Multinationals’ response to repatriation restrictions

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Abstract

We present a model that explains how repatriation restrictions can increase or decrease a multinational’s capital investment in and technology transfer to its subsidiary. Past remittance restrictions influence the multinational’s expectation of current and future repatriation policies which affect its operations. We show that the model can capture the flows of United States multinational’s capital and technology in response to various forms of Brazilian repatriation restrictions seen in the eighties. By comparing steady state level effects of the restrictions, we show countries should expect an inflow of foreign direct investment with the abolishment of restrictions, not an outflow as some countries fear. © 2000 Published by Elsevier Science B.V. All rights reserved.

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1. Introduction

For the past decade more than 50% of the members of the International Monetary Fund have imposed restrictions suspending remittances by Multinational Enterprises (MNEs). These restrictions take the form of blocking...
subsidaries’ remittance of capital, dividends, royalties and fees and/or profit back to their headquarters for days, months or years. Surveys and empirical data suggest that these restrictions affect MNE’s operations. Wallace (1990), in a survey of 300 MNEs, finds repatriation restrictions to be one of the top three factors affecting direct investment decisions. Hines (1997) finds these restrictions have an econometrically significant impact on the actions of MNEs.

This paper provides a theoretical and quantitative look at how repatriation restrictions can increase or decrease an MNE’s capital investment in and technology transfer to its subsidiary. Understanding the link between capital flows and repatriation policies is important since countries who impose restrictions are often concerned about maintaining a minimum level of foreign exchange reserves and their current stock of foreign direct investment. Since technology transferred by MNEs is diffused into the local economy (see Teece, 1976), it is of interest to know how repatriation policies influence the stock of technology available to domestic firms.

Past research in this area has focused on capital account liberalizations’ effect on capital flows.1 This paper differs from their analysis in three important ways. First, this research focuses on the actions of the MNE as restrictions vary through time. Although other work has explained why a country generally experiences a capital inflow as restrictions are lifted, we focus on explaining how capital investment may increase or decrease in the country when restrictions are enforced. Second, this work not only considers the effect remittance policies have on capital flows but, we analyze the effect it has on technology transfers. Third, besides providing the theoretical underpinnings of the analysis, we quantify the effect repatriation policies have on capital and technology flows.

The theoretical analysis provides intuition for how movements in repatriation restrictions affect the MNE’s activities. We show that changes in government restrictions, which alter the MNE’s belief about the expected present discounted value of their remittance, can cause the MNE to reinvest in the subsidiary and wait out the restriction or, cause the MNE to get funds out of the subsidiary immediately. Technology transfer to the subsidiary may increase or decrease as government restrictions affect the MNE’s valuation of the marginal benefit of an additional unit of technology used in the subsidiary. It is the MNE’s belief about the enforcement of current and future restrictions that increase or decrease technology and capital flows.

We quantify the effect of repatriation policies in three ways. First, through impulse responses, we measure how the imposition of restrictions causes capital investment and technology transfer to deviate from their long run mean values. We illustrate that different forms of restrictions, partial versus full blocking of

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1 Some papers include Bacchetta (1992), Bartolini and Drazen (1997a,b) and Itagaki (1989).
funds, can cause tremendously different dynamic effects on these flows. Second, focusing on United States (US) MNEs with subsidiaries in Brazil, we simulate the model with actual repatriation restrictions enforced through the eighties. The model can predict the level increases and decreases in foreign direct investment found in Brazil. Last, we compare the effects of various constant repatriation policies on the stock of foreign direct investment in a country. That is, we compare comparative static levels of the subsidiary’s capital stock under the assumption that the government blocks a constant percent of remittance. Results suggest government can increase the flow of capital, not have capital flee their country as is sometimes feared, by lifting remittance restrictions.

The remainder of the paper is structured as follows. Section 2 reviews repatriation policies of Brazil from the late 1970s through 1990. This highlights and motivates how MNEs’ capital and technology transfer decisions can vary from one episode of repatriation restrictions to another. The model is presented in Section 3. Section 4 provides the theoretical analysis while Section 5 provides quantitative measures of how remittance policies affect the MNE’s operations. Concluding remarks are in Section 6.

2. Repatriation policies and multinational reaction: Case study of Brazil

To understand how repatriation restrictions affect MNEs’ operations, consider US MNEs with subsidiaries in Brazil between 1977 and 1991. We highlight Brazil for two reasons. First, Brazil imposed three episodes of repatriation restrictions during this period. Second, Brazil received a larger inflow of foreign direct investment than any other Latin and South American country.

Brazil’s repatriation restrictions occurred in 1979, 1983 and 1989. The form and length of restrictions varied between episodes. In 1979 funds were frozen completely for a six-month period. At the onset of the 1983 experience (October 1983) MNEs observed some of their funds being converted and some funds blocked. This episode lasted approximately two months. The 1989 experience (starting in June 1989) lasted 4–6 months. During this period the central bank completely blocked funds.

Losses due to these policies not only include the time loss of money while the funds are being held but, include losses due to Brazil having devaluations in their currency while funds were blocked. Quantifying the total loss the MNEs

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2 Business Latin America provides explicit information about each episode of repatriation restrictions. We only examine the period 1977–1991 since up through 1975 Brazil was expropriating firms and in 1991 Brazil overhauled its capital investment policy.
Fig. 1. The loss for the four months that funds were held is $t(1 - rt)!
$t(1 - rt)$, where $t$ is August of 1989, $t + 1$ is December of 1989, $r_t = 2.7\%$ (the four month interest rate), $e_t = 1/2.5 (S/Cr)$ and $e_{t+1} = 1/11$.

MNEs’ responses to these restrictions are seen in Figs. 1 and 2. Fig. 1 plots US MNEs’ reinvested earnings in their Brazilian subsidiaries as a

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3 Remittance data is only reported annually and quoted in dollars when entered into intercompany accounts (when exchange controls are enforced). This reporting does not allow us to quantify the total dollar value of losses MNEs face from periodic restrictions.

4 The loss for the four months that funds were held is $[e_t(1 + r_t) - e_{t+1}]/e_t(1 + r_t)$. where $t$ is August of 1989, $t + 1$ is December of 1989, $r_t = 2.7\%$ (the four month interest rate), $e_t = 1/2.5 (S/Cr)$ and $e_{t+1} = 1/11$. 

percent of their total direct investment position. This captures the percent of the subsidiary’s equity being reinvested in the plant each year. During Brazil’s 1979 and 1983 repatriation restrictions MNEs tried to get funds out of their subsidiaries. These were the only years when MNEs had negative reinvested earnings. When Brazil enforced restrictions in 1989, MNEs reinvested an unusually large level of funds in their subsidiaries. In manufacturing, the subsidiaries reinvested more than twice the equity relative to years when there were no restrictions. Repatriation restrictions, therefore, affect MNE’s operations by either causing the MNE to get funds out of the subsidiary, as in 1979 and 1983, or reinvest an unusually large amount of funds as in 1989.

Fig. 2 uses subsidiaries’ royalties and fees paid to their headquarters as a percent of the foreign direct investment position as a proxy for technology transfer. During Brazil’s 1979 and 1983 restrictions, the royalties and fees ratio falls at least 25% from the previous year. The 1989 restrictions cause royalties and fees remitted to the headquarters to rise to three times the level in the surrounding years. So, repatriation restrictions either substantially increase or decrease the level of technology supplied to the subsidiary.

In the next section we present a model that explains why MNE’s actions differ across episodes of repatriation restrictions.

3. Model

We consider an MNE with two plants: a headquarters in a developed country and a subsidiary in a developing country. The MNE acts as a single entity whose
objective is to maximize profits in terms of the headquarters’ currency. To do this, the MNE decides, each period, how many innovations to produce and share across its plants, the capital stocks of each plant and the amount of funds to remit from the subsidiary.

Each period the headquarters produces innovations that it shares with the subsidiary. Let $L_t(R_{t-1}, R_t)$ denote the labor demand function of the headquarters to produce $R_t$ innovations at date $t$ when the accumulated stock of innovations is $R_{t-1}$. $L_t(R_{t-1}, R_t)$ is assumed to be twice continuously differentiable, increasing and strictly convex in $R_t$ and, non-increasing and concave in $R_{t-1}$. This functional form allows for many interpretations including that past innovations become obsolete. Labor costs are $w_t L_t(R_{t-1}, R_t)$, where $w_t$ is the wage rate in the developed country at date $t$.

The MNE starts a period with a level of capital stock $K_{it}$ in each of its plants, where $i = h$ is for the headquarters and $i = s$ is for the subsidiary. After production, the capital stock depreciates by $\delta$ percent. Prior to the end of date $t$ the MNE chooses capital investment so the end of period capital stock is $K_{it}^{t+1}$. The MNE purchases or sells capital at a price of $p_t K_{it}$ in the developed (developing) country subject to adjustment costs, $\Phi_t(K_{it}^{t+1}, K_{it}) i = h (i = s)$. The adjustment cost function is assumed to be twice continuously differentiable, decreasing and strictly concave in $K_{it}$ and, increasing and strictly convex in $K_{it}^{t+1}$.

Output of plant $i$ is produced using innovations and capital by $R_t F(K_{it}^{t})$, where $F(K_{it}^{t})$ is the physical production of the good, $i = h$ or $s$. The physical production function is assumed twice continuously differentiable, increasing and strictly concave in $K_{it}^{t}$. Each plant sells its output in the international market. The headquarters receives a price of $p_t$ and the subsidiary receives a price of $p_{Ht}$, in the developed and developing country currency respectively. We assume $p_t = e_t p_{Ht}$, where $e_t$ is the exchange rate.

The price of the MNE’s output, $p_t$, could be given in a competitive market, however, more realistically, $p_t$ depends on the MNE’s output. Typically we find MNEs operating in industries with high concentration indices. We assume the

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5 We do not consider an inflow of capital from the headquarters to the subsidiary when repatriation restrictions are imposed.

6 Adjustment costs are needed for the theoretical and quantitative analysis. These costs guarantee the value function (optimal policy function) is twice (once) differentiable and, the capital stock adjusts slowly when repatriation restrictions fluctuate over time.

7 If one prefers, we could assume a competitive market and the theoretical analysis remains unchanged.
MNE operates as an international monopolist and, therefore, the revenue function satisfies the standard assumptions of the Cournot literature.\textsuperscript{8}

Any funds the MNE remits from the subsidiary to its headquarters go through the developing country’s central bank. If there are no repatriation restrictions, then the central bank converts the subsidiary’s remittance, $C_t$, to the developed country’s currency at the exchange rate $e_t$. The headquarters receives $e_tC_t$. If the central bank imposes restrictions, then it either holds all of the subsidiary’s remittance or converts part of the remittance and holds the remainder. When the MNE decides how much to remit from, and reinvest in, the subsidiary it knows the remittance may encounter repatriation restrictions, but it does not learn the severity of the restriction until it relinquishes the funds to the central bank.\textsuperscript{9,10}

We model three forms of repatriation restrictions: no restrictions; full blocking of funds; or partial conversion. Let $\rho_t$ represent repatriation restrictions at date $t$, $\rho_t \in [0, 1]$. $\rho_t = 1$ means there is no repatriation restriction and $\rho_t = 0$ means there is no conversion. Once the subsidiary relinquishes $C_t$ to the central bank, $\rho_t$ becomes known. The headquarters receives $e_t \rho_t C_t$.

The MNE’s expected present discounted profit maximization problem is written as the following dynamic program:

$$V(K_t^h, K_t^s, R_{t-1}, C_{t-1}, \rho_{t-1}, \|_t)$$

$$= \max_{R_t, K_{t+1}^h, K_{t+1}^s} E \left\{ \prod_t^b + e_t \rho_t C_t + \beta V(K_{t+1}^h, K_{t+1}^s, R_t, C_t, \rho_t, \|_{t+1}) | \|_{t-1}, \|_t \right\}$$

subject to

$$\prod_t^b = p() R_t F(K_t^h) - p_{kt} \left[ K_{t+1}^h - (1 - \delta) K_t^h \right.$$

$$+ \Phi_t(K_t^h, K_{t+1}^h)] - w_t L_t(R_{t-1}, R_t),$$

\textsuperscript{8}That is, the revenue function of plant $i$, $\text{Rev}^i = pRF(K^i)$, is twice continuously differentiable in the output of plant $i$, strictly concave in the output of plant $i$; and, marginal revenue of plant $i$ is decreasing in the other plant’s output, $i = h$ or $s$. In addition, the own effects on marginal revenue are greater than the cross effects, i.e., $(\partial^2 \text{Rev}^i/\partial X^i)^2(\partial^2 \text{Rev}^j/\partial X^j)^2 - (\partial^2 \text{Rev}^i/\partial X^i \partial X^j)^2(\partial^2 \text{Rev}^j/\partial X^j)^2 > 0$, $i \neq j$.

\textsuperscript{9}When developing countries impose repatriation restrictions they are not an isolated policy directed towards MNEs. Hence, the severity of restrictions is assumed to be independent of the MNE’s remittance.

\textsuperscript{10}We exclude alternative reinvestment options, such as local financial markets, from the model. As a result, we may under predict the MNE’s total reinvestment in its subsidiary during repatriation episodes where the MNE waits out restrictions. If the MNE could buy bonds, we might see a higher foreign direct investment position when the MNE chooses reinvestment; however, this does not reverse the reinvest versus repatriate decision of the MNE.
\[ C_t = p^s(\cdot) R_t E(K^*_t) - p^b_t [K^*_t+1 - (1 - \delta) K^*_t] \]
\[ + \Phi_t(K^*_t, K^*_t+1)] + (1 - \rho_{t-1}) C_{t-1}, \quad R_t, K^b_{t+1}, K^*_t+1 \geq 0, \]

where \( I_t = \{w_t, p_{kt}, e_t\} \) is information about this period’s wage rate, price of capital and exchange rate, and, \( E \) is the expectations operator conditioned on the information of this period and last period’s repatriation restriction. This period the MNE makes expectations of \( I_{t+1} \) and \( \rho_t \). A stochastic law governs the evolution of these random variables that is defined by a twice continuously differentiable function \( \Psi \) and an independent identically distributed process \( \{e_t\} \),

where \( z_t = \Psi(z_{t-1}, e_t), z_t = \{\rho_t, I_{t+1}\}. \)

Today’s expected value of repatriation restrictions can be based on last period’s restriction or additional information incorporated in \( I_t \). For example, as we will use in the quantitative analysis, the MNE can believe the restrictions follow a first order Markov process. Alternatively, we could have expectations of remittance restrictions being influenced not only by last period’s policy but other variables, such as the developing country’s current trade deficit, foreign exchange reserves and/or tax revenue base, whose levels can signal impending repatriation restrictions (all information we would incorporate in \( I_t \)).

Highlighted in the above framework is the fact that the MNE starts the period knowing the government’s last period repatriation policy. Using last period’s restriction the MNE makes expectations about today’s repatriation restriction. The expected value of the repatriation restriction affects how much capital the MNE invests in each plant and the level of innovations produced by the headquarters. This framework links changes in a government’s repatriation policy with changes in an MNE’s operations.

4. Theoretical analysis

Today’s repatriation restriction affects today’s capital investment and technology transfer decisions. This is due to the fact that profits generated from these actions may be remitted and face repatriation restrictions. Future restrictions may also affect today’s capital investment and technology transfer decisions because funds held by the central bank today can face restrictions in the future. To capture the total effect of the restrictions, define \( \theta_t \) as the present discounted value of one unit of developing country currency repatriated at date \( t \) in terms of the developed country currency. That is, \( \theta_t = \rho_t + \beta(\theta_{t+1}/\theta_t)\rho_{t+1}(1 - \rho_t) + \beta^2(\theta_{t+2}/\theta_t)\rho_{t+2}(1 - \rho_{t+1})(1 - \rho_t) + \ldots \) \( \theta_t \) accounts for the possible delay in the MNE’s headquarters receiving its remittance and, currency depreciations

\[ ^{11} \text{This assumption is needed for the value function (optimal policy function) to be twice (once) differentiable.} \]
during these delays. When remittance restrictions are enforced, \( \theta_t < 1 \), depreciations make restrictions more costly than the same restrictions during a period of constant exchange rates.

Depending on the MNE’s expectations of current and future repatriation restrictions, a change in government repatriation policy may increase or decrease the expected present discounted value of today’s \( (\theta_t) \) and/or tomorrow’s \( (\theta_{t+1}) \) unit of remittance. To illustrate how a change in the government’s repatriation policy alters an MNE’s operations, we determine how changes in today and tomorrow’s expected present discounted value of a unit of remittance influence capital investment and technology transfer. The results are summarized in Propositions 1–3.\(^{12}\) The proofs are left to Appendix A.

**Proposition 1.**

\[
\frac{\partial R_t}{\partial \rho_{t-1}} = a^* \frac{\partial E(\theta_t|\rho_{t-1}, I_t)}{\partial \rho_{t-1}}, \quad a > 0.
\]

That is, a change in the government’s repatriation policy that causes the MNE to believe today’s expected present discounted value of a unit of remittance is increasing, increases the level of innovations produced by the headquarters. Conversely, a change in the government’s repatriation policy that causes the MNE to believe today’s expected present discounted value of a unit of remittance is decreasing, decreases the level of innovations produced by the headquarters.

Since the MNE produces innovations in the developed country, production costs are unaffected by repatriation restrictions. The repatriation policy only affects the subsidiary’s revenue generated by an additional innovation. Proposition 1 tells us the level of innovations produced at the headquarters and transferred to the subsidiary are positively correlated with today’s expected present discounted value of remittance.\(^{13}\)

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\(^{12}\) The propositions tell us if technology transfer and capital investment increase or decrease for a given change in today’s and tomorrow’s expected present discounted value of remittance. To determine country or firm specific actions we need to specify how expectations of repatriation restrictions and exchange rates are formed. This is done in the quantitative section for US MNEs operating in Brazil.

\(^{13}\) If we modeled innovations such that the headquarters hired labor at date \( t \) to produce innovations that become available at date \( t + 1 \) (so as to be symmetric with capital accumulation), then Proposition 1 would state that the level of \( R_t \) is positively correlated with changes in the expectation of \( \theta_{t+1} \), not \( \theta_t \). Repatriation restrictions’ effect on capital investment would be unchanged.
Proposition 2.

\[
\frac{\partial K^*_{t+1}}{\partial \rho_{t-1}} = a^* \frac{\partial E_t(\theta_t | \rho_{t-1}, \mathbb{I}_t)}{\partial \rho_{t-1}} + b^* \frac{\partial E_t(\theta_{t+1} | \rho_{t-1}, \mathbb{I}_t)}{\partial \rho_{t-1}}, \quad a < 0, \quad b > 0.
\]

That is, a change in the government’s repatriation policy that causes the MNE to believe today’s expected present discounted value of a unit of remittance is increasing, decreases capital investment in the subsidiary. While a change in the government’s repatriation policy that causes the MNE to believe tomorrow’s expected present discounted value of a unit of remittance is increasing, increases capital investment in the subsidiary.

Proposition 3.

\[
\frac{\partial K^h_{t+1}}{\partial \rho_{t-1}} = a^* \frac{\partial E_t(\theta_t | \rho_{t-1}, \mathbb{I}_t)}{\partial \rho_{t-1}} + b^* \frac{\partial E_t(\theta_{t+1} | \rho_{t-1}, \mathbb{I}_t)}{\partial \rho_{t-1}}, \quad a > 0, \quad b < 0.
\]

That is, a change in the government’s repatriation policy that causes the MNE to believe today’s expected present discounted value of a unit of remittance is increasing, increases capital investment in the headquarters. While a change in the government’s repatriation policy that causes the MNE to believe tomorrow’s expected present discounted value of a unit of remittance is increasing, decreases capital investment in the headquarters.

Repatriation restrictions effect on the capital stock of the subsidiary is easily understood. Today’s and tomorrow’s expected present discounted value of remittance alter the marginal cost and marginal revenue of investment, respectively. Without repatriation restrictions, \( \theta_t = \theta_{t+1} = 1 \), the capital stocks in each of the MNE’s plants are equal, \( K^*_{t+1} = K^h_{t+1} \). When repatriation restrictions are enforced, the subsidiary’s capital stock may be larger or smaller than that of the headquarters. The level of the capital stock is influenced by the expectations of \( \theta_t \) and \( \theta_{t+1} \). Repatriation restrictions that cause the expected present discounted value of today’s unit of remittance to rise, increase the marginal cost of investing in the subsidiary. Hence, the capital stock in the subsidiary falls. When the government alters its remittance policy in a way that causes the expected present discounted value of tomorrow’s unit of remittance to rise, this increases the marginal revenue of investing in the subsidiary. The capital stock in the subsidiary rises.

Repatriation policies’ effect on the headquarters capital stock comes from two sources. First, because the MNE shares innovations across its plants, the level of the subsidiary’s capital stock influences the headquarter’s capital stock. Since the capital stock of the subsidiary is affected by remittance policies, so is the capital stock of the headquarters. Second, due to the fact that the MNE’s output
influences the price level, changes in $\theta_{t+1}$ affect the marginal revenue of the headquarters. The effect of repatriation restrictions on the headquarter’s capital stock is opposite to that of the subsidiary. The model captures the fact that the MNE shifts capital, and hence production, from one plant to the other in response to remittance policies.

From Proposition 2, we can evaluate how the removal of repatriation restrictions affects the foreign direct investment position of a country. Lifting restrictions causes the expected present discounted value of today’s unit of remittance to rise and, therefore, the MNE decreases the capital stock in its subsidiary. This illustrates why countries fear a capital flight. However, this is not the total effect of lifting restrictions. We also know that removing remittance restrictions causes the MNE to increase its capital stock in the subsidiary since the expected present discounted value of tomorrow’s unit of remittance rises. Whether existing capital leaves a country when it removes restrictions depends on the frequency and strength of restrictions and, the capital stock and innovations in the plants at the time the central bank lifts the restrictions (which influence the values of $a$ and $b$). In the next section, we find that countries with constant repatriation policies can increase their foreign direct investment position, not lose existing capital, when removing restrictions.

5. Quantitative analysis

This section highlights how key variables of the model, such as the subsidiary’s foreign direct investment position ($K^s$), total equity of the multinational ($K^s + K^p$), and technology transfer ($R/K^s$) react to the imposition and lifting of repatriation restrictions. We begin by calibrating the model to data associated with US MNEs operating in Brazil to obtain parameter values for the model. Given this parameterization, we describe the model’s dynamic response to the imposition of various forms of repatriation restrictions. Impulse responses illustrate that capital investment in and technology transfer to the subsidiary may increase or decrease after the onset of restrictions. The level of capital investment and technology transfer depends on the MNE’s expectations of current and future restrictions.

Using the impulse response functions, we perform sensitivity analysis of the model’s parameterization. We find, as is standard in impulse response analysis, that movement of the MNEs operations are not sensitive to alternative values of the parameters of the production and adjustment cost functions. We find the transition probabilities of the partial blocking state are important in determining if the subsidiary remits or reinvests. Our model predicts repatriation after funds are partially blocked, as seen in the data, so long as the MNE’s true estimate of the probability of full conversion is not more than 20% smaller in value than what we estimate from the data.
To illustrate that the model captures MNEs’ reactions to restriction in Brazil over the eighties, we simulate the model and find that the predicted contraction in the subsidiary’s 1983 capital stock and expansion in 1989 are consistent with the data. We also examine how the capital stock of a subsidiary is influenced by different steady state repatriation policies. That is, we compare the comparative static levels of the subsidiary’s capital stock under the assumptions that Brazil imposes polices of blocking various constant percentages of the MNE’s remittance over time. This analysis, although not directly applicable to Brazil, is the type of policy used in many developing countries.\textsuperscript{14} Results suggest developing countries can lift restrictions without the fear of capital fleeing their country.

5.1. Calibration

We begin by explaining how the MNE forms expectations about the random variables in the model. At each date \( t \), the MNE must form expectations about the values of today’s and future repatriation restrictions, future exchange rates, next period’s wage rate and next period’s price of capital. Using information from last period’s repatriation restriction and current prices, we assume the MNE derives expectations as follows:

- wages and the price of capital grow at the rate that has occurred in the developed country for the past decade;
- exchange rates depreciate at the same rate that has occurred last period (for simulation \#1) or, exchange rates depreciates at the rate that has occurred over the last decade (for simulation \#2),\textsuperscript{15} and
- repatriation restrictions follow a first order Markov process (FOMP), where the MNE believes the restriction will take on one of three values, \( \rho \in \{0, 0.5, 1\} \).

The MNE assigns values to \( \text{prob}\{\rho_t = a | \rho_{t-1} = b\} \forall a, b \in \{0, 0.5, 1\} \). This is done by dividing the eighties into two month intervals (so there are 60 periods), assigning each period a 0, 0.5 or 1 and, counting up the number of occurrences of each type of episode. As described in Section 2, Brazil’s 1983 repatriation policy lasted two months and allowed partial conversion. We set \( \rho_t = 0.5 \) for the 1983 episode. Brazil’s 1989 experience lasted 4–6 months and the central bank

\textsuperscript{14} This type of policy is applicable to South Africa whose central bank is reluctant to remove exchange controls for fear of prompting an out surge of capital. Here MNEs face a constant threat of the government implementing these restrictions.

\textsuperscript{15} Meese and Rogoff (1983) show a random walk does at least as well as any model at forecasting the exchange rate in the short run for developed countries. An AR(1) process does not work well in countries who experience large and continually rising inflations. This is the case for Brazil. An AR(1) process based on 1970 data will have large forecast errors by the late 1980s.
completely blocked funds. The MNE realized \( \rho_t = 0 \) during this period of repatriation restrictions. Using this information, we construct the transition probabilities as displayed in Table 1.\(^{16}\)

Below the transition probabilities in Table 1, we report the standard errors of the estimates. Conditional on full blocking or no blocking of funds the standard errors are relatively small. Since there is only one observation where there are partial blocking of funds, we do not report the standard errors associated with this event.\(^{17}\) The statistical stability of \( \text{prob}(\rho_t = x | \rho_{t-1} = 1/2), x = 0, 1/2, 1 \) is of interest, however, since the data we use to calibrate the transition probabilities has only one episode of partial blocking of funds. To address this issue, we perform sensitivity analysis of the transition probabilities in a following section.

To calculate the expectations of today’s and tomorrow’s expected present discounted value of a unit of remittance, the MNE forms expectations of the current and future repatriation restrictions and future exchange rates. These valuations provide the information to evaluate the expected present discounted value of today’s and tomorrow’s unit of remittance. Table 2 reports the values of \( \rho_{t-1}, \Delta e_t, \theta_t, \) and \( \theta_{t+1} \) used in simulation 1. We see repatriation restrictions in the 1980’s were costly to US MNEs. This is because there were large depreciations in Brazil’s exchange rate each time the central bank enforced repatriation restrictions. In the 1989 experience, the expected present discounted value of today’s unit of remittance is less than 50%.

To parameterize the model we assume the following functional forms for the equations.

The production function:

\[
X_t^i = (L_t)^{\alpha}(K_t^i)^{1-\alpha}, \quad i = h \text{ or } s.
\]

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\(^{16}\) If the periods of restrictions are independent and identically distributed then these probabilities are the maximum likelihood estimates.

\(^{17}\) Using the standard formula for variance, one can say the standard error is infinite. However, this formula assumes a large number of observations.
Table 2

Values of repatriation restrictions used in simulation 1

<table>
<thead>
<tr>
<th></th>
<th>$\rho_{t-1}$</th>
<th>$b$, $E_t(e_{t+j}) = b \cdot e_{t+j} \geq 1$</th>
<th>$\theta_t$</th>
<th>$\theta_{t+1}$</th>
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<td>1.97</td>
<td>0.986</td>
<td>0.981</td>
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<td>1/2</td>
<td>1.84</td>
<td>1</td>
<td>0.97</td>
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<td>76.9</td>
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<tr>
<td>1989</td>
<td>0</td>
<td>11.6</td>
<td>0.38</td>
<td>0.540</td>
</tr>
<tr>
<td>1990</td>
<td>1</td>
<td>14.8</td>
<td>0.974</td>
<td>0.964</td>
</tr>
</tbody>
</table>

Labor is hired by the headquarters at date $t$ to produce innovations. The MNE shares these innovations across both plants. Each plant combines the innovations with their current capital stock to produce output at date $t$.

The inverse demand:

$$p_t = A - B(X_t^h + X_t^s).$$

The inverse demand is assumed linear for convenience. Since we assume that the MNE is an international monopolist, the price is a function of the output of both plants.

The adjustment cost function:

$$\Phi_i(K_{t+i}^h, K_{t+i+1}^h) = \eta^h(K_{t+i+1}^h - (1 - \delta)K_{t+i}^h)^2, \quad i = h \text{ or } s.$$

The adjustment cost function is quadratic in investment. This is the same function used by Abel and Eberly (1993) and, Mendoza and Uribe (1995). This function makes it costly for the MNE to make large alterations in the plants’ capital stocks.

In total there are six parameters that we calibrate: $\beta$, $\delta$, $\alpha$, $A$, $B$ and $\eta$. As in Prescott and Parente (1991), $\beta$ is set to 0.98 and $\delta$ is set to 0.08. We assume constant returns to scale and set $1 - \alpha$ to 0.4, as in Lucas (1990). This implies $\alpha = 0.6$. The remaining three parameters are set so the model reproduces MNEs’ data from the Bureau of Economic Analysis’ US Direct Investment Abroad: 1982 Benchmark Survey. Appendix B lists the 1982 benchmark survey and supplemental MNE data we use in the analysis along with more details of the calibration of $A$, $B$ and $\eta$. Table 3 presents the calibrated parameter values. The adjustment cost parameter takes on a value of 0.11 in manufacturing and 0.03 in all industries. This is similar to the calibrated values found in Mendoza and Uribe (1995). The demand equations for all and manufacturing have constants of 3.32 and 4.45 and, slopes of $1.87 \times 10^{-5}$ and $2.4 \times 10^{-5}$, respectively.
Table 3
Calibrated parameter values

<table>
<thead>
<tr>
<th>Industry</th>
<th>$\beta$ discount factor</th>
<th>$\delta$ capital depreciation rate</th>
<th>$\alpha$ labor share</th>
<th>$\gamma$ capital share</th>
<th>$A$ constant in price equation</th>
<th>$B$ slope in price equation</th>
<th>$\eta$ adjustment cost parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-bank</td>
<td>0.98</td>
<td>0.08</td>
<td>0.6</td>
<td>0.4</td>
<td>3.32</td>
<td>$1.87 \times 10^{-5}$</td>
<td>0.03</td>
</tr>
<tr>
<td>Manuf.</td>
<td>0.98</td>
<td>0.08</td>
<td>0.6</td>
<td>0.4</td>
<td>4.45</td>
<td>$2.4 \times 10^{-5}$</td>
<td>0.11</td>
</tr>
</tbody>
</table>

5.2. Impulse response

Given the parameterization above, we describe the model’s dynamic responses to repatriation restrictions by considering impulse responses. We shock the model with a repatriation restriction and compare the multinational’s operations after the shock to that of their long run mean values when there are no repatriation restrictions. The long run mean values are calculated using the invariant distribution probabilities for the case when there were no repatriation restrictions the previous period. That is, the long run mean values are the expected levels of the MNE’s operations when the history of restrictions is such that none have been enforced over a long horizon. We focus on how foreign direct investment ($K^s$), total equity of the multinational ($K^s + K^b$) and technology transfer ($R/K^s$) respond to a repatriation restriction.

For each impulse response, we assume repatriation restrictions are enforced – either full or partial blocking of funds – immediately prior to the onset of date $T$. We assume the exogenous prices, $w$ and $r$, are at their 1982 levels and grow at the rate assumed in 1982. From date $T + 1$ onward, the expected value of the multinational’s actions are calculated using the transition probabilities of the FOMP. That is, since repatriation restrictions take on a finite number of values, the dynamic responses we report are the expected values of the capital stocks and innovations in each period given the history of restrictions and MNE’s operations up to that date.\(^{18}\)

\(^{18}\) At date $T + 1$ the multinational could face full, partial or no blocking of funds with probabilities for each of these actions given in the FOMP. Assuming full blocking of funds at date $T$, the date $T + 1$ expected value of the subsidiary’s capital stock is calculated as: $	ext{prob}(\rho_{T+1} = 0|\rho_T = 0)^s K^s(\rho_{T+1} = 0) + \text{prob}(\rho_{T+1} = 1/2|\rho_T = 0)^s K^s(\rho_{T+1} = 1/2) + \text{prob}(\rho_{T+1} = 1|\rho_T = 0)^s K^s(\rho_{T+1} = 1)$, where $K^s(\rho_{T+1} = x)$ is the capital stock in the subsidiary at date $T + 1$ when the MNE expects $x$ percent of funds to be blocked. At date $T + k$ there are $3^k$ possible states/values of $K^s_{T+k}$. Each value of $K^s_{T+k}$ is calculated given the appropriate level of $K^s_{T+k-1}$ – this is related to the history of repatriation restrictions from date $T$ to $T + k$. 

We present impulse responses as percentage deviations since the model’s variables, \( x \), are affected by the parameterization but \( dx/dx \) is unaffected. Additionally, we are interested in explaining and predicting the movement of \( x \) during repatriation restrictions which is captured in the percentage deviations.

We assume the devaluation follows an AR(1) for this analysis. Note, however, the remarks in footnote 15.

The impulse responses illustrate the percentage deviation between the long run (LR) mean value and expected value of each of the MNE’s operations for each date \( T + j, j = 0, 1, 2, \ldots \). Fig. 3 provides impulse responses for ‘all’ industry data. The first column illustrates how the multinational’s actions are affected when funds are fully blocked immediately prior to the onset of date \( T \). The second column quantifies the effects of a partial blocking of funds. In each of the two scenarios we must consider how the MNE forms expectations of exchange rates. We consider the possibility that there is no exchange rate depreciation (no ER depreciation). This case captures the time loss of remittance without the additional penalty from a devaluation of the local currency when funds are being held by the central bank. The second possibility allows the exchange rate to depreciate while funds are held by the central bank (ER devalued at AR(1)). We assume a constant devaluation each period equal to 14%, the result of an autoregressive estimate of the Brazilian currency over the period 1972–1982.

When remittance are fully blocked by the central bank, we find the capital stock of the subsidiary (\( K^s \)) rises above its long run mean value on impact. With constant exchange rates, the capital stock rises 2.6% above its long run mean value. When a devaluation is expected, the capital stock rises by 2.9%. The rise above the LR mean value can be explained by looking at the transition probabilities. When funds are blocked, there is a high probability that funds will continue to be blocked \((\text{prob}\{\rho_t = 0|\rho_{t-1} = 0\} = 2/3)\). This causes today’s
Fig. 3. Impulse responses for 'all' industries – percent deviation from long run mean value.
expected present discounted value of a unit of remittance to fall and encourages the subsidiary to reinvest in itself and wait out the restrictions.\textsuperscript{21} The subsidiary’s capital stock rises more when there is an expected depreciation since funds held at the central bank lose more value in terms of the developed country currency.

After the initial impact of the repatriation restriction, the subsidiary’s capital stock slowly falls back to the long run mean value. The slow movement back to the long run mean value is driven by the fact that we are considering the expected movement of repatriation restrictions and, there are adjustment costs associated with capital investment.

The effect repatriation restrictions have on total equity ($K^h + K^s$) and technology transfer ($R/K^s$) are seen in the second and third figures, respectively. Movement in the total equity is dominated by movement in the subsidiary’s capital stock. Technology transfer falls below its long run mean value when the subsidiary’s remittance is fully blocked. The decline is greater when a devaluation is expected. At the onset of full blocking of funds, the decline in the expected present discounted value of remittances causes the MNE to lower its valuation of the marginal benefit of an additional innovation. This decreases the technology transferred from the headquarters to the subsidiary.\textsuperscript{22} Over time, technology transfer rises back to its long run mean value and the expected benefit of an additional innovation returns back to its long run mean value.

The multinational’s actions to partial blocking of funds are the opposite of those when funds are fully blocked. Capital invested in the subsidiary and total equity of the multinational fall below their long run mean values by small percentages on impact. The effect is larger when there is an expected depreciation than when the exchange rate is assumed constant. Since funds are assumed to be fully remitted after a partial blocking, $\text{prob}\{\rho_t = 1|\rho_{t-1} = 1/2\} = 1$, the subsidiary takes this opportunity to remit funds back to the headquarters.\textsuperscript{23} Although the MNE does not expect current remittance to be blocked, future repatriation of the subsidiary can face restrictions. As a result, when there is an expected depreciation, the subsidiary remits more than when the exchange rate is assumed constant since future remittance are affected by the depreciation.

Technology transfer rises above its long run mean value at the onset of partial blocking of funds. As with all other impulse responses, the effect is stronger when an exchange rate depreciation is expected than when the exchange rate is

\begin{itemize}
  \item \textsuperscript{21} At the onset of full blocking of funds, $\theta_T < \theta_{t,R}$ and $\theta_{T+1} < \theta_{t,R+1}$. Proposition 2 tells us the capital stock rises (falls) if the effect of $\theta_T(\theta_{T+1})$ dominates.
  \item \textsuperscript{22} At the onset of full blocking of funds, $\theta_T < \theta_{t,R}$. Proposition 1 tells us the level of innovations falls.
  \item \textsuperscript{23} At the onset of partial blocking of funds, $\theta_T = 1 > \theta_{t,R}$ and $\theta_{T+1} > \theta_{t,R+1}$. Proposition 2 tells us the capital stock falls (rises) if the effect of $\theta_T(\theta_{T+1})$ dominates.
\end{itemize}
assumed constant. The onset of partial blocking of funds causes the MNE to increase its valuation of the marginal benefit of an additional unit of technology and, therefore, raise its production of innovations.\textsuperscript{24} Technology transfer, and all other operations, trend back to their long run mean values over time.

Overall, the impulse responses highlight two key features of the model. First, the figures demonstrate that capital investment and technology transfer can rise above or fall below their long run mean values. This is consistent with the data on US MNE’s in Brazil, Figs. 1 and 2. Second, the effect repatriation restrictions have on MNEs operations is enhanced by expected devaluations in the exchange rate.

Fig. 4 contains impulse responses for the capital stock in the subsidiary, total equity of the multinational and technology transfer for ‘manufacturing’ data. Since the results are similar to those of ‘all’ industry data, we will not discuss them and will focus on ‘all’ industry data for the remainder of the impulse responses.

5.3. Sensitivity analysis

We address the sensitivity of the model’s results to the calibrated parameters by examining impulse responses of ‘all’ industry data. We focus on how the impulse responses are affected by changes in the probabilities in the repatriation restriction transition matrix, the adjustment cost and demand parameters.

First, consider the sensitivity of the results to the transition probabilities of the repatriation restrictions. We focus on the capital stock in the subsidiary and perform four tests. Each test examines how the percentage deviation between the long run mean value of the subsidiary’s capital stock and the value in the period immediately after the onset of repatriation restrictions (date $T$) is altered by a change in the transition probabilities. That is, we are focusing on the period when the deviation from the long run mean value is the largest. Table 4 displays the results when we assume the exchange rate is constant. Test 1 (rows 2 and 3) illustrates how the impulse responses are altered by changes in the probabilities associated with the no repatriation restrictions state [i.e., $\text{prob}(\rho_t = j|\rho_{t-1} = 1)$ for $j = 0, 1/2, 1$]. Test 2 (row 4) through Test 4 (row 6) consider how the impulse responses are affected by changes in the probabilities associated with the partial blocking of funds state [i.e., $\text{prob}(\rho_t = j|\rho_{t-1} = 1/2)$ for $j = 0, 1/2, 1$]. We are interested in how the subsidiary’s remittance decision responds to various values of the probabilities associated with the partial blocking of funds state since there was only one observation of partial conversion in the data.

\textsuperscript{24} At the onset of partial blocking of funds, $\theta_T > \theta_{LR}$. Proposition 1 tells us the level of innovations rises.
Test 1 reports the effect on the impulse responses when we adjust the probabilities of staying in the no repatriation restriction state versus going to a state where restrictions are enforced. We consider the prob($\rho_t = 1 | \rho_{t-1} = 1$) = $1 - 2x$ and prob($\rho_t = j | \rho_{t-1} = 1/2$) = $x$, $j = 0, 1/2$, for various values of $x$. The
third column \((x = 1/56)\) reports the percent deviation between the long run value of the subsidiary’s capital stock and the period after funds are fully (row 2) or partially (row 3) blocked as seen in the calibrated model. That is, \(+ 2.55(- 0.12)\%\) represents the increase (decline) in the subsidiary’s capital stock from its long run mean value for the calibrated model when we assume the exchange rate is constant and the government imposes full (partial) blocking of funds immediately prior to date \(T\). This is the value reported in Fig. 3 at date \(T\). Each consecutive column increases the probability that repatriation restrictions will be enforced – increasing the probability that full or partial restrictions will be enforced by \(x\) percent, where \(x = 5, 10, \ldots, 30\). For every value of \(x\), we find the subsidiary continues to reinvests when faced with full blocking of funds and remits funds when faced with partial blocking of funds. Combining this result with the fact that the standard errors are relatively small in this state, we conclude that the subsidiary’s remittance decision is not sensitive to changes in these transition probabilities.

Tests 2–4 consider how the impulse response of a partial repatriation restriction shock is affected by changing the probabilities associated with a partial blocking of funds state. Test 2 (row 4) assumes that when funds are partially blocked they either continue to be partially blocked or become freely converted. We let the \(\text{prob}(\rho_t = 1/2 | \rho_{t-1} = 1/2) = x\) and \(\text{prob}(\rho_t = 1 | \rho_{t-1} = 1/2) = 1 - x\) for \(x = 0.0, \ldots, 0.9\). Test 3 (row 5) assumes that when funds are partially blocked they may become freely converted or, with equal probability, are partially or fully blocked. We consider the \(\text{prob}(\rho_t = 1 | \rho_{t-1} = 1/2) = 1 - 2x\) and \(\text{prob}(\rho_t = j | \rho_{t-1} = 1/2) = x, j = 0, 1/2, \text{for } x = 0.0, \ldots, 0.49\). Test 4 (row 6) assumes that when funds are partially blocked they either become fully blocked or freely converted. We let the \(\text{prob}(\rho_t = 0 | \rho_{t-1} = 1/2) = x\) and \(\text{prob}(\rho_t = 1 | \rho_{t-1} = 1/2) = 1 - x\) for \(x = 0.0, \ldots, 0.9\).

Column two in each test \((x = 0)\) reports the percent deviation between the long run mean value of the subsidiary’s capital stock and the level of capital when funds are partially blocked immediately prior to date \(T\) as seen in the calibrated model. The consecutive columns increase the probability of funds remaining blocked. Test 2 illustrates that when the probability of full conversion remains greater than 70% (partial blocking of funds remains less than 30%), funds are remitted to the headquarters. Once the probability that partial conversion becomes at least 30%, however, the subsidiary begins to reinvest. Test 3 assumes that when funds are not fully converted they are either partially or fully blocked. Here the subsidiary remits funds as long as the probability of full conversion remains above 60% \((x = 0.2)\). If we consider the extreme case that once funds are partially blocked they are never freely converted \((x = 0.49)\), then reinvestment becomes quite large. Test 4 examines the case where funds that are partially blocked either become fully blocked or freely converted. If full conversion remains greater than 80% then the subsidiary remits funds to the headquarters. When the probability that funds become fully blocked is at least
Table 4
Sensitivity of subsidiary’s capital stock to transition probabilities

Test 1 (No blocking of funds transition probabilities): Prob[\(\rho_t = 0|\rho_{t-1} = 1\)] = Prob[\(\rho_t = 1/2|\rho_{t-1} = 1\)] = x; Prob[\(\rho_t = 1|\rho_{t-1} = 1\)] = 1 - 2x

Test 2 (Partial blocking of funds transition probabilities): Prob[\(\rho_t = 0|\rho_{t-1} = 1/2\)] = 0; Prob[\(\rho_t = 1/2|\rho_{t-1} = 1/2\)] = x; Prob[\(\rho_t = 1|\rho_{t-1} = 1/2\)] = 1 - x

Test 3 (Partial blocking of funds transition probabilities): Prob[\(\rho_t = 0|\rho_{t-1} = 1/2\)] = Prob[\(\rho_t = 1/2|\rho_{t-1} = 1/2\)] = x; Prob[\(\rho_t = 1|\rho_{t-1} = 1/2\)] = 1 - x

Test 4 (Partial blocking of funds transition probabilities): Prob[\(\rho_t = 0|\rho_{t-1} = 1/2\)] = x Prob[\(\rho_t = 1/2|\rho_{t-1} = 1/2\)] = 0; Prob[\(\rho_t = 1|\rho_{t-1} = 1/2\)] = 1 - x

All industries, \(K^c\)

<table>
<thead>
<tr>
<th>(Shock-LR mean value)/LR mean value</th>
<th>(x = 0)</th>
<th>(x = 1/56)</th>
<th>(x = 0.1)</th>
<th>(x = 0.2)</th>
<th>(x = 0.3)</th>
<th>(x = 0.4)</th>
<th>(x = 0.49)</th>
<th>(x = 0.6)</th>
<th>(x = 0.7)</th>
<th>(x = 0.8)</th>
<th>(x = 0.9)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Test 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date <strong>(T = ) Full blocking</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Test 1</strong></td>
<td>-</td>
<td>2.55%</td>
<td>2.09%</td>
<td>1.77%</td>
<td>1.61%</td>
<td>1.87%</td>
<td>2.45%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Date <strong>(T = ) Partial blocking</strong></td>
<td>-</td>
<td>0.12%</td>
<td>-0.47%</td>
<td>-1.19%</td>
<td>-2.04%</td>
<td>-2.76%</td>
<td>-2.94%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Test 2</strong></td>
<td>-0.12%</td>
<td>-0.09%</td>
<td>-0.05%</td>
<td>0.002%</td>
<td>0.10%</td>
<td>0.14%</td>
<td>0.25%</td>
<td>0.43%</td>
<td>0.47%</td>
<td>0.32%</td>
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<td>Date <strong>(T = ) Partial blocking</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Test 3</strong></td>
<td>-0.12%</td>
<td>-0.08%</td>
<td>0.10%</td>
<td>0.72%</td>
<td>1.57%</td>
<td>2.37%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Date <strong>(T = ) Partial blocking</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Test 4</strong></td>
<td>-0.12%</td>
<td>-0.04%</td>
<td>0.07%</td>
<td>0.17%</td>
<td>0.55%</td>
<td>1.05%</td>
<td>1.71%</td>
<td>2.81%</td>
<td>4.34%</td>
<td>7.05%</td>
<td>-</td>
</tr>
<tr>
<td>Date <strong>(T = ) Partial blocking</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
20%, the subsidiary reinvests. When partial conversion is a strong signal that funds will be fully blocked \((x = 0.9)\), reinvestment is quite large.

In summary, tests 2–4 show that in the partial blocking state, if the probability of full conversion falls below 70%, the subsidiary reinvests. This is contrary to the US–Brazilian experience. Our model is consistent with the US–Brazilian experience to the extent that the MNE views the probability of full conversion to be greater than 80%. That is, as long as the probability is greater than 80% the subsidiary remits funds to their headquarters.

Next we consider the sensitivity of the model’s results to changes in the adjustment cost and demand parameters when the multinational faces full blocking of funds immediately prior to date \(T\) and expects no change in the exchange rate.\(^{25}\) Fig. 5 illustrates that a 10% decline in adjustment costs \((\phi)\) or demand function parameters \((A\) and \(B)\) have relatively no effect on the impulse responses of the multinational’s activities. The first column captures the impulse responses for the calibrated model and for the model when adjustment costs are reduced by 10%. In some figures we cannot separate the calibrated response from that of the model where the adjustment cost is reduced by 10%. The second and third columns illustrate that there are minor differences between the impulse responses of the calibrated model and the model where we reduce the demand parameters by 10%. Overall, the predicted movement in the MNE’s operations is not sensitive to these parameter values.

5.4. Simulation

Simulating the model requires, as in the impulse responses, solving the second order difference equations of the headquarters’ and subsidiary’s capital stocks. Since we propose two ways of forming expectations of future exchange rates, two simulations are conducted. Simulation 1 depreciates future exchange rates by the same percentage that occurred last period. Simulation 2 uses a decade average depreciation. Results are more accurate with Simulation 1 and, therefore, are discussed in detail.

The simulation results are shown in Figs. 6 and 7. Fig. 6 plots the model’s predicted and actual capital stock for ‘all’ industry subsidiaries; whereas, Fig. 7 presents the model’s predicted and actual capital stock for ‘manufacturing’ subsidiaries.\(^{26}\) The model’s predicted response to the repatriation restrictions is consistent with the actual data. Simulation 1 is more accurate in predicting the percent change in the subsidiary’s capital stock during an episode of restrictions. The model also performs better for ‘all’ industries than ‘manufacturing’.

\(^{25}\) The conclusions of all sensitivity analysis do not change if we consider partial blocking of funds and/or an exchange rate depreciation.

\(^{26}\) Actual data is detrended using a quadratic time trend.
Simulation 1 accurately predicts a decrease in the subsidiary’s capital stock due to the 1983 restrictions. In ‘all’ industries, the actual capital stock of subsidiaries fell 2.4% while the model predicts a 2.8% decrease. The actual capital stock in ‘manufacturing’ industries fell 2.2% and the model predicts a fall by 1.6%. The decline in the subsidiary’s capital stock is due to the fact that at the
onset of the 1983 restrictions ($\rho_{t-1} = 1/2$) today’s expected present discounted value of a unit of remittance increases to one. The MNE believes today’s threat of restrictions is nonexistent and therefore takes capital out of the subsidiary. Also, tomorrow’s expected present discounted value of the remittance decreases, another reason for the MNE to remit funds from the subsidiary today.

In 1989, simulation 1 predicts the growth in the subsidiary’s capital stock similar to that seen in the data. The actual increase in ‘all’ industries was 12.9%
while the model predicted a 13.1% increase. In ‘manufacturing’ the actual increase in the subsidiary’s capital stock was 13.1% while the model predicted a 2.8% increase. The inaccuracy of the increase in the capital stock of ‘manufacturing’ can be due to the opposing effects of today’s and tomorrow’s expected present discounted values of a unit of remittance. When the MNE sees the restrictions enforced in 1989, it believes today’s expected present discounted value of remittance is decreasing and, therefore, reinvests in the subsidiary. The MNE also believes the expected present discounted value of tomorrow’s remittance is decreasing. This signals the MNE to remit capital from the subsidiary. The effect of today’s expected present discounted value of remittance dominates tomorrow’s effect, allowing the capital stock in the subsidiary to increase. Nevertheless, the effect of tomorrow’s present discounted value of remittance dampens the increase in the subsidiary’s capital stock.

These results suggest that central banks should evaluate the impact of their repatriation restrictions. For Brazil, partial remittance causes multinationals to remit funds; whereas, full blocking of funds causes reinvestment. Since the central bank had low foreign exchange reserves in each instance of restrictions, we see that partial conversion put a strain on their reserves but full blocking of funds may have increased reserves. Hence if the central bank faces low reserves and considers repatriation restrictions, they should not consider allowing partial conversion of multinationals’ remittance.

5.5. Steady state

We examine the steady state of the model to evaluate how Brazil’s foreign direct investment position is affected by various constant levels of repatriation restrictions. Although this is not the type of restriction imposed in Brazil, the results provide a basis for many developing countries who have continuous repatriation restriction policies. The results suggest that countries who continually threaten and/or impose restrictions can increase their capital investment, not lose existing capital as is sometimes feared, if they credibly abolish their restrictions.

Using the calibrated parameters from the 1982 benchmark survey, we measure the percentage decline in the subsidiary’s capital stock from a benchmark of no repatriation restrictions to a situation when the government blocks a given percentage of funds. Table 5 provides the results. The top row of Table 5 indicates the steady state level of repatriation restrictions. $\rho = 1$ means there is no restriction. The second row illustrates the percentage deviation in the foreign direct investment position between the case of no remittance restrictions to one with constant restrictions for ‘all’ industry data. E.g., when $\rho = 95$ the subsidiaries’ capital stock is 0.1% lower than when there are no repatriation restrictions. As restrictions increase the subsidiary’s capital stock continues to decline. The last row of Table 5 analyzes ‘manufacturing’ data. We again find that as
Table 5
Steady state percentage losses in Brazil’s FDIP due to repatriation restrictions

<table>
<thead>
<tr>
<th>$\rho$</th>
<th>1</th>
<th>0.99</th>
<th>0.95</th>
<th>0.9</th>
<th>0.8</th>
<th>0.7</th>
<th>0.6</th>
<th>0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K^* \text{ (All)}$</td>
<td>–</td>
<td>–0.52</td>
<td>–2.7</td>
<td>–5.6</td>
<td>–12.6</td>
<td>–21.7</td>
<td>–34.4</td>
<td>–54.4</td>
</tr>
<tr>
<td>$K^* \text{ (Manuf.)}$</td>
<td>–</td>
<td>–0.065</td>
<td>–3.3</td>
<td>–7.1</td>
<td>–16.0</td>
<td>–28.2</td>
<td>–46.8</td>
<td>–83.1</td>
</tr>
</tbody>
</table>

restrictions increase the subsidiary’s capital stock continues to decline from the level that would exist without any threat of repatriation restrictions.

Overall, we conclude that countries who use constant repatriation restriction policies should expect an increase in their foreign direct investment position if they abolish their restrictions. The increase in foreign direct investment will be smaller for countries that rarely use restrictions than countries who have severe restrictions. This suggests that countries, like South Africa, who rarely use their exchange controls but are afraid to lift them in fear of prompting an out surge of capital, are falsely afraid.

6. Conclusion

This paper provides both a theoretical and quantitative look at how repatriation restrictions affect an MNE’s operations of capital investment in and technology transfer to its subsidiary. It explains how an MNE’s operations can increase during some episodes of repatriation restrictions and decrease during others. The MNE’s actions are based on its expectations of current and future repatriation restrictions and exchange rates. A change in the government’s repatriation policy alters the MNE’s expectations of restrictions and, therefore, their operations.

Quantitatively the model captures the effect of repatriation restrictions on capital investment in and technology transfer to the MNE subsidiaries by three means. Through impulse response functions we show how various forms of restrictions produce tremendously different effects on the flows of capital and technology as is evident in the data. Second, by focusing on US MNEs with subsidiaries in Brazil, we show that model simulations can capture foreign direct investment flows as seen in the eighties. Last, an analysis of steady state repatriation restrictions finds that a country who abolishes their repatriation policy will see an inflow, not outflow, of capital investment into their country. This is consistent with many countries who have recently lifted restrictions and the results apply to countries, like South Africa, who still allow the central bank to impose restrictions.
7. For further reading


Acknowledgements

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Appendix A

Define \( S_{t+1} = \{K^h_{t+1}, K^s_{t+1}, R_t\} \).

The dynamic programming problem is:

\[
V(S_t, C_{t-1}, \rho_{t-1}, \|_t) = \max_{S_{t+1} \in \Gamma(S_t, C_{t-1}, \rho_{t-1}, \|_t)} E_t \left[ W(S_{t+1}, S_t, C_{t-1}, \rho_t, \|_t) \right]
+ \beta V(S_{t+1}, C(S_{t+1}, S_t, C_{t-1}, \rho_{t-1}, \|_t), \rho_t, \|_{t+1}) | \rho_{t-1}, \|_t],
\]

where \( W(S_{t+1}, S_t, C_{t-1}, \rho_{t}, \|_t) \) is the return function of the MNE at date \( t \) and \( \Gamma(S_t, C_{t-1}, \rho_{t-1}, \|_t) \) represents the set of feasible values for \( S_{t+1} \).

At date \( t \) the MNE maximizes:

\[
E_t \left[ W(S_{t+1}, S_t, C_{t-1}, \rho_t, \|_t) \right]
+ \beta V(S_{t+1}, C(S_{t+1}, S_t, C_{t-1}, \rho_{t-1}, \|_t), \rho_t, \|_{t+1}) | \rho_{t-1}, \|_t],
\]

Differentiating with respect to the choice variables, \( S_{t+1} \), we have

\[
\hat{W}_{S_{t+1}} + \beta \hat{V}_{S_{t+1}} + \beta \frac{\partial C}{\partial S_{t+1}} \hat{V}_{C_t} = 0,
\]

where

\[
\hat{W}_{S_{t+1}} = \frac{\partial E_t(W | \rho_{t-1}, \|_t)}{\partial S_{t+1}}, \quad \hat{V}_{S_{t+1}} = \frac{\partial E_t(V | \rho_{t-1}, \|_t)}{\partial S_{t+1}}, \quad \hat{V}_{C_t} = \frac{\partial E_t(V | \rho_{t-1}, \|_t)}{\partial C_t}.
\]

This assumes an interior solution. I.e., \( K^s_{t+1}, K^h_{t+1}, L(R_t, R_{t-1}) > 0 \). The production of innovations can be guaranteed by assuming a large enough fraction of past innovations become obsolete each period.
Define the optimal policy function as \( g(S_t, C_{t-1}, \rho_{t-1}, I_t) \). \( g(S_t, C_{t-1}, \rho_{t-1}, I_t) \) represents the values of \( K^{h}_t, K^{r}_t \) and \( R_t \) that maximize the MNE’s return at date \( t \) given the known values of the state and exogenous variables.

Plug \( g(S_t, C_{t-1}, \rho_{t-1}, I_t) \) in the first order condition for \( S_{t+1} \), totally differentiate with respect to \( \rho_{t-1} \) and solve for \( g_{\rho_{t-1}} \): \(^{27}\)

\[
g_{\rho_{t-1}} = - A^{-1} B D_2,
\]

where

\[
A = \hat{W}_{S_{t+1}S_{t+1}} + \beta \hat{V}_{S_{t+1}S_{t+1}} + \beta \frac{\partial^2 C_t}{(\partial S_{t+1})^2} \hat{V}_{C_t},
\]

\[
B = \hat{W}_{S_{t+1}D_t} + \beta \hat{V}_{S_{t+1}D_t} + \beta \frac{\partial C_t}{\partial S_{t+1}} \hat{V}_{C_D_t},
\]

\[
D_1 = (\theta_t, \theta_{t+1}), \quad D_2 = \begin{vmatrix} \frac{\partial E_t(\theta_t|\rho_{t-1}, I_t)}{\partial \rho_{t-1}} \\ \frac{\partial E_t(\theta_{t+1}|\rho_{t-1}, I_t)}{\partial \rho_{t-1}} \end{vmatrix}
\]

The derivation of \( B D_2 \) can be seen more clearly by considering a particular element of \( S_{t+1} \). Consider \( K^{r}_t \). The derivative of the return function with respect to \( K^{r}_t \) is

\[
\frac{\partial W}{\partial K^{r}_t} = \left( e_t \rho_t + \beta \frac{\partial V}{\partial C_t} \right) \frac{\partial C_t}{\partial K^{r}_t}, \quad \text{(A.1)}
\]

\[
\frac{\partial V}{\partial C_t} = e_{t+1} \rho_{t+1} (1 - \rho_t) + \beta (1 - \rho_t) \frac{\partial V}{\partial C_{t+1}}. \quad \text{(A.2)}
\]

The envelope theorem with respect to \( C_t \) is as follows.

Plugging Eq. (A.2) iteratively into Eq. (A.1) we have

\[
\frac{\partial W}{\partial K^{r}_t} = (e_t \rho_t + \beta e_{t+1} \rho_{t+1} (1 - \rho_t) + \cdots) \frac{\partial C}{\partial K^{r}_t} = (e_t \rho_t) \frac{\partial C}{\partial K^{r}_t} = e_t \rho_t \left( - p^{\nu_t} \left[ 1 + \frac{\partial \phi_t}{\partial K^{r}_t} \right] \right).
\]

\(^{27}\)Santos and Vigo (1995) provide sufficient conditions for the value function to be twice continuously differentiable with respect to the endogenous state variables in a model with uncertainty.
Hence $\hat{W}_{K_{i+1}^t, D_1}^{C_1}$ is

$$\frac{\partial^2 W}{\partial K_{i+1}^t \partial c_{i-1}} = e_t \left( -p_{kt}^* \left[ 1 + \frac{\partial \phi_t}{\partial K_{i+1}^t} \right] \right) \frac{\partial E_t \theta_t}{\partial c_{t-1}} \left( -p_{kt}^* \left[ 1 + \frac{\partial \phi_t}{\partial K_{i+1}^t} \right] \right) \frac{\partial E_t \theta_t}{\partial c_{t-1}}.$$

Next apply the envelope theorem with respect to $K_t$:

$$\frac{\partial V}{\partial K_t} \frac{\partial \text{Rev}^{h}}{\partial K_t} \left( e_t \rho \beta \frac{\partial V}{\partial C_t} \right) \left( \frac{\partial \text{Rev}^{h}}{\partial K_t} \right)^{p_{kl}} \left[ \frac{\delta}{\partial K_t^s} \right], \quad (A.3)$$

where $\text{Rev}^{i}$ is the revenue of plant $i$, $i = h$ or $s$.

Update Eq. (A.3) one period and plug in Eq. (A.2). $\beta \hat{V}_{K_{i+1}^t, D_1}^{C_1}$ becomes

$$E_t e_{t+1} \beta \left[ \frac{\partial \text{Rev}^{h}}{\partial K_t^s} + p_{kl}^* \frac{\partial \phi_t}{\partial K_t^s} \right] = E_t \beta \left[ \frac{\partial \text{Rev}^{h}}{\partial K_t^s} + p_{kl}^* \frac{\partial \phi_t}{\partial K_t^s} \right].$$

The other terms of $BD_2$ can be similarly derived.

Since each proposition looks at specific elements of the $A^{-1}$ and $B$ matrices, the simplest approach to prove the propositions is to manipulate the entire matrices and then consider the relevant components for each proposition.

$$A = \begin{bmatrix} \hat{V}_{K_t^h, K_t^h} - r_i \Phi_{K_t^h, K_t^h} & \hat{V}_{K_t^h, K_t^h} & 0 \\ \hat{V}_{K_t^h, K_t^h} & \hat{V}_{K_t^h, K_t^h} - r_i \Phi_{K_t^h, K_t^h} \theta_i & 0 \\ 0 & 0 & \hat{V}_{R_R, C} + \frac{\hat{W}_{R_R, C}}{\beta} \end{bmatrix},$$

$$A^{-1} = \begin{bmatrix} a_{11}^{-1} & a_{12}^{-1} & a_{13}^{-1} \\ a_{21}^{-1} & a_{22}^{-1} & a_{23}^{-1} \\ a_{31}^{-1} & a_{32}^{-1} & a_{33}^{-1} \end{bmatrix} = \begin{bmatrix} a_{22} & a_{12} & 0 \\ a_{21} \gamma & a_{11} \gamma & 0 \\ 0 & 0 & a_{33} \end{bmatrix},$$

where

$$\gamma = a_{11} a_{22} - a_{12} a_{21} = \hat{V}_{K_t^h, K_t^h} - \hat{V}_{K_t^h, K_t^h} \Phi_{K_t^h, K_t^h},$$

$$\text{sign}[A^{-1}] = \begin{bmatrix} - & + & 0 \\ + & - & 0 \\ 0 & 0 & - \end{bmatrix},$$
\[ B = \begin{bmatrix}
  b_{11} & b_{12} \\
  b_{21} & b_{22} \\
  b_{31} & b_{32}
\end{bmatrix}, \]

\[
= -p_{kt} \left[ 1 + \frac{\partial \Phi_t}{\partial K_t^{h+1}} \right] E_t \beta \left[ \frac{\partial \operatorname{Rev}^n_t}{\partial K_t^{h+1}} + p_{kt+1} \left[ \delta - \frac{\partial \Phi_t+1}{\partial K_t^{h+1}} \right] \right],
\]

\[
F(K_t^h) \frac{\partial \operatorname{Rev}^{h+s}}{\partial X_t^h} (\rho = 1) \quad 0
\]

\[
\text{sign } [B] = \begin{bmatrix}
  0 & - \\
  - & + \\
  + & 0
\end{bmatrix}
\]

\[
\frac{\partial K_t^h}{\partial \rho_{t-1}} = - \left[ a_{11}^{-1} b_{21} \right] \frac{\partial E_t(\theta_t|\rho_{t-1}, \emptyset)}{\partial \rho_{t-1}} - \left[ a_{11}^{-1} b_{12} + a_{12}^{-1} b_{22} \right] \frac{\partial E_t(\theta_{t+1}|\rho_{t-1}, \emptyset)}{\partial \rho_{t-1}},
\]

\[
\frac{\partial K_t^s}{\partial \rho_{t-1}} = - \left[ a_{21}^{-1} b_{21} \right] \frac{\partial E_t(\theta_t|\rho_{t-1}, \emptyset)}{\partial \rho_{t-1}} - \left[ a_{21}^{-1} b_{12} + a_{22}^{-1} b_{22} \right] \frac{\partial E_t(\theta_{t+1}|\rho_{t-1}, \emptyset)}{\partial \rho_{t-1}},
\]

\[
\frac{\partial R_t}{\partial \rho_{t-1}} = - \left[ a_{33}^{-1} b_{31} \right] \frac{\partial E_t(\theta_t|\rho_{t-1}, \emptyset)}{\partial \rho_{t-1}}.
\]

Hence

\[
\frac{\partial K_t^h}{\partial \rho_{t-1}} = \left[ + \right] \frac{\partial E_t(\theta_t|\rho_{t-1}, \emptyset)}{\partial \rho_{t-1}} + \left[ - \right] \frac{\partial E_t(\theta_{t+1}|\rho_{t-1}, \emptyset)}{\partial \rho_{t-1}},
\]

\[
\frac{\partial K_t^s}{\partial \rho_{t-1}} = \left[ - \right] \frac{\partial E_t(\theta_t|\rho_{t-1}, \emptyset)}{\partial \rho_{t-1}} + \left[ + \right] \frac{\partial E_t(\theta_{t+1}|\rho_{t-1}, \emptyset)}{\partial \rho_{t-1}},
\]

\[
\frac{\partial R_t}{\partial \rho_{t-1}} = \left[ + \right] \frac{\partial E_t(\theta_t|\rho_{t-1}, \emptyset)}{\partial \rho_{t-1}}. \]
Appendix B

The explicit data used in calibrating the model is the following:

<table>
<thead>
<tr>
<th>Data</th>
<th>Source</th>
<th>Variable in model</th>
<th>Years needed to calibrate/simulate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of research and development employees at the parent</td>
<td>Bureau of Economic Analysis (BEA), US Direct Investment Abroad: 1982 Benchmark Survey (Bench Survey)</td>
<td>$L_t$</td>
<td>1982</td>
</tr>
<tr>
<td>Compensation for research and development employees at the parent</td>
<td>BEA, Bench Survey</td>
<td>$w_t L_t$</td>
<td>1982</td>
</tr>
<tr>
<td>Dollar value of sales of the plants</td>
<td>BEA, Bench Survey and Survey of Current Business, various issues</td>
<td>$p \cdot R \cdot F(K')$</td>
<td>1981–1983</td>
</tr>
<tr>
<td>Producer price index</td>
<td>BEA, Survey of Current Business, various issues</td>
<td>Used for $p_t - p_{t-10}$</td>
<td>1970–1990</td>
</tr>
<tr>
<td>US Brazilian exchange rate</td>
<td>International Monetary Fund, International Financial Statistics Yearbook</td>
<td>$e_t$ and $e_t - e_{t-1}$</td>
<td>1980–1990</td>
</tr>
</tbody>
</table>

There are three first order conditions of the model:

$$
\begin{align*}
[EQN1] \, E_t \left[ R_{t+1} & \frac{dF}{dK^h_{t+1}} \left[ p_{t+1} + \frac{dp}{dX} [R_{t+1} F(K^h_{t+1})] \\
& + \theta_{t+1} R_{t+1} F(K^s_{t+1}) \right] \right] \\
& - \frac{1}{\beta} p_{kt} \left[ 1 + \frac{\partial \phi_t}{\partial K^h_{t+1}} \right] + E_t p_{kt+1} \left[ (1 - \delta) + \frac{\partial \phi_{t+1}}{\partial K^h_{t+1}} \right] = 0,
\end{align*}
$$
Alternative ways to forecast the exchange rate include an AR(1) process or using a ten year rolling average depreciation rate. The former is not convincing for Brazil who had continuous and growing depreciation rate over the 1970–1989 period. The latter is an option which we consider in the simulation section.

\[\begin{align*}
\text{[EQN2]} & \quad E_t \left[ \theta_{t+1} \left\{ R_{t+1} \frac{dF}{dK_{t+1}^h} \right\} \right] + \frac{1}{\theta_{t+1}} \left\{ R_{t+1} F(K_{t+1}^h) \right\} \\
& \quad + \left[ \left( 1 - \delta \right) + \frac{\partial \phi_{t+1}}{\partial K_{t+1}^s} \right] \\
& \quad - E_t \frac{\theta_t}{\tilde{\beta}} \left[ 1 + \frac{\partial \phi_t}{\partial K_{t+1}^s} \right] = 0,
\end{align*}\]

\[\begin{align*}
\text{[EQN3]} & \quad E_t \left\{ \left( F(K_{t+1}^h) + \theta_{t+1} F(K_{t+1}^s) \right) \left[ p_{t+1} + \frac{dp}{dX} \left( R_{t+1} F(K_{t+1}^h) \right) \right] \\
& \quad + R_{t+1} F(K_{t+1}^s) \right\} - \frac{\partial L_{t+1}^{-1}}{\partial R_{t+1}} = 0.
\end{align*}\]

We use these three equations to solve for three unknowns: \(B, \eta\) and \(E_t(R_{t+1})\). To solve for these three variables, we substitute in 1982 values for the remaining variables in these equations. The values come from the above table as follows:

**Step 1:** Index \(K^s_{1982} = 100\).

**Step 2:** Given the 1982 dollar value of the direct investment position in the subsidiary, \(p_{82} K^s_{1982}\), back out \(p_{82}\).

**Step 3:** Use the producer price index and \(p_{82}\) to obtain \(p_{83}\).

**Step 4:** Use the dollar value of sales in each plant along with the mathematical representation, \(Sales_i = p \cdot R \cdot F(K^i) \) \(i = h\) or \(s\), and the subsidiary’s capital stock to back out the headquarter’s capital stock. That is, \(K^h_{1982} = \left[ \left( \frac{Sales^h}{Sales^s} \right) \cdot F(K^s) \right]^{1/\alpha} \).

**Step 5:** Use the number of research and development employees, \(L_{82}\), and compensation for these employees, \(w_{82} L_{82}\), to obtain the wage rate \(w_{83}\). Then use the employment cost index to obtain \(w_{83}\).

**Step 6:** Use the data on research and development employees, \(L_{82}\), to obtain \(R_{82} = (L_{82})^\delta\). Use this value of innovations along with sales and capital stock data to obtain an equation solving for \(A\) in terms of our other unknowns. \(P = A - B[X^h + X^s] = sales^s/RF(K^i)\).

**Step 7:** Use the US-Brazilian exchange rate series to construct one or more ways to forecast future exchange rates. In calibrating the model, we use last period’s depreciation rate as the expected depreciation rate in future periods.\(^{28}\)

Using these steps we solve for our desired parameters: \(A, B\) and \(\eta\).

\(^{28}\)Alternative ways to forecast the exchange rate include an AR(1) process or using a ten year rolling average depreciation rate. The former is not convincing for Brazil who had continuous and growing depreciation rate over the 1970–1989 period. The latter is an option which we consider in the simulation section.
Appendix C

Using the method and notation from Judd’s (1992) article on ‘Projection methods for solving aggregate growth models’, I approximate the optimal policy function, \( g \), of the headquarters’ and subsidiary’s capital stocks. It will take the form:

\[
g(K_h^t, K_s^t, \rho_{t-1}, \theta_t) = \sum_{i=1}^{n^h} \sum_{j=1}^{n^s} a_{ij} \Psi_{ij},
\]

where

\[
\Psi_{ij} = T_{i-1}(2((K^h_i - K^h_{m})/(K^h_M - K^h_m)) - 1)
\times T_{j-1}(2((K^s_i - K^s_m)/(K^s_M - K^s_m)) - 1).
\]

The \( T \)’s are the Chebyshev polynomials defined over \([-1, 1]\); \( n^h \) and \( n^s \) and the number of coefficients you want to estimate for the Chebyshev coefficients; \( K^i_M \) and \( K^i_m \), \( i = h \) or \( s \), are the maximum and minimum values the capital stocks can take for the headquarters and subsidiary, respectively; and \( a_{ij} \) are Chebyshev coefficients of the optimal policy function.

The simulation works as described in Judd’s paper. The residual functions are the Euler equations of \( K^h_t \) and \( K^s_t \) in the model. At date \( t \) the simulation solves for an optimal policy function (\( a_{ij} \)’s) that gives \( K^h_t \) and \( K^s_t \) and, using these values in this optimal policy function, \( K^h_{t+2} \) and \( K^s_{t+2} \) which make the Euler equations equal to zero. The only complication in this technique is that the Euler equations of \( K^i_t \) contain the term \( E_t(R_{t+1}) \). Hence, inside the solving algorithm is a subroutine which takes \( K^h_t \) and \( K^s_t \) from the optimal policy function and solves for the optimal \( E_t(R_{t+1}) \) which is then plugged into the residual function.

References