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HOARDING INTERNATIONAL RESERVES VERSUS A PIGOVIAN TAX-CUM-SUBSIDY SCHEME: REFLECTIONS ON THE DELEVERAGING CRISIS OF 2008-9, AND A COST BENEFIT ANALYSIS

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ABSTRACT

In this paper we outline a Pigovian tax-cum-subsidy scheme that deals with concerns about the costs and efficacy of hoarding international reserves (IR) as a means of self-insurance against a deleveraging crisis. We overview the degree to which IR provided self-insurance to Emerging Markets (EMs) during the 2008-9 crisis, pointing out that the fear of losing IR constrained the use of a pre-crisis IR war-chest. EMs found that their initial large stock of IR were not enough to prevent runs on their IR and large currency depreciations, runs that were abated in some countries only with the proliferation of deep swap-lines. The experience of EMs during the crisis raises concerns regarding the efficacy of hoarding IR as means of self-insurance. We outline the case for supporting self-insurance by imposing a tax on external borrowing. We focus on a model of an emerging market, where entrepreneurs finance tangible investments via bank intermediation of foreign borrowing. Bank intermediation exposes the economy to the risk of deleveraging, inducing a costly premature liquidation of tangible investments; a risk that increases with the ratio of aggregate external borrowing to IR. In these circumstances, price taking economic agents ignore their marginal impact on the expected cost of a deleveraging crisis, and external borrowing is associated with negative fire-sale congestion externalities. We show that an optimal borrowing tax reduces the distorted activity (external borrowing), and induces borrowers to finance the precautionary hoarding of international reserves.

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The global financial crisis is a watershed event that calls for a reexamination of the global financial architecture. In this paper we focuse on one aspect of this re-evaluation: the implications of the crisis on emerging markets (EMs) use of precautionary measures aiming at mitigating their exposure to financial crises. The global liquidity crisis renewed the debate about the desirability of unfettered financial integration of developing countries. It also raises questions about the degree to which hoarding a large stockpile of international reserves (IR) suffices to deal with the financial exposure of EMs in an efficient way. We overview this debate, and assess possible future options.

In Section 1 we discuss the degree to which IR provided self-insurance to EMs during the deleveraging crisis of 2008-9, pointing out that the record is mixed. Half of the EMs depleted not more than a 1/3 of their initial stock of IR, and the other half adjusted mostly by depreciation, with small changes of their IR. Several EMs found that initial large IR war-chests were not enough to prevent runs on IR and large depreciations; runs that were abated in some countries only with the proliferation of deep swaps lines. This raises a concern about the desirability and the efficacy of hoarding large stocks of IR as a mean of self-insurance. In section 2 we outline the case for supplementing hoarding IR with a tax on external borrowing, and a subsidy for hoarding IR. We describe a model of an emerging market where entrepreneurs finance investment via bank intermediation of foreign borrowing. Such bank intermediation exposes the economy to the risk of sudden stop and a deleveraging crisis that may induce costly premature liquidation of tangible investment. Hoarding IR mitigates this risk. We show that the optimal allocation involves a tax on external borrowing, and a subsidy on hoarding IR.

The logic of this Pigovian tax-cum-subsidy scheme follows from the negative externalities associated with large inflows of capital. If reserves are not plentiful, a deleveraging crisis induces a large number of banks to liquidate investments at the same time. This would depress the selling price of tangible capital, increasing the cost of deleveraging -- the fire-sale effect. Large deleveraging in emerging markets increases the demand for foreign currency. If foreign currency reserves are limited, the deleveraging pressure would bid up the price of foreign currency, requiring each bank to liquidate more of its investment to fund a given deleveraging pressure. While each bank takes potential fire-sale prices as given, as a group, they induce the fire-sale prices. This leads to a fire-sale externality, akin to congestion [see Krugman (2000) on the experience of Korea in the 1997-8 crisis].[1] We show that the fire-sale externality *reduces* the marginal social benefit of borrowing below the private benefit, and *increases* the marginal social benefit of hoarding IR above the private one. The optimal tax-cum-subsidy scheme reduces the distorted activity (external borrowing), inducing the borrowers to co-finance the precautionary hoarding of IR by means of the borrowing tax. Such a scheme may mitigate some of the recent concerns dealing with the costs of hoarding and using IR for self-insurance purposes. In section 3 we close the paper with a discussion.

1. IR as self-insurance during a crisis: the crisis experience of EMs

The experience of Korea during the last fifteen years outlines the contours of the debate about self-insurance by means of hoarding reserves. To recall, following the 1997-8 East Asian crisis, Korea embraced financial integration, buffered with large hoarding of international reserves. The large stock of IR provided Korean authorities with precautionary saving to cushion against sudden stops and deleveraging. Figure 1 overviews these trends during 1992-2008, tracing the short & long run external debt to GDP ratio, share of foreign ownership of stock market, and IR to GDP ratio in Korea.[2] The financial integration led to rapid increase in the foreign ownership share of Korean stock market, from less than 5% in 1992 to more than 40% in 2004. During the same period of time, the valuation of Korean stocks held by foreigners to Korea's GDP reached about 30%. While IR/GDP ratio hovered around 5% before the East-Asian crisis, the financial upheaval triggered by the crisis induced major change in the hoarding of international reserves, reaching more than 25% of the GDP by 2004. By that time, Korea's IR exceeded its the short term external debt by more than 2.5. In 2004, Korea's IR exceeded its total external debt, and Korean's international reserves matched the market value of Korean's stocks held by foreigners.

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[1] Bhattacharya and Gale (1987) investigated this externality in banking, and Caballero and Krishnamurthy (2004) in international finance.

[2] I am gratefully to Yeonho Lee for sharing the data. The data cover through mid-2008, before the global liquidity crunch. See Aizenman, Lee and Rhee (2007), where we show that the 1997-8 crisis led to a structural change in the hoarding of Korea's international reserves -- the Korean monetary authority gives much greater attention to a broader notion of 'hot money,' inclusive of short-term debt and foreigners' shareholding.

Less than ten years after the 1997-8 East Asian crisis, Korea's IR/GDP seemed to be more than adequate using conventional yardsticks -- IR that exceeded short term debt, allowing financing several quarters of imports. Indeed, observers raised questions about the growing costs of stockpiling these reserves, asserting that their level in emerging Asia exceeded the social optimum [see Jeanne and Ranciere (2005)]. The onset of the global liquidity crisis and the ensued deleveraging changed this perception. During the first stage of the crisis, Korea's reserves have dropped by roughly $60 billion in half a year, a decline of about 25%. Indeed, reserves were key to the bailout package that the Korean government unveiled in the second half of 2008. The center-piece of the package was a $100 billion three-year government guarantee for banks' debt issued abroad before July 2009. This sum was more than sufficient to cover Korean banks' foreign debt maturing by June 2009, estimated by the Korean Ministry of Strategy and Finance to be about $80 billion. Yet, observes noted that, despite the large hoarding of international reserves used to finance the bailout package, market concerns were not abated:

> "Similar guarantees had failed to allay fears of financial meltdown at the beginning of the Asian crisis in 1997 and they failed again. As in 1997, the market reactions were indifferent. Only when Korea secured a swap line amounting to $30 billion from the Fed on October 30 the foreign exchange market settled down somewhat, but not very long. The foreign exchange rate shot up to 1,509 won per dollar three weeks after the swap had been announced, which was apparently not enough to remove uncertainties surrounding Korea's ability to service its foreign debt. Korea also managed to arrange won-local currency swaps with the central banks of both China and Japan, each amounting to an equivalent of $30 billion on December 13. Only when it was made clear that the Fed would renew the swap agreement, foreign investors' confidence in the Korean economy improved and stability in the foreign exchange market returned toward the end of the first quarter of 2009."
>
> Yung Chul Park (2009)

Looking beyond Korea, other EMs cushioned the adjustment to the global financial crisis by a combination of exchange rate depreciation and partial depletion of their IR.[3] However, after

[3] A bailout similar to the one in Korea was instrumented by the Bank of Russia. The Russian bailout was implemented in context of intensified involvement of the Russian state in managing its vast natural resources, including a willingness to impose what amounted to *de facto* capital controls. Russia's large stock of reserves before the crisis (exceeding $600 billion) had prevented a complete collapse of its banking system.

the first phase of the adjustment, Central Banks have been reluctant to further draw down their reserves. Figure 2 portrays the international reserves dynamics during the first year of the crisis in Korea, India, Russia, Poland and Malaysia, July 08-March 09, reporting the ratio of IR (US dollar) relative to their level in July 08. The inverted S curve is consistent with the "fear of losing international reserves." Central banks used a share of their international reserves in the first quarters of the crisis to finance deleveraging pressures, mitigating thereby their currency depreciation. Yet, after losing not more than third of their initial reserves, countries became more averse to further drawing down their international reserves. The choice of the speed of drawing-down accumulated international reserves is a delicate one. It hinges, amongst other things, on the anticipated future course of the global economy, the domestic adjustment capacity and the degree of financial integration of the country in question. The trade-offs for a country like India differ from those of Chile, as India is less integrated to the global financial system and its government has less room for fiscal adjustment due to its significant and growing fiscal deficits. Brazil, Chile and others have preferred to adjust mostly through exchange rate depreciations, saving their IRs for even leaner years, should a prolonged period of weakness in their terms of trade occur.

Further insight about the 'fear of losing IRs' can be gained by looking at the differential patterns of using IRs during the crisis across all EMs. Aizenman and Yi (2009) investigated the adjustment of 21 EMs during the window of the crisis, and found a mixed and complex picture. [4] Intriguingly, only about half of the EMs relied on depleting their international reserves as part of the adjustment mechanism. To gain further insight, we compared the pre-crisis IR/GDP ratio of countries that experienced sizable depletion of their IR, to that of countries that did not, and find different patterns between the two groups. Trade related factors (trade openness, primary goods export ratio, especially large oil exports) seem to be more significant in accounting for the pre-crisis IR/GDP ratio of countries that experienced a sizable depletion of their IR in the first phase

[4] The EMs' sample is composed of the countries listed in the FTSE and MSCI emerging market list. It did not include Singapore and Hong-Kong because of their special economic structure, specializing in *entrepôt* services. In addition, due to the dramatic effect of the IMF's aid on Hungary's reserves changes, it was excluded from the sample (Hungary's IR had increased nearly by half in the two months after the IMF's stabilization package). The study also excluded Morocco and Pakistan due to unavailability of the relevant data.

of the crisis. Our findings suggest that countries that internalized their large exposure to trade shocks before the crisis, used their IR as a buffer stock in the first phase of the crisis. Their IR losses followed an inverted logistical curve. After a rapid initial depletion of reverses, within seven months they reached a markedly declining rate of IR depletion, losing not more than one-third of their pre crisis IR. In contrast, countries whose pre-crisis demand for IRs was more sensitive to financial factors, refrained from using IR, and preferred to adjust through currency depreciations.[5]

Prior to the crisis, observers viewed hoarding IR as reflecting several causes, including the "fear of floating" [Calvo and Reinhart (2002)]; and precautionary and/or mercantilist motives [Aizenman and Lee (2007)]. However, during the recent "flight to quality" and deleveraging observed in the first phase of the crisis, the "fear of losing IR" played a key role in shaping the actual use of IR by EMs. This suggests that EMs' adjustment was constrained more by their fear of losing international reserves than by their fear of floating. A possible interpretation for the fear of losing IR is the apprehension of a country that reducing its IR/GDP ratio below the average of its reference group would increase its vulnerability to deleveraging and sudden stops [see Cheung and Qian (2009) for "keeping with Joneses" evidence dealing with East Asia]. These factors also suggest greater demand for regional pooling arrangements and swap lines [see Rajan et al. (2005) and Aizenman and Pasricha (2008)] as well as possible new roles of International Financial Institutions.

The limited efficacy of the large stockpile of IR in preventing a run on well managed countries during a crisis calls into question the desirability of unfettered capital mobility. While hoarding international reserves prevented a replay of the 1997-8 crisis dynamics in Korea, the large depreciation of the Koran Won renewed concerned about the exposure to balance sheet

[5] Intriguingly, the average exchange rate depreciation rate from 8-08 to 2-09 was about 30% in both EMs that depleted their IR and those that refrained from depleting IR. A hypothesis that can explain this observation is that the shocks affecting the EMs that opted to deplete their IR were larger than the shocks impacting EMs that refrained from using their IR. Testing this possibility requires more data, not available presently, including the deleveraging pressures and balance sheet positions during the crisis. This hypothesis, if valid, implies that countries prefer to adjust to bad shocks first via exchange rate depreciation, supplementing the adjustment with partial depletion of their IR only when the shocks are deemed to be too large to be dealt with using only exchange rate adjustment.

effects associated with depreciation. At the limit, eliminating the balance sheet exposure may require hoarding dollar liquidity per dollar external liability, practically nullifying the gains from financial integration [Park (2009)]. We turn now to evaluate possible future developments of policies and financial mechanisms to deal with these concerns.

2. International reserves at times of global financial distress: reflections and assessment of future options.

A constructive way to evaluate the role of international reserves during the crisis is to apply the perspective of insurance mitigating exposure to risky activities. The self-insurance benefits associated with international reserves can be understood using two benchmarks: no self-insurance, and full self-insurance. In the early 1990s Korea refrained from hoarding international reserves for self-insurance against sudden stops – Korea's IR/GDP ratio was low (about 5%), similar to the IR/GDP ratios of OECD countries. The low Korea's IR/GDP ratio at that time reflected the presumption that by virtue of limited financial integration, a history of high growth and an impressive record of adjustments to adverse shocks, Korea was not exposed to sudden stop events. The 1997-8 crisis vividly illustrated that Korea and all emerging markets embarking on financial integration are exposed to sudden stop events. The 1997-8 crisis induced a regime switch wherein Korea's IR/GDP ratio more than quintupled within less than ten years, reducing thereby the expected costs of possible sudden stops. Similar massive hoarding of IR were observed for most Emerging Asia in the aftermath of the 1997-8 crisis, with Latin America and the Oil exporting countries joining the trend of hoarding IR in the early 2000s.

With most insurance schemes, agents rarely get full insurance against the relevant hazard, as a typical insurance comes with loading factors, deductibles, moral hazard, and other constraining features. Full insurance is frequently too costly to attain, and rarely observed. This applies to personal hazard like health and car insurance, as well as to the macro self-insurance services provided by hoarding international reserves. Hence, with partial insurance, one should expect that the insurance would mitigate but not eliminate the adverse effects of the hazardous event. In the context of financial integration, fully insuring against deleveraging may entail too costly hoarding, as at the limit the portfolio investment of foreign agents and the external borrowing of domestic agents should be matched by an equivalent level of international reserves. Such a scheme implies that the country is fully insured at too high a cost. Yet, this argument does not negate the beneficial effects of self-insurance, because the alternative of no self-insurance would be costly as well [see the East-Asian crisis]. Thus, the question facing the central bank is to find the optimal level of self-insurance.

The theory of optimal insurance suggests that with hazards impacted by agents' behavior, optimality calls for a mixture of partial insurance and preventive methods reducing the frequency and intensity of the calamity [installing fire alarm and external lights in a house, driving a car at a lower speed, equipping a car with air-bags, etc…]. This logic applies equally well to emerging markets' exposure to sudden stops and deleveraging shocks, when a country may supplement hoarding international reserves with policies that would reduce its exposure to capital flight. As was pointed out by Rodrik (2006), such policies may include proactive steps to reduce exposure to external debt.

In the next section we outline the case of supplementing hoarding IR with a Pigovian tax scheme. The logic of the scheme follows from the negative externalities associated with large inflows of capital. Specifically, Eichengreen, Hausmann and Panizza (2003), and the related balance sheet literature showed that external debt associated with maturity and currency mismatches increase the downside risk of costly sudden stops crises. Greater balance sheet exposure frequently entails higher real depreciation triggered by deleveraging, inducing greater distress of the domestic banking system, and ultimately higher expected forgone output costs of a sudden stop and deleveraging crisis. As most agents are price takers, each ignores its marginal impact on increasing the expected cost of such a crisis. This in turn entails a fire-scale externality akin to "congestion", calling for a Pigovian tax scheme.

2.1 Optimal hoarding of international reserves and a Pigovian tax-cum-subsidy scheme

We construct a minimal model to explain the optimal self-insurance offered by international reserves in mitigating the output effects of liquidity shocks. The structure of the model is akin to Diamond and Dybvig (1983) -- investment in a long term project should be undertaken prior to the realization of liquidity shocks.[6] Hence, the liquidity shock may force

[6] Our model follows the tradition of Bryant (1980) or Diamond and Dybvig (1993) in that the source of liquidity shock lies with the lender, rather than the borrower (Holmstrom and Tirole, 1998). However, our model assumes away the market equilibrium among lenders (be it the risk of runs or the difficulty of the decentralized provision of liquidity). Abstracting from the question whether market-based liquidity

costly liquidation of the earlier investment, reducing second period output. As our focus is on developing countries, we assume that all financial intermediation is done by banks, relying on a debt contract. We simplify further by assuming that there is no separation between the bank and the entrepreneur – the entrepreneur is the bank owner, using it to finance the investment. The time line is summarized in Figure 3.

At the beginning of period 1 entrepreneurs fund investment by external borrowing D to finance planned second period capital, $K_{2,p}$, and banks' reserves, R; $K_{2,p} = D - R$. At the end of period one, *after* the commitment of investment capital, a deleveraging liquidity shock Z materializes. A fraction *z* of foreign lenders demands their deposits back, Z = *z*D. Assuming away sovereign risk and bankruptcy constraints, the deleveraging shock is first met by selling reserves. Any excess of the liquidity shock zD above reserves R is met by pre-mature costly liquidation of $MAX\{0, zD - R\}$. The liquidation reduces the actual second period capital from $K_{2,p}$ to K_2, at a rate that depends on the adjustment cost, θ: $K_2 = K_{2,p} - (1+\theta)MAX\{Z - R,\ 0\}$. Premature liquidation implies that the impatient depositors get their money back without any interest payment. Only patient depositors are paid interest rate ρ upon the realization of the investment. Final output is produced at period 2, according to a Cobb-Douglas production. The second period output finances the repayment of outstanding debt left to maturity, $D(1-z)(1+\rho)$. Unused reserves hoarded in period 1, $MAX\{R - Z,\ 0\}$, provide the bank with a risk free return in the second period, $(1+r_f)MAX\{R - Z,\ 0\}$.

The second period output is:

(1) $$Y_2 = [K_{2,p} - (1+\theta)MAX\{Z - R,\ 0\}]^{\alpha}; \quad \text{where} \quad 0 \le \theta < 1, \text{ and } \alpha < 1.$$

Recalling that $K_{2,p} = D - R$, the net capital after liquidation is:

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insurance is available, we focus on the implication of large adjustment cost—including but not restricted to the liquidation cost—on the demand for reserves as self-insurance. In a similar vein, no distinction is made between the private sector and the monetary authorities which maintain the stock of international reserves.

(2) $$K_2 = \begin{cases} D - R - (1+\theta)(Z-R) = D - Z - \theta(Z-R) & if \quad Z > R \\ \\ D - R & if \quad Z \le R \end{cases}$$

It is convenient to normalize the liquidity shock by the level of deposits, denoting the normalized liquidity shock by z:

(3) $Z = zD$; $\quad 0 \le z < \tau \le 1$, associated with a probability density function $f(z)$.

Depositors are entitled to a real return of r_D on the loan that remains deposited for the duration of investment. Assuming risk neutrality, and that the agents' subjective discount rate is ρ, competitive intermediation implies that

(4) $$\frac{(1+r_D)\int_0^\tau (1-z) f(z)dz}{1+\rho} - \int_0^\tau (1-z) f(z)dz = 0 \Rightarrow r_D = \rho .$$

Net reserves held until period 2 are assumed to yield a return of r_f, $r_f \le \rho$.[7] We denote the marginal liquidity shock associated with liquidation by z^*, $\quad z^* = R/D$. The expected second period surplus [i.e., net income after paying depositors] is:

(5) $$\begin{aligned} E[\Pi] = \int_0^{z^*} (D-R)^\alpha f(z)dz + \int_{z^*}^{\tau} (D - Z - \theta[Z-R])^\alpha f(z)dz + \\ (1+r_f)\int_0^{z^*} [R - Z] f(z)dz - (1+\rho)\int_0^{\tau} (D-Z) f(z)dz. \end{aligned}$$

It is the sum of the expected output, plus the income associated with unused reserves (i.e., reserves net of liquidation), minus the repayment to depositors who get a return of ρ on the net

[7] Our model deals with a developing country, where balance sheet concerns frequently induces the authorities to resist depreciation due to the resultant balance sheet costs. In these circumstances, private banks' reserves are frequently held and managed by the Central Bank, after being swapped with domestic currency. Hence, the IR in our discussion are interchangeable with international reserves. To simplify the analysis, we refrain from modeling other possible adjustments to deleveraging shocks, including sovereign default, massive real depreciation, and bankruptcies.

deposit position, $D-Z$. Applying (3) and the definition of the z*, we re-write the expected surplus as

$$(5')\qquad \begin{aligned} E[\Pi] = D^{\alpha}\left[\int_0^{z*}(1-z*)^{\alpha} f(z)dz + \int_{z*}^{\tau}(1-z-\theta[z-z*])^{\alpha} f(z)dz\right] + \\ D\left[(1+r_f)\int_0^{z*}(z*-z)f(z)dz - (1+\rho)\int_0^{\tau}(1-z)f(z)dz\right]. \end{aligned}$$

2.2 The competitive, *Laissez faire* equilibrium

The FOC determining the optimal demand for international reserves is

$$(6)\qquad \begin{aligned} 0 = D^{\alpha-1}\left[-\alpha(1-z*)^{\alpha-1}\int_0^{z*} f(z)dz + \theta\int_{z*}^{\tau}\alpha(1-z-\theta[z-z*])^{\alpha-1} f(z)dz\right] + \\ (1+r_f)\int_0^{z*} f(z)dz. \end{aligned}$$

This condition is equivalent to:

$$(7)\qquad [MP_{K_{2,p}} - (1+r_f)]\cdot \Pr[Z<R] = \theta E\left[MP_{K_2} \mid Z>R\right],$$

where MP_K is the marginal productivity of capital; $\Pr[Z<R]$ the probability that the liquidity shock is below the level of reserves (equals also $\Pr[z<z*]$), and $E[Y \mid Z>R]$ stands for $\int_{z*}^{\tau} Y f(z)dz$ for variable Y. Optimal hoarding is reached when the expected opportunity cost of holding reserves (the LHS of (7)) equals the expected precautionary benefit of holding reserves (the RHS of (7)). This benefit equals to the savings in liquidation cost achieved by extra dollar reserves, θ, times the expected marginal product of capital in states associated with liquidation.

The first order condition characterizing optimal deposit is:

$$(8)\qquad \begin{aligned} 0 = \alpha D^{\alpha-1}\left[\int_0^{z*}(1-z*)^{\alpha-1} f(z)dz + \int_{z*}^{\tau}(1-z-\theta[z-z*])^{\alpha-1}(1-z[1+\theta])f(z)dz\right] - \\ \{(1+r_f)\int_0^{z*} z f(z)dz + (1+\rho)\int_0^{\tau}(1-z)f(z)dz\} \end{aligned}$$

This condition is equivalent to:

(9) $$MP_{K_{2,p}} \cdot \Pr[Z < R] + E\left[MP_{K_2}\{1 - z(1+\theta)\} \mid Z > R\right] = (1 + r_f) \cdot E\left[z \mid Z < R\right] + (1+\rho)\left[1 - E(z)\right],$$

The LHS of (9) is the expected marginal product of borrowed funds: the sum of the expected marginal product of capital in states where reserves cover the liquidity shock (Z < R), plus the expected marginal product of capital net of liquidation cost in states where the liquidity shock exceeds reserves (Z > R). The RHS of (9) is the expected cost of borrowing: the opportunity cost of marginal reserves funding deleveraging when Z < R (the first term) plus the expected marginal return on deposits held to maturity (the second term).

2.3 Fire-sale congestion externalities and deleveraging.

The discussion above focused on the perspective of the representative bank, which is assumed to be a price taker. The bank ignores the fire-sale effect – bank's attempt to liquidate capital tends to depress the selling price of capital facing *all* banks. Aggregate liquidation requires each bank to liquidate more of its investment to fund a given deleveraging pressure, increasing thereby the liquidation cost, θ. Specifically, we assume that the liquidation cost, θ, depends positively on aggregate liquidation by n identical banks, LQ:

(10) $$\theta = \theta(LQ), \quad \theta' > 0, \; LQ = n \cdot D_i Max[z - z^*, 0],$$

where D_i is the liquidation of the representative bank. For a representative bank, $LQ_i = D_i MAX[z - z^*, 0]$. We denote by $\eta_{\theta,i}$ the elasticity of the liquidation cost with respect to the deleveraging by bank i, $\eta_{\theta,i} = \dfrac{\partial \log \theta}{\partial \log[D_i (z - z^*)]}$. We assume a large enough number of identical banks, n, so that the deleveraging elasticity of each bank is negligible. Yet, the combined effect of *all* banks deleveraging, $n \cdot \eta_{\theta,i}$, is sizable. The gap between the negligible liquidation elasticity of each bank and the sizable macro deleveraging elasticity manifests the fire-sale congestion externality. The focus of our analysis is on the optimal tax-cum-subsidy called to deal with this externality.

The first order conditions for optimal hoarding and borrowing from the planner's perspective are:

(7a) $$[MP_{K_{2,p}} - (1+r_f)] \cdot \Pr[Z < R] = \theta E\left[MP_{K_2}(1+n\cdot\eta_{\theta,i}) \mid Z > R\right].$$

(9a) $$\begin{aligned} &MP_{K_{2,p}} \cdot \Pr[Z < R] + E\left[MP_{K_2}\{1 - z(1+\theta[1+n\cdot\eta_{\theta,i}])\} \mid Z > R\right] = \\ &(1+r_f)\cdot E\left[z \mid Z < R\right] + (1+\rho)\left[1 - E(z)\right] \end{aligned}.$$

Comparing the FOCs pairs of the atomistic bank with the planner's FOCs [(7) to (7a), and (9) to (9a), respectively] reveals that in states of deleveraging [i.e., when $z > z^*$], the fire-sale externality increases the marginal social benefit of hoarding IR by $n\cdot\eta_{\theta,i}\theta_i MP_{K_2}$, and reduces the marginal social benefit of borrowing by $n\cdot\eta_{\theta,i}\theta_i zMP_{K_2}$.

2.4 Policies supporting the optimal allocation

The welfare consequences of fire-sale externality may be alleviated by taxing foreign borrowing at a rate t, and possibly subsidizing hoarding international reserves at a rate s. We assume that the tax revenue is yielding the risk free interest rate. The introduction of these policies modifies the bank's problem to

(11) $$\begin{aligned} E\left[\Pi\right] &= D^{\alpha}\left[\int_0^{z*}(1-t-z*)^{\alpha} f(z)dz + \int_{z*}^{\tau}(1-t-z-\theta[z-z*])^{\alpha} f(z)dz\right] + \\ &D\left[(1+r_f)(1+s)\int_0^{z*}(z*-z)f(z)dz - (1+\rho)\int_0^{\tau}(1-z)f(z)dz\right]. \end{aligned}$$

The optimization of (11) provides bank's FOC for optimal hoarding reserves and borrowing:

(7b) $$[(1-t)MP_{K_{2,p}} - (1+r_f)(1+s)] \cdot \Pr[Z < R] = \theta E\left[MP_{K_2} \mid Z > R\right].$$

(9b) $$\begin{aligned} &(1-t)MP_{K_{2,p}} \cdot \Pr[Z < R] + E\left[MP_{K_2}\{1 - t - z(1+\theta)\} \mid Z > R\right] = \\ &(1+r_f)(1+s)\cdot E\left[z \mid Z < R\right] + (1+\rho)\left[1 - E(z)\right] \end{aligned}.$$

The social planner's objective, V_p, is to maximize the expected utility of the representative bank plus net revenue from the tax-cum-subsidy scheme, taking into account the fire-sale effect of deleveraging:

$$(12)\quad \begin{aligned} V_p = D^{\alpha}\left[\int_0^{z^*}(1-t-z^*)^{\alpha} f(z)dz + \int_{z^*}^{\tau}(1-t-z-\theta[z-z^*])^{\alpha} f(z)dz\right] + \\ D\left[(1+r_f)\int_0^{z^*}(z^*-z) f(z)dz - (1+\rho)\int_0^{\tau}(1-z) f(z)dz\right] + tD(1+r_f). \end{aligned}$$

The planner's FOCs determining the optimal hoarding and borrowing are, respectively

$$(7c)\quad [(1-t)MP_{K_{2,p}} - (1+r_f)]\cdot \Pr[Z<R] = \theta(1+n\cdot\eta_{\theta,i})E\left[MP_{K_2} \mid Z>R\right].$$

$$(9c)\quad \begin{aligned} t(1+r_f) + (1-t)MP_{K_{2,p}}\cdot \Pr[Z<R] + E\left[MP_{K_2}\{1-t-z[1+\theta(1+n\cdot\eta_{\theta,i})]\} \mid Z>R\right] = \\ (1+r_f)\cdot E\left[z \mid Z<R\right] + (1+\rho)\left[1-E(z)\right] \end{aligned}.$$

Case a: Borrowing tax policy

Suppose first that the policy maker sets the borrowing tax at a rate that induces the bank to internalize the fire-sale externality. Comparing (9b) and (9c), while setting s = 0, we find the optimal tax needed to induce banks to internalize the borrowing externality:

$$(13)\quad t = \frac{\theta n\cdot\eta_{\theta,i}E\left[zMP_{K_2} \mid Z>R\right]}{1+r_f}.$$

The tax equals the externality [$\theta n\cdot\eta_{\theta,i}$], times the expected cost of deleveraging pressure when Z > R, measured in terms of the marginal productivity of capital (i.e., $E\left[zMP_{K_2} \mid Z>R\right]$).

Case b: Borrowing tax-cum-hoarding IR policy

The borrowing tax policy stated in (13) may fall short of inducing the optimal demand for international reserves. Achieving optimal borrowing and hoarding reserves requires two policy instruments -- an external borrowing tax and an international reserves subsidy. We infer the optimal borrowing tax-cum-hoarding subsidy by applying the pairs of FOCs, (7b) & (7c) and (9b) & (9c):

(14)
$$s = \theta n \cdot \eta_{\theta,i} \frac{E\left[MP_{K_2} \mid Z > R\right]}{(1+r_f)\Pr\left[Z < R\right]};$$
$$t = \frac{\theta n \cdot \eta_{\theta,i} E\left[zMP_{K_2} \mid Z > R\right] - s(1+r_f)E\left[z \mid Z < R\right]}{1+r_f}.$$

It can be shown that the net tax revenue collected by the authorities is positive:[8]

$$(15)\quad t(1+r_f)D - s(1+r_f)\int_0^{z^*}(R - zD)f(z)dz = \theta n \cdot \eta_{\theta,i} E\left[(Z-R)MP_{K_2} \mid Z > R\right] > 0.$$

The net tax revenue equals the product of the fire-sale externality [$\theta n \cdot \eta_{\theta,i}$], times the expected liquidation costs in states where Z > R, $E\left[(Z-R)MP_{K_2} \mid Z > R\right]$. While subsidizing hoarding IR is costly, equation (15) shows that the fiscal revenue from the borrowing tax *exceeds* the cost of funding the hoarding subsidy.

Figure 4 summarizes this discussion. It plots the expected marginal productivity of investment funded by external borrowing, drawn for a given level of international reserves. Curve EMP_D^{PR} corresponds to the conditions facing the atomistic entrepreneur, in the absence of borrowing taxes. The debt threshold level $\tilde{D}$ is the lowest external debt that induces liquidation [defined by $\tilde{D} = IR/\tau$]. A further increase in external debt increases the expected cost of

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[8] Note that $t(1+r_f)D - s(1+r_f)\int_0^{z^*}(R - zD)f(z)dz = D[t(1+r_f) - s(1+r_f)\int_0^{z^*}(z^* - z)f(z)dz]$.

Applying (14) we find that

$$D\left\{t(1+r_f) - s(1+r_f)\int_0^{z^*}(z^* - z)f(z)dz\right\} = D\left\{\theta n\eta_{\theta,i}E\left[zMP_{K_2} \mid Z > R\right] - s(1+r_f)E\left[z \mid Z < R\right] - s(1+r_f)\int_0^{z^*}(z^*-z)f(z)dz\right\} =$$
$$D\left\{\theta n\eta_{\theta,i}E\left[zMP_{K_2} \mid Z > R\right] - s(1+r_f)E\left[z^* \mid Z < R\right]\right\} = D\{\theta n\eta_{\theta,i}E\left[zMP_{K_2} \mid Z > R\right] - z^*\theta n\eta_{\theta,i}E\left[MP_{K_2} \mid Z > R\right]\} =$$
$$\theta n\eta_{\theta,i}D\left\{E\left[zMP_{K_2} \mid Z > R\right] - z^* E\left[MP_{K_2} \mid Z > R\right]\right\} = \theta n\eta_{\theta,i}E\left[D(z - z^*)MP_{K_2} \mid Z > R\right] = \theta n\eta_{\theta,i}E\left[(Z-R)MP_{K_2} \mid Z > R\right]$$

liquidation. In the absence of tax-subsidy policies, external borrowing is given by D_0. Curve EMP_D^{SO} is the expected social marginal benefit of borrowed funds. It coincides with EMP_D^{PR} as long as the probability of costly liquidation is zero (for $D < \tilde{D}$). For $\tilde{D} < D$, the planner's curve EMP_D^{SO} is below the entrepreneur's curve ($EMP_D^{PR} > EMP_D^{SO}$), because it takes into account the negative fire-sale externality associated with marginal borrowing. For the given initial IR, the optimal external borrowing is $\widehat{D}$, well below D_0. The fire-sale externality is given by the dotted line, *CE* (proportionate to $\theta n \eta_{\theta,i}$). The optimal borrowing tax is defined by that externality, shifting curve EMP_D^{PR} downwards. Note that Figure 4 is a partial equilibrium treatment, drawn for a given level of international reserves. A similar figure can be drawn for the bank's and the planner's demands for IR. In comparison to the initial, no borrowing tax equilibrium, the impact of policies is to reduce the distorted activity (external borrowing), thereby inducing the borrowers to co-finance the precautionary hoarding of international reserves by means of the borrowing tax.

3. Discussion

The external borrowing-tax-cum-IR-subsidy outlined in our paper may mitigate the concerns about the costly hoarding of large stockpile of IR needed to self insure against deleveraging crisis. A challenge associated with the tax-cum-subsidy scheme is the dynamic nature of the optimal policies – the tax and the subsidy rate should vary with the external borrowing/GDP ratio, and with other factors impacting the risk of deleveraging crises.[9], [10]
The unfolding crisis of 2008-9 may be a watershed of financial globalization. Emerging markets that embraced rapid financial integration before the crisis found that they are overly exposed to deleveraging propagated from the US. The current crisis vividly illustrates that even a large stock of IR may not provide efficient self-insurance against deleveraging. In this paper we outline a tax-cum-subsidy policy dealing with fire-sale externalities associated with deleveraging risks. Our hope is that such a scheme would alleviate concerns about the cost and the efficacy of hoarding IR, thereby preventing the execution of more drastic policies that may further curtail financial integration.

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[9] Our proposed tax scheme is akin to a borrowing tax in the presence of costly sovereign default and moral hazard [see Aizenman and Turnovsky (2002)], yet the scheme applies even in the absence of moral hazard. See Kletzer (1984) for a model of possible inefficiencies associated with sovereign risk, and Levy Yeyati (2008) for the moral hazard challenge facing the central bank in a dollarized economy.

[10] The design of the FDIC deposit insurance scheme in the US may be viewed as generating similar outcomes as the tax-cum-subsidy scheme outlined in this paper. The FDIC charges insurance premiums on bank deposits at a rate that ideally should reflect the riskiness of banks' investments. The insurance premium is akin to a tax on banks' borrowing. The provision of insurance by the FDIC acts in ways similar to subsidizing hoarding liquid resources to provide self-insurance.

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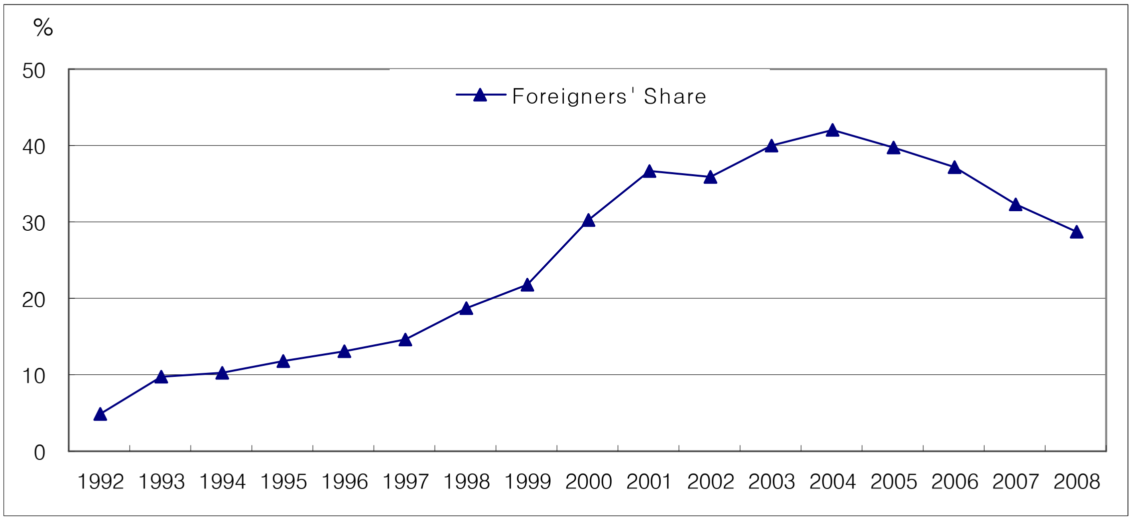
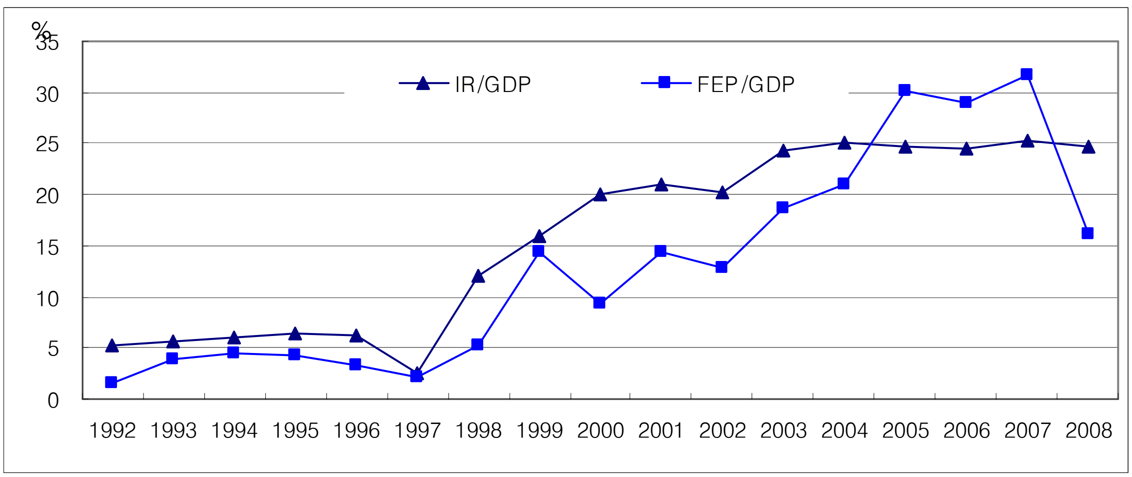
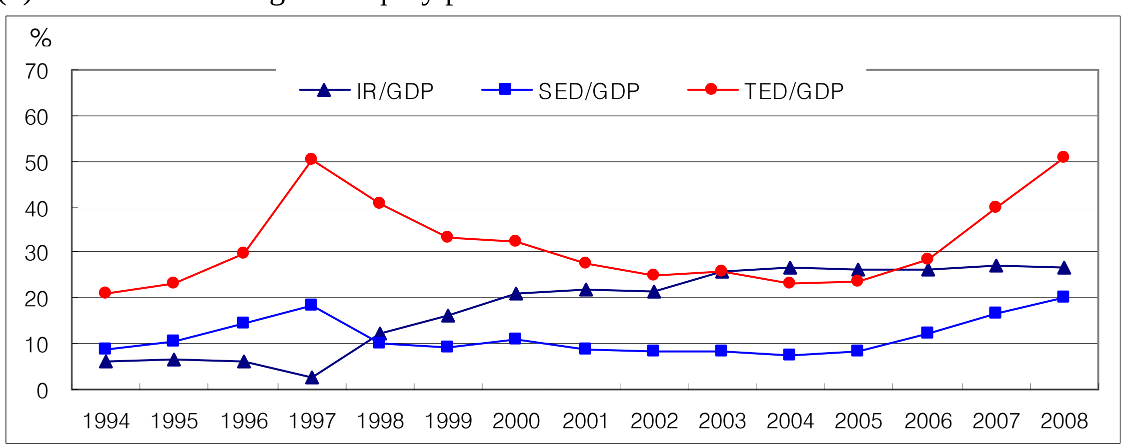
Figure 1 – Korean Experience 1994-2008.



(a) Foreigner's share of Korean's equity market



(b) IR/GDP and foreigners' equity position/GDP



(c) IR/GDP and External Debt/GDP

The data cover through mid-2008, before the global liquidity crunch. FEP = foreigners' equity position based on market value of foreigners' shareholdings. SED = short-term external debt, TED = total external debt.

Figure 2

International reserves and the deleveraging crisis, 8-08 to 3-09,

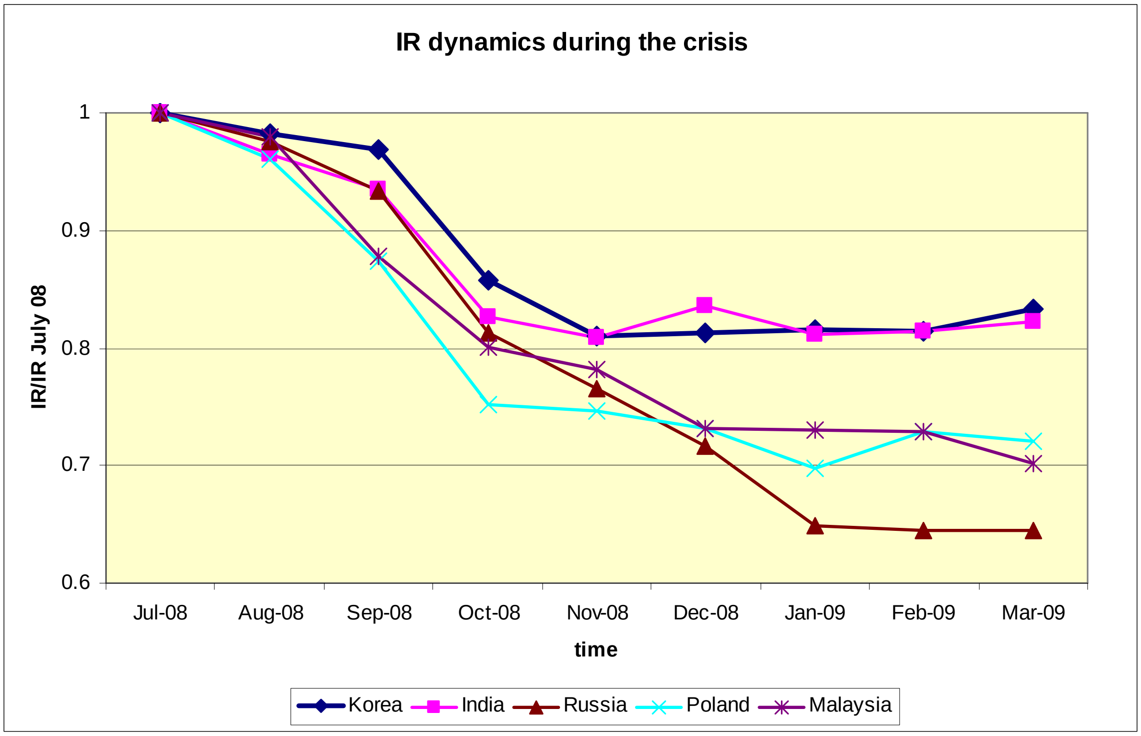


Figure 3

The time line

Beginning of period 1:
External borrowing D, financing planed investment and hoarding reserves
$$K_{2,p} = D - R \quad .$$

↓

End of period 1:
Liquidity shock Z = z*D* materializes, reducing the net capital to K_2;
$$K_2 = K_{2,p} - (1+\theta) MAX \left\{0, zD - R\right\}.$$

↓

Period 1:
Output Y_2 materializes, $Y_2 = A(K_2)^{\alpha}$;
Depositors are paid $D(1-z)(1+\rho)$;
Net reserves yield $MAX[(R-Z)(1+r_f);0]$.

Figure 4

Sudden stop and external borrowing: the case of congestion externality and optimal external borrowing tax