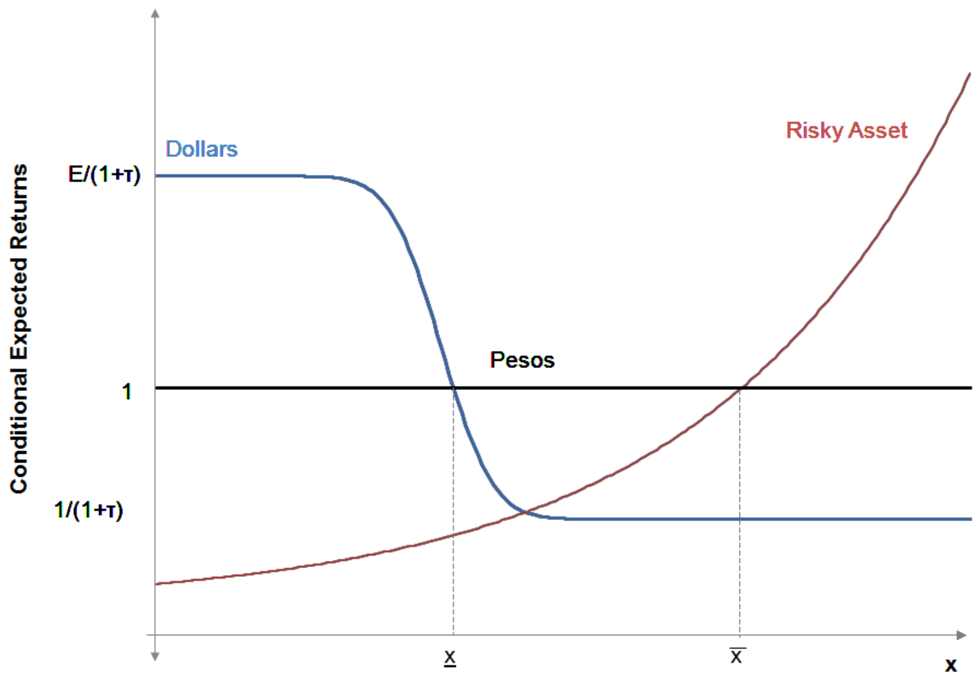

Figure 8: **Cross-section of conditional expected returns of the investment opportunities.**

Figure (8) displays the cross-sectional conditional expected returns of the investment opportunities. Under the normality assumptions about ϑ, the conditional expected return of the risky asset is exponential on x, given by equation (24). The conditional expected return on the dollar investment is monotonically decreasing in x, since a lower x is associated with a higher probability of devaluations. The intersections between dollar and pesos, and pesos and the risky asset determine the thresholds.

The agent's risky asset demands under monotone strategies is given below,

$$a(x,p) = \begin{cases} \frac{1}{p} & \text{if} \quad x > \overline{x} \\ 0 & \text{otherwise} \end{cases} \tag{45}$$

As before, I define the risky asset's aggregate demands as the mass of investors with signals above $\overline{x}(z)$, each of whom allocates his initial endowment, i.e. times $1/p$.

$$\text{Risky Asset:} \quad A(\theta,p) = \int_{\overline{x}(z)}^{1} \frac{1}{p} d\Phi\left(\sqrt{\alpha_x}(x-\theta)\right) = \frac{1}{p}\left(1-\Phi\left(\sqrt{\alpha_x}(\overline{x}(z)-\theta)\right)\right) \tag{46}$$

$$\text{Dollars:} \quad D(\theta,p) = \int_{0}^{\underline{x}(z)} \frac{1}{1+\tau} d\Phi\left(\sqrt{\alpha_x}(x-\theta)\right) = \frac{1}{1+\tau}\Phi\left(\sqrt{\alpha_x}(\underline{x}(z)-\theta)\right) \tag{47}$$

$$\text{Pesos:} \quad M(\theta,p) = \int_{\underline{x}(z)}^{\overline{x}(z)} 1 d\Phi\left(\sqrt{\alpha_x}(x-\theta)\right) = \Phi\left(\sqrt{\alpha_x}(\overline{x}(z)-\theta)\right) - \Phi\left(\sqrt{\alpha_x}(\underline{x}(z)-\theta)\right) \tag{48}$$

Consider now the market-clearing price function $p(\theta, u)$ under monotone strategies. The market price enables us to derive the belief function $\mu(x, p)$, which incorporates the information conveyed in equilibrium by p. If the investor uses threshold rules, the demand for risky assets is equal to the measure of agents who receive a signal above $\overline{x}(z)$ times $(1/p)$. In equilibrium, the market-clearing condition requires that

$$1 - \Phi(\sqrt{\alpha_x}(\overline{x}(z) - \theta)) = \Phi(u) \tag{49}$$

I now formally define the equilibrium in this setting.

Definition 6 *A monotone perfect Bayesian equilibrium consists of a threshold $\theta^*(z) \in \mathbb{R}_+$, investor's strategies $\{\underline{x}(z), \overline{x}(z)\} \in \mathbb{R}^2$, a price function $p(\theta, u) \in \mathbb{R}_+$ and posterior beliefs $\mu(x, p) \in [0, 1]$, such that (i) $\{\underline{x}(z), \overline{x}(z)\}$ and $\theta^*(z)$ satisfy (43), (44) and (41) given $\mu(x, p)$ and $p(\theta, u)$, (ii) the asset market clears according to (49), for all (θ, u), and (iii) $\mu(x, p)$ satisfies the Bayes' rule given by (22), whenever is possible.*

6.5 Equilibrium characterization

Rearranging condition (41), the threshold $\theta^*(z)$ is determined by the marginal investor $\underline{x}(p)$ demanding dollars,

$$\log(\theta^*) = \vartheta^*(z) = \underline{x}(z) - \frac{\Phi^{-1}((1+\tau)R)}{\sqrt{\alpha_x}} \tag{50}$$

From the asset market clearing condition (49), the marginal investor purchasing the risky asset, $\overline{x}(z)$, is determined as a function of the pair (θ, u). As motivated above, noise traders prevent the market price from fully revealing the true realization of ϑ. I define z as the composite of the fundamental sources of risk in the economy. Given that the asset price reflects investor $\overline{x}$(z)'s conditional expectations, the market price depends on (θ, u) only through z, but not on θ and u separately.

$$\overline{x}(z) = \vartheta - \sqrt{\frac{1}{\tau_x}}u \equiv z \tag{51}$$

From equation (51), the identity of the marginal investor changes with different realization of the fundamentals.

If $\underline{x}(z) < \overline{x}(z)$, condition (43) determined $\underline{x}(z)$. In this case, there is a strictly positive aggregate demand for pesos, and the conditional expected return of the risky asset for investor $\underline{x}(z)$ is such that $\frac{\mathbb{E}[\theta - p|\underline{x}(z), p]}{p} < 0$.

$$\Phi\left(\sqrt{\alpha_x + \alpha_z + \alpha_\vartheta}\left(\vartheta^*(z) - \frac{-1/2 + \alpha_x \underline{x}(z) + \alpha_z z}{\alpha_\vartheta + \alpha_x + \alpha_z}\right)\right) = \frac{\tau}{E - 1} \tag{52}$$

Imposing the result from equation (50), the lower threshold is uniquely determined by the realization of z, revealed in the market price.

$$\underline{x}(z) = \frac{1}{\alpha_\vartheta + \alpha_z}\left[\sqrt{\alpha_x + \alpha_z + \alpha_\vartheta}\Phi^{-1}\left(\frac{\tau}{E-1}\right) + \frac{\Phi^{-1}((1+\tau)R)}{\sqrt{\alpha_x}}(\alpha_x + \alpha_z + \alpha_\vartheta) + \frac{1}{2} + \alpha_z z\right] \quad (53)$$

The indifference condition (44), determines the market price. Note that, given the monotonicity on x, $\mathbb{E}[e_1 \mid \overline{x}(z), p] < (1+\tau)$, and, in equilibrium, investor $\overline{x}(z)$ is indifferent between the risky asset and holding pesos.

$$p(\theta, u) = \mathbb{E}[\theta \mid \overline{x}(z), p] \quad (54)$$

Otherwise, if $\tau = 0$ pesos are dominated and $\underline{x}(z) = \overline{x}(\text{z})$. The only relevant threshold is determined by the market clearing condition eq:thresh2. The price reflects the indifference condition of the marginal investor between the risky asset and dollars.

$$p(\theta, u) \equiv p(z) = \frac{\mathbb{E}[\theta \mid \overline{x}(p), p](1+\tau)}{\pi(\overline{x}(p), p)(E-1) + 1} \quad (55)$$

The following lemma characterize the market price as a function of the threshold z.

Lemma 7 *The price function $p(z)$ given by (55) is monotone in z.*

The following proposition characterize the monotone equilibrium in this framework.

Proposition 8 *Under imperfect knowledge, there is a unique equilibrium in monotone strategies with positive capital controls, $\tau > 0$, $p(\theta, u)$ is given by (54), investor's strategies $\{\underline{x}(z), \overline{x}(z)\}$ are given by (51) and (43), and the threshold for the regime status $\theta^*(z)$ given by (50).*

Figure (9) display the equilibrium market price and the aggregate demand for dollars as a function of the state of the economy θ. Panel (a) shows how the price of the underlying increases for good states of the economy, associated with high realizations of θ, while the opposite happens during more fragile states. The dashed line depicts the market price under common knowledge, abstracting from the risk of the currency crisis. Panel (b) shows the behavior of the aggregate demand for dollars (solid line) and the initial level of reserves (dashed line). The threshold $\theta^*(z)$ is determined by the intersection of the two lines.

7 Cross-listing Asset Model

In the previous section, I show how the equilibrium asset price of a non-cross-listed asset is determined when investors are heterogeneously informed, and the domestic country is fragile to a speculative attack. In particular, the asset price declines in states in which the probability of devaluation increases. The result is driven by investors rationally anticipating a devaluation and turning to invest in dollars, which become relatively more attractive.

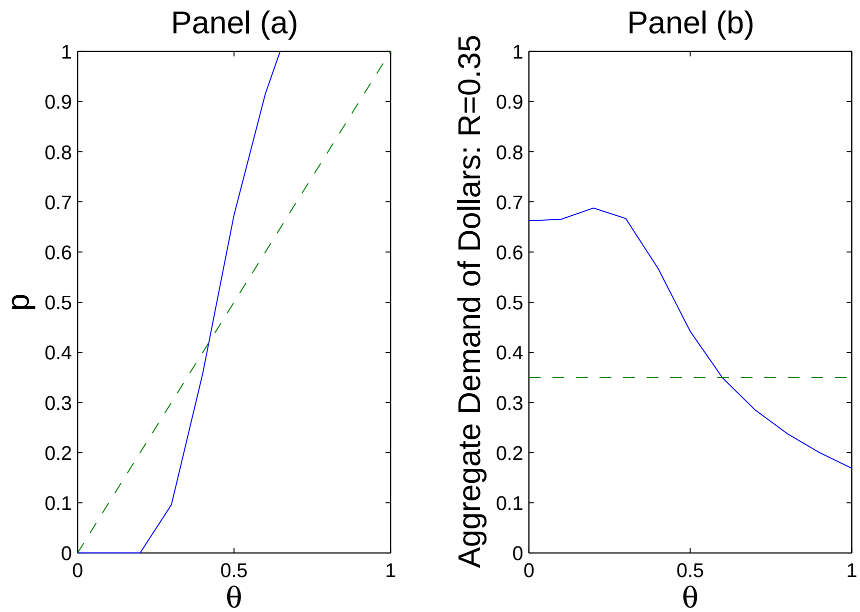

Figure 9: Panel (a) displays the asset price for different realizations of θ. Panel (b) displays the aggregate demand for dollars: D. The parameter values used are $E = 2$, $R = 0.35$, $t = 0.5$, $\sigma_x = 0.1$, $\sigma_u = 0.5$.

In this section, I extend the model to allow investors to trade on cross-listed asset in an attempt to provide an analytical framework to assess the price dynamics of a broader class of asset prices, prior to currency crises. I consider the full-model, with the domestic market opening at $t = 0$ and the foreign market opening at $t = 1$.

I focus the analysis on domestic assets that have a corresponding American Depositary Receipt (ADR). One of advantages of studying ADRs (over other types of cross-listed asset) is that they represents claims over the same cash-flow stream as the domestic asset, although the former pays dividends in dollars. For this reason, ADRs provides an ideal instrument to measure investor's expectations on the future exchange rate.

In contrast with the results from the previous section, empirical evidence suggests that prior to the currency crises the price of cross-listed stocks experience a bigger increase than the price of non-cross-listed stock. The price of cross-listed assets does not only reflects the expectation over future dividends, but also the value of the option to convert the underlying into ADRs. With weaker fundamentals, the option becomes more valuable, creating the divergent dynamic in prices.

Comparing the differences in the price of the underlying and the corresponding ADR, it is to obtain a measure of the expected exchange rate. I define the ratio of the prices as the ADR shadow exchange rate. I this section, I analyze whether this is a good predictor of the post-devaluation exchange rate.

The mechanism is as follows. Consider an investor with an initial position in pesos, who beliefs the home country might be subject to the devaluation. Assume the investor wants to take a position in dollars, to capture the returns on the devaluation. The investor has two options. First, the investor can go to the CB. Alternatively, the investor can acquire the domestic asset, and make the cross-market transaction (CMT) as explain before. In this way, the domestic cross-listed asset reflects not only the value of expected dividends, but also value from the option to use the CMT. Given that investors in the foreign market do not account for this option, the price in the foreign market remains relatively low, and the ADR shadow exchange rate increases above the prevailing exchange rate.

In the rest of the section, I explore the pricing implication of arbitrage in terms of the cross-listing assets. Then, I examine the model with information and market frictions and discuss the necessity of the market structure assumed. This model allow me to replicate the behavior of the ADR shadow exchange rate. By contrasting the conclusion of this section with the previous one, I assess the predicting power of the ADR shadow exchange rate over simply following the stock market.

7.1 Alternative dollar investments

Cross-listing assets provide investors in the home country an alternative technology to acquire dollars. As stated before, in the model I assume each investor is endowed with the technology to convert shares of the underlying stock into shares of ADR. The conversion takes place overnight. As I describe below, this market friction is key for the law of one price to cease to hold.

The cross-market transaction (CMT) requires the investor to *(a)* purchase shares of the domestic cross-listed asset using pesos, *(b)* convert these shares into dollar-denominated shares of ADR, and finally *(c)* re-sell the ADR shares in New York, to receive in exchange dollars. Although it may not seem as such, the cross-market premium is quite elementary for actual traders. It is worth to emphasize that the CMT provides a legal way through which investors can transfer wealth outside the country.

In order to assess the full implication of arbitrage and the role of the market structure, I consider the return of each of the alternative technologies to obtain dollars. I assume that the dollar positions are unfolded at $t = 2$ (after the CB's decision), at the prevailing exchange rate. In section 2, I explain the implications of arbitrage under perfect information. In this section, I explore the importance of information frictions.

Assume that investors observe that domestic asset price, $p \in \mathcal{I}$. The conditional expected return from dollars, aquired from the CB, is

$$\text{Return on dollars:} \qquad \frac{\mathbb{E}[e_2 \mid \mathcal{I}]}{(1+\tau)} \tag{56}$$

On the other hand, the expected return on the CMT is

$$\text{Return on CMT:} \qquad \frac{\mathbb{E}[e_2 \tilde{p} \mid \mathcal{I}]}{p} \tag{57}$$

Consider the case that the investor can seamlessly convert the shares of underlying into ADRs. From (57), if $\tilde{p} \in \mathcal{I}$ the arbitrage between those technologies imposes strict conditions. In the absence of capital controls (and for that matter, foreign exchange controls), $\tau = 0$, and abstracting from transaction costs, the law of one price implies $p = \tilde{p}$. Empirical evidence reports this condition during tranquil times (when investors are not expecting a devaluation), illustrated for example in figure (4).

In order to capture the anticipatory behavior of the ADR shadow exchange rate to the currency crises, $\tilde{p}$ should remain a random variable at $t = 0$, although this is not a sufficient condition. For this reason, I assume that the trading in the foreign market occurs one period after the trading session in the domestic market.

Consider now the case when $\tilde{p} \notin \mathcal{I}$. In this case, according to the no arbitrage condition (if the investor only considers the investment with dollar returns), the prices should be related as follows,

$$p = \mathbb{E}[\tilde{p} \mid \mathcal{I}] + \frac{cov(e_2, \tilde{p} \mid \mathcal{I})}{\mathbb{E}[e_2 \mid \mathcal{I}]} \qquad \Rightarrow \qquad \frac{p}{\mathbb{E}[\tilde{p} \mid \mathcal{I}]} < 1 \tag{58}$$

In order to understand the intuition behind the previous equation consider an investor who believes the probability of devaluation is low. Conditional on her information, $\mathbb{E}[e_2 \mid \mathcal{I}]$ is close to 1, and the covariance term vanishes. Therefore, the price in the domestic market reflects the expected price of the underlying. On the other hand, if the investor believes the $\pi(x, p)$ is high, the second term reflects the premium the investor demands for holding the exchange rate risk, present in $\tilde{p}$.

In order to breakdown the previous counterfactual result, I introduce two information frictions: heterogeneously informed investors, and the release of new information at $t = 1$. First, the investor pricing the underlying and the one pricing the ADR might disagree in their beliefs. Second, even though the price $\tilde{p}$ contains the exchange rate risk, the option value to wait and receive more information increases the valuation of the underlying. This effect is relatively stronger when the investor is more uncertain about the outcome of the CB decision.

For simplicity, in this section I assume pesos are strictly dominated for the domestic investor, that implies $m = M = 0$. This assumption is without loss of generality and qualitative results are not affected, and allowing me to concentrate the attention in the marginal investor whose trade off is the risky asset or dollars.

7.2 The sequence of events:

At the beginning of the game, nature draws θ, which remains unknown to the agents. The CB commits to intervene/defend the peg at the cost of losing reserves R.

- At $t = 0$: The domestic market opens. The investor i observes the private signal x_i, and chooses her portfolio of risky asset and dollars. The investor holding shares of the domestic asset can convert them into ADRs.

- At $t = 1$: The foreign market opens. The foreign investor observes the private signal $\tilde{x}$, and chooses his portfolio of dollars and ADRs. The investor i chooses whether to keep or sell the shares of ADR.

- At $t = 2$: The CB determines whether the regime collapses: if and only if $D \geq R$.

- At $t = 3$: Assets payoffs are realized and the investors consume.

7.3 Equilibrium

I now formally define an equilibrium in this setting. Let $a(x,p) : \mathbb{R}_+^2 \to [0, \frac{1}{p}]$ and $d(x,p) : \mathbb{R}_+^2 \to [0, \frac{1}{(1+\tau)}]$ denote the the domestic investor's demands for the domestic asset and dollars, respectively. Denote $\kappa(x,p,\tilde{p}) : \mathbb{R}_+^3 \to [0,1]$ the proportion of ADR shares the domestic investor keeps, and $a(x,p,\tilde{p}) : \mathbb{R}_+^3 \to \mathbb{R}_+$ the demand for ADRs by the foreign investor. Let $D(\theta,p) : \mathbb{R}_+^2 \to [0, \frac{1}{(1+\tau)}]$ and $A(\theta,p) : \mathbb{R}_+^2 \to [0, \frac{1}{p}]$ represent the aggregate demands of the dollars and risky asset, respectively, and $K(\theta,p,\tilde{p}) : \mathbb{R}_+^3 \to [0,1]$ the proportion of ADR shares kept by domestic investors. The market price functions are $p(\theta,u) : \mathbb{R}_+^2 \to \mathbb{R}_+$ and $\tilde{p}(\theta,u,\tilde{x}) : \mathbb{R}_+^3 \to \mathbb{R}_+$. Finally, let $\mu_0(x,p) : \mathbb{R}_+^2 \to [0,1]$ and $\mu_1(x,p,\tilde{p}) : \mathbb{R}_+^3 \to [0,1]$ denote the domestic investor's posterior cdf of ϑ, and let $\tilde{\mu}(\tilde{x},p,\tilde{p}) : \mathbb{R}_+^3 \to [0,1]$ denote foreign investor's the posterior cdf of ϑ, conditional on observing signal x and market prices p and $\tilde{p}$.

Definition 9 *An equilibrium consists of domestic investor's strategies at* $t = 0$ $\{a(x,p), d(x,p)\}$*, and strategies at* $t = 1$ $\{\kappa(x,p,\tilde{p})\}$*, aggregate asset demands* $\{A(\theta,p), D(\theta,p)\}$ *and aggregate ADR supply* $1-K(\theta,p,\tilde{p})$*, foreign investor's strategy* $\tilde{a}(x,p,\tilde{p})$*, a price functions* $p(\theta,u)$ *and* $\tilde{p}(x,p,\tilde{x})$*, and posterior beliefs* $\{\mu_0(x,p), \mu_1(x,p,\tilde{p}), \tilde{\mu}(\tilde{x},p,\tilde{p})\}$*, such that, (i)* $\{a(x,p), d(x,p)\}$ *solves the programs (7) given* $\mu_0(x,p)$*, price* $p(\theta,u)$ *and* $m = 0$*, and* $\kappa(x,p,\tilde{p})$ *solves (9) given* $\mu_1(x,p,\tilde{p})$ *and price* $\tilde{p}(\theta,u,\tilde{x})$*, (ii) aggregate demands are computed according to (10), (iii)* $\tilde{a}(x,p,\tilde{p})$ *solves program (12) given* $\tilde{\mu}(x,p,\tilde{p})$ *and price* $\tilde{p}(\theta,u,\tilde{x})$*, (iv) the domestic and foreign asset market clears for all* (θ,u)*, (v) the regime changes if and only it* $D(\theta,p) > R$*, and (vi)* $\mu_0(x,p)$*,* $\mu_1(x,p,\tilde{p})$ *and* $\tilde{\mu}(x,p,\tilde{p})$ *satisfy the Bayes' rule, whenever is possible.*

7.4 Equilibrium Characterization

In order to characterize the equilibrium, first I consider the optimal investment decision of the foreign investor. The foreign investor's demand for the ADR is given by the following equation,

$$\tilde{a}(\tilde{x},p,\tilde{p}) = \begin{cases} \infty & \text{if} \quad \mathbb{E}[\frac{\theta}{e_2} \mid \tilde{x},p,\tilde{p}] > \tilde{p} \\ \in [0,\infty) & \text{if} \quad \mathbb{E}[\frac{\theta}{e_2} \mid \tilde{x},p,\tilde{p}] = \tilde{p} \\ 0 & \text{otherwise} \end{cases} \tag{59}$$

From this equation, the market clearing condition at $t = 1$ requires that the price of the ADR reflects the conditional expectation of the foreign investor: $\tilde{p} = \mathbb{E}[\frac{\theta}{e_2} \mid \tilde{\mathcal{I}}]$.

Now consider the problem of the domestic investor. The domestic investor's optimal supply decision of ADRs at $t = 1$ is described below. With the new signal incorporated in the information set $\mathcal{I}_1$, the domestic agent keeps the shares if the expected return is above the re-selling return.

$$\kappa(x, p, \tilde{p}) = \begin{cases} 1 & \text{if} \quad \mathbb{E}[\theta \mid x, p, \tilde{p}] > \tilde{p}\mathbb{E}[e_2 \mid x, p, \tilde{p}] \\ \in [0, 1] & \text{if} \quad \mathbb{E}[\theta \mid x, p, \tilde{p}] = \tilde{p}\mathbb{E}[e_2 \mid x, p, \tilde{p}] \\ 0 & \text{otherwise} \end{cases} \tag{60}$$

Compared with the benchmark model, the domestic investor's expected return of the underlying considers option of reselling the ADR at $t = 1$. The domestic agent's demand for the underlying is given by the following equation,

$$a(x, p) = \begin{cases} \frac{1}{p} & \text{if} \quad \mathbb{E}[w^a \mid x, p]/p > \frac{\mathbb{E}[e_1 \mid x, p]}{1+\tau} \\ \in \left[0, \frac{1}{p}\right] & \text{if} \quad \mathbb{E}[w^a \mid x, p]/p = \frac{\mathbb{E}[e_1 \mid x, p]}{1+\tau} \\ 0 & \text{otherwise} \end{cases} \tag{61}$$

The expected continuation value, w^a, is given by

$$\begin{aligned} \mathbb{E}[w^a \mid x, p] &= \mathbb{E}\left[\max\{\mathbb{E}[\theta \mid x, p, \tilde{p}], \tilde{p}\mathbb{E}[e_2 \mid x, p, \tilde{p}]\} \mid x, p\right] \\ &= \underbrace{\mathbb{E}[\theta \mid x, p]}_{\text{expected dividends}} + \underbrace{\mathbb{E}[\max\{0, \mathbb{E}[\tilde{p}e_2 - \theta \mid x, p, \tilde{p}]\} \mid x, p]}_{\text{option value}} \end{aligned} \tag{62}$$

The indifference condition of the domestic investor is

$$\frac{\mathbb{E}[w^a \mid x, p]}{p} = \frac{\mathbb{E}[e_2 \mid x, p]}{1 + \tau} \tag{63}$$

The first term coincides with the indifference condition from the previous section, showing the expected dividend payoffs. The second term captures the effect caused from cross-listing the asset.

The investor's demand for dollars is obtained using the $t = 0$ constraint given by equation (6), and imposing $m = 0$: $d(x, p) = (1 - pa(x, p))/(1 + \tau)$.

7.5 Asymmetric information

Building on the results from the previous section, I focus on monotone equilibria in order to analyze the asymmetric information framework. Given the simplifying assumption that $m = M = 0$, the domestic investor's strategies as $t = 0$ are described by a threshold level x^*. There is also a threshold level $\hat{x}$ that described the strategy at $t = 1$. An investor sells the ADR if and only if her private signal x is below $\hat{x}$.

Definition 10 *A monotone perfect Bayesian equilibrium consists of a threshold $\theta^*(p) \in \mathbb{R}_+$, domestic investor's strategies $\{x^*(p), \hat{x}(p,\tilde{p})\} \in \mathbb{R}^2_+$, a foreign investor strategy $\tilde{a}(\tilde{x},p) \in \mathbb{R}_+$, price functions $p(\theta,u) \in \mathbb{R}_+$ and $\tilde{p}(\theta,u,\tilde{x}) \in \mathbb{R}_+$ and posterior beliefs $\mu(x,p) \in [0,1]$ and $\mu(x,p,\tilde{p}) \in [0,1]$, such that (i) $\{x^*(p), \hat{x}(p,\tilde{p})\}$ and $\theta^*(p)$ satisfy (61), (60) and (41) given $\mu(x,p)$ and $p(\theta,u)$, (ii) $\tilde{a}(x,p)$ solves the program (12) given $\tilde{\mu}(x,p,\tilde{p})$ (iii) the asset market clears according to (49), for all (θ,u), and (iv) $\mu(x,p)$ and $\mu(x,p,\tilde{p}) \in [0,1]$ satisfy the Bayes' rule given by (22), whenever is possible.*

7.5.1 Equilibrium Characterization

Same as in the previous section, condition (41) determines the threshold $\theta^*(p)$, as a function of $x^*(p)$. The asset market clearing condition (49) also remains unchanged and the marginal investor $x^*(p)$ is characterized by equation (51). The threshold $\hat{x}(p,\tilde{p})$ is determined by the following condition,

$$\mathbb{E}[\theta \mid \hat{x}(p), p, \tilde{p}] = \tilde{p}\mathbb{E}[e_1 \mid \hat{x}(p), p, \tilde{p}] \tag{64}$$

Define $\tilde{\pi}(\tilde{x},p,\tilde{p}) = \Pr(\theta < \theta^* \mid \tilde{x},p,\tilde{p})$ as the posterior probability of devaluation of the foreign investor. It is easy to show that $\tilde{\pi}(\tilde{x},p,\tilde{p})$ is decreasing in $\tilde{x}$. From condition (59), the ADR price is determined by

$$\tilde{p}(\theta,u,\tilde{x}) = \mathbb{E}[\frac{\theta}{e_2} \mid \tilde{x}, p, \tilde{p}] \tag{65}$$

The following lemma establishes the monotonicity of $\tilde{p}(\theta,u,\tilde{x})$ on $\tilde{x}$. Given that there are no noise traders in the foreign market, there is perfect revelation of the private signal of the foreign investor.

Lemma 11 *The price function $\tilde{p}(\cdot,\tilde{x})$ given by (51) is monotone in $\tilde{x}$.*

The indifference condition for the marginal agent x^* determines the market price p,

$$p(\theta,u) = \frac{\mathbb{E}[w^a \mid x^*(p), p](1+\tau)}{\mathbb{E}[e_1 \mid x^*(p), p]} \tag{66}$$

As stated before the price of the underlying asset not only reflects the expected dividend payments but also the value of information.

Proposition 12 *Under asymmetric information, there is a unique equilibrium in which, $p(\theta,u)$ is given by (66) and $\tilde{p}(\theta,u,\tilde{x})$ is given by (65), investor's strategy $\{x^*(z), \hat{x}(z)$ are given by (51) and (64), and the threshold for the regime status θ^* given by (49).*

Figure (10) replicates the evidence shown in section 3. The figure displays the official exchange rate and the ADR shadow exchange rate as functions of the difference between the realization of

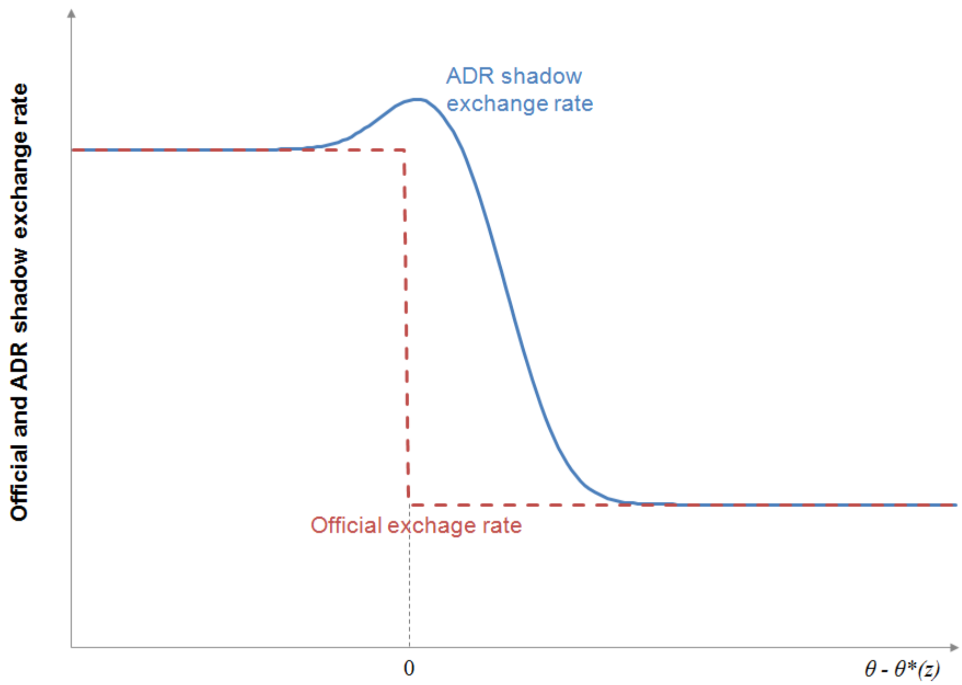

Figure 10: Official and ADR shadow exchange rate. The parameter values used are $E = 2$, $R = 0.35$, $t = 0.5$, $\sigma_x = 0.1$, $\sigma_u = 0.5$.

theta and the threshold level $\theta^*(p)$. For realizations of θ well above the $\theta^*(p)$, the currency peg is supported and the ADR shadow exchange rate coincides with the official exchange rate. When the state approaches to the threshold, a larger mass of investors are uncertain about the outcome of the game, and for that reason, prefer to acquire the underlying in an attempt to wait for the next period until new information is revealed in order to take an irreversible action.

Note that for realizations of θ around $\theta^*(p)$, the premium on the underlying is such that the ADR shadow exchange rate is above the post-devaluation level. The reason is that capital controls impose a potential loss on the dollar investment. The investor trying to hedge against the devaluation is willing to take an equivalent loss on dollars.

8 Conclusion

Currency crisis are usually associated with large output declines and fiscal cost and have drastic effects on firms with balance sheet mismatches. Notably, high uncertainty increases the hedging cost against the effects devaluations exposing agents to the currency crises risk. For this reason, being able to accurately predict the outbreak of a crises is critical.

In this paper, I have shown how information frictions can contribute in the understanding of the anatomy of currency crises, studying the behavior of asset prices in the proximity of a currency crisis. Although the second generation model of currency crises have been able to shed some light in this respect, the empirical implications of these models are narrow and, in some case, not validated by empirical evidence. The challenge is to identity the currency crises risk from other factors affecting the asset pricing. I show evidence that cross-listing assets are good instruments to pin down this risk. I focus on American Depositary Receipts (ADRs), as a tool to measure investors' expectations with respect to the post-devaluation exchange rate. The breakdown of the law of one price (LooP) imposed by arbitrage can account for the currency crises risk.

I develop a theoretical model that captures the impact of currency crises on the pricing of the ADR market. This paper proposes two extensions to the second generation models of currency crises. First, I replace the main source of the uncertainty from the balance sheet of the central bank to the performance of the domestic asset. In this way, the model resembles more closely to sudden reversal of capital flows when investors unfold the position on local currency. Second, I introduce cross-listing assets into the model.

Using ADRs, investors in the local economy make a cross-market trade to acquire dollars. Note that this provides investor with an alternative technology to access dollars, other than going to the central bank. In this way, the price of the underlying asset encompasses not only the expectations of future dividend payments but also the value of the option to convert the underlying and get dollars. The hedging opportunity makes the price of the underlying to increase in more fragile states. In turn, this causes the value of the option embedded in the underlying to increase. The price of the underlying cross-listed stock increases relatively to non-cross-listed stocks, and to its corresponding ADR. The model is able to replicate quantitatively the breakdown of the LooP in the proximity of a currency crisis.

9 Appendix

Table 2: Investments payoffs (for the Appendix)

	No Devaluation	Devaluation
Pesos	1	1
Risky Asset	θ	θ
Dollar	1	E

Table (1) below[19], summarizes the net payoffs of the different investments. The left column conditions payoffs on a failing attack, while the right column displays the payoffs for the opposite case. Without capital controls ($\tau = 0$), pesos are weakly dominated by dollar and the investor's decision becomes binomial. Conditioning on the realized p, the net payoff of the risky asset is also

[19] Table (2) in the appendix displays the matrix of gross payoffs.

independent on the regime status. However, the risky asset price fluctuates depending on the CB's decision. In particular, p is such that the marginal investor is indifferent between investing in the risky asset or the alternatives for the asset market to clear.

Given that the investor converts the dollar back to consume it the net payoff of the dollar investment is $e_2 - (1+\tau)$. If there is no devaluation, the payoff of dollars is negative, equal to $-\tau$. In this case, the risky asset becomes relatively more attractive and the asset price increases such that only a fraction of the investor's demand the risky asset in equilibrium. On the other hand, if there is a devaluation, the asset price decreases since the return on the dollar investment increases. Otherwise, the investor would strictly prefer dollars. Assume that $E - 1 - \tau > 0$. The asset price fluctuates with the regime's status which is ultimately be determined by the fundamentals of the model, $\{\theta, u\}$, where u determines the stochastic measure of noise traders.

Proof of Lemma 2. The measure of stochastic noise traders $\Phi(u)$ is inelastic with respect to the price. Consequently, the investor can learn about u from observing the market price p. Imposing the market-clearing condition, $A(\theta, p) = S(p, u)$, into equation (34) implies that there is a devaluation if,

$$\Phi(u) < 1 - (1+\tau)R \tag{67}$$

If there is a devaluation, the investor's has to be indifferent between acquiring the risky asset and dollars and the market price accommodates such that $p = \frac{\theta(1+\tau)}{E}$. On the other hand, if there is no devaluation, $\Phi(u) > 1 - (1+\tau)R$. In this case, the indifference condition between acquiring the risky asset and pesos has to be satisfied. The market price then only reflects the dividend payment: $p = \theta$.

Therefore, observing $p = \theta$ perfectly coordinates investors to the risky asset/peso indifference and there is no devaluation in equilibrium. The opposite conclusion is true if $p = \frac{\theta(1+\tau)}{E}$. ■

Proof of Lemma 7. The proof consists in three steps. First note that, from the clearing market condition that the threshold $\overline{x}(z)$ corresponds to the realization of z. Then, given that the market price p reveals z, the conditional expectation of the marginal investor $\overline{x}(z)$, are increasing in the private signal for the risky asset, and decreasing for the dollar. Finally, the market price p is a monotone function of the realization of the private signal of the marginal investor $\overline{x}(z)$.

$$sign(\frac{\partial p(z)}{\partial z}) = sign(\frac{\partial \mathbb{E}[\theta \mid \overline{x}(z), z]}{\partial z}\mathbb{E}[e_1 \mid \overline{x}(z), z] - \mathbb{E}[\theta \mid \overline{x}(z), z]\frac{\partial \mathbb{E}[e_1 \mid \overline{x}(z), z]}{\partial z}) > 0 \tag{68}$$

■

Proof of Lemma 11. The ADR price is given by

$$\begin{aligned}\tilde{p}(\theta,u,\tilde{x}) &= \frac{1}{E}\tilde{\pi}\tilde{x},p,\tilde{p}\mathbb{E}[\frac{\theta}{e_2}\mid \tilde{x},p,\tilde{p},\theta<\theta^*]+(1-\tilde{\pi}(\tilde{x},p,\tilde{p}))\mathbb{E}[\frac{\theta}{e_2}\mid \tilde{x},p,\tilde{p},\theta\geq\theta^*] \\ &= \mathbb{E}[\frac{\theta}{e_2}\mid \tilde{x},p,\tilde{p}]+\left(\frac{1}{E}-1\right)\tilde{\pi}(\tilde{x},p,\tilde{p})\mathbb{E}[\frac{\theta}{e_2}\mid \tilde{x},p,\tilde{p},\theta<\theta^*]\end{aligned} \tag{69}$$

Taking derivatives with respect to $\tilde{x}$ yield the result.

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