Monetary Policy Transmission in Emerging Markets: An Application to Chile

Pierre-Olivier Gourinchas*
University of California at Berkeley NBER and CEPR

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Abstract

This paper discusses the role of financial spillovers in the transmission of U.S. and domestic monetary policy to emerging market economies. With weak financial spillovers, a U.S. monetary tightening is expansionary. With moderate financial spillovers, a U.S. monetary tightening is contractionary. With strong financial spillovers, a *domestic* monetary tightening becomes expansionary. Implications for the role of the exchange rate regime and the trilemma/dilemma debate are discussed. The model is adapted and estimated using Chilean data. Results indicate that financial spillovers are intermediate, suggesting that monetary impulses transmit positively from the U.S. to Chile and that a floating exchange rate remains a key plank of the policy response.

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1 Introduction

A critical question for emerging market policymakers is how to adjust to monetary policy changes in the center. A core tenet of modern macroeconomic theory is that peripheral countries should let their exchange rate float when financial conditions abroad change. This allows the nominal and real exchange rates to absorb the brunt of the required adjustment. This is the standard Mundell Fleming prescription for floating exchange rates. Specifically, when the U.S. Federal Reserve tightens its policy, a country like Chile should let its currency depreciate. Under the standard analysis, the Fed tightening slows down economic activity in the U.S., depressing the demand for Chilean exports. The depreciation of the peso offsets partly or even fully this negative impulse, helping to prop up the Chilean economy.

A number of policymakers and academics have recently challenged that view. On the policy side, some emerging market policymakers have complained about the effect of U.S. monetary policy on their economy. When, on August 27, 2010, chairman Bernanke announced that the Federal Reserve would pave the way for a second round of quantitative easing, capital flows to emerging markets surged, their currencies strongly appreciated, and policymakers in the region feared, not that their economy would enter a recession, but instead that it would would overheat. Conversely, when on May 22, 2013, chairman Bernanke announced that the Federal Reserve would take a step down in the pace of asset purchases (the so-called 'tapering'), markets reacted strongly, pulling out of many emerging market economies and their currencies depreciated precipitously. Again, instead of expecting a domestic boom driven by a surge in exports, policymakers in the region worried that their economy would slump.

On the theory side, the excellent work of Hélène Rey in her Jackson Hole lecture (Rey (2013)) and subsequent writings, has argued forcefully that flexible exchange rates cannot insulate economies from the global financial cycle. In her analysis, the appreciation of the currency that follows a monetary easing at the center strengthens domestic balance sheets, encourages leverage and further credit growth, boosting economic activity in the periphery. Conversely, the depreciation that follows a monetary tightening at the center weakens domestic balance sheets, forces deleveraging and limits credit growth, weakening economic activity in the periphery. Currency movements and capital inflows reinforce each other, leading to potentially excessive credit cycles in emerging market economies. In such an environment, monetary impulses originating in the center amplify the global financial cycle and transmit positively to the periphery: tighter U.S. monetary policy is contractionary abroad too.

What should emerging market policymakers do? Clearly, if depreciations are contractionary and appreciations expansionary, a floating currency may not provide much insulation. Yet it does not follow that a fixed exchange rate is preferable. The reason is that a fixed exchange rate, under capital mobility, requires a domestic monetary policy stance that mimics the center. But the transmission of a *domestic* monetary policy impulse to the domestic economy may still operate as usual. In that case, the best response to a tightening in the center that causes a recession in the periphery is to ease monetary policy. That the domestic currency depreciate even more as a byproduct is irrelevant. What matters is the net transmission of domestic monetary policy. If instead domestic authorities peg their currency, they will be forced to mimic the contractionary policy of the center, resulting in a domestic recession.

This argument would break down if a domestic monetary tightening were instead expansionary. In that case, the optimal response to the tightening in the center would be a tightening in the periphery as the latter would counteract the contractionary impulse from the center. A number of policymakers, e.g. Gudmundsson (2017) or Başçı et al. (2008) make such a claim. Such a *'perverse'* transmission of monetary policy could occur if financial spillovers from asset prices and currency movements were so strong as to overcome the usual channels of monetary policy: as monetary authorities tighten policy, the induced capital inflows, appreciation of the domestic currency and relaxation of borrowing constraint would lead to an expansion of economic activity, despite higher real interest rates.

The purpose of this paper is to clarify these issues in two steps. First, section 2 presents a simple Mundell-Fleming inspired model of a small open economy with financial spillovers. It describes the different channels through which both monetary policy in the center, or in the country, transmits to the economy. Conceptually, the model shows that there are three different channels through which U.S. monetary policy affects the domestic economy. First, when the U.S. tightens monetary policy, the demand for local goods falls because U.S. aggregate demand declines. Second, under floating rates, a tightening of U.S. monetary policy causes a depreciation of the domestic currency against the U.S. dollar. Under the usual conditions, this depreciation stimulates domestic aggregate demand. Third, the depreciation may reduce the collateral value of domestic assets, and tighten the balance sheet of domestic financial intermediaries leading to a sequence of develeraging and decline in credit, adversely affecting economic activity in the periphery.

Within this very stylized model, the paper establishes that the transmission of monetary policy (both center and periphery) depends on the strength of the financial spillovers. When financial spillovers are moderate or nil the model boils down to the Mundell Fleming framework: A Fed tightening is expansionary abroad, as in Krugman (2014)'s analysis. When financial spillovers are intermediate, U.S. monetary policy transmits positively: everything else equal, a Fed tightening causes a recession abroad due to the interaction between U.S. monetary policy and the financial cycle. But domestic monetary policy, while less effective, still operates in a normal way. In order to stabilize output, it is optimal to lower domestic policy rates, i.e. to let the domestic currency depreciate even further. Thus, in this intermediate case, the trilemma still operates in the sense that flexible exchange rate are optimal. Finally, when financial spillovers are sufficiently severe, the transmission of domestic monetary policy becomes ‘perverse’: a domestic tightening is expansionary. In that case, stabilizing output requires limiting currency fluctuations.

Which case is the relevant one for an emerging market economy? Sections 3 and 4 attempt to answer this question. Section 3 presents a standard New Keynesian model of a small open economy that allows for financial spillovers: in the model, some households face a borrowing limit that depends on the level of the real exchange rate. An appreciation of the currency, by increasing the collateral of domestic agents, raises this borrowing limit. The model also features a working capital constraints, so that increases in interest rates raise the marginal cost of production for firms, as well as dominant currency pricing, in the sense of Casas et al. (2016) and a commodity sector dedicated to exports, as is the case for many emerging market economies. The model validates the insights from the simple Mundell Fleming set-up: the transmission of both U.S. and domestic monetary policy depends on the strength of the financial spillovers.

Section 4 estimates the previous model with Bayesian techniques using data for Chile between 1999 and 2015. The key question of interest is: how strong are financial spillovers? The answer, at least for the case of Chile and through the lens of this particular model, is that financial spillovers are intermediate. It follows that the concern of emerging market policymakers is valid: a tightening in the center transmits a contractionary impulse to their country, via the depreciation of their currency and the amplification via the global financial cycle. But this finding does not overturn the basic conclusion of the Mundell Fleming analysis: the transmission of domestic monetary policy is not perverse, and therefore flexible exchange rates remain the primary line of defense against foreign monetary policy and global financial cycles alike.

This paper touches upon a number of literatures. First, there is an abundant literature on financial spillovers in emerging market economies, the global financial cycle and the Mundellian trilemma/dilemma. Recent contributions include Borio and Zhu (2012), Bruno and Shin (2014), Bruno and Shin (2015), Farhi and Werning (2014), Aoki et al. (2015), Blanchard (2016), Devereux et al. (2015) or Rey (2013) and Taylor and Obstfeld (2017). The paper also borrows from the literature on the New Keynesian model and its estimation with Bayesian methods. Key references include Galí (2008), Galí and Monacelli (2005), Iacoviello (2015), Mendoza (2010), Gourinchas et al. (2016), and An and Schorfheide (2007). Finally, the paper borrows from the recent literature on dominant currency paradigm, e.g. Casas et al. (2016), Gopinath (2015), Gopinath and Itskhoki (2010), and Devereux et al. (2007).

Section 2 presents the simple Mundell Fleming style model. Section 3 presents the full fledged New Keynesian model of a small open emerging market economy. Section 4 estimates the model for Chile and section 5 concludes.

2 A Simplified Model in the Spirit of Mundell Fleming

This section explores the different channels of transmission of domestic and US monetary policy using a deliberately old-fashioned 'Mundell Fleming' framework modified to allow for financial spillovers and risk premia. The model is similar to Blanchard (2016) and Bernanke (2017). The pros and cons of such a simplified model are well-known: what it lacks in micro-foundations and intertemporal trade-offs, we hope to gain in simplicity and clarity of exposition. This is perfect for our purpose, which is to build intuition for the different channels of transmission of U.S. and domestic monetary policy. The next section performs a fuller investigation using a state of the art dynamic stochastic general equilibrium model, estimated with Bayesian methods on Chilean data.

The model has two countries: a small domestic economy and a large foreign country (the U.S.). Foreign variables are denoted by a star. Domestic and foreign output are determined by the following system of equations:

$$\begin{aligned} Y &= A + NX \quad (1a) \\ A &= \xi - cR - fE \quad (1b) \\ NX &= a(Y^* - Y) + bE \quad (1c) \\ Y^* &= A^* = \xi^* - cR^* \quad (1d) \\ E &= d(R^* - R) + \chi \quad (1e) \end{aligned}$$

Domestic output Y is equal to the sum of domestic absorption A and net exports NX. Domestic absorption depends on an aggregate demand shifter ξ, which includes among other things the stance of fiscal policy. It also depends (negatively) on the domestic monetary policy rate R. We assume that absorption is also negatively impacted by a depreciation of the nominal exchange rate E.[1] This captures any *financial spillover* that arises via movements in the exchange rate. For instance, a depreciation of the domestic currency could tighten collateral constraints by reducing the foreign currency value of domestic assets, inducing a domestic credit crunch. It could also impact aggregate demand via a decline in domestic wealth, relative to foreign wealth. The parameter $f \geq 0$ captures in a simple way the strength of these spillovers, with $f = 0$ corresponding to the usual Mundell Fleming case.

Net exports NX depend positively on U.S. output Y^*, negatively on domestic output Y, and positively on the exchange rate E. U.S. output is determined similarly, with the modification that the U.S. is assumed large relative to the foreign country and can therefore be treated as a closed economy: U.S. output equal U.S. absorption A^*, which depends positively on the U.S. aggregate demand shifter ξ^* and negatively on the U.S. policy rate R^*.

Finally, as in Blanchard (2016), we assume that the exchange rate depends on the difference between the foreign and domestic policy rates $R^* - R$, as well as on a risk premium shock χ. The first term captures the determinants of the exchange rate under Uncovered Interest Parity (UIP). The

[1] We adopt the convention that an increase in E represents a depreciation of the domestic currency.

second captures deviations from UIP due to changes in risk premia. A higher U.S. policy rates relative to the domestic rate tends to depreciate the domestic currency, with the coefficient d measuring the expected duration of the interest rate differential. An increase in domestic risk premium χ also forces an immediate depreciation of the currency. In line with the recent literature on the role of U.S. monetary policy for the global financial cycle, we assume that χ is positively correlated with the U.S. policy rate R^*. We make this dependency explicit by writing $\chi(R^*) = gR^* + \chi$ with $g > 0$ and χ representing autonomous movements in risk premia.

All coefficients $a...g$ are weakly positive. Absent shocks, all variables, including output, the trade balance, the policy rates and the exchange rate, are normalized to zero. Solving the model yields the following expression for domestic output as a function of the demand shocks (ξ and ξ^*), the risk premium χ, domestic and U.S. policy rates R and R^*.

$$Y = \frac{1}{1+a}\left[\xi + a\xi^*) + (b-f)\chi + ((f-b)d - c)R + ((b-f)(d+g) - ac)R^*\right] \tag{2}$$

The International Transmission of U.S. Monetary Policy.

Equation (2) encapsulates the various channels through which U.S. monetary policy affects the domestic economy. Consider first the standard Mundell Fleming case $f = g = \chi = 0$. Whether a U.S. monetary policy tightening is expansionary or contractionary at home depends on the sign of $bd - ac$. The intuition is simple: bd captures the effect of a U.S. monetary tightening via the depreciation of the domestic currency which stimulates the trade balance (the 'trade channel' of exchange rates); ac captures the effect of the U.S. tightening via lower U.S. aggregate output which depresses domestic exports. Thus, $bd - ac$ captures the effect of a U.S. tightening on the domestic trade balance. As is well-known, it is possible within the traditional Mundell Fleming framework for a U.S. tightening to be contractionary at home (i.e. to contract the domestic trade balance) if the effect of lower economic activity in the US dominates the effect of a more depreciated domestic currency.

U.S. monetary policy has two additional effects on domestic output when f or g are strictly positive. First, the term $-fd$ captures the negative impact of the domestic currency's depreciation on absorption via financial spillovers. This is the 'financial channel' of exchange rates, opposite in sign to the trade channel bd. Second, the term $(b - f)g$ reflects the impact of rising risk premia due to the U.S. tightening (risk off): a higher risk premium depreciates the exchange rate, with a stimulative direct effect bg via the trade balance. This is the effect emphasized by Krugman (2014): absent financial spillovers, an increase in risk premia is good news for domestic output. The terms $-fg$ represents the offsetting effect due to financial spillovers. It is immediate from (2) that the effect of U.S. monetary policy on the global financial cycle ($g > 0$) simply amplifies the role of U.S. monetary policy on domestic output from d to $d + g$.

The overall effect of U.S. monetary policy on home output depends on the strength of financial spillovers. To fix ideas, suppose that $bd - ac > 0$, so that a U.S. monetary policy tightening would expand domestic output in a Mundell Fleming world. It is immediate to verify that the same U.S. monetary tightening becomes contractionary at home if $f > \underline{f}$ where

$$\underline{f} = b - \frac{ac}{d + g} > 0. \tag{3}$$

That condition is more likely to be satisfied the stronger is the impact of U.S. rates on exchange rates (d) and the stronger is the global financial cycle (g). For future use, we define $\phi_{R^*} \equiv \partial Y / \partial R^* = ((b - f)(d + g) - ac)/(1 + a) = (d + g)(\underline{f} - f)/(1 + a)$ as the partial response of output to U.S. policy rates.

The (Perverse) Transmission of Domestic Monetary Policy.

Let us now consider the transmission of domestic monetary policy on the home economy. The analysis is simpler since a change in the stance of domestic monetary policy has no effect abroad, under our small open economy assumption. According to (2), an increase in the domestic policy rate R affects domestic output through three channels. First, it directly reduces domestic absorption ($-c$). Second, the domestic currency appreciates, which dampens further aggregate demand via the trade balance ($-db$). Lastly, the appreciation stimulates aggregate demand via financial spillovers (fd).

While the first two effects are contractionary, the last one is expansionary. Could the net effect also be expansionary, i.e. could a monetary policy tightening be 'perversely' expansionary? For this to be the case, financial spillovers need to be strong enough to overcome the usual channels of transmission of domestic monetary policy. In that scenario, a central bank tightening its policy rate would find itself faced with a wave of net capital inflows, a strongly appreciating currency and an increase in aggregate demand...

In recent years, the possibility that monetary policy transmission may indeed be 'perverse' has been more than a theoretical curiosum. Many policymakers in small open economies have complained that attempts to cool their economy by raising the policy rate were thwarted and ultimately counterproductive: higher domestic rates attracted foreign capital, appreciating the currency, increasing domestic wealth, relaxing borrowing constraints and pushing the economy ahead. Gudmundsson (2017) for Iceland, or Başçı et al. (2008) for Turkey essentially make this point.

Within the context of our simple model, a perverse transmission of domestic monetary policy occurs when $f > \bar{f}$ where

$$\bar{f} = b + \frac{c}{d}. \tag{4}$$

This condition is more likely to obtain the more responsive exchange rates are to interest rates (higher d) and the lower the aggregate demand effect of monetary policy (lower c). Further, a direct comparison of (3) and (4) reveals that $\bar{f} > \underline{f}$. It follows immediately that the transmission of domestic monetary policy can only be perverse if a U.S. monetary tightening has a contractionary impact on the domestic economy ($f > \bar{f}$ implies $f > \underline{f}$), while the reverse is not true. For future use, we define $\phi_R \equiv \partial Y/\partial R = ((f-b)d-c)/(1+a) = d(f-\bar{f})/(1+a)$ as the partial response of domestic output to the domestic policy rate. Note that $\phi_R < 0$ under 'standard' monetary policy transmission while $\phi_R > 0$ under a 'perverse' monetary transmission.

Optimal Monetary Policy.

Assume that home cares about output deviations from steady state, and may also care about the trade balance as in Bernanke (2017). Specifically, consider the following ad-hoc loss function:

$$\mathcal{L} \equiv \frac{1}{2}\mathbb{E}Y^2 - \alpha \mathbb{E}NX, \tag{5}$$

where $\mathbb{E}$ denotes the expectation operator. The coefficient $\alpha > 0$ measures the importance of a possible 'mercantilist' motive, i.e. the weight given by the small open economy policymaker to the trade balance above and beyond its effect on aggregate demand. Given our small country assumption, we assume that the domestic policymaker takes U.S. shocks and policies (ξ^*, R^*) and output Y^* as given when setting its own policy rate R so as to minimize $\mathcal{L}$.

Under perfect foresight, the optimal level of output satisfies:

$$Y^o = -\alpha \left[a + \frac{bd}{\phi_R}\right]. \tag{6}$$

When $\alpha = 0$, it is immediate that $Y^o = 0$, i.e the policymaker does not distort output away from its potential value. When $\alpha > 0$ the policymaker typically distorts output in order to enjoy a larger trade surplus. Whether this will be associated with a higher or lower level of output depends on the response of output to the domestic policy rate, i.e. on the nature of the transmission of monetary policy. In the standard case where $\phi_R < 0$, the desire to run trade surpluses will push output above potential ($Y^o > 0$): stimulating the trade balance requires depreciating the currency by cutting the policy rate which stimulates output.[2] When monetary policy transmission is 'perverse' ($\phi_R > 0$), stimulating the trade balance still requires depreciating the currency by cutting the policy rate, but

[2]This is true when $bd - ac > 0$ as was assumed above.

this now negatively affects output ($Y^o < 0$).

From equation (2) and (6) we can solve for the optimal policy rate:

$$R^o = \frac{1}{\phi_R}\left[Y^o - \frac{\xi + a\xi^*}{1+a} - \frac{b-f}{1+a}\chi - \phi_{R^*}R^*\right]. \tag{7}$$

The first term inside the brackets captures the impact of the mercantilist motive on the policy rate. Because, as discussed above, Y^o and ϕ_R have opposite signs, a mercantilist motive always leads to lower policy rates: $Y^o/\phi_R < 0$. On the other hand, the optimal policy response to aggregate demand shocks ($\xi + a\xi^*$), risk premium shocks (χ) and foreign policy rate R^*) depends on whether the transmission of monetary policy is 'standard' ($\phi_R < 0$) or 'perverse' ($\phi_R > 0$). In particular, the optimal pass-through from center policy rate R^* to domestic policy rate R satisfies $\partial R^o/\partial R^* = -\phi_{R^*}/\phi_R$. Importantly, this pass-through is non-monotonous as we vary the strength of financial spillovers. We can distinguish three cases:

1. **Weak financial spillovers** ($f \leq \underline{f}$). In the limit $f = 0$, this corresponds to the traditional Mundell Fleming case. When financial spillovers are weak, a tightening in the center is expansionary abroad ($\phi_{R^*} > 0$) while domestic monetary policy operates in the usual way ($\phi_R < 0$). It follows that the optimal response to a tightening abroad is a domestic tightening: $\partial R/\partial R^* > 0$.[3]

2. **Intermediate financial spillovers** ($\underline{f} < f < \bar{f}$). A tightening at the center is contractionary at home ($\phi_{R^*} < 0$). Since domestic monetary policy transmission operates in the 'standard' way ($\phi_R < 0$), the optimal response is to cut domestic the policy rate: $\partial R/\partial R^* < 0$. This

[3]Whether the passthrough of foreign rates to domestic ones is larger or smaller than one depends on the impact of U.S. monetary policy on risk premia (g). When g is low, one can show that $0 < \partial R/\partial R^* < 1$. To see why consider the case with $g = 0$. If $R = 0$, a U.S. monetary tightening is expansionary at home. Suppose instead that domestic authorities set $R = R^*$. This prevents the depreciation of the domestic currency and therefore mutes the trade channel of exchange rates. However, both the domestic and foreign tightening impact negatively domestic aggregate demand via their effect on domestic absorption and export demand. It follows that it is optimal to tighten but less than one for one, and to let the currency depreciate. If the impact of U.S. monetary policy on risk premia is large, then domestic policy rates may have to rise significantly to counter the increase in risk premia, yielding a pass-through in excess of one. Still, in that case the exchange rate depreciates.

case is interesting since it suggests that the optimal response to changes in the center's monetary policy stance is in the opposite direction. Tightening U.S. monetary policy require easing abroad and vice versa. A direct implication is that the domestic currency needs to depreciate in response to a U.S. monetary tightening.

3. **Strong financial spillovers** ($\bar{f} < f$). A U.S. tightening is contractionary at home, which requires *raising* policy rates to stabilize output. Furthermore, since $-\phi_{R^*}/\phi_R = (d+g)/d(f - \underline{f})/(f - \bar{f}) > 1$ when $f > \bar{f}$, it follows that $\partial R/\partial R^* > 1$: the passthrough of center policy rates to domestic ones is always in excess of one.[4] A direct implication is that the domestic currency now needs to *appreciate* in response to a U.S. tightening.

Substituting R^o into equation (1e) and using the definition of ϕ_R, ϕ_{R^*}, $\underline{f}$ and $\bar{f}$, we can solve for the optimal exchange rate:

$$E^o = -\frac{(d+g)(\bar{f} - \underline{f})}{f - \bar{f}} R^* - \frac{c/d}{f - \bar{f}} \chi - \frac{d}{\phi_R} \left(Y^o - \frac{\xi + a\xi^*}{1+a} \right) \tag{8}$$

As discussed above, equation (8) tells us that the optimal response of the exchange rate depends on the strength of financial spillovers. In particular, under a 'standard' transmission, the domestic currency *depreciates* when R^* increases. Conversely, in the case of a 'perverse' transmission, the domestic currency *appreciates* following a tightening in the center.

Exchange Rate Regime and the Trilemma/Dilemma debate.

As equations (7)-(8) illustrates, the optimal policy consists in setting $R = R^o$ or equivalently $E = E^o$. It follows, somewhat trivially, that a fixed exchange rate is never optimal. But this misses a larger question: does the exchange rate play a stabilizing or de-stabilizing role on the domestic economy. It is well known that a country cannot simultaneously let capital flow freely, set its own

[4]Again, the reason is quite intuitive. Consider a tightening in the center. If $R = 0$ this is contractionary at home. Suppose now that $R = R^*$. This mutes the trade channel of exchange rates. As before, the domestic and foreign tightening still impact negatively aggregate demand via domestic absorption and export demand, so this remains contractionary at home. Stimulating the economy requires raising interest rates, $R > R^*$, so as to appreciate the currency.

monetary policy, and stabilize its exchange rate. This is known as the Mundellian Trilemma. Indeed, equation (1e) characterizes the equilibrium exchange rate that obtains given the configuration of domestic and foreign policy rates and risk premia when capital is freely mobile. Under the Trilemma, floating exchange rates free monetary policy to pursue domestic objectives.

A question arises naturally: to what extent, under floating exchange rates, do currency movements hinder or facilitate the adjustment of the domestic economy? This question is intimately related to the recent Trilemma/Dilemma debate.

The policy 'Trilemma' has been challenged recently, most forcefully in Rey (2013) and Rey (2016). In her 2013 Jackson Hole piece, Rey argues that the deep interrelations between monetary policy at the center (the U.S.), global capital flows, and leverage in the financial sector can render domestic monetary policy ineffective in small open economies, even under a floating exchange rate regime. In a financially globalized world, conventional monetary policy may be swamped by global capital inflows and outflows, themselves driven by global factors. Instead of a Trilemma these economies may face a Dilemma: either control capital flows (or regulate the domestic financial sector via macroprudential tools) or lose the capacity to conduct independent monetary policy, regardless of the exchange rate regime. This global financial cycle could impact the domestic economy in a variety of ways. For instance, it may impart large movements in risk premia (χ in equation (1e)) as global markets swing from risk-on to risk-off and vice versa. Alternatively, increased financial globalization often means larger mismatched cross-border gross positions. This amplifies the impact of changes in currency values on the balance sheet of financial and non-financial corporate entities, with potentially large effects on domestic absorption (f in equation (1b)). Both channels are present in the simple model presented above.

To explore further this question, assume that all fluctuations arise from foreign monetary policy (R^*) or exogenous shifts in risk premia (χ) and that both shocks are independent with mean 0 and variance $\sigma^2_{R^*}$ and σ^2_{χ} respectively. Consider the following two regimes: a floating regime (f) where the domestic policy rate is constant ($R = 0$). This captures the idea that domestic policy may be constrained for reasons outside the model and allows us to evaluate directly the (de)stabilizing effect of exchange rates. The other regime is a currency peg (p), where the policy rate is set so as to maintain a constant exchange rate: $R = (1 + g/d)R^* + \chi/d$, according to UIP condition (1e). We can evaluate the loss function (5) under both regimes, denoted $\mathcal{L}^f$ and $\mathcal{L}^p$ respectively:[5]

$$\mathcal{L}^f = \left(\frac{b-f}{1+a}\right)^2 \sigma_\chi^2 + \left(\frac{(d+g)(f-\underline{f})}{1+a}\right)^2 \sigma_{R^*}^2 \tag{9}$$

$$\mathcal{L}^p = \left(\frac{b-\bar{f}}{1+a}\right)^2 \sigma_\chi^2 + \left(\frac{(d+g)(\bar{f}-\underline{f})}{1+a}\right)^2 \sigma_{R^*}^2. \tag{10}$$

If floating (with $R = 0$) is preferred to a peg in the absence of financial spillovers ($f = 0$) then it is easy to check that floating remains preferred to a peg as long as financial spillovers are not strong:[6]

$$\mathcal{L}^f < \mathcal{L}^p \iff f < \bar{f}.$$

There are two important implications of this result. First, the mere existence of financial spillovers and risk premia is not enough to overturn the Mundellian Trilemma. When financial spillovers are intermediate (i.e. $\underline{f} < f < \bar{f}$), it is still preferable to let the currency float (even if the policy rate is constant) rather than adopt a peg. The reason is that the 'shock-absorbing' properties of the exchange rate still insulate the domestic economy reasonably well against the global financial cycle. Second, and more importantly, the model says that it is only when the transmission of monetary policy is 'perverse' –in the sense that a tightening is expansionary– that a peg becomes preferable to a floating regime. In other words, the Dilemma's intuition that exchange rates may not be insulating when financial spillovers are strong enough is correct, but, it requires financial spillovers so strong as to overturn how monetary policy works.

The policy implications of living in such an environment would be considerable and would require a a radical re-thinking of the way in which monetary policy transmits to the domestic economy and

[5] This is obtained by substituting equilibrium output Y from (2) into the loss function. Observe that since the shocks are centered, the 'mercantilist' term drops out since $\mathbb{E}NX = 0$.

[6] It is easy to check that floating is preferred to a peg when $f = 0$ if and only if $b < c/d$. This is a reasonable benchmark since it corresponds to the usual Mundell Fleming environment.

how monetary policy should be conducted. In a world with $\phi_r < 0$, equation (7) tells us that policy rates need to be increased aggressively in response to increases in risk premia (χ) or in foreign policy rates (R^*). Equation (7) conveys a stronger message: policy rates also need to be *tightened* when the economy slows down ($\partial R^o / \partial \xi < 0$). If this is indeed the world we live in, it would require a major retooling of the monetary policy framework for small open economies.

Casual observation may lead to some skepticism. One would imagine that monetary authorities would have long ago figured out that, whenever they tightened their policy rate, their economy seemed to grow faster, not slower. Similarly, one presumes that central banks following an inflation targeting rule would have noted with some alarm that raising policy rates pushed domestic price inflation up, not down, as the economy picked up speed.[7] Ultimately, though, this is an empirical question: are financial spillovers sufficiently large to overturn the usual transmission of monetary policy? This is the question to which we turn in the next two sections.

Literature to cite: Kearns and Patel (2016) Shin on risk premium. Also Rey Agrippino etc...

3 Model

We now present a small open economy model with financial spillovers. In the next section, the model is estimated using data for Chile. The small open economy, denoted H (for Home) trades goods and assets with the rest of the world, denoted U (for the $U.S.$). U is large and we take its dynamics as exogenous from the perspective of H. In particular, we will assume that the foreign price level is constant.

The model is a standard New Keynesian macro model in the spirit of Galí (2008) and Casas et al. (2016) : Home's manufacturing sector produces differentiated goods for the domestic and export market, with prices that are sticky in the currency in which they are invoiced. Domestic households consume domestic manufactured goods and imported ones. The model departs from the canonical

[7] The effect on consumer price inflation could be more muted thanks to the effect of the appreciation of the currency on imported goods.

New Keynesian framework along the following dimensions:

- Dominant currency pricing: most goods sold on foreign markets are invoiced in U's currency (the dollar), whether produced by U or not.
- Strategic complementarities: the elasticity of substitution between varieties is not constant, so optimal markups vary as in Kimball (1995).
- Financial spillovers: There are two types of households, savers and borrowers who differ according to their rate of time preference. Borrowers face a borrowing limit that varies with the exchange rate.
- Working capital: Firms need to fund a fraction of their input cost with an intra-period loan.
- Copper: The domestic economy is endowed with a commodity (copper), entirely destined to the export market. The dollar value of the commodity output fluctuates exogenously. This shifts H's resource constraint and affects the equilibrium exchange rate.

3.1 Households

3.1.1 Preferences and Heterogeneity

We introduce financial spillovers in the model via household balance sheets. There is a unit measure of households. Households are heterogenous in their rate of time preference as in Eggertsson and Krugman (2012) and Gourinchas et al. (2016). A measure $1-\chi$ of households is patient. These households will be saver in equilibrium. We index them with $i = s$ and denote their discount factor $\beta_b = \beta$. The remaining measure χ is impatient. They will be borrowers in equilibrium. We index them with $i = b$ and denote their discount factor $\beta_b < \beta$. Household i consumes a bundle of traded manufactured goods C_t^i, supplies a differentiated variety of labor N_t^i at wage W_t^i and maximizes lifetime preferences given by:

$$U^i = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_i^t \left(\frac{(C_t^i)^{1-\sigma_c}}{1-\sigma_c} - \frac{(N_t^i)^{1+\varphi}}{1+\varphi} \right), \tag{11}$$

where $\sigma_c > 0$ is the household's coefficient of relative risk aversion and $\varphi > 0$ is the inverse of the Frisch elasticity of labor supply.

Each household maximizes (11) subject to the following budget constraint:

$$P_t C_t^i = W_t^i N_t^i + \Pi_t + B_t^i - (1 + i_t) B_{t-1}^i + \mathcal{E}_t COP_t \tag{12}$$

In (12), P_t denotes the price index for the domestic consumption basket C_t, Π_t are the (per capita) nominal profits from the domestic manufacturing sector, rebated back to households, B_t^i denotes one-period domestic risk-free debt (or savings when $B_t^i < 0$) issued at time t, i_t is the domestic nominal interest rate in period t, COP_t denotes the exogenous dollar revenues (per capita) from the commodity sector (copper) and $\mathcal{E}_t$ denotes the nominal exchange rate, defined as the local currency value of the dollar, so that an increase in $\mathcal{E}_t$ represents a depreciation of the domestic currency.

3.1.2 Strategic Complementarities

We follow Casas et al. (2016) and assume that the consumption aggregator C is implicitly defined by a Kimball (1995) homothetic demand aggregator:

$$\sum_{j \in \{H,U\}} \frac{1}{|\Omega_j|} \int_{\omega \in \Omega_j} \gamma_j \Upsilon \left(\frac{|\Omega_j| C_j(\omega)}{\gamma_j C} \right) d\omega = 1. \tag{13}$$

where $C_j(\omega)$ denotes the consumption of variety ω produced in country j, Ω_j is the mass of varieties produced in j, γ_j is a taste parameter that captures home bias in consumption with $\sum_j \gamma_j = 1$, and where the function $\Upsilon(.)$ satisfies $\Upsilon(1) = 1$, $\Upsilon'(.) > 0$ and $\Upsilon''(.) < 0$.

The domestic price index P_t satisfies:

$$P_t C_t = \sum_j \int_{\Omega_j} P_{j,t}(\omega) C_{j,t}(\omega) d\omega$$

We later specialize the demand structure to the Klenow and Willis (2006) specification:

$$C_{j,t} \;=\; \gamma_j \left(1 - \epsilon \ln \frac{\sigma z_{j,t}}{\sigma - 1} \right)^{\sigma/\epsilon} C_t$$

where $z_{j,t} = (P_{j,t}/P_t)D_t$ and $D_t \equiv \sum_j \int_{\Omega_j} \Upsilon'\left(\frac{|\Omega_j|C_{j,t}(\omega)}{\gamma_j C_t}\right)\frac{C_{j,t}(\omega)}{C_t}d\omega$. These preferences collapse to the standard CES representation when $\epsilon = 0$. With this specification, the elasticity of demand for goods from country j, $\tilde{\sigma}_{j,t}$, and the elasticity of the markup $\Gamma_{j,t}$ are controlled by σ and ϵ:

$$\tilde{\sigma}_{jt} = \frac{\sigma}{1-\epsilon\ln\frac{\sigma z_{j,t}}{\sigma-1}}$$
$$\Gamma_{j,t} = \frac{\epsilon}{\sigma-1+\epsilon\ln\frac{\sigma z_{j,t}}{\sigma-1}}$$

In a symmetric steady state, $\tilde{\sigma} = \sigma$ and $\Gamma = \epsilon/(\sigma-1)$.

3.1.3 Wage Dynamics

Households are subject to a Calvo friction when setting wages in local currency: in any given period, they adjust their wage with probability $1-\delta_w$, and maintain the previous-period nominal wage otherwise. As we will see, each household faces a downward sloping demand for the specific variety of labor they supply given by, $N_t^i = \left(\frac{W_t^i}{W_t}\right)^{-\vartheta} N_t$, where $\vartheta > 1$ is the constant elasticity of labor demand and W_t is the aggregate wage rate. As is well known, optimal wage setting gives rise to a standard wage-inflation equation (see Galí (2008)):

$$\pi_t^w = \beta\mathbb{E}_t\pi_{t+1}^w - \lambda_w\left(w_t - \sigma_c c_t - \varphi n_t - \mu^w\right), \tag{14}$$

where π^w denotes domestic nominal wage inflation, $w = \ln(W/P)$ is the (log) real wage, c and n are (log) aggregate consumption and labor supply, μ^w is the steady state (log) wage markup and $\lambda_w = (1-\delta_w)(1-\beta\delta_w)/(\delta_w(1+\vartheta\varphi))$ is derived from the Calvo wage setting process.

3.2 Output

3.2.1 The Manufacturing Sector

Each home manufacturer produces a unique variety ω that is sold both domestically and internationally. The production function uses only labor N_t:

$$Y_t^m(\omega) = e^{a_t}N_t(\omega), \tag{15}$$

where a_t is an aggregate productivity shock that follows:

$$a_t = (1 - \rho_a)\bar{a} + \rho_a a_{t-1} + \sigma^a \varepsilon_t^a \tag{16}$$

with ε^a i.i.d. mean zero and unit variance.

The labor input N_t is a CES aggregator of the individual varieties supplied by each household i,

$$N_t = \left[\int_0^1 \left(N_t^i \right)^{(\vartheta-1)/\vartheta} di \right]^{\vartheta/(\vartheta-1)}$$

with $\vartheta > 1$. Given our assumptions, the demand for each labor variety satisfies:

$$N_t(i) = \left(\frac{W_t(i)}{W_t} \right)^{-\vartheta} N_t, \tag{17}$$

with

$$W_t = \left[\int \left(W_t^i \right)^{1-\vartheta} di \right]^{\frac{1}{1-\vartheta}}.$$

Markets are segmented so firms can set different prices in each market. The firm's per-period profits are then given by:

$$\Pi_t = P_{H,t} Y_{H,t}^m + P_{U,t} Y_{U,t}^m - \mathcal{MC}_t Y_t^m \quad , \tag{18}$$

where $Y_{j,t}^m$ denotes the demand for h goods from country j, $P_{j,t}$ the price of domestic goods sold in market j expressed in domestic currency, and $\mathcal{MC}_t$ the nominal marginal cost. Market clearing for each manufactured good requires $Y_{H,t}^m + Y_{U,t}^m = Y_t^m$.

3.2.2 Total Output

Nominal gross domestic product $P_t^y Y_t$ consists of nominal manufacturing output $P_{H,t} Y_{H,t}^m + P_{U,t} Y_{U,t}^m$ and output from the copper sector $\mathcal{E}_t COP_t$ where P_t^y denotes the GDP deflator. We assume that the dollar endowment of copper follows:

$$\ln COP_t = \rho^{co} \ln COP_{t-1} + \sigma^{co} \varepsilon_t^{co}, \tag{19}$$

where ε_t^{co} is an i.i.d. shock with mean zero and unit variance.

3.3 Price Setting

Manufacturing firms choose the price at which they sell their variety at home and abroad. As in Galí (2008) we make the Calvo pricing assumption that firms are randomly chosen to reset their prices with probability $1-\delta_p$. In addition, we follow Casas et al. (2016), and assume that most firms sets their prices in dollars on exports markets (whether H or U) while they set prices in local currency in their domestic market.

If we denote θ_{ij}^k the fraction of firms from country i selling in market j in currency k, we adopt the following parametrization based on data available from the Bank of Chile:

$$\theta_{UH}^U = 0.8627 \quad ; \quad \theta_{HU}^U = 0.9434;$$

Under our assumptions, and following the derivations in Galí (2008) and Casas et al. (2016), we obtain the following generic Phillips curve:

$$\pi_{ij,t}^k = \beta \mathbb{E}_t \pi_{ij,t+1}^k + \frac{\lambda_p}{1+\Gamma}(\mathrm{mc}_{ij,t}^k + \Gamma(p_{j,t}^k - p_{ij,t}^k) + \mu^p) \tag{20}$$

where $\pi_{ij,t}^k$ is the inflation rate for goods from country i sold in country j in currency k, and $\mathrm{mc}_{ij,t}^k = \ln(MC_t^i/(\mathcal{E}_{i,t}^k P_{ij,t}^k))$ is the ratio of nominal marginal cost of production in country i, to the price of goods of these goods sold in country j in currency k, $P_{ij,t}^k$ (in currency k), converted into i's currency with the nominal exchange rate between k and i, $\mathcal{E}_{i,t}^k$.[8] In other words, $mathrmmc_{ij,t}^k$ is the opposite of the (log) markup for goods from i sold in j in currency k. $\lambda_p = (1-\beta\delta_p)(1-\delta_p)/\delta_p$ is derived from the Calvo price setting process. According to (20), strategic complementarities ($\Gamma > 0$) dampen the responsiveness of the inflation rate to markup costs, and increase the responsiveness of the inflation rate to export prices, relative to the destination price index, since firms optimally prefer to keep their price close to their competitors'.

[8] With our assumptions, $\mathcal{E}_{i,t}^i = 1$, while $\mathcal{E}_{H,t}^U = \mathcal{E}_t$.

3.4 Financial Frictions

3.4.1 Household Balance Sheet

We assume that borrowers are subject to the following borrowing limit

$$B_t \leq \frac{\bar{B}_t}{\chi}. \tag{21}$$

In the equilibrium of the model, impatient households are the borrowers since $\beta_b < \beta$. We assume that they are sufficiently impatient so as to hit their borrowing constraint in all periods:

$$B_t^b = \frac{\bar{B}_t}{\chi}.$$

In our notation, B_t^b is a the per capita level of debt of impatient borrowers, while $\chi B_t^b = \bar{B}_t$ is the aggregate lending capacity of the financial sector to households. We introduce financial spillovers by assuming that this lending capacity $\bar{B}_t$ fluctuates over time and is directly affected by the exchange rate. Specifically, we postulate the following process:

$$\bar{b}_t \equiv \ln(\bar{B}_t/P_t) = \bar{b} + \rho_b(\bar{b}_{t-1} - \bar{b}) - \psi_{be}(e_t - \bar{e}) + \zeta_t^b \tag{22}$$

where $\psi_{be} \geq 0$ denotes the intensity of the financial spillovers and $e_t = \ln \mathcal{E}_t/P_t$ is the (log) of the real exchange rate, with $\bar{e}$ its steady state value. This assumption captures the fact that the domestic financial sector needs to intermediate foreign capital into domestic loans, and its capacity to do so varies with the exchange rate. A real depreciation of the domestic currency (an increase in e relative to its steady state $\bar{e}$) limits the ability of the domestic financial sector to originate loans in domestic currency when $\psi_{be} > 0$. Different values of ψ_{be} correspond to different degrees of tightness of the financial constraint described in section 2 (the coefficient f in that model). ζ_t^b captures exogenous shifts in the borrowing constraint and is assumed to follow:

$$\zeta_t^b = \rho^b \zeta_{t-1}^b + \sigma^b \varepsilon_t^b,$$

where ε_t^b is an i.i.d. mean zero unit variance shock.

3.4.2 Working Capital

We assume that firms need to pay a share $0 \leq \psi_{wc} \leq 1$ of their production costs in advance of production via an intra-period loan funded at rate i_t. The nominal marginal cost of production is thus

$$\mathcal{MC}_t = \frac{W_t}{e^{a_t}}(1 + \psi_{wc} i_t). \tag{23}$$

This provides a simple and quite general way through which a tightening of funding conditions affects firms' marginal costs.

3.5 Interest Rates and World Demand

We close the model by assuming the following specification for domestic and foreign interest rates. First, domestic nominal interest rate follow an inflation targeting Taylor rule (in logs) with inertia:

$$i_t = \bar{i} + \rho_{iH}(i_t - \bar{i}) + (1 - \rho_{iH})(\phi_{pH}\pi_t^h + \phi_{yH}(y_t - \bar{y})) + \zeta_t^{mH} \tag{24}$$

In (24), ϕ_{pH} represents the sensitivity of policy rates to domestic price inflation π_t^H while ϕ_{yH} represents the sensitivity to the output gap $y_t - \bar{y}$. $\bar{i}$ is the target nominal interest rate, equal to the steady state real interest rate $1/\beta - 1$. ζ_t^{mH} denotes an innovation to H's monetary policy and is assumed to follow:

$$\zeta_t^{mH} = \rho^{mH}\zeta_{t-1}^{mH} + \sigma^{mH}\varepsilon_t^{mH},$$

where ε_t^{mH} is an i.i.d. zero mean unit variance shock.

The domestic nominal interest rate i_t and the dollar funding cost r_t^* are related by the uncovered interest rate parity relationship (UIP) which takes the following (log-linearized) form:

$$i_t = r_t^* + \mathbb{E}_t(e_{t+1} - e_t + \pi_{t+1}) \tag{25}$$

The funding costs r_t^* denotes the rate at which domestic financial intermediaries can obtain dollar funding from abroad. As is common in the literature, we assume that this dollar funding rate increases with the amount of net external debt NFA_t, so as to ensure stationarity of the log-linearized small open economy problem, as in Schmitt-Grohe and Uribe (2003), and can also be subject to sudden stops:

$$r_t^* = i_t^U - \psi_b(e^{NFA_t - N\bar{F}A} - 1) + \zeta_t^{rp} \tag{26}$$

where i_t^U is the dollar policy rate, ψ_b is a small strictly positive number, and ζ_t^{rp} captures exogenous risk premium shocks that follow:

$$\zeta_t^{rp} = \rho^{rp}\zeta_{t-1}^{rp} + \sigma^{rp}\varepsilon_t^{rp}$$

where ε_t^{rp} is an i.i.d. mean zero unit variance shock.

Finally, we assume that U's monetary policy and output can be captured by the following (block-exogenous) log-linear representation:

$$i_t^U = \bar{i} + \rho_{iU}(i_{t-1}^U - \bar{i}) + (1 - \rho_{iU})\phi_{yU}(y_t^U - \bar{y}^U) + \zeta_t^{mU} \tag{27a}$$

$$y_t^U = \bar{y}^U + \rho_{yU}(y_{t-1}^U - \bar{y}^U) - (1 - \rho_{yU})\phi_{iU}(i_t^U - \bar{i}) + \zeta_t^{yU} \tag{27b}$$

Equation (27a) states that U's monetary authorities follow a a targeting rule with inertia. Since we assume that the price level in U is stabilized, this policy rule that targets U's output deviations $y_t^U - \bar{y}^U$. Equation (27b) states that U.S. output responds to U.S. monetary policy. This allows U's monetary policy to impact Home via both the trade channel of exchange rates, but also via slower/faster growth in U (the terms bd and ac in the simplified model of the previous section). ζ_t^{mU} and ζ_t^{yU} denote respectively the exogenous components of U's monetary policy and U's aggregate demand. We assume they follow:

$$\zeta_t^{mU} = \rho^{mU}\zeta_{t-1}^{mU} + \sigma^{mU}\varepsilon_t^{mU}$$

$$\zeta_t^{yU} = \rho^{yU}\zeta_{t-1}^{yU} + \sigma^{yU}\varepsilon_t^{yU}$$

where ε_t^{mU} and ε_t^{yU} are i.i.d. mean zero unit variance shocks.

Equations like (27a)-(27b) are often estimated for the U.S., for instance in Rudebusch and Svensson (1999).

3.6 Equilibrium and Discussion

Given the above assumptions, we can now define a competitive equilibrium.

Definition 1 (Equilibrium) *A competitive equilibrium of the monopolistically small open economy H consists of:*

a) Both types of households maximizing utility over consumption and labor supply subject to the borrowing constraint (4),

b) Manufacturing firms maximizing profits over labor demand and prices in each market.

c) Markets for labor and domestic manufacturing goods clearing.

d) Exogenous shocks to H and U's monetary policy, ε_t^{mH} and ε_t^{mU}, copper revenue ε_t^{co}, productivity ε_t^{a}, risk premia ε_t^{rp}, borrowing limit ε_t^{b}, and U's aggregate demand ε_t^{yU}.

■

The model features a number of channels through which U's monetary policy can affect H's economy. The increase in policy rate i^U slows down economic activity in U, according to (27b). This decreases the demand for H's exports. The increase in i^U also raises H's dollar funding cost, which depresses H's real exchange rate according to (25). This increases the price of H's imports (priced in dollars) relative to H's domestic manufactures and stimulates H's economy (Casas et al. (2016) emphasize that under dominant currency pricing, the expenditure switching motive operates mostly via imports). Next, the depreciation of the local currency increases the value of the endowment of commodities $\mathcal{E}_t COP_t$, which stimulates aggregate demand. Finally, the depreciation of the domestic currency tightens the borrowing limit $\bar{B}_t$ of impatient households according to (22). This forces borrowers to de-lever, contracting aggregate demand.

The approach adopted in this paper is similar to Gourinchas et al. (2016): rather than micro-found all the channels, it presents a more flexible and pragmatic representation that hopes to capture the important trade-offs. This is not without limitations. Most obviously, the use of some reduced form relationships, such as eq. (22), or (27a)-(27b) is subject to a Lucas critique: the relevant parameters may not be invariant to policy change. This is particularly relevant for ψ_{be}, the parameter that captures the strength of the financial spillovers from the exchange rate to the balance sheet of the private sector. Different models would undoubtedly have different predictions in terms of the specific linkages between capital flows, currency value, and domestic aggregate demand. The stronger micro-foundations of many of these models also come at a cost: they may be too restrictive. In the absence of a canonical macro-finance model, we view the 'pragmatic approach' as one that balances the need for rigorous theoretical formulation and the need for intellectual flexibility.

4 Financial Spillovers: the Case of Chile

This section describes how we estimate the model using data on the Chilean economy between 1999 and 2015. The model features seven shocks, which we list here for convenience: shocks to the policy rates in H and U (ε^{mH} and ε^{mU}), to dollar copper revenues (ε^{co}), to manufacturing productivity (ε^{a}), to the risk premium (ε^{rp}), to the borrowing limit (ε^{b}) and to global demand (ε^{yU}). We estimate the model using standard Bayesian techniques. To do so, we feed into the model seven observable series: the Chilean and U.S. policy rates, the ratio of Chile's copper exports to its output, the ratio of Chile's trade balance to output, the terms of trade in the manufacturing sector, the ratio of Chile's credit to the non-financial sector to output, and an estimate of Chile's output gap. Each series is detrended and described in detail in Appendix A.

Figure 4 reports these seven variables, together with Chile's consumer price inflation, the ratio of its net foreign assets to output and the peso-USD real exchange rate. The latter variables will be used to assess the external validity of the estimated model. Over the period we consider, Chile's copper exports increased substantially, from 9% of GDP in 2002 to 22.6% in 2007 (panel e). This was driven by a strong increase in the dollar price of copper, from $1,560 per metric ton, to $7,131 over the same period. The overall trade balance is dominated by copper exports and shows a similar pattern, improving from 2.3% of GDP to 13.2% (panel d). The net foreign asset position steadily improves over the same period, from a large debtor position of -44 percent of output to 0 (panel h). Output increases substantially over the same period, with the estimated output gap moving from -2.2% to +3.7% (panel (b)). The rise in copper prices induces a 28 percent real appreciation of the peso against the dollar (panel i), and the non-copper trade balance deteriorates from -6.7 to -9.4 percent of GDP. The global financial crisis of 2008 shows up in the data with a sharp slowdown of the Chilean economy in 2009, the output gap decreasing by more than 5% (panel b), a collapse in trade (both manufactures and commodities) (panel d), and an aggressive policy response both in Chile and in the United States (panel a). Because we are interested in estimating the strength of financial spillovers, we directly include a measure of the private credit to GDP (filtered) in the series we feed into the model. Through the lens of the model, this corresponds to the debt of impatient households $\bar{B}_t$ (panel c). This measure indicates that global financial conditions were improving rapidly right before the crisis followed by a sharp contraction in the borrowing limit in 2009 and 2010. It is interesting to note that, at least for Chile, the unconditional correlation between private credit to GDP and the real exchange rate is not very strong, indicating that financial spillovers arising from movements in the exchange rate may not play a critical role. After a sharp decline during the crisis, Chile's CPI inflation rebounded in 2011 (panel g) prompting the monetary authorities to raise the policy rate (panel a).[9]

We use a combination of calibration and estimation. We calibrate parameters that affect steady state variables. Most of the calibrated parameters take standard values for small open economies and are reported in Appendix A. We estimate the remaining 17 parameters (the persistence ρ^i and

[9]Since 1999, the Banco Central de Chile follows an Inflation Targeting regime. The inflation target rate has been about $3\% \pm 1\%$ for most of that period.

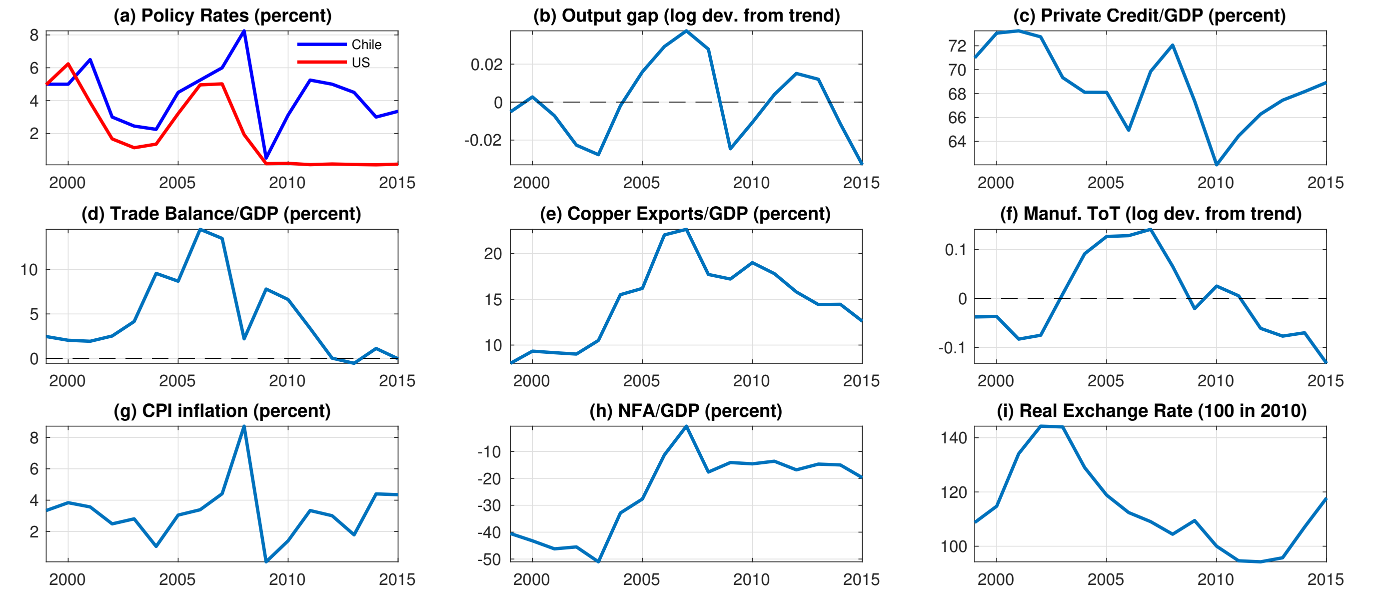

Figure 1: Observables: Filtered Data. Detailed description and sources in Appendix A

volatility σ^i of the seven shocks, plus the strength of the financial spillovers as measured by ψ_{be}, χ_{wc} and ϕ_b) using standard Bayesian estimation techniques as in An and Schorfheide (2007).

4.1 Impulse Responses

We begin by illustrating, in the context of the model, how the strength of financial spillovers shapes the transmission of U.S. and domestic monetary policy impulses to Chilean output. Figure 2 reports the impulse response function to a U.S. monetary policy tightening, at the estimated parameter values, but with $\psi_{be} = 0$, i.e. when the balance sheet channel is turned off. As in the textbook Mundell-Fleming model described in section 2, the tightening of U.S. monetary policy is expansionary in Chile. The currency depreciates, which pushes up CPI inflation and triggers a domestic monetary tightening. Higher domestic interest rates depress the consumption of patient households, but impatient households' consumption increases, due to the higher wealth. The manufacturing terms of trade are largely unresponsive, since both exports and import prices are mostly set in dollars, as documented extensively by Casas et al. (2016).

Contrast this result with the one that obtains when financial spillovers are intermediate. Our

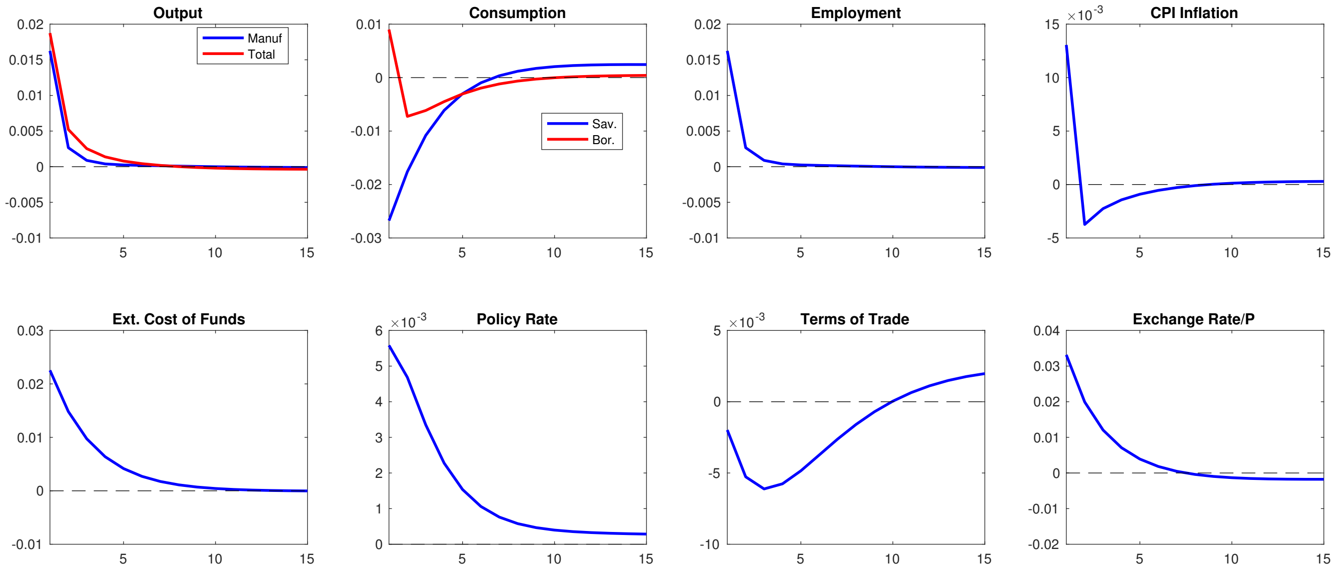

Figure 2: Impulse Response to a U.S. Monetary Tightening, low spillovers ($\psi_{be} = 0$).

simple Mundell-Fleming analysis suggested that a U.S. monetary tightening could become contractionary as the balance sheet of domestic agents would be adversely impacted by the depreciation of the local currency. Figure 3 shows that this is indeed the case in the full-fledge model. The impulse responses are estimated for an intermediate level of financial spillovers, in this case $\psi_{be} = 3$. The depreciation of the local currency tightens the borrowing constraint of impatient households, forcing them to delever. Aggregate consumption now contracts, pushing the home economy into a recession. The optimal local response to the U.S. tightening is to reduce policy rates.

While financial spillovers are now strong enough to overturn the transmission of foreign monetary policy, they are not sufficient to overturn the transmission of domestic monetary policy. Figure 4 reports the impulse response to a domestic monetary policy tightening under the maintained assumption that spillovers are intermediate. As expected, the tightening leads to an appreciation of the domestic currency. This appreciation relaxes the borrowing constraint of impatient households, but this effect is not sufficient to stimulate aggregate demand and output and employment decline.

Contrast this last result with the case where the financial spillovers are strong (i.e. $\psi_{be} = 20$). Figure 5 shows the results. We now observe that output briefly increases with a domestic tight-

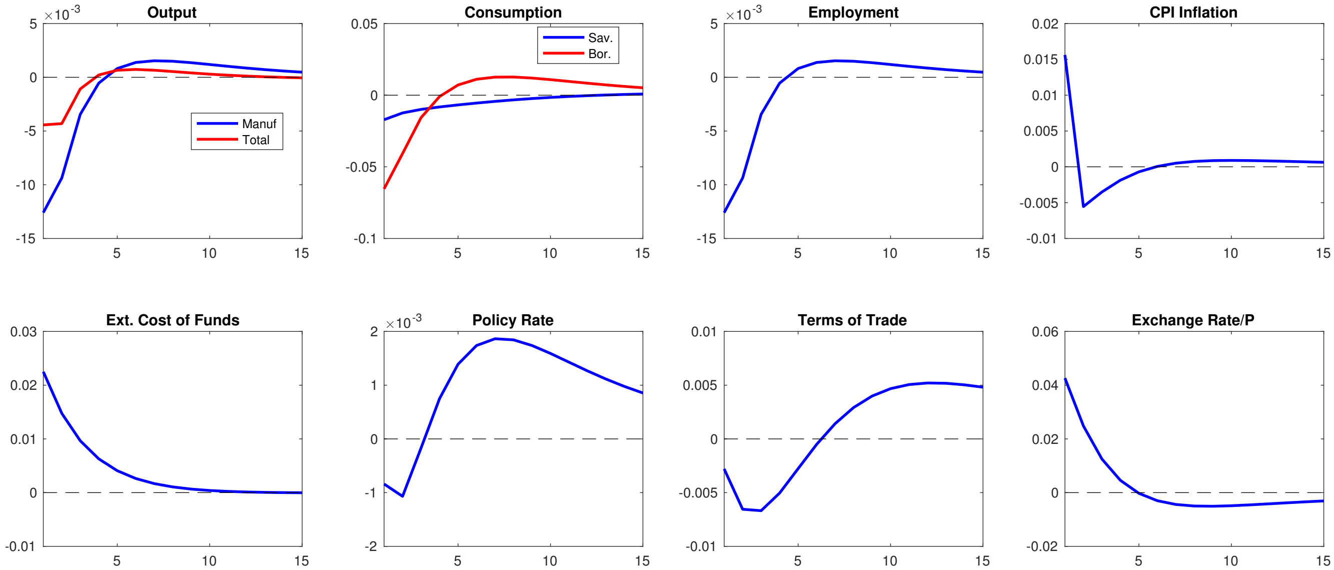

Figure 3: Impulse Response to a U.S. Monetary Tightening, intermediate spillovers ($\psi_{be} = 3$).

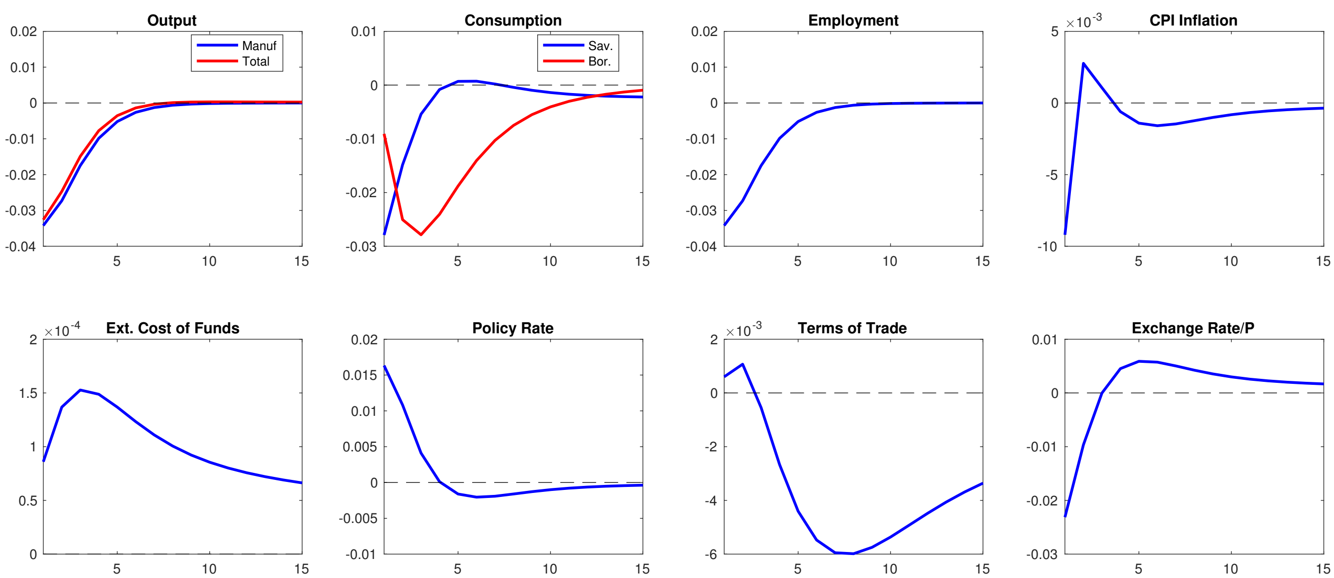

Figure 4: Impulse Response to a Local Monetary Tightening, intermediate spillovers ($\psi_{be} = 3$).

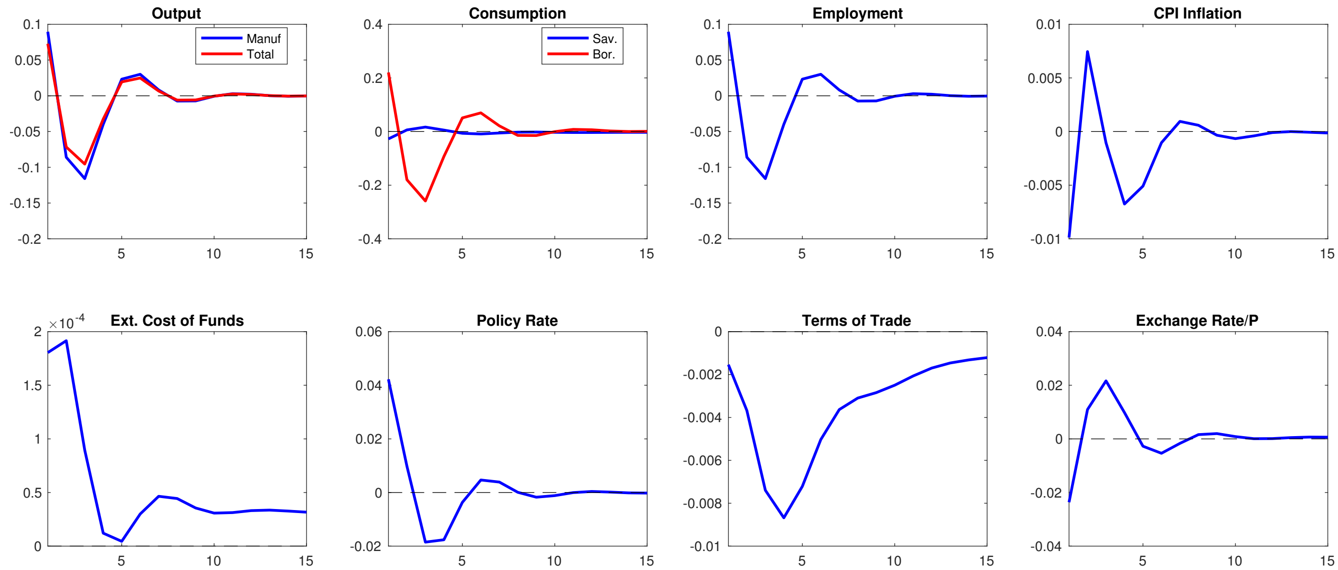

Figure 5: Impulse Response to a Local Monetary Tightening, strong spillovers ($\psi_{be} = 20$).

ening, driven by the consumption of impatient agents who enjoy a relaxation of their borrowing constraint. The fuller model is thus able to capture the three different regimes described in section 2: when financial spillovers are weak, the model functions like a standard Mundell-Fleming model: U.S. monetary tightening are expansionary. When financial spillovers are intermediate, a tightening at the center is contractionary -thanks to the contraction in borrowers' balance sheet- but home monetary policy remains expansionary. Finally, when financial spillovers are strong, the model indicates that the transmission of domestic monetary policy becomes perverse: a domestic tightening, via the appreciation of the domestic currency becomes expansionary.

4.2 Estimation

We solve the model by log-linearization methods around a zero inflation steady state. The estimation results, along with our choice of priors, are described in Table 2 in Appendix A. As the previous discussion illustrates, a key parameter is the strength of financial spillovers, ψ_{be}. We estimate $\psi_{be} = 4.96$ with a 90% confidence interval between 3.39 and 6.54.

Figures 6-9 report the Bayesian impulse response functions at the estimated parameters for four shocks: a U.S. and local monetary policy tightenings, a funding cost shock and a shock to the dollar value of copper revenues. Looking at the first two figures, it is immediate that the results are consistent with the case of 'intermediate' financial spillovers: both a U.S. or a local monetary policy tightening are contractionary. This results suggest that, for Chile at least, the textbook prediction that a tightening in the U.S. will be expansionary at home is incorrect. Nevertheless, this finding does not overturn the general logic of the Mundell Fleming framework. In particular, floating exchange rate remain highly desirable since the optimal response to a U.S. tightening may be a reduction in policy rates at home. Figure 8 reports the response to the external risk premium ε^{rp}. The increase in risk premia triggers a real depreciation that tightens the borrowing constraint, forcing impatient households to delever and pushing the economy into a recession. Hence our estimates also indicate that a risk-off episode can be quite contractionary for the local economy, even if exchange rates are floating, unlike Krugman (2014)'s analysis.

Finally, Figure 9 presents the response to a shock to copper revenues in US dollars, which can be interpreted as an increase in the price of copper. Higher copper prices lead to an appreciation of the currency, as is often documented for commodity currencies. It is well known that the dollar exchange rate of small commodity exporters (such as Chile) is strongly correlated with the dollar price of the main commodities (see Chen et al. (2010)): an increase in the dollar price of copper represents an exogenous improvement in the terms of trade of these countries, often impacting a large fraction of their exports. The increase in resources translates into a real appreciation. This appreciation relaxes the borrowing constraint of the borrowers who increase their consumption further. While total output increases, manufacturing output declines, due to the increased competition from foreign manufacturing output and manufacturing employment declines.

Figure 10 compares the model and predicted evolutions for Chile's CPI inflation (filtered) and the ratio of its net foreign asset to its output.

These two variables do not enter into the estimation procedure, so they provide a window on

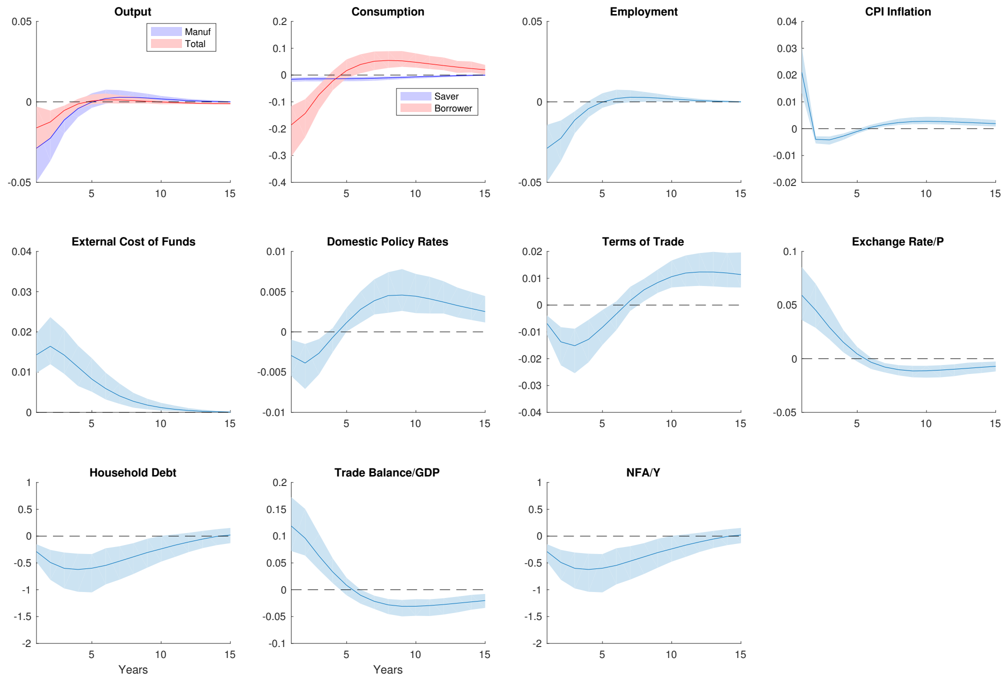

Figure 6: Bayesian IRF: U.S. Monetary Policy

the ability of the estimated model to capture Chile's outcomes. Overall, the model does a reasonable good job for both variables. As in the data, CPI inflation increases between 2002 and 2008. It collapses in 2009 as economic activity slows down sharply. Inflation in the model rebounds more rapidly than in the data, but remains below the target inflation. The predicted NFA position of Chile improves rapidly as copper revenues surge in the early 2000s. In fact, the model predicts that it continues to rise after 2008, towards 60% of GDP, above the 40% of GDP observed in the data.

To illuminate further how the estimated model accounts for Chile's recent macroeconomic history, Figure 11 reports the posterior shocks, estimated from the smoother of the Kalman Filter. The figure reveals that a major negative shock to dollar copper revenues occurs in 2008, followed by a sharp contraction in credit supply and a risk premium shock in 2011, while both U.S. and Chilean monetary policies turned very expansionary in 2009 and 2010.

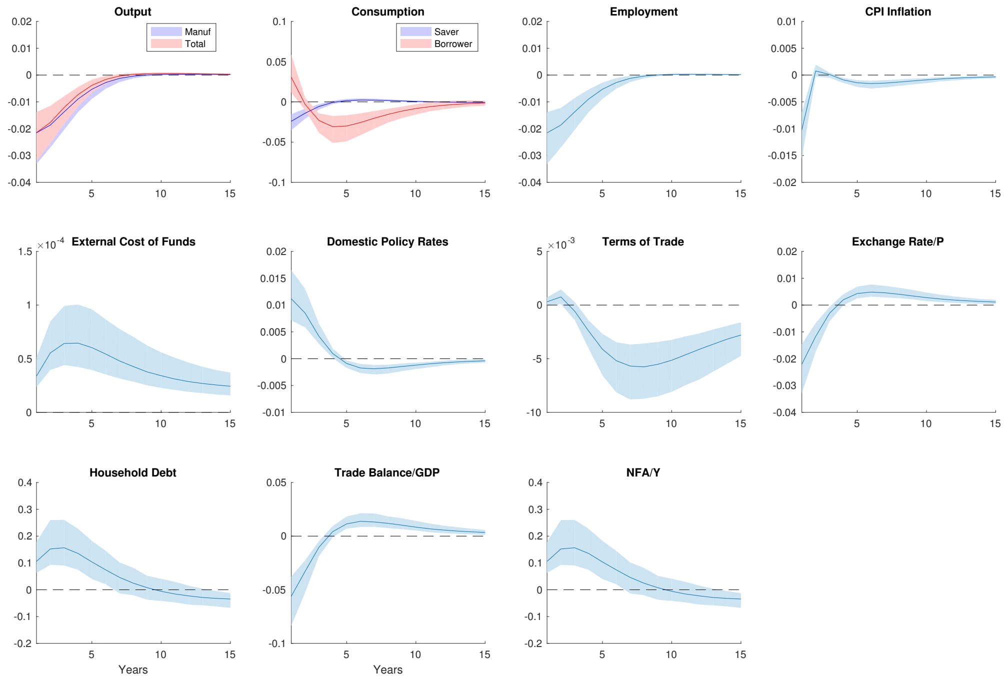

Figure 7: Bayesian IRF: Chile Monetary Policy

5 Conclusion

How do U.S. and domestic monetary policy transmit to a small open emerging market economy? In the terminology of Secretary of Defense Donald Rumsfeld, this is a 'known unknown': despite the practical importance of this question for policy makers around the world, we know that we know very little about it.

This paper argues that the answer to this question depends on the strength of financial spillovers. In a world with limited financial spillovers, the transmission is broadly in line with the standard analysis of Mundell and Fleming: U.S. monetary policy tightenings are expansionary abroad, and it is optimal to let the nominal exchange fluctuate so as to absorb the brunt of the adjustment. As financial spillovers increase, this conclusion is not necessarily warranted any longer. First, for intermediate levels of the spillovers, U.S. monetary policy transmits positively: a tightening in the center is contractionary abroad. These effects can be further amplified by the global financial cycle.

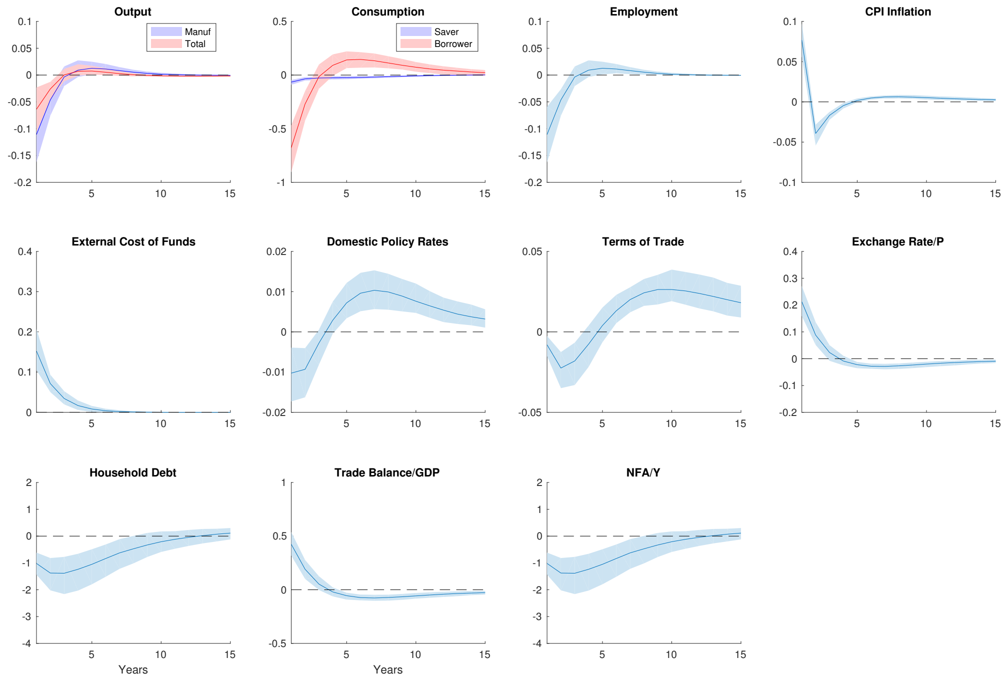

Figure 8: Bayesian IRF: External Risk Premium

With intermediate financial spillovers, a depreciation of the domestic currency is contractionary, as it tightens domestic financial constraints and reduces domestic net worth.

This validates the concern of emerging market policymakers that worry that monetary policy in the U.S. may generate volatility in their own economy. But the case of intermediate spillovers indicate that domestic monetary policy still operate in a 'normal' way so that the best response to a U.S. tightening is to reduce domestic policy rates, and to let the currency depreciate further. This is so, despite the negative effect of the currency depreciation on domestic activity. Therefore, the presence of financial spillovers does not, per se, invalidate a key result of the 'Trilemma': exchange rate flexibility is even more important, despite the more limited effectiveness of domestic monetary policy.

Second, if financial spillovers become really strong, the transmission of domestic monetary pol-

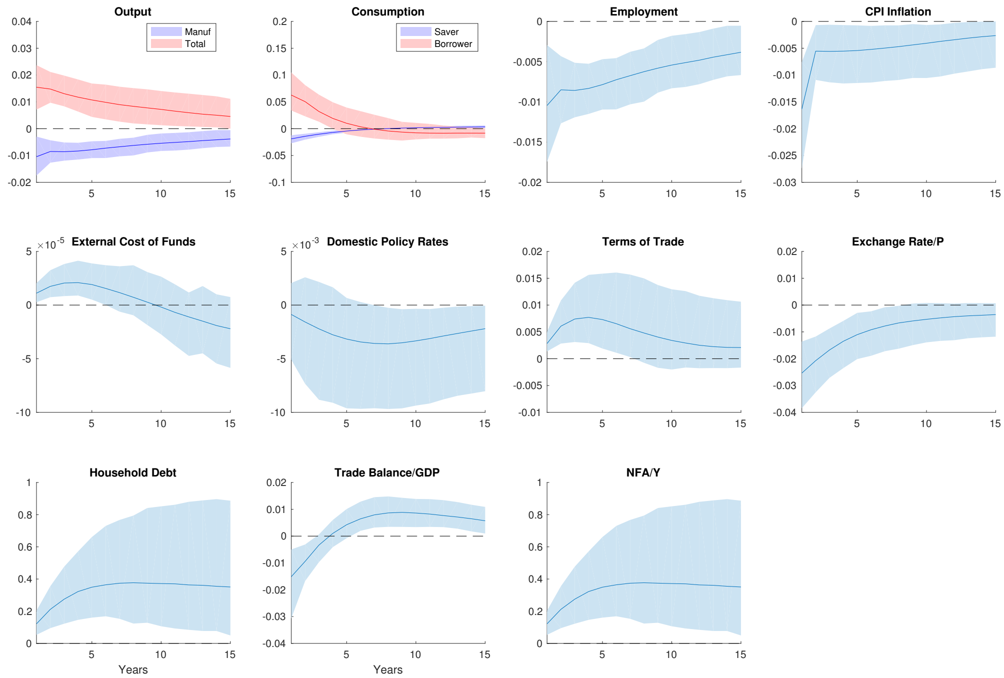

Figure 9: Bayesian IRF: Copper Shock

icy itself is altered: a tightening of the policy rate, because of its impact on the value of the currency, would become expansionary, not contractionary. Our analysis shows that it is only in the case of such 'perverse' transmission of monetary policy that exchange rate flexibility becomes less effective.

While some policymakers have argued that indeed higher policy rates are expansionary and not contractionary, the issue is mostly an empirical one. The paper estimates a small scale DSGE model to the Chilean economy, a leading example of a small open emerging economy. The resulting estimates indicate, at least for that country and for the recent period, that financial spillovers are intermediate. It follows from our analysis that exchange rate flexibility is even more important than in the Mundell Fleming case.

How can we reconcile our analysis with the common view that exchange rate flexibility looses its effectiveness when depreciations are contractionary? We offer two possible explanations. First, the

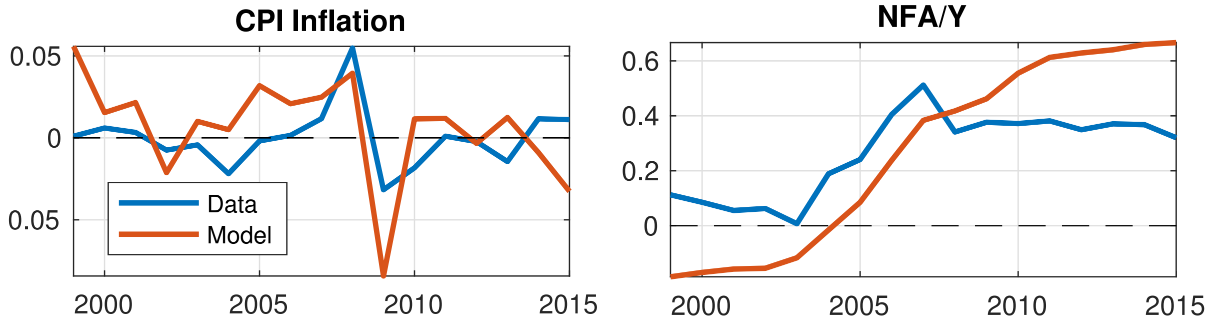

Figure 10: Estimated vs. Predicted variables

distributional effects of exchange rate changes are more complex in presence of financial spillovers. In addition to the usual distinction between exporters who gain and consumers who lose (the former benefitting from a depreciation, the latter suffering because of the adverse terms of trade effect), financial spillovers imply that borrowers and financial intermediaries may suffer from a depreciation of the local currency. The political economy may be adversely affected. Second, because monetary policy loses some of its effectiveness when financial spillovers are intermediate, larger movements in policy rates may be needed to stabilize the economy. This also increases the within-country distributional consequences of monetary policy. Further, it makes it more likely that monetary policy will be constrained at the effective lower bound.

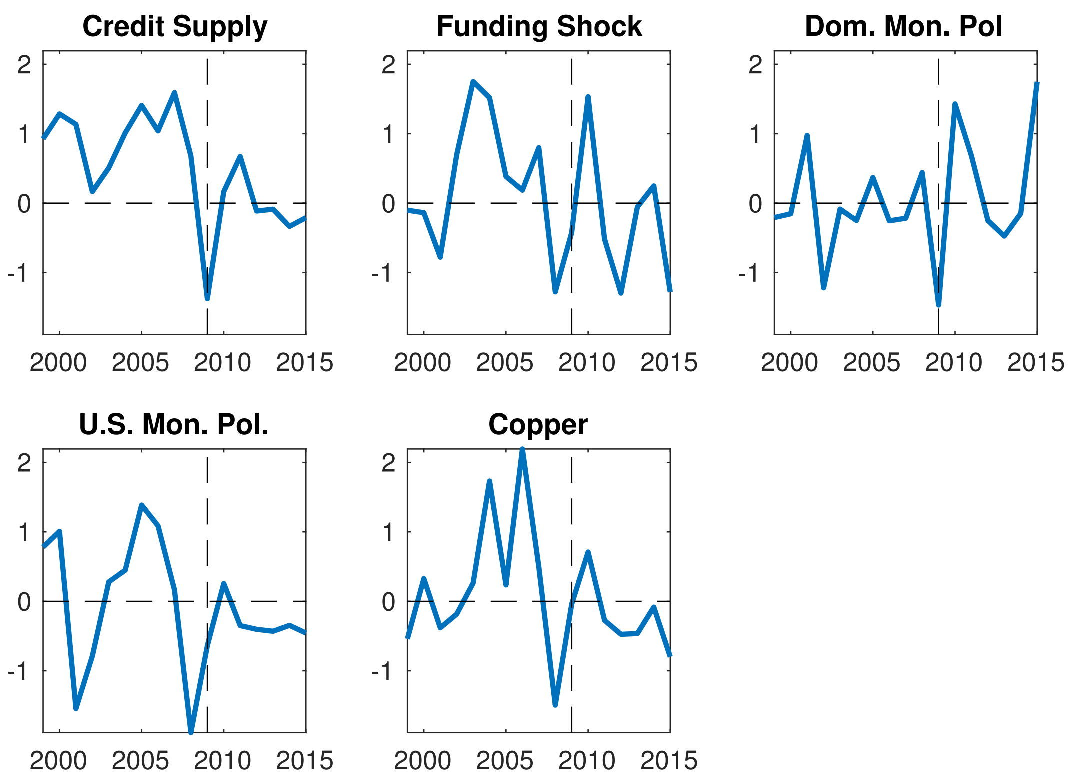

Figure 11: Smoothed Posterior Shocks

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A Appendix

A.1 Data Sources

All data are annual

- U.S. policy rate: Effective Federal Funds Rate. Source: FRED. Code: FEDFUNDS.
- Chile's policy rate: After 1995, Central Bank policy rate. Source: International Financial Statistics (IFS). Code: FPOLMPA. Before 1995: Chile Central Bank Minimum Interest Rate. Source: Global Financial Database (GFD). Code: IDCHLD.
- Chile's output gap: Real Gross Domestic Product. Source: IFS. Code: NGDPRIX. The output gap is constructed as the deviation of (log) real output from a linear trend.
- Chile's private credit to GDP. Other Deposit Corporations Survey, Claims on Other Sectors, Claims on Private Sector, National Currency. Source: IFS. Code: FOSAOPXDC
- Chile's Gross Domestic Product: Nominal, National Currency. Source: IFS. Code NGDPXDC
- Chile's Trade Balance: Exports minus imports, divided by nominal output. Exports: External Sector, Exports of Goods and Services, Nominal, National Currency. Source: IFS. Code: NXXDC. Imports: External Sector, Imports of Goods and Services, Nominal, National Currency. Source: IFS. Code: NMXDC.
- Copper Exports: Copper exports FOB, millions of US dollars. Source: Banco Central de Chile.
- Dollar Nominal exchange rate: Source: OECD Financial Indicators.
- Manufacturing Terms of Trade: Ratio of export deflator to import deflator. Source: Banco Central de Chile (internal source).
- Chile's Net Foreign Asset Position: Before 2011 from Lane and Milesi-Ferretti (2007)'s External Wealth of Nations database (Mark II), millions of current USD. After 2011: Source: IMF Balance of Payment. Code: 228IFRBP6USD.A.
- Chile's CPI inflation: Consumer Price Index, All items, Percent Change. Source: IFS. Code: PCPIPCCPAPT.
- Chile dollar real exchange rate: constructed as $\mathcal{E}P^*/P$ where $\mathcal{E}$ is the dollar peso nominal exchange rate, P^* is the U.S. CPI. Source: OECD Main Economic Indicators (via FRED). Code: CPALTT01USA661S and P is the Chilean CPI. Source OECD Main Economic Indicators (via FRED). Code: CHLCPIALLAINMEI.

A.2 Filtering

For the estimation of the model, variables are filtered as follows:

- the U.S. and Chilean policy rates are centered on $1/\beta - 1$.
- Chile's output gap is computed as the (log) deviation from a linear trend estimated over the period 1999-2015.
- (log) Private credit to GDP is computed as the deviation of log private credit to GDP from a linear trend estimated over the period 1990-2015. It is then centered on the average credit to GDP in the data (0.68).
- Chile's manufacturing terms of trade: the (log) manufacturing ToT are measured in deviation from a linear trend for the period 1999-2015 and centered on the model-implied steady-state manufacturing terms of trade.
- Chile's CPI inflation are de-meaned since the model implies zero steady state inflation.

A.3 Calibration

Table 1 contains 19 parameters calibrated from the literature and existing data. The discount factor for patient households is set at 0.97, a common value in the literature. The fraction of impatient households is set to 0.65, as in Gourinchas et al. (2016). The openness coefficient is set to 0.3. The inverse Frisch elasticity and the coefficient of relative risk aversion are set to 1. The steady state elasticity of substitution between varieties of goods and of labor is set to 6. We assume a superelasticity of demand $\varepsilon = 1$ so that the steady states elasticity of the markup to prices is $\Gamma = \varepsilon/(\sigma - 1) = 1/5$, a relatively low value. The Calvo pricing parameters are set to 0.65, for both wages and prices. The NFA adjustment cost is set to a small positive number, to ensure stationarity while leaving the system's dynamics largely unchanged. The coefficients of the Taylor rule in H and U are consistent with parameters often employed in the literature. We set the inertial coefficients ρ_{iH} and ρ_{iU} to 0.66 which corresponds to a first order autoregressive coefficient of 0.9 on quarterly data (see Coibion and Gorodnichenko (2011) for some estimates for the U.S.) We set the coefficients on inflation and the output gap in Chile to 1.5 and 0.5 respectively. Finally, we set the coefficient on global output in the U.S. Taylor rule to 0.1, which corresponds to a coefficient of 0.5 on U.S. output and takes into account the fact that U.S. output represents about $1/5$ of world output. Next, we measure a quarterly serial correlation of world output of 0.89, which translates to $\rho_{yU} = 0.6$ at an annual frequency. We borrow the coefficient ϕ_{iU} of the impact of lagged U.S. policy rates on world output from Rudebusch and Svensson (1999). These authors estimate a semi-elasticity of lagged U.S. interest rates on world output of -0.1. Assuming that U.S. output represents $1/5$ of world output, this coefficient is equal to $-5(1 - \rho_{yU})\phi_{iU}$ from which we infer that $\phi_{iU} = 0.05$. Lastly, the coefficients θ_{ij}^{U} are obtained from the Banco Central of Chile as the share of exports and imports invoiced in US dollars.

Parameter	Description	Value
β	discount factor	0.97
χ	fraction of impatient consumers	0.65
γ	openness coefficient	0.7
φ	inverse Frisch elasticity	1
σ_c	CRRA	1
σ	steady state elasticity of substitution between goods	2
ε	superelasticity of demand	1
ϑ	elasticity of substitution between labor varieties	2
δ_p	price stickiness	0.65
δ_w	wage stickiness	0.65
ψ_b	NFA adjustment cost	0.001
ρ_{iH}	inertia in H's Taylor rule	0.66
ϕ_{pH}	Taylor rule inflation coefficient	1.5
ϕ_{yH}	Taylor rule output gap coefficient	0.5
ρ_{iU}	inertia in U's Taylor rule	0.66
ϕ_{yU}	Taylor rule output coefficient for U.S.	0.1
ρ_{yU}	serial correlation in global output	0.6
ϕ_{iU}	impact of lagged US rate on world output	0.05
θ_{UH}^{U}	share of H's imports in U.S. dollars	0.8627
θ_{HU}^{U}	share of H's exports in U.S. dollars	0.9434

Table 1: Calibrated Parameters.

A.4 Estimation

We estimate 18 parameters. We set priors in the $[0, 1]$ interval, except for ψ_{be} for which we assume a Gamma prior. Table 2 reports the prior and posterior mean of the estimated coefficients.

Parameter	Description	Dist.	Prior Mean	Prior S.D.	Posterior Mean	90% Interval	
ρ^{rp}	funding shock	beta	0.85	0.10	0.48	0.35	0.62
σ^{rp}		beta	0.20	0.10	0.15	0.10	0.20
ρ^{mH}	home monetary shock	beta	0.5	0.1	0.36	0.23	0.50
σ^{mH}		beta	0.70	0.20	0.02	0.01	0.02
ρ^{mU}	U.S. monetary shock	beta	0.5	0.1	0.50	0.37	0.65
σ^{mU}		beta	0.70	0.20	0.02	0.01	0.02
ρ^{b}	borrowing limit	beta	0.25	0.1	0.36	0.17	0.53
σ^{b}		beta	0.70	0.20	0.20	0.10	0.27
ρ^{a}	productivity	beta	0.85	0.10	0.89	0.81	0.99
σ^{a}		beta	0.20	0.10	0.10	0.04	0.16
ρ^{co}	copper	beta	0.85	0.10	0.90	0.83	0.99
σ^{co}		beta	0.70	0.20	0.20	0.13	0.26
ρ^{yU}	global output	beta	0.85	0.10	0.77	0.63	0.90
σ^{yU}		beta	0.20	0.10	0.06	0.03	0.09
ψ_{be}	financial spillover	gamma	2.00	1.00	4.96	3.29	6.54
χ_{wc}	working capital	beta	0.80	0.10	0.76	0.61	0.90
ρ_{b}	persistence borrowing limit	beta	0.85	0.10	0.93	0.87	0.98

Table 2: Priors and Posteriors. The table presents Bayesian estimates of model parameters. It specifies the distribution for the prior, its mean, standard deviation, as well as posterior mean and 90% confidence interval.