OPTIMAL TAX RATES ON GROSS CAPITAL FLOWS

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Abstract: This study seeks to find optimal tax rates on gross capital flows. I construct a simple three-period model of pecuniary externalities where private domestic agents do not consider the effect of borrowing or overseas investment decision on their own financial constraint. The model differs from previous efforts in that it explicitly differentiates gross inflows (i.e., borrowing from foreign investors) from gross outflows (i.e., overseas investment in foreign assets) to reflect the significant increase of gross outflows in emerging economies. I show that the optimal tax rate on gross inflows is 0.8%p higher when foreign assets are included in the model, which is due to greater unintended side effects of borrowing through the channel of foreign asset prices. The findings generalize previous models that only use net flows by illustrating how externalities can be corrected with Pigouvian tax on borrowing as well as subsidy on overseas investment. This study also provides new policy insights into capital flow management by suggesting separate management of gross inflows and outflows.

Keywords: Capital Flow Management, Gross International Capital Flows, Pecuniary Externalities, Pigouvian Taxation

JEL Codes: F32, F38, G18, H23

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1 Introduction

Financial crises, big or small, are usually associated with abrupt and volatile capital movement. When the liberalization of capital flows took place in the 1980s, Emerging Market Economies (EMs) began to experience a sudden reversal of capital flows or "sudden stops" as Advanced Economies (AEs) withdrew their invested funds before or during a crisis. In response to sudden stops of capital, EMs introduced unconventional capital flow management measures—for example, taxing capital inflows to prevent future crises.[1] The role of capital flow management was emphasized even further in the wake of the 2008 Global Financial Crisis when abundant capital flowed into EMs due to expansionary monetary policies of AEs. The IMF has also made a change to its stance accordingly: capital flow management can be used as a complementary measure to prevent financial crises and promote stable economic growth (IMF, 2012).

In the meantime, macroeconomic studies began to investigate how volatile capital flows can lead to a financial crisis and explore optimal policies that can mitigate the impacts. On the theoretical side, models of externalities provide theoretical tools to explain why capital flows can cause externalities or unanticipated side effects that amplify financial instability. They also examine how managing capital flows with policy measures can correct externalities and result in improved welfare. According to this strand of theoretical literature, excessive borrowing during normal times could render an economy more vulnerable to a financial crisis, providing a "natural rationale" for the taxation of international borrowing (Jeanne and Korinek, 2010). Empirical studies, on the other hand, focus on identifying the drivers of capital flows (e.g., US monetary

[1] Rebucci and Ma (2019) note that taxes on capital flows have been used countercyclically since the 1990s. For example, Chile imposed a tax on short-term capital inflows from 1991 to 1998 (Forbes, 2007). In the wake of the global financial crisis, many countries (e.g., Brazil) actively utilized taxes on capital flows (Rebucci and Ma, 2019).

policy as an external factor and productivity growth as a domestic factor) and analyzing the effectiveness of capital flow management measures. They thus provide important insights from financial and macro data that can enhance theoretical models in terms of practical relevance.

Recently, an increasing volume of empirical studies began to highlight the need to separate capital flow data into gross capital inflows and outflows (Forbes and Warnock, 2012; Broner et al., 2011; Davis and van Wincoop, 2018; Cavallo et al., 2017). Most studies on capital flow management, particularly theoretical models, only use net capital flows without disaggregating it into gross capital inflows and outflows for the sake of simplicity (Jeanne and Korinek, 2010; Bianchi, 2011; Benigno et al., 2013; Bianchi and Mendoza, 2018). Only few recent models in theoretical studies use gross capital inflows and outflows instead of net flows (Jeanne and Sandri, 2020; Caballero and Simsek, 2020). However, empirical evidence illustrates the importance of using gross flows: gross flows are more volatile compared to net flows and an offsetting relationship exists between gross inflows and outflows, which reduces the fluctuation of net flows. This reflects the reality of EMs where domestic investors have increased overseas investment (i.e., gross outflows) in the mid-2000s. Thus, the movement of net inflows is often different from that of gross inflows. This implies that traditional modeling with net flows may overlook the role of gross outflows in understanding the underlying mechanism and management of capital flows. My theoretical model, on the other hand, considers the role of gross outflows by incorporating foreign assets to find the implications for capital flow management in terms of optimal tax rates.

As a benchmark, I follow the theoretical model by Jeanne and Korinek (2010), which derives optimal tax rates based on net capital flows. Unlike their model, this study attempts to find optimal tax rates on *gross* capital flows. My model differs from previous efforts in that it explicitly differentiates gross inflows from gross outflows. By including gross outflows (foreign assets) in the model, externalities or unintended side effects of gross inflows on financial constraint becomes more severe via foreign asset prices. Intuitively, increasing the size of borrowing during normal times will increase the size of repayment, which reduces net worth in the next period. This will tighten the collateral constraint not only via domestic asset prices (as indicated in Jeanne and Korinek and other models that only use net flows) but also via foreign asset prices. This implies a greater amount of excessive borrowing and thus a social planner should impose a higher tax rate than in a model where gross outflows are not considered.

The contributions of this study are twofold. First, the findings will add to the existing literature on international capital flows and sudden stops as it attempts to bridge the gap between empirical and theoretical literature. Secondly, the results can provide new policy insights on capital flow management. According to the IMF, each country developed its unique capital flow management measures, a majority of which impose different measures on gross capital inflows and outflows.[2] For example, Kazakhstan, Korea, and Singapore have only regulated gross inflows. However, there is little empirical evidence and theoretical reasoning on managing inflows and outflows separately. By deriving and comparing optimal tax rates for gross capital inflows and outflows, my study can provide theoretical support and practical guidelines to countries using capital flow management tools.

[2] According to the IMF 2019 Taxonomy Capital Flow Management Measures, countries introduced different measures to manage capital flows. However, the IMF's definition of gross capital flows differs from the definition in related literature such as Forbes and Warnock (2012) and this paper. For example, gross capital inflows in the IMF paper refers to capital flows—including both foreign and domestic—that "enter" home country; whereas in this paper, gross capital inflows indicate "foreign" capital inflows (foreigners to home country).

2 Related Literature

This study incorporates both theoretical and empirical literature on capital flows. Theoretically, it builds on the literature on financial crises and international capital flows. Related studies focus on explaining the externalities of international capital flows. According to the theoretical models of externalities, capital flows can create pecuniary externalities that are not internalized by private agents; they do not consider the effect of their borrowing decision on their own collateral constraint via asset prices. While acknowledging both the benefits and costs of capital flows, this strand of literature emphasizes that some of the benefits and costs are external to private agents.

Models of Externalities

Jeanne and Korinek (2010), for example, use a simple three-period model with collateral constraints to show pecuniary externalities.[3] They find that domestic agents do not internalize the external effect of their decisions on the price of collateralized domestic asset in their foreign borrowing limit, which leads to inefficient resource allocation. Bianchi (2011) also finds that pecuniary externalities of capital flows result from the feedback effect between borrowing decisions and financial constraints. The model introduces relative prices between tradable and non-tradable goods. Unlike Jeanne and Korinek (2010), however, non-tradable incomes are pledged as collateral instead of domestic assets.

[3] There are two types of externalities in the literature: pecuniary and aggregate demand externalities. While pecuniary externalities are associated with financial instability, aggregate demand externalities are associated with a friction of a price or wage rigidity based on New Keynesian approach. According to the view of aggregate demand externalities, "prudential interventions [capital controls or capital flow managements] in financial markets become desirable to manage the expansion to reduce the cost of the contraction" (Rebucci and Ma, 2019: 9) as there is a constraint on the optimal use of monetary policy, such as a liquidity trap or a fixed exchange rate in the contractionary phase of the cycle. (See Rebucci and Ma, 2019: 9)

Some further extensions were made to the existing models of externalities. The study by Benigno et al. (2013) incorporates a two sector (tradable and non-tradable) production economy into the model. Bianchi and Mendoza (2018), following Jeanne and Korinek's assumption that domestic assets serve as collateral, analyze pecuniary externalities in a dynamic model with price-dependent collateral constraints. They state that "forward-looking nature of asset prices causes the optimal policy under commitment to be time inconsistent: The regulator promises lower future consumption to prop up current asset prices when the constraint binds, but ex post, keeping this promise is suboptimal" (2018: 630). Jeanne and Korinek (2010b, 2019) also study an infinite discrete time model that confirms pecuniary externalities and the role of taxation on debt. According to these models, the market will be able to determine how to allocate capital once the externalities of international capital flows are well identified and regulated (Erten et al., 2019).

The studies on externalities are often linked to the subject of *overborrowing*. Most theoretical models suggest that overborrowing occurs in normal times, which often triggers a sudden reversal of capital flows in the event of a financial crisis. Thus, an ex-ante (Pigouvian) tax on net capital flows or net foreign borrowing is considered as an optimal policy to prevent such sudden stops. Bianchi (2011) as well as Jeanne and Korinek (2010) observe that externalities can lead to excessive borrowing in general and a tax on debt will bring welfare gains. Bianchi and Mendoza (2018) confirm the benefits of an optimal tax rate on debt by illustrating overborrowing in their dynamic set-up. Jeanne and Korinek (2010b, 2019) also demonstrate pecuniary externalities in their dynamic set-up, stating that externalities "always give rise to over-borrowing" and "a state-dependent Pigouvian tax on borrowing or equivalent quantity regulations may induce borrowers to internalize theses externalities and increase welfare" (2019: 16). Benigno et al. (2013), on the contrary, find that private agents may *underborrow* rather than overborrow in normal times when incorporating production economy into their model subject to a collateral constraint.[4]

Role of Gross Capital Flows

One of the common features of these existing models of externalities is that net capital flows are used instead of gross capital flows (See Jeanne and Korinek, 2010, 2019; Bianchi, 2011; Benigno et al., 2013; Bianchi and Mendoza, 2018). In other words, they do not differentiate gross inflows and outflows. This may be partly because the models focus on the net worth of indebted agents (Jeanne and Sandri, 2020), and the differentiation between gross inflows and outflows could only add to the complexity of the models. Also, the relative size of gross outflows (by domestic investors) compared to gross inflows (by foreigners) was negligible in emerging economies until the 1990s. Thus, the gross outflows of domestic investors were often ignored in literature. However, with further liberalization of capital in the mid-2000s, domestic investors began to play a sizable role in the emerging markets as the volume of their overseas investment increased. The argument for capital controls has intensified accordingly, particularly after the 2008 Global Financial Crisis. As a result, the scope of empirical studies expanded: they began to emphasize the need to differentiate foreigners (i.e., gross inflows) from domestic investors (i.e., gross outflows).

[4] They argue there exists two forces that affect the agent's borrowing decision. The first force comes from pecuniary externalities regardless of existence of production in the model. This ensures the private agent's overborrowing in normal times. The second force, which is the main feature of the model with the two-sector production, comes from the social planner's ability to relax its collateral constraint by increasing the relative price of non-tradable when the constraint binds with the reallocation of labor toward the tradable sector for given total labor supply. This tends to make the social planner increase the borrowing compared to the private agent, indicating the private agent's underborrowing in normal times.

In fact, a growing volume of empirical studies highlight the role of gross inflows and outflows. The study by Forbes and Warnock (2012) paved the way in extending the traditional literature on sudden stops from focusing only on net capital flows movements to differentiating gross capital inflows and outflows. In their study, extreme capital flow movements are classified into four types based on gross flows by foreign and domestic investors: surge, stop, flight, and retrenchment. By doing so, Forbes and Warnock attempt to explain why many countries received abnormally high amounts of net capital flows during the Global Financial Crisis. If the episodes are correctly identified based on gross flows, the puzzling behavior of net flows could be explained as driven more by the behavior of domestic agents—rather than foreigners—who returned their overseas investment home (retrenchment). Broner et al. (2011) observe that gross capitals are not only large but volatile compared to net capital flows. Their study also finds that when foreigners invest in an economy, its domestic agents are more likely to invest abroad and vice versa. A similar point is made by Caballero and Simsek (2020), who state that "empirically, capital outflows are highly correlated with inflows, meaning that local investors come home as foreign investors leave the country" (2020: 2289). This implies net capital flows are often *less* volatile because gross inflows and outflows tend to offset each other.

In the same vein, Davis and van Wincoop (2018) provide empirical evidence that financial globalization has significantly strengthened the correlation between gross capital inflows and outflows in both AMs and EMs. Similarly, according to the IMF (2013), EMs that are found to be relatively resilient against capital flow fluctuations are the ones that were able to offset foreign (gross) capital inflows with resident (gross) outflows. Additional support for this argument comes from Cavallo et al. (2017), who observe that sudden stops can be prevented if domestic investors repatriate some of their foreign investment when foreigners stop lending. These empirical findings shed light on the importance of differentiating gross inflows and outflows to understand and hence draw policy implications.

However, only a couple of very recent theoretical models have attempted to do distinguish gross capital inflow and outflows. Jeanne and Sandri (2020), for example, use a simple three-period model with a focus on the role of foreign reserves by private sector (as opposed to public foreign reserves). In their model, domestic investors still borrow from foreign investors only by issuing domestic bonds. Domestic agents choose the amount of illiquid domestic investment projects and liquid foreign assets. Holding liquid foreign assets in cash implicitly corresponds to increasing gross outflows in their model. Under this set-up, they derive unconventional outcome of underborrowing in normal times. Thus, it is optimal to increase foreign borrowing to accumulate foreign liquidity, which increases the price of domestic bond. Caballero and Simsek (2020) also present a model of gross capital flows where fickle global investors cause surges and retrenchments in capital flows. Interestingly, they introduce two types of domestic agents, banks and distressed sellers, whereas Jeanne and Sandri suppose a representative domestic agent.

The model of the present study shares similar features to the models above, especially Jeanne and Sandri (2020). I also use a simple three-period model under pecuniary externality that includes asset prices in the collateral constraints. However, unlike Jeanne and Sandri (2020) who use a preference shock, I use an endowment shock following the model of Jeanne and Korinek (2010). More importantly, Jeanne and Sandri implicitly assume that a domestic country is receiving funds from a foreign country and domestic agents partly save the fund as liquid cash as private reserves. The present study, however, allows that domestic investors can actively invest abroad. While Jeanne and Sandri's model shows underborrowing that requires a subsidy for borrowing, I derive the typical overborrowing and positive optimal tax rates with my model. Also, the focus of this study is on finding optimal tax rates on gross inflows and outflows, unlike Caballero and Simsek (2020) where the focus is on policy coordination among countries and the policy instruments are simplified to binary options (either allow or ban capital inflows).

3 The Model

3.1 Baseline Model

Set up

As a benchmark, I use Jeanne and Korinek (2010)'s simple three-period model. The model is not only the seminal work in the literature of capital flows but also simple and clear to focus on the implication of incorporating gross capital flows instead of net capital flows. Following their model, I assume a small open economy with identical domestic agents (normalized to one) in a one-good world. The domestic agent borrows from foreign investors in period 0 and makes a repayment in periods 1 and 2. In period 1, the agent's ability to roll over debt may be restricted by a collateral constraint. For example, if the domestic agent borrows too much (overborrow) and high volume of capital inflows moves into the economy in period 0, then the corresponding amount of repayment should be returned to foreigners in periods 1 and 2. An endowment shock in period 1 can tighten the collateral constraint, and if binding, the shock may trigger a sudden reversal of capital flows or a sudden stop.

The domestic agent initially owns one unit of domestic assets, and the price of domestic assets at period t is denoted by P_t. Domestic asset market is assumed to be perfectly competitive but only accessible to the domestic agent. According to Jeanne and Korinek (2010, 2010b), the rationale behind the restriction that foreign investors cannot buy or sell domestic assets is that foreigners "have a strong comparative disadvantage in managing it" (2010: 403). Also, domestic agents "derive benefits from the control rights that ownership provides" (2010b: 6). I make an additional assumption that the domestic agent not only borrows from foreigners, but also invests in foreign asset markets. The resident's overseas investment can be rationalized by, for example, an international asset diversification motive.[5] I assume that the domestic agent does not own any foreign asset at period 0, and the price of foreign asset at period t is denoted by Q_t. Foreign asset market is assumed to be accessible to the domestic agent. This asymmetry can be explained with the modeling of domestic and foreign countries after EMs and AEs, respectively. It is more likely for EM agents to have access to AE asset markets than vice versa due to factors such as different financial openness or institutional development.

An endowment of income *e* is revealed and obtained in period 1. The long-term, two-period investment on domestic projects yields fixed return y that materializes in period 2. Based on Jeanne and Korinek (2010), I assume that only return y, not endowment *e*, can be pledged as collateral on loans from foreigners in period 1. Due to collateral constraint, endowment shock (low realization) of *e* may trigger sudden stops of capital. This utility form enables to fix its period-2 marginal utility of consumption to one. The riskless world interest rate is normalized to zero. The first-best level of consumption must be the same in periods 0 and 1, and therefore given by c* that satisfies equal marginal utility of consumption, $u'(c^*) = 1$. Under these assumptions, the representative

[5] Caballero and Simsek (2020) state in their study that "an extensive literature studies capital flows in frictionless models of international risk sharing (see, e.g., Grubel 1968; Cole and Obstfeld 1991; van Wincoop 1994; Lewis 2000; Coeurdacier and Rey 2013). The main reason for diversification in our paper is different from the reasons highlighted in this literature. In our model, investments abroad provide valuable liquidity to local banks during fire sales" (2020: 2291).

domestic agent maximizes own life time utility subject to the budget constraints in periods 0 to 2 and the collateral constraint in period 1 as follows:

(1) $U = u(c_0) + u(c_1) + c_2$

(2) $c_0 + \gamma_1 Q_0 = d_1^i + (1-\theta_1)P_0$ (where $\gamma_1 Q_0 = d_1^o$)

(3) $c_1 + d_1^i = e + d_2^i + (\theta_1 - \theta_2)P_1 + (\gamma_1 - \gamma_2)Q_1$ (where $\gamma_2 Q_1 = d_2^o$)

(4) $c_2 + d_2^i = \theta_2 y + \gamma_2 Q_2$

(5) $d_2^i \leq \theta_1 P_1 + \gamma_1 Q_1.$

d_t^i is the debt to be repaid at the beginning of period t and this the amount corresponds to gross capital *inflows* in period t-1, so I use the superscript 'i.' Also, d_t^o is the amount of gross capital *outflows* in period t-1 using superscript 'o.' Then, net capital inflows in period t-1 can be defined as $d_1 \left(\equiv d_1^i - d_1^o\right)$. Using net capital flows, the budget constraints are essentially the same as the Jeanne and Korinek's model. θ_t is the quantity of the domestic collateral asset held by the domestic agent at the beginning of period t.[6] According to Jeanne and Korinek, since domestic collateral asset cannot be sold to foreigners, θ_t must be equal to 1 in a symmetric equilibrium where all domestic agents behave in the same way.

Here, I make an additional assumption that γ_t is the quantity of the foreign asset held by the domestic agent at the beginning of period t with price Q_t. Since foreign assets can be sold to domestic agents, there is no restriction that γ_t must be one in a symmetric equilibrium. Also, this foreign asset is purchased by the domestic agent in period t-1 with price Q_{t-1}. Therefore, the amount

[6] According to Jeanne and Korinek, "Domestic agents can buy or sell the domestic asset in a perfectly competitive domestic market, but in a symmetric equilibrium we must have $\theta_1 = 1$" (2010: 404).

of gross capital *outflows*, d_t^o equals $\gamma_t Q_{t-1}$. The domestic agent faces a collateral constraint as in equation (5), the micro-foundation being that the domestic agent can walk away from the agent's own debt when foreigners seize the agent's domestic asset and sell it to another domestic agent in the domestic market with price P_1. I make an additional assumption that the foreign asset held by the domestic agent can also be pledged as collateral. It has the similar micro-foundation: foreigners can seize the foreign asset and sell it to other foreigners in the foreign market with price Q_1.[7]

Competitive Equilibrium (Laissez-faire)

The competitive (laissez-faire) equilibrium is solved using backward induction. A decentralized domestic agent makes decisions in period 0 and 1 by determining the amount of borrowing (gross capital inflows), domestic asset holding, and foreign asset holding (gross capital outflows) for each period. Taking net worth $m_1 (\equiv e - d_1^i + \gamma_1 Q_1 \equiv m_1^i + \gamma_1 Q_1)$ as given[8], the domestic agent solves for the period-1 equilibrium first:

(6) $$V_{ce}(m_1) = \max_{d_2^i, \gamma_2, \theta_2} u(c_1) + c_2 + \lambda_{ce}\left(\theta_1 P_1 + \gamma_1 Q_1 - d_2^i\right), \text{ or}$$

$$V_{ce}(m_1) = \max_{d_2^i, \gamma_2, \theta_2} u\left(e - d_1^i + d_2^i + (\theta_1 - \theta_2)P_1 + (\gamma_1 - \gamma_2)Q_1\right)$$

$$+\theta_2 y + \gamma_2 Q_2 - d_2^i + \lambda_{ce}\left(\theta_1 P_1 + \gamma_1 Q_1 - d_2^i\right)$$

where λ_{ce} is the shadow cost of the collateral constraint. The first-order condition for θ_2 gives asset pricing equation for domestic asset, $P_1 = y/u'(c_1)$. This implies that domestic asset price in

[7] The ability as collateral can be different between domestic and foreign assets. This asymmetry is explained in detail in the extension part.
[8] Note that the value of holding foreign asset is evaluated with current period-1 price of foreign asset, Q_1, not Q_0.

period 1 equals its expected return of domestic asset times the marginal utility of period-2 consumption (equal to 1 from the lifetime utility form) divided by the marginal utility of period-1 consumption. Similarly, the first-order condition for γ_2 provides foreign asset pricing equation, $\mathrm{Q}_1 = \mathrm{Q}_2/u'(c_1)$. This means foreign asset price in period 1 is determined at which expected period-2 price of foreign asset times the marginal utility of period-2 consumption divided by the marginal utility of period-1 consumption.[9] Finally, the first-order condition for d_2^i implies $u'(c_1) = 1 + \lambda_{ce}$. If the equilibrium is unconstrained (i.e., $\lambda_{ce} = 0$), then $c_1 = c^*$ and thus $P_1 = y$ and $\mathrm{Q}_1 = \mathrm{Q}_2$.[10] The focus of this study is on the constrained equilibrium where collateral constraint is binding (i.e., $\lambda_{ce} > 0$). By substituting out $d_2^i = \theta_1 \mathrm{P}_1 + \gamma_1 \mathrm{Q}_1$, the budget constraint in period 1 becomes as follows:

(7) $$c_1 = m_1^i + (2\theta_1 - \theta_2)\mathrm{P}_1 + (2\gamma_1 - \gamma_2)\mathrm{Q}_1 \quad \text{(where } m_1^i \equiv e - d_1^i\text{), or}$$

$$c_1 = m_1 + (2\theta_1 - \theta_2)\mathrm{P}_1 + (\gamma_1 - \gamma_2)\mathrm{Q}_1 \quad \text{(where } m_1 \equiv m_1^i + \gamma_1 \mathrm{Q}_1\text{).}$$

If I assume $\theta_t = 1$ in equilibrium, the equations above can be re-written by substituting domestic and foreign asset pricing equations:

(8) $$c_1 = m_1^i + \frac{y + (2\gamma_1 - \gamma_2)\mathrm{Q}_2}{u'(c_1)} \quad \text{or} \quad c_1 = m_1 + \frac{y + (\gamma_1 - \gamma_2)\mathrm{Q}_2}{u'(c_1)}.$$

[9] Although the domestic country is a small open economy, the domestic agent's overseas investment determines the price of foreign assets in this model, which may not be the case. It is more reasonable to assume that foreign asset price is partially, not solely, affected by domestic investors. To reflect this concern, I can incorporate some exogenous parameters (e.g., EM's share in AE's asset market or financial openness) that restricts the range of γ_t, that weakens the impact on foreign asset price in a future study. Or, I can also incorporate an endogenous premium of foreign asset price into the model. In this setup, if domestic agent increases overseas investment, due to the ensuing high demand, domestic agents will be required to pay a premium although foreign asset price without the premium does not change. ($\tilde{Q} = \bar{Q}$ + premium) This setup can align with the basic premise that a small open economy takes world prices as given and cannot change world prices. While keeping in mind this limitation of the present model, I still assume that foreign asset pricing depends on resident's overseas investment for the sake of simplicity.

[10] According to Jeanne and Korinek (2010), this can happen "if and only if the value of collateral (or net worth) is high enough to cover period-2 debt" (2010: 404).

One point worth noting here is that if I assume that $\gamma_1 = \gamma_2$, i.e., the domestic agent invests in foreign assets and re-invest them all in period 1 (and holds them until period 2), the second equation in (8) presents the same formula in Jeanne and Korinek (2010) as below:

$$(9) \qquad c_1 = m_1^i + \frac{y + \gamma_1 Q_2}{u\prime(c_1)} \qquad \text{or} \qquad c_1 = m_1 + \frac{y}{u\prime(c_1)}.$$

This is consistent with the general notion that the model using gross capital flows will simply be a direct generalization of the model using net capital flows. Yet by focusing on the first equation in (9) using net worth defined as m_1^i ($\equiv e - d_1^i$), which only considers the endowment minus debt repayment in period 1, the results explicitly indicate that foreign asset price also plays a role in a similar way as domestic asset price does in decision making.[11]

Without imposing the additional assumption of $\gamma_1 = \gamma_2$, equation (8) will be used hereafter as a general setup. As c_1 increases, the left-hand-side of the equation (8) increases along the 45-degree line, and the right-hand-side also increases assuming the typical decreasing marginal utility of consumption with $u'(c) > 0$ and $u''(c) < 0$. This is consistent with Jeanne and Korinek (2010). To rule out the multiplicity, I assume that the slope of the right-hand-side is smaller than 1.[12] Then, the left and right sides intersect only once at $c_1 = c^*$. In this set up, a small decrease in endowment *e* in period 1 will tighten a collateral constraint, thus reducing the period-1 consumption level. This means that current marginal utility of consumption in period 1 increases against the next period consumption. This will affect both domestic and foreign asset prices. The domestic agent becomes

[11] This suggests that pecuniary externalities can arise from the impact on foreign asset prices as well as domestic asset prices in the collateral constraint, which is discussed later.

[12] $(y + (2\gamma_1 - \gamma_2)Q_2)\frac{d\left(1/u'(c)\right)}{dc} < 1$. Since $Q_2 > 0$ and $(2\gamma_1 - \gamma_2) > 0$, the slope of the right-hand-side in this study is steeper than that in Jeanne and Korinek (2010)'s model, $y\frac{d\left(1/u'(c)\right)}{dc} < 1$. This implies that the condition in this study is more difficult to satisfy than the benchmark model.

less likely to invest in any assets since the agent highly values current period-1 consumption compared to period-2 consumption. Thus, both asset prices in period 1, $\mathrm{P}_1 = y/u'(c_1)$ and $\mathrm{Q}_1 = \mathrm{Q}_2/u'(c_1)$ will decrease, again leading to the tightening of the collateral constraint. Jeanne and Korinek (2010) explains this as "the general mechanism behind standard models of financial acceleration or (Fisher's) debt deflation" (2010: 404).

In period 0, with anticipating the period-1 equilibrium, the representative domestic agent solves period-0 maximization problem as below:

(10) $$\mathcal{L}_{ce} = \max_{d_1^i, \gamma_1, \theta_1} u(c_0) + E_0 V_{ce}(m_1)$$

$$\text{where } V_{ce}(m_1) = \max_{d_2^i, \gamma_2, \theta_2} u(c_1) + c_2 + \lambda_{ce}\left(\theta_1 \overline{P_1}, + \gamma_1 \overline{\mathrm{Q}_1} - d_2^i\right).$$

One essential feature in the literature of pecuniary externalities is that the decentralized agent takes the asset prices as given. Following this, I also assume that the agent does not internalize the impact of the agent's own borrowing or overseas investment decision in period 0 on asset prices in the collateral constraint in period 1. The first-order condition with respect to d_1^i gives $u'(c_0) = E_0[u'(c_1)]$, and this equation can determine period-0 equilibrium borrowing, d_1^i. Since the left-hand-side decreases and the right-hand-side increases in d_1^i, a unique solution can be derived. The first-order conditions for θ_1 and γ_1 provide asset pricing equations, respectively.[13] As already noted, I assume $\theta_t = 1$ in equilibrium, implying that domestic agents always invest in long-term domestic projects and hold them until period 2.

[13] $\mathrm{P}_0 = E_0[\{2u'(c_1) + \lambda_{ce}\}\overline{\mathrm{P}_1}]/u'(c_0)$, $\mathrm{Q}_0 = E_0[\{2u'(c_1) + \lambda_{ce}\}\overline{\mathrm{Q}_1}]/u'(c_0)$

Social Planner Allocation

A constrained social planner faces the same lifetime utility function and constraints as decentralized domestic agents. The only difference to competitive equilibrium (laissez-faire) is that the social planner internalizes asset pricing equations when making a decision in period 0. That is, the social planner considers the impact of borrowing decisions in period 0 on the asset prices and hence the collateral constraint in period 1. Using backward induction, the social planner chooses the same allocation in period 1 as in laissez-faire. Denoting λ_{sp} as the shadow cost on the collateral constraint for the social planner, the first-order condition for d_2^i in period 1 is similar to that of competitive equilibrium, $u'(c_1) = 1 + \lambda_{sp}$. I can write the same reduced form for period-1 equilibrium consumption and asset prices as increasing functions of net worth, $c(m_1), P(m_1)$ and $Q(m_1)$. Anticipating this period-1 equilibrium, the social planner solves period-0 maximization problem as below:

(11) $$\mathcal{L}_{sp} = \max_{d_1^i, \gamma_1, \theta_1} u(c_0) + E_0 V_{sp}(m_1)$$

$$\text{where } V_{sp}(m_1) = \max_{d_2^i, \gamma_2, \theta_2} u\big(c(m_1)\big) + c_2 + \lambda_{sp}\big(\theta_1 P(m_1) + \gamma_1 Q(m_1) - d_2^i\big)$$

by internalizing $P(m_1) = y/u'(c_1)$ and $Q(m_1) = \mathrm{Q}_2/u'(c_1)$. The first-order condition for d_1^i gives $u'(c_0) = E_0\left[u'(c_1) + \lambda_{sp}\{\theta_1 P'(m_1) + \gamma_1 Q'(m_1)\}\right]$. Since both asset prices increase the function of net worth, m_1 $(P', Q' > 0)$ and the focus is on the equilibrium with binding collateral constraint $(\lambda_{sp} > 0)$, the social planner will make the agents consume less and borrow less in period 0 than under decentralized decision. This means that private agents who do not internalize the impact of their borrowing decision will borrow too much in period 0 (normal times). This confirms the previous findings of overborrowing by using gross capital flows.

Furthermore, the first-order condition for d_1^i determines the social planner's allocation depending on foreign asset price as well as domestic asset price. This means there can be another source of pecuniary externalities. For example, if a decentralized domestic agent borrows one additional unit so that the agent needs to repay in period 1, which pressures to reduce period-1 consumption. Thus, marginal utility of period-1 consumption becomes relatively higher than before so that the domestic agent is not likely to invest in any assets. Hence the decrease in both asset prices. A decline in foreign asset price as well as in domestic asset price will tighten the collateral constraint. Since the decentralized agent does not consider these external effects on any asset price, pecuniary externalities arise from both domestic and foreign asset prices in the collateral constraint of the present model.

Pigouvian Tax on Gross Capital Inflows (Borrowing)

Externalities can be corrected by Pigouvian taxation on borrowing, as widely suggested by the models that use net flows. I first focus on taxation on borrowing in comparison with the benchmark model, and then consider tax-cum-subsidy on overseas investment. The optimal level of borrowing (gross inflows) can be implemented in a decentralized economy with a tax rate τ_1^i on period-0 borrowing d_1^i and the tax is rebated in a lump-sum fashion. Recall that d_1^i is the debt to be repaid at the beginning of period t and this amount corresponds to gross inflows in period t-1. I assume that the tax is levied when gross inflows move into the domestic economy in period 0 and reduce the amount of borrowing at hand for the domestic agent. The timing of taxation implies an *ex-ante* policy in normal times. The budget constraints in period 0 and 1 are now modified as follows:

(12) $$c_0 + \gamma_1 \mathrm{Q}_0 = (1 - \tau_1^i) d_1^i + (1 - \theta_1) \mathrm{P}_0,$$

(13) $$c_1 + d_1^i = e + d_2^i + (\theta_1 - \theta_2)\mathrm{P}_1 + (\gamma_1 - \gamma_2)\mathrm{Q}_1 + Transfer.$$

Anticipating the same period-1 equilibrium, the representative domestic agent under the Pigouvian tax solves period-0 maximization problem again in period 0:

(14) $$\mathcal{L}_{ce} = \max_{d_1^i, \gamma_1, \theta_1} u\big((1-\tau_1^i)d_1^i + (1-\theta_1)\mathrm{P}_0 - \gamma_1 \mathrm{Q}_0\big) + E_0 V_{ce}(m_1)$$

$$\text{where } V_{ce}(m_1) = \max_{d_2^i, \gamma_2, \theta_2} u(c_1) + c_2 + \lambda_{ce}\big(\theta_1 \overline{P_1} + \gamma_1 \overline{\mathrm{Q}_1} - d_2^i\big).$$

The first-order condition with respect to d_1^i gives $u'(c_0) = E_0[u'(c_1)]/(1-\tau_1^i)$. The optimal tax rate can be obtained by equating two first-order conditions for d_1^i under laissez-faire and social planner's allocation: $u'(c_0) = E_0[u'(c_1)]/(1-\tau_1^i) = E_0\big[u'(c_1) + \lambda_{sp}\{\theta_1 P'(m_1) + \gamma_1 Q'(m_1)\}\big]$. This yields optimal tax rate on borrowing as follows:

(15) $$\tau_1^{i,*} = \frac{E_0\big[\lambda_{sp}\{\theta_1 P'(m_1) + \gamma_1 Q'(m_1)\}\big]}{E_0\big[u'(c_1) + \lambda_{sp}\{\theta_1 P'(m_1) + \gamma_1 Q'(m_1)\}\big]}.$$

If I do not consider foreign assets in the model (i.e., $\gamma_1 Q'(m_1) = 0$), the optimal tax rate in equation (15) is basically consistent with the optimal tax rate in Jeanne and Korinek (2010).[14]

I use a numerical illustration in order to compare the results between this study and Jeanne and Korinek (2010). I follow the same set-up as their study by using log utility form and uniformly distributed endowment shocks on $[\bar{e} - \varepsilon, \bar{e} + \varepsilon]$ and the same parameter values ($\bar{e} = 1.3$, $y = 0.8$), but I additionally estimate γ_1 (=0.04) and assume that $\gamma_1 = \gamma_2$ and $\mathrm{Q}_2 = \mathrm{Q}_0 = y$ for simplicity.[15] With the latter assumption on Q_2, I eliminate the search-for-yield motives of domestic agents. I

[14] According to Jeanne and Korinek (2010), $\tau = \frac{E_0[\lambda_{sp} P'(m_1)]}{E_0[u'(c_1)]}$ where $1 + \tau \equiv \frac{1}{1-\tau^i}$. Hence, $\tau^{i,*} = \frac{E_0[\lambda_{sp} P'(m_1)]}{E_0[u'(c_1) + \lambda_{sp} P'(m_1)]}$.

[15] See the Appendix B for the numerical illustration in detail.

find that given the same endowment shocks with 10% maximum deviation ($\varepsilon \cong 0.13$) from the mean, $\bar{e}$, optimal tax rate on borrowing (gross inflows) is around 2.1%. When I restrict $\gamma_1 = 0$ to exclude the foreign asset channel, the optimal tax rate is only 1.3%, which is the same as Jeanne and Korinek (2010). This shows that when considering gross outflows, the optimal tax rate on gross inflows should be (0.8%p or 57%) higher due to larger externalities or unintended side effects of borrowing via the foreign asset price channel.

Tax-cum-Subsidy on Gross Capital Outflows (Overseas Investment)

In addition to a tax on gross capital inflows (borrowing), one might consider a tax (or subsidy) on gross capital outflows.[16] I assume that a tax is levied when gross outflows move to foreign asset market in period 0 and increase the amount of expenditure on overseas investment for the domestic agent from $\gamma_1 Q_0$ to $(1+\tau_1^o)\gamma_1 Q_0$.[17] Since domestic tax authority imposes this tax on the domestic investor, the actual amount of gross capital outflows is still measured by the quantity purchased by the domestic agent times foreign asset price, $\gamma_1 Q_0$. Thus, a tax rate τ_1^o on period-0 overseas investment $d_1^o (= \gamma_1 Q_0)$ can be included in the budget constraints with the tax on borrowing and adjusted lump-sum transfer in periods 0 and 1 as follows:

(16) $$c_0 + (1+\boldsymbol{\tau_1^o})\gamma_1 Q_0 = (1-\boldsymbol{\tau_1^i})d_1^i + (1-\theta_1)P_0,$$

(17) $$c_1 + d_1^i = e + d_2^i + (\theta_1 - \theta_2)P_1 + (\gamma_1 - \gamma_2)Q_1 + Transfer'.$$

[16] Domestic countries do have policy tools to control its domestic residents' overseas investment. Those regulations that deter the overseas investment can be replaced with tax on gross capital outflows, and on the contrary, policy encouragements can be modeled as subsidy (negative tax).
[17] I can also extend the study by considering the timing of taxation on gross outflows. Since domestic tax authorities can impose tax on domestic residents' earnings from foreign asset market when returned, period 1 (ex-post) taxation can be more natural way to tax on gross outflows. Moreover, since foreign asset prices in period 0 and 1 are different, timing of taxation on gross outflows can be an important issue in investment decision.

In period 0, the representative domestic agent solves period-0 maximization problem below:

(18) $$\mathcal{L}_{ce} = \max_{d_1^i, \gamma_1, \theta_1} u\left((1-\boldsymbol{\tau_1^i})d_1^i + (1-\theta_1)P_0 - (1+\boldsymbol{\tau_1^o})\gamma_1 Q_0\right) + E_0 V_{ce}(m_1)$$

$$\text{where } V_{ce}(m_1) = \max_{d_2^i, \gamma_2, \theta_2} u(c_1) + c_2 + \lambda_{ce}\left(\theta_1 \overline{P_1}, +\gamma_1 \overline{Q_1} - d_2^i\right).$$

The first-order condition with respect to d_1^i gives $u'(c_0) = E_0[u'(c_1)]/(1-\tau_1^i)$, which does not depend on τ_1^o. Thus, tax (> 0) on gross outflows does not affect gross inflows in this setup, while it reduces gross outflows.[18] A decrease in gross outflows leads to lower net worth in period 1, which may trigger the downward spiral through collateral constraint. On the contrary, a negative tax, i.e., a subsidy, can work in the opposite direction by raising net worth in period 1. As a result, it can be inferred that the subsidy on gross outflows together with the tax on gross inflows can effectively correct pecuniary externalities. Also, policy implications can be drawn: a country can operate two separate measures of capital flow managements on gross inflows and outflows.

This type of policy intervention, which raises net worth in period 1, is also considered in previous literature. For example, Jeanne and Korinek (2010) discuss bailouts. They note that bailouts during a crisis are "another common policy instruments that aim to loosen binding constraints by directly transferring resources to constrained agents" (2010: 406). Also, bailouts have two important limitations: lack of resources for bailouts and moral hazard concerns (when bailouts are anticipated, agents increase borrowing). Unlike bailouts during a crisis, an ex-ante

[18] Foreign asset price in period 0 is affected by the tax on outflows: $Q_0 = E_0\left[\left\{2u'(c_1) + \lambda_{lf}\right\}\overline{Q_1}\right]/(1+\tau_1^o)u'(c_0)$. For example, increasing a tax rate (> 0) on outflows implies reducing foreign asset price in period 0. Therefore, even if I restrict that γ_1 is fixed, the actual amount of gross capital outflows, $\gamma_1 Q_0$, decreases accordingly, while after-tax expenditure on overseas investment, $(1+\tau_1^o)\gamma_1 Q_0$, remains the same as before.

subsidy on gross outflows in normal times can work in a similar way without raising the moral hazard problem.[19]

This study is also closely related to the recent study by Jeanne and Sandri (2020), which use gross flows in their modeling. Although the present study shares common features with their model under the three-period model with collateral constraints, there are also differences in the setup including different shocks (endowment versus preference shock). More importantly, while foreign assets are considered as private foreign reserves in Jeanne and Sandri's model, I regard foreign assets as active overseas investment. Jeanne and Sandri believe that accumulation of private reserves can help raise domestic asset prices that loose collateral constraint in a crisis. In other words, the decentralized private agents only accumulate little foreign assets as they do not internalize the positive external benefits of reserves. Also, in Jeanne and Sandri's study, the overall size of borrowing should be increased to accumulate more private foreign reserves. Thus, due to the positive externalities of private reserves, ironically, private agents underborrow during normal times, which is contrary to the conventional wisdom. Unlike their model, the present study confirms overborrowing results in normal times, while positive externalities from residents' overseas investment partially offset negative externalities from borrowing.[20]

[19] The concern over resources for subsidy remains. However, by using Pigouvian taxation on gross inflows together, it can alleviate this issue. This may raise distributional issue between borrowers (tax payers) and investors (subsidy recipient), which is not the case in this model with one representative identical domestic agent.

[20] According to their model, public foreign reserves can also work to correct positive externalities. Public foreign reserves as well as currency swaps can complement or substitute the subsidy on overseas investment by relaxing collateral constraints in a crisis.

3.2 Extension: Asymmetry of Collateralizability

The baseline model assumes that both domestic and foreign assets can serve as collateral. It is also implicitly assumed that their role as collateral is basically the same as long as they have the same market value. In reality, one type of assets can possess hidden perks compared to another type of asset. For instance, suppose that a country holds two types of foreign assets that have the same market value: one is export proceeds payable under specific sales contract, and the other is US Treasury Bill. Even if the assets have the same market value, their actual value as collateral can differ. Foreign creditors would prefer the US Treasury Bill since it is safe and highly tradable, and hence easily seized and sold in case of default. Thus, it can be viewed that this type of foreign assets can have better ability as collateral (collateralizability or pledgeability) than other types of foreign assets. Similarly, domestic assets can also have different collateralizabilities by type. This indicates, in general, there can be an asymmetry in the "relative" ability of domestic and foreign assets as collateral in the baseline model.

As an extension of the baseline model, I consider this asymmetry of ability as collateral between domestic and foreign assets. Since this study use both gross inflows and outflows unlike previous models using only net flows, the asymmetry can be explicitly incorporated into the model. Specifically, I add parameters κ^d and κ^f as coefficients of domestic and foreign collateral assets in the collateral constraint, which reflect the ability as collateral. Thus, the collateral constraint (5) becomes as follows:

(19) $$d_2^i \leq \kappa^d \theta_1 P_1 + \kappa^f \gamma_1 Q_1.$$

To note, I restrict that $\kappa^d = \kappa^f (\equiv \tilde{\kappa})$, then the constraint becomes $d_2^i \leq \tilde{\kappa}(\theta_1 P_1 + \gamma_1 Q_1)$, which shows partial pledgeability of both domestic and foreign collateral assets. The fact that assets can only partially serve as collateral can be also found in the previous studies. (Benigno et al., 2013, Fornaro, 2015; Jeanne and Sandri, 2020). By allowing the difference between κ^d and κ^f, this extension can generalize the existing models to the case of asymmetry of collateralizability between domestic and foreign assets.[21] Without the loss of generality, by normalizing κ^d to be one, κ^f ($\equiv \kappa$) alone captures the degree of asymmetry. Then, the collateral constraint (19) becomes

(20) $$d_2^i \leq \theta_1 P_1 + \kappa \gamma_1 Q_1$$

where κ is assume to be greater than 0. $\kappa = 1$ (i.e., no asymmetry) provides the same collateral constraint in the baseline model. If κ is less than 1, foreign assets are worth less to foreign creditors as collateral compared to domestic assets (e.g., export proceeds payable under the sales contract). If κ is larger than 1, foreign assets are worth more to foreign creditors as collateral compared to domestic assets (e.g., US Treasury Bill). In the meantime, the formulas for budget constraints remain the same. This is because I assume that κ can change the ability as collateral only, thus it does not change the formulas for expenditure on foreign asset in period 0, $\gamma_1 Q_0$, nor retrenchment value of foreign asset in period 1, $\gamma_1 Q_1$.[22]

With the new collateral constraint, the results are slightly affected. In period 1, the competitive equilibrium is determined based on the equation as follows:[23]

(21) $$c_1 = m_1^i + \frac{y + ((1+\boldsymbol{\kappa})\gamma_1 - \gamma_2)Q_2}{u\prime(c_1)} \quad \text{or} \quad c_1 = m_1 + \frac{y + (\boldsymbol{\kappa}\gamma_1 - \gamma_2)Q_2}{u\prime(c_1)}.$$

The slope of right-hand-side of equation (21) is positively related to the size of κ. For example, when κ is greater than 1, constrained equilibrium level of period-1 consumption increases.

[21] Bianchi (2011) also includes separate fraction parameters κ^T and κ^N in the collateral constraint for tradable and non-tradable incomes respectively.
[22] This setup causes that net worth, $m_1 (\equiv e - d_1^i + \gamma_1 Q_1 \equiv m_1^i + \gamma_1 Q_1)$ in period 1 does not depend on the size of κ.
[23] The derivation is provided in the Appendix A.

Intuitively, when foreign assets gain better ability as collateral, this can loosen the collateral constraint in period 1 so that consumption can be increased.

In period 0, the first-order condition with respect to d_1^i gives $u'(c_0) = E_0[u'(c_1)]$ where $c_0 = d_1^i + (1 - \theta_1)P_0 - \gamma_1 Q_0$ and $c_1 = (e - d_1^i) + (2\theta_1 - \theta_2)P_1 + \big((1+\kappa)\gamma_1 - \gamma_2\big)Q_1$. Based on Jeanne and Korinek's model (2010), the equilibrium level of borrowing can be uniquely determined since both sides of the condition is decreasing in d_1^i. The borrowing increases with larger κ.[24] This can be interpreted that the anticipation of a loose collateral constraint in period 1 makes the domestic agent borrow more in period 0.

The social planner, who internalizes the impact of borrowing on asset prices in the collateral constraints, will decide the optimal level of borrowing using following first-order condition for d_1^i: $u'(c_0) = E_0\big[u'(c_1) + \lambda_{sp}\{\theta_1 P'(m_1) + \kappa\gamma_1 Q'(m_1)\}\big]$. Focusing on constrained equilibrium with binding collateral constraint ($\lambda_{sp} > 0$), it can be inferred that in the case of large κ (> 1), the social planner will make the agents consume and borrow even less in period 0 than laissez-faire decision in Jeanne and Korinek's model (2010). This suggest that external effects can be intensified, requiring the social planner to impose higher Pigouvian tax on borrowing. That is, optimal tax rate on borrowing ($\tau_1^{i,*}$) should be an increasing function of κ, and this can be confirmed in the formula for optimal tax rates as below and generalizes the baseline model.[25]

(22) $$\tau_1^{i,*} = \frac{E_0\big[\lambda_{sp}\{\theta_1 P\prime(m_1) + \boldsymbol{\kappa}\gamma_1 Q\prime(m_1)\}\big]}{E_0\big[u\prime(c_1) + \lambda_{sp}\{\theta_1 P\prime(m_1) + \boldsymbol{\kappa}\gamma_1 Q\prime(m_1)\}\big]}.$$

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[24] The optimal level of d_1^i satisfies the condition: $u'\big(d_1^i + (1-\theta_1)P_0 - \gamma_1 Q_0\big) = E_0\big[u'\big((e - d_1^i) + (2\theta_1 - \theta_2)P_1 + \big((1+\kappa)\gamma_1 - \gamma_2\big)Q_1\big)\big]$. Thus, κ is positively related to d_1^i.

[25] In case of κ=1 (no asymmetry) and γ_1=0 (no overseas investment), $\tau^{i,*} = \frac{E_0[\lambda_{sp}P\prime(m_1)]}{E_0[u\prime(c_1) + \lambda_{sp}P\prime(m_1)]}$.

4 Conclusion

This paper has attempted to incorporate the growing importance of gross capital flows into theoretical modeling by differentiating gross capital inflows (borrowing from foreigners) from gross outflows (overseas investment in foreign assets). In this view, I extend the model of Jeanne and Korinek (2010) to find separate optimal tax rates on gross capital inflows and outflows. The main feature of my model is that the representative domestic agent not only borrows from the foreign investor but also actively invests in foreign assets.

The results replicate and generalize the results of the benchmark model. The decentralized agent does not internalize the external impact of the agent's own borrowing and investment decisions in normal times. As a result, the agent tends to overborrow in normal times as noted by Jeanne and Korinek (2010). Also, in a case where the social planner only manages gross flows by imposing a tax, the optimal tax rate on gross inflows is found to be approximately 2.1%. This is 0.8%p or 57% higher than the optimal rate (1.3%) in the benchmark model, which does not include foreign assets. Therefore, the difference is due to greater unintended side effects of borrowing through the channel of foreign asset prices. The findings of this study indicate that externalities can be corrected with Pigouvian tax on borrowing as well as Pigouvian subsidy on overseas investment. This can provide new policy insights into capital flow management, especially for countries that use one-sided capital flow management as well as countries that want to find an optimal policy mix to manage gross inflows and outflows.

The challenge for future research will be to extend the present model in a finite horizon (three periods) to an infinite horizon that may enable a generalization of the results. This would not only help elaborate the welfare comparison under diverse policy regimes, but also explain the distributional effect of tax-cum-subsidy on capital flows. By incorporating idiosyncratic shocks on endowment income, we can examine whether capital flow management can improve wealth distribution using various inequality indices. It is also possible to extend the present model by incorporating exchange rates. This would help explain an additional source of financial amplification and obtain a better understanding of the channel, providing further insights into financial crises and the policies that can help prevent them.

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Appendix A: Derivation with Asymmetry Parameter

Budget Constraints and Collateral Constraint

(A.1) $c_0 + \gamma_1 Q_0 = d_1^i + (1 - \theta_1)P_0$ (where $\gamma_1 Q_0 = d_1^o$)

(A.2) $c_1 + d_1^i = e + d_2^i + (\theta_1 - \theta_2)P_1 + (\gamma_1 - \gamma_2)Q_1$ (where $\gamma_2 Q_1 = d_2^o$)

(A.3) $c_2 + d_2^i = \theta_2 y + \gamma_2 Q_2$

(A.4) $d_2^i \leq \theta_1 P_1 + \boldsymbol{\kappa}\gamma_1 Q_1$

Competitive Equilibrium (Laissez-faire)

Taking net worth $m_1(\equiv e - d_1^i + \gamma_1 Q_1 \equiv m_1^i + \gamma_1 Q_1)$ as given, the domestic agent solves for the period-1 equilibrium first:

(A.5) $V_{ce}(m_1) = \max_{d_2^i, \gamma_2, \theta_2} u(c_1) + c_2 + \lambda_{ce}\left(\theta_1 P_1 + \boldsymbol{\kappa}\gamma_1 Q_1 - d_2^i\right)$, or

$$V_{ce}(m_1) = \max_{d_2^i, \gamma_2, \theta_2} u\left(e - d_1^i + d_2^i + (\theta_1 - \theta_2)P_1 + (\gamma_1 - \gamma_2)Q_1\right)$$

$$+\theta_2 y + \gamma_2 Q_2 - d_2^i + \lambda_{ce}\left(\theta_1 P_1 + \boldsymbol{\kappa}\gamma_1 Q_1 - d_2^i\right).$$

By substituting $d_2^i = \theta_1 P_1 + \boldsymbol{\kappa}\gamma_1 Q_1$, the budget constraint in period 1 becomes as follows:

(A.6) $c_1 = m_1^i + \theta_1 P_1 + \boldsymbol{\kappa}\gamma_1 Q_1 + (\theta_1 - \theta_2)P_1 + (\gamma_1 - \gamma_2)Q_1$ (where $\gamma_2 Q_1 = d_2^o$),

$c_1 = m_1^i + (2\theta_1 - \theta_2)P_1 + ((1 + \boldsymbol{\kappa})\gamma_1 - \gamma_2)Q_1$ (where $m_1^i \equiv e - d_1^i$), or

$c_1 = m_1 + (2\theta_1 - \theta_2)P_1 + (\boldsymbol{\kappa}\gamma_1 - \gamma_2)Q_1$ (where $m_1 \equiv m_1^i + \gamma_1 Q_1$).

If I assume $\theta_t = 1$ in equilibrium, the equations above can be re-written by substituting domestic and foreign asset pricing equations:

(A.7) $c_1 = m_1^i + \frac{y + ((1+\boldsymbol{\kappa})\gamma_1 - \gamma_2)Q_2}{u'(c_1)}$ or $c_1 = m_1 + \frac{y + (\boldsymbol{\kappa}\gamma_1 - \gamma_2)Q_2}{u'(c_1)}$.

One thing to note here is that if I assume that $\boldsymbol{\kappa}\gamma_1 = \gamma_2$, the second equation in (A.7) presents the same formula as Jeanne and Korinek (2010)'s study as below:

(A.8) $c_1 = m_1^i + \frac{y+\gamma_1 Q_2}{u\prime(c_1)}$ or $c_1 = m_1 + \frac{y}{u\prime(c_1)}$.

In period 0, with anticipating the period-1 equilibrium, the representative domestic agent solves period-0 maximization problem as below:

(A.9) $\mathcal{L}_{ce} = \max_{d_1^i, \gamma_1, \theta_1} u(c_0) + E_0 V_{ce}(m_1)$

where $V_{ce}(m_1) = \max_{d_2^i, \gamma_2, \theta_2} u(c_1) + c_2 + \lambda_{lf}\left(\theta_1 \overline{P}_1, + \boldsymbol{\kappa}\gamma_1 \overline{Q_1} - d_2^i\right)$,

$$\mathcal{L}_{ce} = \max_{d_1^i, \gamma_1 \theta_1} u\left(d_1^i + (1-\theta_1)P_0 - \gamma_1 Q_0\right)$$

$$+E_0\left[u(c_1) + \theta_2 y + \gamma_2 Q_2 - d_2^i + \lambda_{ce}\left(\theta_1 \overline{P_1} + \boldsymbol{\kappa}\gamma_1 \overline{Q_1} - d_2^i\right)\right]$$

where $c_1 = m_1^i + (2\theta_1 - \theta_2)\overline{P_1} + ((1+\boldsymbol{\kappa})\gamma_1 - \gamma_2)\overline{Q_1}$ (where $m_1^i \equiv e - d_1^i$), or

$c_1 = m_1 + (2\theta_1 - \theta_2)\overline{P_1} + (\boldsymbol{\kappa}\gamma_1 - \gamma_2)\overline{Q_1}$ (where $m_1 \equiv m_1^i + \gamma_1 Q_1$).

The first-order condition with respect to d_1^i gives $u'(c_0) = E_0[u'(c_1)]$, and this equation can determine period-0 equilibrium borrowing, d_1^i. Since the left-hand-side decreases and the right-hand-side increases in d_1^i, a unique solution can be derived. The first-order conditions for θ_1 and γ_1 provide asset pricing equations, respectively.[26]

Social Planner Allocation and Pigouvian Tax

I can write the same reduced form for period-1 equilibrium consumption and asset prices as increasing functions of net worth, $c(m_1), P(m_1)$ and $Q(m_1)$.[27] Anticipating this period-1 equilibrium, the social planner solves period-0 maximization problem as below:

(A.10) $\mathcal{L}_{sp} = \max_{d_1^i, \gamma_1, \theta_1} u(c_0) + E_0 V_{sp}(m_1)$

where $V_{sp}(m_1) = \max_{d_2^i, \gamma_2, \theta_2} u\left(c(m_1)\right) + c_2 + \lambda_{sp}\left(\theta_1 P(m_1) + \boldsymbol{\kappa}\gamma_1 Q(m_1) - d_2^i\right)$,

$P(m_1) = y/u'(c_1)$, and $Q(m_1) = Q_2/u'(c_1)$, $c_1 = c(m_1)$.

[26] $P_0 = E_0\left[\left\{(2u'(c_1) + \lambda_{lf}\right\}\overline{P_1}\right]/u'(c_0)$, $Q_0 = E_0\left[\left\{(1+\boldsymbol{\kappa})u'(c_1) + \boldsymbol{\kappa}\lambda_{lf}\right\}\overline{Q_1}\right]/u'(c_0)$

[27] Note that net worth $m_1(\equiv e - d_1^i + \gamma_1 Q_1 \equiv m_1^i + \gamma_1 Q_1)$ in period 1 does not depend on the size of κ.

Note that first derivatives with respect to d_1^i are $-P'(m_1)$, $-Q'(m_1)$, and $-c'(m_1)$.

(A.10')

$$\mathcal{L}_{sp} = \max_{d_1^i,\gamma_1\theta_1} u\big(d_1^i + (1-\theta_1)\mathrm{P}_0 - \gamma_1\mathrm{Q}_0\big)$$

$$+E_0\left[u\big(c(m_1)\big) + \theta_2 y + \gamma_2\mathrm{Q}_2 - d_2^i + \lambda_{sp}\left(\frac{\theta_1 y + \boldsymbol{\kappa}\gamma_1\mathrm{Q}_2}{u'(c_1)} - d_2^i\right)\right]$$

where $c_1 = m_1^i + (2\theta_1 - \theta_2)\overline{\mathrm{P}_1} + ((1+\boldsymbol{\kappa})\gamma_1 - \gamma_2)\overline{\mathrm{Q}_1}$ (where $m_1^i \equiv e - d_1^i$), or

$$c_1 = m_1 + (2\theta_1 - \theta_2)\overline{\mathrm{P}_1} + (\boldsymbol{\kappa}\gamma_1 - \gamma_2)\overline{\mathrm{Q}_1} \text{ (where } m_1 \equiv m_1^i + \gamma_1\mathrm{Q}_1)$$

by internalizing $P(m_1) = y/u'(c_1)$ and $Q(m_1) = \mathrm{Q}_2/u'(c_1)$. The first-order condition for d_1^i gives $u'(c_0) = E_0\big[u'(c_1) + \lambda_{sp}\{\theta_1 P'(m_1) + \boldsymbol{\kappa}\gamma_1 Q'(m_1)\}\big]$.

Social planner, who internalizes the impact of borrowing on asset prices in the collateral constraints, will decide the optimal level of borrowing using following first-order condition for d_1^i: $u'(c_0) = E_0\big[u'(c_1) + \lambda_{sp}\{\theta_1 P'(m_1) + \boldsymbol{\kappa}\gamma_1 Q'(m_1)\}\big]$. Focusing on a constrained equilibrium with binding collateral constraint ($\lambda_{sp} > 0$), it can be inferred that in the case of large κ (> 1), the social planner will make the agents consume and borrow *even less* in period 0 than laissez-faire decision in the benchmark model (κ = 1).

The externalities can be corrected by Pigouvian taxation on borrowing. The optimal level of borrowing (gross capital inflows) can be implemented in a decentralized economy with a tax rate τ_1^i on period-0 borrowing d_1^i and the tax is rebated in a lump-sum fashion. The budget constraints in period 0 and 1 are now modified as follows:

(A.11) $$c_0 + \gamma_1\mathrm{Q}_0 = (1-\tau_1^i)d_1^i + (1-\theta_1)\mathrm{P}_0$$

(A.12) $$c_1 + d_1^i = e + d_2^i + (\theta_1 - \theta_2)\mathrm{P}_1 + (\gamma_1 - \gamma_2)\mathrm{Q}_1 + Transfer.$$

Anticipating the same period-1 equilibrium (since then the lump-sum transfer does not change the results), the representative domestic agent under the Pigouvian tax solves period-0 maximization problem again in period 0:

(A.13) $$\mathcal{L}_{ce} = \max_{d_1^i,\gamma_1,\theta_1} u\big((1-\tau_1^i)d_1^i + (1-\theta_1)\mathrm{P}_0 - \gamma_1\mathrm{Q}_0\big) + E_0 V_{ce}(m_1)$$

where $V_{ce}(m_1) = \max_{d_2^i,\gamma_2,\theta_2} u(c_1) + c_2 + \lambda_{ce}\big(\theta_1\overline{P_1}, +\boldsymbol{\kappa}\gamma_1\overline{\mathrm{Q}_1} - d_2^i\big).$

The first-order condition with respect to d_1^i gives $u'(c_0) = E_0[u'(c_1)]/(1-\tau_1^i)$. The optimal tax rate can be obtained by equating two first-order conditions for d_1^i under laissez-faire (with tax) and social planner's allocation: $u'(c_0) = E_0[u'(c_1)]/(1-\tau_1^i) = E_0\left[u'(c_1) + \lambda_{sp}\{\theta_1 P'(m_1) + \boldsymbol{\kappa}\gamma_1 Q'(m_1)\}\right]$. This yields optimal tax rate as:

(A.14) $$\tau_1^{i,*} = \frac{E_0\left[\lambda_{sp}\{\theta_1 P\prime(m_1)+\boldsymbol{\kappa}\gamma_1 Q\prime(m_1)\}\right]}{E_0\left[u\prime(c_1)+\lambda_{sp}\{\theta_1 P\prime(m_1)+\boldsymbol{\kappa}\gamma_1 Q\prime(m_1)\}\right]}.$$

The results are also consistent with the model of Jeanne and Korinek (2010).

Appendix B: Numerical Illustration

I basically follow the methodology and parameter values by Jeanne and Korinek (2010) in order to compare the results with their study that use net flows.

Assumptions

I use log utility functions for period 0 and 1, so that lifetime utility of representative agents in equation (1) becomes: U = $\log(c_0) + \log(c_1) + c_2$. Endowment shock in period 1 is assumed to be uniformly distributed in $[\bar{e}-\varepsilon, \bar{e}+\varepsilon]$. I assume $\theta_t = 1$ and $\gamma_1 = \gamma_2$ in equilibrium. The domestic agent holds its endowed domestic asset until period 2. Also, the domestic agent invests in foreign assets and re-invest them all in period 1 (and holds them until period 2).

Equation (9), $c_1 = m_1^i + \frac{y+\gamma_1 Q_2}{u\prime(c_1)}$, has a solution $c_1 \geq 0$ if and only if $m_1^i = e - d_1^i \geq 0$. For the lowest realization of e (= $\bar{e}-\varepsilon$), the inequality should also hold. This implies the condition that $\varepsilon < \bar{e} - d_1^i$. To ensure the uniqueness of equilibrium, the following condition should hold: $(y + (2\gamma_1 - \gamma_2)Q_2)\frac{d(1/u'(c))}{dc} = y + \gamma_1 Q_2 < 1$.[28] By defining $m_1^{i*}(\equiv 1 - y - \gamma_1 Q_2) > 0$, the equilibrium level of consumption is as follows: $c_1 = \min\left(\frac{m_1^i}{m_1^{i*}}, c^*\right)$. Domestic asset pricing equation ($P_1 = y/u'(c_1)$) implies that $P_1 = yc_1 = y * \min\left(\frac{m_1^i}{m_1^{i*}}, 1\right)$.

I focus on the situation where the economy is constrained with a non-zero probability. If $\bar{e} < 1 + m_1^{i*} + \gamma_1 Q_0 + \varepsilon$, then there is a positive probability that the collateral constraint binds in period 1. The constraint binds if and only if $m_1^i < m_1^{i*}$, or equivalently, $e < m_1^{i*} + d_1^i$. As a result, the calibrations of parameters should satisfy the condition (B.1) so that the economy will not be constrained without uncertainty ($\varepsilon = 0$), but may be constrained for significantly large endowment shocks.

(B.1) $$1 + m_1^{i*} + \gamma_1 Q_0 < \bar{e} < 1 + m_1^{i*} + \gamma_1 Q_0 + \varepsilon$$

[28] see footnote 12

Competitive Equilibrium

Suppose that the economy is constrained in period 1 with a positive probability. The first-order condition, $u'(c_0) = E_0[u'(c_1)]$, can determine period-0 equilibrium level of borrowing, d_1^i. This level, denoted as $d_1^{i,ce}$, can be solved with using the uniform distribution of endowment shocks.

(B.2) $$LHS = u'(c_0) = \frac{1}{c_0} = \frac{1}{d_1^i - \gamma_1 Q_0}$$

$$RHS = E_0[u'(c_1)] = E_0\left[\frac{1}{c_1}\right] = E_0\left[\frac{1}{\min\left(\frac{m_1^i}{m_1^{i*}}, 1\right)}\right] = E_0\left[\frac{1}{\min\left(\frac{e - d_1^i}{m_1^{i*}}, 1\right)}\right]$$

$$= \frac{1}{2\varepsilon}\int_{\bar{e}-\varepsilon}^{m_1^{i*}+d_1^i} \frac{m_1^{i*}}{e - d_1^i}\, de + \frac{1}{2\varepsilon}\int_{m_1^{i*}+d_1^i}^{\bar{e}+\varepsilon} 1\, de$$

$$= \frac{1}{2\varepsilon}\left[m_1^{i*}\log\left(\frac{m_1^{i*}}{\bar{e} - \varepsilon - d_1^i}\right) + \bar{e} + \varepsilon - m_1^{i*} - d_1^i\right]$$

Since $c_1 < 1$ in the constrained region and $c_1 = 1$ in the unconstrained region, $E_0[u'(c_1)] > 1$ with a log utility form (and this is same for strictly concave utility form). This implies $d_1^i < 1 + \gamma_1 Q_0$. Also, $d_1^i > \bar{e} - \varepsilon - m_1^{i*}$ from the assumption that the economy is constrained with a non-zero probability. In the range of $[\bar{e} - \varepsilon - m_1^{i*}, 1 + \gamma_1 Q_0]$, LHS is strictly decreasing and RHS is strictly increasing with d_1^i. ($\frac{\partial RHS}{\partial d_1^i} = \frac{1}{2\varepsilon}\left[\frac{m_1^{i*}}{\bar{e}-\varepsilon-d_1^i} - 1\right]$) This means there is a unique solution d_1^i in this range. The solution can be numerically solved given the parameters m_1^{i*}, $\bar{e}$, ε, and $\gamma_1 Q_0$.

Social Planner Allocation and Pigouvian Tax

From the optimality condition, $u'(c_1) = 1 + \lambda_{ce}$, this can be shown that $\lambda_{ce} = \frac{1}{c_1} - 1 = \left(\frac{m_1^{i*}}{m_1^i} - 1\right)^+$. From the asset pricing equations for domestic and foreign assets, $P(m_1) = y * \min\left(\frac{m_1^i}{m_1^{i*}}, 1\right)$ and $Q(m_1) = Q_2 * \min\left(\frac{m_1^i}{m_1^{i*}}, 1\right)$, $P'(m_1) = \frac{y}{m_1^{i*}}$ and $Q'(m_1) = \frac{Q_2}{m_1^{i*}}$ in constrained region ($m_1^i < m_1^{i*}$) and $P'(m_1) = Q'(m_1) = 0$ in unconstrained region ($m_1^i > m_1^{i*}$).

Now the period-0 first-order condition for social planner, $u'(c_0) = E_0\big[u'(c_1) + \lambda_{sp}\{P'(m_1) + \gamma_1 Q'(m_1)\}\big]$ can determine period-0 equilibrium level of borrowing, d_1^i. This level, denoted as $d_1^{i,sp}$, can also be solved using the similar method as competitive equilibrium.

(B.3)
$$LHS = u'(c_0) = \frac{1}{c_0} = \frac{1}{d_1^i - \gamma_1 Q_0}$$

$$RHS = E_0\big[u'(c_1) + \lambda_{sp}\{P'^{(m_1)} + \gamma_1 Q'^{(m_1)}\}\big]$$

$$= E_0\left[\frac{1}{\min\left(\frac{e-d_1^i}{m_1^{i*}}, 1\right)} + \lambda_{sp}\{P'^{(m_1)} + \gamma_1 Q'^{(m_1)}\}\right]$$

$$= \frac{1}{2\varepsilon}\int_{\bar{e}-\varepsilon}^{m_1^{i*}+d_1^i}\left(\frac{1}{e-d_1^i} + 1 - \frac{1}{m_1^{i*}}\right) de + \frac{1}{2\varepsilon}\int_{m_1^{i*}+d_1^i}^{\bar{e}+\varepsilon} 1 \; de$$

$$= 1 + \frac{1}{2\varepsilon}\left[\log\left(\frac{m_1^{i*}}{\bar{e}-\varepsilon-d_1^i}\right) - 1 - \frac{d_1^i - \bar{e} + \varepsilon}{m_1^{i*}}\right]$$

Numerically, I confirm that, in the range of $[\bar{e} - \varepsilon - m_1^{i*}, 1 + \gamma_1 Q_0]$, the borrowing level determined by the social planner is smaller than the borrowing level chosen by private domestic agent. This implies there exists excessive borrowing (overborrowing) in period 0. $d_1^{i,sp}$ satisfies

(B.4)
$$\bar{e} - \varepsilon - m_1^{i*} < d_1^{i,sp} < d_1^{i,ce} < 1 + \gamma_1 Q_0$$

The social planner can impose tax on borrowing. From the equation (15), the optimal tax rate on borrowing (gross inflows) satisfies

(B.5)
$$\tau_1^{i,*} = \frac{E_0[\lambda_{sp}\{P'(m_1)+\gamma_1 Q'(m_1)\}]}{E_0[u'(c_1)+\lambda_{sp}\{P'(m_1)+\gamma_1 Q'(m_1)\}]}, \text{ or}$$

$$\frac{1}{1-\tau_1^{i,*}} = \frac{E_0[u'(c_1)+\lambda_{sp}\{P'(m_1)+\gamma_1 Q'(m_1)\}]}{E_0[u'(c_1)]} = \frac{1}{(d_1^i-\gamma_1 Q_0)E_0[u'(c_1)]}$$

From equations (B.2) evaluated at $d_1^{i.sp}$ and (B.3),

(B.6)
$$E_0[u'(c_1)] = \frac{1}{2\varepsilon}\left[m_1^{i*}\log\left(\frac{m_1^{i*}}{\bar{e}-\varepsilon-d_1^{i,sp}}\right) + \bar{e} + \varepsilon - m_1^{i*} - d_1^{i,sp}\right] = m_1^{i*}\left(\frac{1}{d_1^{i,sp}} - 1\right) + 1$$

This implies

(B.7) $$\frac{1}{1-\tau_1^{i,*}} = 1 + \frac{\tau_1^{i,*}}{1-\tau_1^{i,*}} = \frac{1}{(d_1^i - \gamma_1 Q_0)} * \frac{1}{m_1^{i*}\left(\frac{1}{d_1^{i,sp}} - 1\right) + 1} = \frac{1}{\left(1 - \frac{\gamma_1 Q_0}{d_1^{i,sp}}\right)\left(m_1^{i*} + (1 - m_1^{i*}) d_1^{i,sp}\right)},$$ or

$$\tau_1^{i,*} = 1 - \left(1 - \frac{\gamma_1 Q_0}{d_1^{i,sp}}\right)\left(m_1^{i*} + (1 - m_1^{i*}) d_1^{i,sp}\right)$$

It is also worth noting that when using a different notation for tax rate ($\dot{\tau}$) from Jeanne and Korinek (2010), there exists one-to-one relationship as follows: $1 + \dot{\tau} \equiv \frac{1}{1-\tau^i}$.

Calibration

Following Jeanne and Korinek (2010), I also use the same parameter values for mean of endowment shock ($\bar{e} = 1.3$) and return of domestic asset in period 2 ($y = 0.8$). For the sake of simplicity, I additionally assume that foreign asset price in period 2 is same as the price of foreign asset in period 0 as well as the return for domestic asset ($Q_2 = Q_0 = y$). By doing so, I can eliminate the search-for-yield motives of domestic agents. Thus, numerical solutions depend on parameters values y, $\bar{e}$, ε and γ_1. By using the parameter values, for ε between 0 and 0.3 using evenly spaced grid with 50 grid points, I compute the numerical solution for $d_1^{i,ce}$, $d_1^{i,sp}$ and $\tau_1^{i,*}$

I derive the range of parameter value for γ_1 from the condition that ensures the uniqueness of equilibrium, ($\gamma_1 Q_2 < 1 - y$). This implies that $\gamma_1 Q_2$ is strictly less than 0.2, or γ_1 cannot exceed 0.25 given $y = 0.8$. In the numerical illustration, I estimate $\gamma_1 Q_0$ by using the 10-year average gross capital outflows to GDP ratio in 26 economies across the world that introduced capital flow management.

Table B.1. Parameters values

Group A (from Jeanne and Korinek, 2010)	Group B (new in this study)
• $\bar{e} = 1.3$ • $y = 0.8$	• $\gamma_1\ (= \gamma_2) = 0.04\ (< 0.25)$ • $Q_2 = Q_0\ (= y) = 0.8$

The estimates for $\gamma_1 (= 0.04)$ is calculated as follows. First, I constructed annual dataset from 2011 to 2020 for 36 economies that introduced capital flow management since 2000 according to IMF 2019 Taxonomy of Capital Flow Management Measures. Then, I calculate nominal GDP in U.S. dollars by using nominal GDP in domestic currency and nominal exchange rates using period average exchange rate in IMF International Financial Statistics data. To obtain gross capital outflows data, I followed the method by Cavallo et al. (2017). From the IMF Balance of Payment (BoP) data, I sum up net acquisition of financial assets for all components in financial accounts including direct investment, portfolio investment, financial derivatives, and other investment. The values are denominated by U.S. dollars. Due to the lack of data, six economies in Group 3 of Table B.2 are excluded. The statistics are reported in Table B.2. The medians are 3.0% in Group 1 and 3.2% by adding Group 2.[29] This implies the estimate for γ_1 is 4.0% or 0.04.

Table B.2. Gross Capital Outflows to GDP ratio

Group	Economies included	Statistics
Group 1 (26 economies)	Argentina (2.9), Australia (0.5), Barbados (8.4), Belarus (8.4), Bolivia (1.5), Brazil (3.5), Canada (8.3), China, P.R.: Mainland (3.3), Costa Rica (2.5), Ecuador (4.5), Georgia (3.5), India (3.2), Indonesia (1.4), Kazakhstan (5.0), Korea (6.0), Madagascar (2.2), Malaysia (7.8), New Zealand (0.3), Nigeria (2.2), North Macedonia (3.6), Peru (2.0), Russia (3.2), Seychelles (1.7), Sri Lanka (0.4), Ukraine (2.2), Uzbekistan (3.9)	Median = 3.0% Average = 3.3% Max = 8.4% Min = 0.3%
Group 1 and 2 (30 economies)	Group 1, China, P.R.: Hong Kong (43.8), China, P.R.: Macao (45.7), Singapore (50.2), Iceland (-10.4)	Median = 3.2% Average = 7.1%
Group 3 (6 economies)	Cyprus, Democratic Republic of Congo, Ghana, Greece, Liberia, CEMAC	-

The numbers inside ( ) indicates 10-year average gross capital outflows to GDP ratio in percentage from 2011 to 2020.

Numerical Illustration

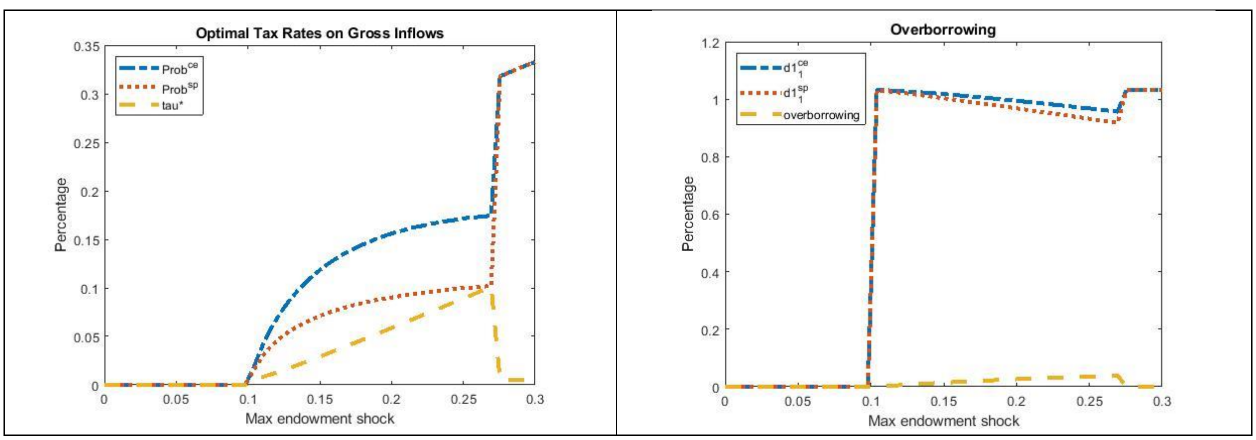
In the numerical illustration using the specific parameters values, I focus on the region where ε is between 0.1 and 0.28. From condition (B.1), for $\varepsilon > \bar{e} - 1 - m_1^{i*} - \gamma_1 Q_0 = 0.1$, the constraint is binding with positive probability, where this study is focused on. The size of borrowing (d_1^i) increases as the size of endowment shock increases, but d_1^i reaches its upper limit set by the condition on borrowing $d_1^i < 1 + \gamma_1 Q_0 = 1.032$. This corresponds to $\varepsilon \cong 0.275$.

[29] Using domestic consumption instead of GDP, I find the similar results: the median is 4.0%. In this case, estimates for γ_1 becomes 5% (0.05). This slightly increases optimal tax rates from 2.1% to 2.2% for $\varepsilon \cong 0.13$.

I find that given the same endowment shocks with 10% maximum deviation ($\varepsilon \cong 0.13$) from the mean, $\bar{e}$, optimal tax rate on borrowing (gross inflows) is around 2.1%. When I restrict $\gamma_1 = 0$ to exclude the foreign asset channel, the optimal tax rate is only 1.3%, which is the same as Jeanne and Korinek (2010). This shows that with considering gross outflows, the optimal tax rate on gross inflows should be (0.8%p or 57%) higher considering the increased unintended side effect (externalities) of borrowing via foreign asset price channel. If the size of shock is large as $\varepsilon \cong 0.27$, then, the social planner should impose 10.1% tax on borrowing, and this is 1.6%p or 19% higher than the optimal tax rates, 8.5%, which derived from no foreign investment assumption that corresponds to Jeanne and Korinek (2010)'s study.

The left panel of Figure B.1 shows the probabilities of sudden stops calculated using the uniformly distributed endowment shocks, and the right panel of Figure B.1 illustrates $d_1^{i,ce}$ and $d_1^{i,sp}$ over the range of maximum endowment shock parameter (ε). The difference of optimal level of borrowing in competitive equilibrium and social planner's allocation implies the size of overborrowing. For example, given the endowment shock, $\varepsilon \cong 0.13$, the social planner can reduce the size of borrowing by imposing 2.1% tax, and this will help alleviate the probability of sudden stops by 3.7%p (from 9.7% to 6.0%).[30]

Figure B.1. Optimal Tax Rates on Borrowing ($\gamma_1 = 0.04$)



[30] The probability of sudden stop is calculated using the uniform distribution following Jeanne and Korinek (2010): $Prob^{ce} = \frac{1}{2\varepsilon}\int_{\bar{e}-\varepsilon}^{m_1^{i*}+d_1^i} 1\ de = \frac{1}{2} - \frac{\bar{e}-m_1^{i*}-d_1^{i,ce}}{2\varepsilon}$ and $Prob^{sp} = \frac{1}{2\varepsilon}\int_{\bar{e}-\varepsilon}^{m_1^{i*}+d_1^i} 1\ de = \frac{1}{2} - \frac{\bar{e}-m_1^{i*}-d_1^{i,sp}}{2\varepsilon}$.