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Rates in Constrained Economies**

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Net Foreign Assets, Productivity and Real Exchange Rates in Constrained Economies*

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Abstract

Empirical evidence suggests that real exchange rates (RER) behave differently in developed and developing countries. We develop an overlapping generations two-sector exogenous growth model in which RER determination may depend on the country's capacity to borrow from international capital markets. The country faces a constraint on capital inflows. With high domestic savings, the RER only depends on productivity spread between sectors (Balassa-Samuelson effect). If the constraint is too tight and/or domestic savings too low, the RER depends on both net foreign assets (transfer effect) and productivity. We then analyze the empirical implications of the model and find that, in accordance with the theory, the RER is mainly driven by productivity and net foreign assets in constrained countries and by productivity in unconstrained countries.

JEL Classification: E39; F32; F41.

Keywords: Real exchange rate; capital inflows constraint; overlapping generations.

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1 Introduction

A recurrent question in International Macroeconomics concerns the main long-run determinants of real exchange rates (RER). There is, however, no consensus yet on this question. Among the most often quoted determinants we can find productivity, terms of trade and net foreign assets (NFA) [see Chinn (2006)]. Empirical evidence suggests that these determinants change significantly as we vary periods and countries considered. This is especially relevant in recent times, since the resolution of global economic imbalances can lead to large readjustments of external wealth with important consequences for equilibrium RERs and exchange rate policies of emerging markets.

The empirical literature on the Balassa-Samuelson (BS) effect shows that RER appreciation may be related to productivity growth but not systematically. It seems to have special relevance for countries like Japan, some OECD countries [Canzoneri *et al.* (1999)] and transition economies [Égert *et al.* 2003, 2006]. Ito *et al.* (1999) show that RER and growth are positively correlated in Japan, Korea, Taiwan, Hong Kong whereas the correlation remains negative for Indonesia, Thailand, Malaysia, Philippines and China. Hong Kong, Taiwan and Singapore combine a high growth rate and a small appreciation. For other Asian countries except China, Singapore, Taiwan and Thailand, Chinn (2000a) finds that productivity explains RER only when public spending and oil prices are taken into account. Chinn (2000b), using panel data, finds that the RER requires around 5 years to converge to the level predicted by BS. Bergin *et al.* (2006) also report that the BS effect is not stable through time, but it appears to have become more important in recent decades. The fit of the standard BS theory to explain RER changes seems to be very poor and largely country- and period-specific.¹

In line with the theory that emphasizes the role of foreign assets for equilibrium RERs, Lane and Milesi-Ferretti (2004) have developed a model that highlights the transfer effect - which relates RER to NFA. Using a database that covers 64 industrial and less developed countries between 1970 and 1998, they show that a rise in NFA appreciates the RER, especially for countries that have low income, low openness, or foreign exchange restrictions. The theoretical model they present links international payments to the RER through an adjustment of labor supply². However, their model does not address why developing countries experiment higher transfer effects than others.

Linking together this diverse set of results, our study contributes to this literature in two

¹See García-Solanes and Torrejón-Flores (2009) for further evidence on the different importance of the BS effect for rich and poor countries. Chong *et al.* (2010) provide new evidence based on a local projections approach.

²Obstfeld and Rogoff (1995) and Galstyan (2007) also develop models in which international payments affect the relative price of the non-traded good through a labor supply adjustment.

ways. First, it presents a model that reconciles these empirical findings in which RER determination depends on the country's capacity to borrow from international capital markets. Second, it analyzes whether the behavior of RER data is consistent with the main results of the model, focusing on whether the long-run relationship between the RER and its main determinants depends on the financial constraints faced by countries.

As emphasized by Rogoff (1992) and De Gregorio *et al.* (1994), imperfect factor mobility is a necessary condition in a two-sector model for the real exchange rate to be determined by factors other than technological conditions. We relax the assumption of perfect capital mobility using an overlapping generations setting of a two-sector economy with a capital inflows constraint. We assume that the amount the country can borrow on the international capital market is an exogenous fraction of per-capita income.³ This fraction represents the trust of foreign investors about local institutions, creditworthiness, and the ease of cross-border financial transactions. Using such a specification, we are able to determine analytically the threshold level of the constraint below (above) which the country converges to a financially constrained (unconstrained) steady state. If the constraint is not too tight - or if there are high domestic savings - the constrained economy will become unconstrained in the long-run. Otherwise, if investors are not confident - or there are low domestic savings - the country will converge to the constrained steady state. We investigate the consequences of a foreign transfer and a productivity shock in this setting. The RER behavior differs widely between those two kinds of steady states.

Two main conclusions arise from this model regarding the behavior of the RER. In the unconstrained steady state, the RER will exclusively be determined by the Balassa-Samuelson effect. Conversely, in the constrained steady state, the RER will depend on supply and demand of non-traded goods. In this case, a productivity shock operates through a demand effect and not only through the Balassa-Samuelson effect. In the same way, an international transfer from abroad will appreciate the RER, whereas this is not the case in the unconstrained steady state. This transfer effect is higher in less open economies. This is consistent with Lane and Milesi-Ferretti's (2004) empirical results.

We then test the long-run implications of the model for RER behavior. The econometric specification used arises from the expression for the RER from a linearized version of the model. We estimate separate RER models for financially constrained and unconstrained economies, selected using the Chinn and Ito (2007) measure of external financial openness. The findings are supportive of the implications of the model in the long-run, with the RER driven mainly by productivity in financially open countries and by both productivity and

³Gente (2006) introduces a [2x2] setting in the Obstfeld and Rogoff (1996) constrained economy model, but with a constraint depending on wages. Calibrating of the constrained steady state, Gente (2006) shows that productivity growth combined with fertility decline may explain the RER depreciation experienced by Asian countries.

NFA for countries with restricted access to international finance.

The paper is organised as follows. Section 2 presents the theory model. Section 3 analyses the steady state solution of the model for constrained and unconstrained economies. Section 4 presents the econometric evidence, and Section 5 provides some conclusions.

2 The model

The model is a variant of Obstfeld and Rogoff (1996) constrained economy overlapping generations model in which there are two production sectors: a tradable sector and a non tradable sector. In this setting, the real exchange rate R denotes the relative price of non tradable to tradable goods. The constraint the country faces on capital inflows is⁴

$$B_{t+1} \geq -\eta N_t y_t \tag{1}$$

where B_{t+1} denotes the NFA of the domestic country in terms of traded goods, and $\eta > 0$ is the proportion of total income ($N_t y_t$) the domestic country can borrow, where N_t is total population and y_t is *per capita* income. The η parameter reflects the ease of access the country has to international capital flows and may be related to institutional features such as restrictions to capital and current account transactions⁵. The smaller η the more constrained the country is to capital inflows. Because of the way the constraint is specified, a RER appreciation attracts capital flows⁶ and may fill in a lack of domestic savings that accelerates growth temporarily or increases permanently long-run income per capita. In the model we present below, agents live for two periods and only work in their first period of life. Making use of overlapping generations, our model allows the steady state to be constrained or unconstrained. The credit constraint we impose can not only slow down absolute convergence⁷ but also prevent it from occurring even in the long-run.

⁴As mentioned above, Gente (2006) assumes that the constraint on capital inflows only depends on the wage and not on total income. We use a more general specification (See Section 2.2 for further details).

⁵Our purpose in this paper is not to explain or estimate the η parameter. This constraint may be the consequence of some capital market imperfections such as sovereign risk. We view our constraint as a reduced form of a more complete model. However, it serves our purpose of emphasizing the role of financial constraints for RER determination.

⁶In Rodrik (2008), capital inflows are related to traded inputs and a real appreciation also increases capital inflows as in our model.

⁷As it would have been the case with an infinite horizon agent [Barro, Mankiw and Sala-i-Martin (1995), Lane (2001)].

2.1 Individuals

The economy consists of a sequence of individuals who live for two periods. In the second period of her life, each individual gives birth to $1 + n$ others so that the per period rate of population growth is n . At time t , each generation consists of N_t identical individuals who make decisions concerning consumption and savings.

The intertemporal preferences of an individual belonging to generation t are represented by

$$U(c_t^Y, c_{t+1}^o) = \beta \ln c_t^Y + (1 - \beta) \ln c_{t+1}^o \quad (2)$$

where c_t^Y and c_{t+1}^o are respectively composite consumption when young and composite consumption when old; $\beta \in (0, 1)$ denotes individuals' thrift.

Let c_N and c_T be, respectively, the spending allocated into non-traded and traded goods. Instantaneous preferences are defined according to a Cobb-Douglas aggregator:

$$u(c_T, c_N) = c_T^\alpha c_N^{1-\alpha}, \quad 0 < \alpha < 1 \quad (3)$$

Following Obstfeld and Rogoff (1996), the small economy faces a constraint on capital inflows (1). The consequence of this assumption is that the domestic return on capital may be higher than the world return. The budget constraints for each generation are

$$\pi_t c_t^Y + (1 + n) k_{t+1} + (1 + n) b_{t+1} = w_t \quad (4)$$

$$\pi_{t+1} c_{t+1}^o = (1 + r_{t+1}^d) (1 + n) k_{t+1} + (1 + \bar{r}) (1 + n) b_{t+1}, \quad (5)$$

where k_{t+1} is total capital stock per young agent in terms of traded good prices $k_{t+1} = K_{t+1}/N_{t+1}$, b_{t+1} are net foreign assets per young agent $b_{t+1} \equiv B_{t+1}/N_{t+1}$, w_t are wages earned when young, and n is the rate of population growth. The price of the tradable good is normalized at unity and π_t is the consumer price index. The domestic return on capital is the market interest rate r_{t+1}^d whereas the world return \bar{r} is fixed according to the small open economy assumption. The maximization problem of an individual born in period t under the constraints (4), (5) (1) gives⁸

$$\pi_t c_t^Y = \beta \left[w_t - \frac{r_{t+1}^d - \bar{r}}{1 + r_{t+1}^d} (1 + n) b_{t+1} \right] \quad (6)$$

$$\pi_{t+1} c_{t+1}^o = (1 - \beta) \left[(1 + r_{t+1}^d) w_t - (r_{t+1}^d - \bar{r}) (1 + n) b_{t+1} \right] \quad (7)$$

$$\begin{aligned} c_T &= \alpha \pi c \\ R c_N &= (1 - \alpha) \pi c \end{aligned} \quad (8)$$

⁸The maximization program is solved in two steps: first, the individual chooses $\pi_t c_t$ and b_{t+1} to maximize lifetime utility, and then chooses the optimal composition of consumption between c_T and c_N to maximize instantaneous utility.

From equations (6) and (7), individuals consume a proportion β of their life-cycle income during the first period of life and the remaining in the second. Life-cycle income consists of

- the wage w ,
- the capital gain agents may realize borrowing at world rate \bar{r} to invest in domestic capital whose return r^d is higher than \bar{r} .

Equations (8) gives the allocation of total consumption spending between the two goods at each period, where the price index is $\pi = \phi(\alpha) R^{1-\alpha}$, with $\phi(\alpha) \equiv \alpha^{-\alpha} (1 - \alpha)^{\alpha-1}$.

2.2 Production Sectors

Investment transforms instantaneously a unit of tradable good into a unit of installed capital: $K_{t+1} = I_t$ and capital fully depreciates after one period ($\delta = 1$). The representative firm produces in the two sectors, the traded (T) and the non-traded (N) sector.

$$\begin{aligned} \underset{I_t, K_{Tt}, L_{Tt}}{Max} \quad & F(K_{Tt}, L_{Tt}) + RH(K_{Nt}, L_{Nt}) - wL_t - I_t \\ \text{s.t.} \quad & K_{t+1} = I_t \\ & K_{Tt} + K_{Nt} = K_t \\ & L_{Tt} + L_{Nt} = L_t \end{aligned} \tag{9}$$

with L_t being total labor supply, and K_i and L_i the amount of capital stock and labor supply used in sector $i = T, N$ respectively. $F(\cdot)$ and $H(\cdot)$ are the traded and non-traded sector production functions. Dropping time indices, optimal allocation of factors is given by

$$a_T f'(k_T) = a_N R h'(k_N) \tag{11}$$

$$a_T [f(k_T) - k_T f'(k_T)] = a_N R [h(k_N) - k_N h'(k_N)] \tag{12}$$

where $k_i \equiv K_i / (l_i L)$ is the capital-labor ratio, and the share of labor used in sector i is $l_i = L_i / L$, $i = T, N$. The intensive form production functions are $F(k_T, 1) \equiv f(k_T)$, $H(k_N, 1) \equiv h(k_N)$. Finally, a_i is the total factor productivity level of sector $i = T, N$. According to (11) and (12), k_N and k_T depend only on RER whereas the allocation of labor depends both on the capital-labor ratio and the RER. Hence, $k_N \equiv k_N(a_T, a_N, R)$ and $k_T \equiv k_T(a_T, a_N, R)$, while $l_N \equiv l_N(a_T, a_N, k, R)$ and $l_T \equiv l_T(a_T, a_N, k, R)$. From (9), (10), (11) and (12), the optimal factor allocation implies

$$\begin{aligned} \frac{\partial k_N}{\partial R} &= \frac{a_T f}{R^2 a_N h''(k_N - k_T)} \\ \frac{\partial k_T}{\partial R} &= \frac{R a_N h}{f'' a_T (k_N - k_T)} \end{aligned} \tag{13}$$

Similarly, $\partial l_N / \partial k \gtrless 0$ if $k_N \gtrless k_T$ and $\partial l_N / \partial R > 0$. When the tradable sector is capital intensive, a real appreciation leads to an increase in both capital intensities k_N and k_T whereas labor moves from the traded to the non-traded sector. These factor movements reflect that a real appreciation makes the non-tradable sector more attractive. Assuming perfect intersectoral mobility, the returns on capital $r^d = a_T f'(k_T(a_T, a_N, R)) - 1 \equiv r^d(a_T, a_N, R)$ and labor $w = a_T [f(k_T(a_T, a_N, R)) - f'(k_T(a_T, a_N, R)) k_T(a_T, a_N, R)] \equiv w(a_T, a_N, R)$ only depend on the RER (R) and productivity. A RER appreciation, profitable to the non-traded sector which is labor intensive, will increase wage and reduce the domestic interest rate⁹. An exogenous rise in traded (non-traded) sector productivity increases (decreases) domestic interest rates and reduces (increases) wages when the traded sector is capital intensive. Unless otherwise stated, we will omit the productivity terms (a_i) when there is no productivity change so that: $k_T \equiv k_T(R)$, $k_N \equiv k_N(R)$, $l_N \equiv l_N(k, R)$, $r^d \equiv r^d(k, R)$, $w \equiv w(k, R)$.

Per capita total income depends on both the RER and per capita capital stock: $y \equiv (1 + r^d(R))k + w \equiv y(R, k)$ with

$$\frac{\partial y}{\partial k} = 1 + r^d \quad (14)$$

$$\frac{\partial y}{\partial R} = R h(k_N(R)) l_N(k, R) \quad (15)$$

Notice that a RER appreciation and a rise in per capita capital stock both exert a positive effect on total income and relaxes the constraint. Equations (1) and (14) mean that a rise in domestic savings allows the country to borrow more on international capital markets. This is due to the way the constraint is specified because the amount the country can borrow depends on per-capita income instead of only the wage as in Gente (2006), where only the RER appreciation may relax the constraint.

2.3 The temporary equilibrium in the constrained case

We will focus on the case where the capital inflows constraint binds, at least initially, with a capital intensive traded sector. This creates a gap between domestic and world returns on capital. This gap - in a similar way as a risk premium¹⁰ - reflects the fact that many developing countries do not have full access to international capital markets: the return on domestic capital r_{t+1}^d must be higher than the world market interest rate \bar{r} to offset the perceived risky return due to, for instance, a restrictive capital account regime.

The period- t temporary equilibrium conditions are as follows:

(i) **Capital market equilibrium.** Given the optimal intersectoral factor allocation

⁹In a similar fashion as a Stolper-Samuelson effect.

¹⁰Similar results could potentially be obtained by considering country-risk.

$k_T(R)$ and $k_N(R)$, net foreign assets per capita are given by

$$b_{t+1} = -\frac{\eta y(R_t, k_t)}{1+n} \quad (16)$$

Let $\Gamma(R_{t+1}) \equiv \eta [r^d(R_{t+1}) - \bar{r}] [1 + r^d(R_{t+1})]^{-1}$ be the *arbitrage premium* which depends on the interest rate gap between domestic and world capital markets and on proportion η of the income agents can borrow. The higher Γ the higher the capital gain agents realize. Therefore, capital per worker is

$$k_{t+1} = [1 - \beta + \eta - \beta \Gamma(R_{t+1})] \frac{w(R_t)}{1+n} + [\eta - \beta \Gamma(R_{t+1})] \frac{1 + r^d(R_t)}{1+n} k_t \quad (17)$$

(ii) **Labor market equilibrium.** The inelastic labor supply N_t is equal to the labor demand L_t . Given the capital market equilibrium, the wage w equalizing labor supply and demand is defined by

$$w(R_t) \equiv f(k_T(R_t)) - k_T(R_t) f'(k_T(R_t)) \quad (18)$$

(iii) **Non-tradable goods market equilibrium.** There are N_t young agents and N_{t-1} old agents. Hence, the equilibrium on the non tradable goods market is

$$(1 - \alpha) (N_t \pi_t c_t^Y + N_{t-1} \pi_t c_t^o) = R_t Y_N(R_t, k_t) \quad (19)$$

with $Y_N(R_t, k_t) \equiv l_N(R_t, k_t) N_t h(k_N(R_t))$. Consumption spending is given by equations (6) and (7).

Equation (17) describes the allocation of saving between both assets. It offers a first dynamic relationship between the RER and the capital-labor ratio. Using (16), (18) and (19), with consumption spending given by (6) and (7), we get a second dynamic relationship between R and k .

The intuition behind the dynamics is the following. In such a constrained economy, the amount the country can borrow on world market is limited to a fraction of total income. In this 2-sector 2-factor model, total income does not only depend on the capital-labor ratio but also depends on RER. A RER appreciation - or an increase in the capital-labor ratio - increases total income in terms of traded good and then loosens the constraint. The country can borrow more, increases its capital stock and total output, loosening the constraint again. This mechanism will help the country converging to an unconstrained steady state if non-traded consumption is sufficiently high and if the constraint is not too tight (if η not too small). Otherwise the country will remain constrained in the long-run¹¹.

¹¹When the tradable sector is labor intensive, it is the RER depreciation that helps the country converge to an unconstrained steady state. We do not focus on this case in what follows because it is less frequently observed and corresponds to a preliminary stage of development [Ito, Isard and Symanski (1999)].

In the existing literature, there are constrained economy models like Barro, Mankiw and Sala-i-Martin (1995) or Lane (2001) that focused on the convergence speed issue. Indeed, in those constrained economy models the country systematically converges to an unconstrained steady state and the question of interest is to know at what speed. In our model, the country may converge in the long-run to a steady state that could either be constrained or unconstrained¹². Hence, the important question here is to study the relationship between NFA and RER in both types of equilibrium.

3 Steady state

There are two kinds of steady state: constrained and unconstrained. However, these two steady states do not exist simultaneously¹³. The country may converge to an unconstrained steady state if the constraint is not too severe (high η), domestic saving is high (low β) or if agents consume enough non-traded goods (low α). The relationship between RER, NFA and productivity depends on the kind of steady state the economy converges to.

3.1 Constrained or unconstrained?

We now aim at determining the threshold level of the constraint, $\tilde{\eta}$ such that if $\eta < \tilde{\eta}$, the country will remain constrained in the long-run (see Appendix B). We will then proceed into three stages. First, we describe the constrained steady state. Second, we describe the unconstrained steady state. Third, we determine the threshold level of the constraint $\tilde{\eta}$.

3.1.1 A constrained steady state

The constrained steady state is denoted by a *. If the country remains constrained even in the long-run, the steady state (k^*, R^*) is defined¹⁴ by the following system

$$k^* = \frac{w(R^*)}{1+n} \frac{(1-\beta) + \eta - \beta\Gamma(R^*)}{1 - (\eta - \beta\Gamma(R^*)) \frac{1+r^d(R^*)}{1+n}} \quad (20)$$

$$\left[\beta + \frac{1+r^d(R^*)}{1+n} (1-\beta) \right] \left[w(R^*) + \frac{r^d(R^*) - \bar{r}}{1+r^d(R^*)} \eta y(R^*, k^*) \right] = \frac{y_N(R^*, k^*) R^*}{1-\alpha} \quad (21)$$

Equation (20) gives the long-run allocation of saving. In this constrained economy, capital per capita k is financed by domestic saving plus capital inflows. Equation (21) is the long-run non-traded good market clearing condition. Both the long-run capital-labor ratio and

¹²This is due to the presence of overlapping generations and the fact that there is no need for the time preference rate to equalize the world interest rate.

¹³We can show, using a simple Cobb-Douglas example, that, when the unconstrained steady state exists, the constraint is no longer respected and then the constrained steady state does not exist.

¹⁴To guarantee potential existence, we assume that $\eta < (1+n)/(1+\bar{r})$.

RER are determined by those two conditions. Then, the constraint gives net foreign assets: $b^* = -\eta y(R^*, k^*) / (1 + n)$.

3.1.2 An unconstrained steady state

An over-bar denotes the unconstrained steady state. It is the standard steady state that occurs in a two-sector two-factor small open economy model. The country has perfect access to the international capital market so that

$$r^d(\bar{R}) = \bar{r} \quad (22)$$

That is, domestic return on capital converges to the world one. Equation (22) determines the long-run RER that depends only on the world interest rate¹⁵. The long-run RER determines the wage and hence the demand for non-traded goods (left hand side of equation (23)). Domestic capital \bar{k} clears the non-traded good market

$$\left[\beta + \frac{(1 + \bar{r})(1 - \beta)}{1 + n} \right] w(\bar{R}) = \frac{y_N(\bar{R}, \bar{k}) \bar{R}}{1 - \alpha} \quad (23)$$

Finally, the net foreign assets fill the gap between domestic capital \bar{k} and domestic saving

$$\bar{b} = \frac{w(\bar{R})}{1 + n} (1 - \beta) - \bar{k} \quad (24)$$

In this unconstrained steady state the standard Balassa-Samuelson effect holds since the RER depends only on the supply side of the model.

3.1.3 The threshold level

The level of the constraint, η , is exogenous and could be interpreted as the penalty imposed by international investors to a country because of lack of creditworthiness and institutional restrictions to financial flows. We take this penalty as given and determine whether this η -penalty is severe enough to allow the developing country to converge to the unconstrained steady state. We focus on the case where $k_0 < \bar{k}$. Let $\tilde{\eta}$ be the threshold level of the constraint such that

- when $\eta \geq \tilde{\eta}$, the country converges to the unconstrained steady state and we recover the standard small open economy setting
- when $\eta < \tilde{\eta}$, the country converges to the constrained steady state and remains constrained in the long-run.

¹⁵The RER is also determined here by the productivity spread between sectors: $r^d(a_N, a_T, R) = \bar{r}$ with $\partial r^d / \partial a_N < 0, \partial r^d / \partial a_T > 0$ when the traded sector is capital intensive.

A special case of this model would be $\eta = 0$ where the country would be so constrained that net foreign assets would be zero. This case would correspond to a closed economy setting.

A rise in $\tilde{\eta}$ makes convergence to the constrained steady state more likely to occur. We can characterize the threshold level $\tilde{\eta}$ in a simple Cobb-Douglas case.

Example: The Cobb-Douglas case. We assume Cobb-Douglas technologies in both sectors. Let the long-run propensity to consume the non-traded good be

$$\Psi = (1 - \alpha) [\beta + (1 - \beta) (1 + \bar{r}) / (1 + n)]$$

After a bit of algebra (see Appendix B) we can show that

$$\tilde{\eta} = \frac{\frac{1+n}{1+\bar{r}} [\nu + \Psi (\rho - \nu)] - (1 - \beta) (1 - \nu)}{1 + \Psi (\rho - \nu)}$$

Where ρ and ν are the elasticities of output with respect to capital in the traded and non-traded sectors respectively. We assume that the total propensity to consume the non-traded good Ψ is lower than unity and that the traded sector is capital intensive. This means that $1 + \Psi (\rho - \nu) > 0$. This implies that a rise in Ψ enhances convergence to the unconstrained steady state¹⁶. The intuition behind this result is simply that a rise in non-traded goods consumption tends to appreciate the RER. This RER appreciation relaxes the constraint and helps the country reaching the unconstrained steady state. In the same way, the threshold level $\tilde{\eta}$ depends on n and β since population growth and time preference influence both propensity to consume Ψ and savings.¹⁷

Calibration. We assume that half of the consumption is spent on non-traded goods. Assuming that each generation lives for 25 years, the world interest factor is $1 + \bar{r} = 1.37$ which means that the world real interest rate is about 1.25% per year, and $n = 0.6$, corresponding to a rate of population growth of 1.9% per year. In accordance with Beine et al. (2001), let $\beta = 0.6$ to have a domestic rate of time preference of around 3.56%. Using those figures, the threshold level is $\tilde{\eta} = 0.129$ which means that a steady-state constrained economy cannot borrow more than 13% of GDP. Figure 1 represents the long-run equilibrium. The constrained steady state is represented for $\eta = 0.1$ and the unconstrained steady state for $\eta = 0.2$. In the constrained steady state, the domestic real interest rate exceeds the world interest rate and more resources are allocated to the production of the traded good. Since domestic interest rate and RER are negatively related, the RER is lower in the constrained steady state than in the unconstrained

¹⁶Since $\eta < (1 + n) / (1 + \bar{r})$, we have $\partial \tilde{\eta} / \partial \Psi < 0$.

¹⁷We have that $\partial \tilde{\eta} / \partial n > 0$, and $\partial \tilde{\eta} / \partial \beta > 0$.

one. We choose the elasticities of output with respect to capital per capita for the two sectors to match empirical evidence: 40% of total output is traded with 37% of labor being employed in that sector [Mahbub Morshed and Turnovsky (2004)]. With $\nu = 0.4$ and $\rho = 0.2$ the traded sector is capital intensive. Then, we have $l_T^* = 39.24\%$ and $\bar{l}_T = 37.70\%$ whereas $y_T^*/y^* = 43.51\%$ and $\bar{y}_T/\bar{y} = 41.62\%$ (See Table 1). In the constrained steady state, production factors are over-allocated in the traded sector: the lower the RER, the higher the return on traded production.

[Figure 1]

[Table 1]

3.2 Net Foreign Assets and the RER

The relationship between NFA and RER, the so-called transfer effect, will depend on the nature of the steady state the economy converges to. Let T_t denote a transfer received from abroad. Then capital market equilibrium becomes

$$s_t + T_t = (1 + n) [b_{t+1} + k_{t+1}]$$

We can consider T as an unrequited transfer from the rest of the World. Like savings, this transfer will be used for asset accumulation.

3.2.1 Unconstrained steady state

Long-run equilibrium is given by equations (23) and (22). The introduction of the transfer changes NFA accumulation

$$\bar{b} = T + \frac{w(\bar{R})}{1+n} (1 - \beta) - \bar{k} \quad (25)$$

A transfer will increase NFA. Since RER is exclusively determined by productivity and world interest rates: there is no transfer effect and NFA do not affect the RER.

3.2.2 Constrained steady state

In the constrained steady state, long-run equilibrium is given by equations (20) and (21) and the constraint still binds

$$b^* = -\frac{\eta y(R^*, k^*)}{1+n}$$

The introduction of the transfer T changes equation (20) that becomes

$$k^* = \frac{\frac{w(R^*)}{1+n} [(1 - \beta) + \eta - \beta \Gamma(R^*)] + \frac{T}{1+n}}{1 - \frac{1+r^d(R^*)}{1+n} \left(\eta - \beta \eta \frac{r^d(R^*) - \bar{r}}{1+r^d(R^*)} \right)}$$

A transfer will have two kinds of effects

(i) a direct effect: a rise in T increases the capital-labor ratio. Since the non-traded sector is labor intensive, this rise in capital reduces non-traded output and leads to a RER appreciation.

(ii) an indirect effect: a transfer increases total production and loosens the constraint. As a result, capital stock increases more and this reinforces the RER appreciation. The higher η - the more the country is allowed to borrow on international markets - the higher the RER appreciation.

As in Lane and Milesi-Ferretti (2004), the transfer effect increases with the size of the non-traded sector: the less open (low α) the country, the higher the direct effect. However, our model shows analytically that the transfer effect depends also on the country's access to external borrowing. It holds only in the constrained economy case, that is, when $\eta < \tilde{\eta}$. Conversely, when $\eta \geq \tilde{\eta}$ the transfer effect does not hold.

Calibration: The transfer effect An international transfer can be considered as an exogenous increase in savings. Figure 2 depicts the consequences of a transfer on steady state. The transfer shifts the (CM) curve upwards. In the unconstrained steady state, it does not affect domestic interest rate -because the equilibrium lies at the intersection between (WIR) and (CM). In the constrained steady state, the domestic interest rate increases and more resources are allocated to the production of the non-traded good. It follows that in this case, RER appreciates whereas RER is not affected by the transfer in the unconstrained steady state¹⁸.

[Figure 2]

3.3 Productivity and the RER

In this 2x2 model total output increases not only with the capital-labor ratio and total factor productivity but also with RER appreciation [See equations (14) and (15)]. However, the relationship between the RER and productivity still depends on the nature of the steady state the economy converges to.

3.3.1 Unconstrained steady state

The long-run equilibrium is given by equations (23) and (24). The RER is exclusively determined by the world interest rate and productivity spread between sectors according to

$$r^d(a_T, a_N, R) = \bar{r} \quad (26)$$

¹⁸ The transfer also relaxes the constraint moving the equilibrium to the left part of the Figure. If the transfer is high enough, it can help the constrained economy reach an unconstrained steady state.

with $\partial r^d/\partial a_T > 0$. An increase in traded productivity will directly generate a RER appreciation (Balassa-Samuelson effect).

3.3.2 Constrained steady state

RER and the capital-labor ratio clear the non-traded goods market and the long-run equilibrium is given by

$$b^* = -\frac{\eta y(a_T, R^*, k^*)}{1+n}$$

$$k^* = \frac{w(a_T, R^*)}{1+n} \frac{(1-\beta) + \eta - \beta \Gamma(a_T, R^*)}{1 - (\eta - \beta \Gamma(a_T, R^*)) \frac{1+r^d(a_T, R^*)}{1+n}}$$

with $\partial w/\partial a_T < 0$ and $\partial r^d/\partial a_T > 0, \partial \Gamma/\partial a_T > 0$. The constraint always binds so that NFA are determined by output. The Balassa-Samuelson effect does not hold here in the sense that equation (26) no longer applies. The RER does not only depend on productivity and world interest rate but instead results from the interaction between demand and supply of non-traded output. A rise in traded goods productivity a_T leads to changes in both demand and supply of non-traded goods and will generate:

(i) an ambiguous effect on non-traded goods demand¹⁹ due to a rise in domestic return on capital combined with a wage decrease.

(ii) a decrease in non-traded output

(iii) an ambiguous effect on total output

The third effect will affect the country's capacity to borrow on international markets. A rise in total output will relax the constraint, increase capital stock, and decrease non-traded output. Conversely, a decrease in total output will tighten the constraint, reducing capital stock and increasing non-traded output. Since this third effect is ambiguous, the relationship between traded productivity and RER is difficult to characterize in this constrained steady state. For economies with high rate of time preference and/or not allowed to borrow enough on international markets, the Balassa-Samuelson effect may be reversed: a rise in traded productivity may lead to a RER depreciation. Otherwise (high β and/or high η), the RER still appreciates as in the unconstrained case but operating here through a demand effect and not only through a productivity channel as in the unconstrained case. It is hence possible that productivity can have an ambiguous effect on the RER for financially constrained countries.

¹⁹With a simulation exercise, we can show that, in the vast majority of cases, demand for non-traded goods will decrease.

4 RER behavior: empirical evidence

We are interested on the implications of the model for the behavior of the RER. In order to empirically assess the different effects of productivity and NFA on the RER in constrained and unconstrained economies, we focus on the long-run behavior derived from the steady state of the model.²⁰ We estimate the long-run cointegration vector for the RER and split the sample according to the degree of restrictiveness to foreign capital inflows.

Our econometric specification derives from the log-linearization of the equilibrium conditions for both constrained and unconstrained cases. The log-linearized expression for R in the constrained steady state (R^C) is obtained by combining equations (20) and (21) with the log-linearized first order conditions. We consider a benchmark steady state where the domestic interest rate is equal to population growth ($r^{d*} = n$) with $n > \bar{r}$. We denote a variable x_0^* as the value of x at this benchmark constrained steady state. Let \hat{x} denote the percentage deviation from this steady state. The NFA/GDP ratio is defined as $z = b/y$. In the remaining, we focus on the Cobb-Douglas production function case. After several transformations²¹ we obtain the following expression:

$$\hat{R}^C = [1 + \varepsilon (\xi_1 + \xi_2)] \hat{a}_T - \hat{a}_N + \varepsilon \left[\frac{\chi}{(1 - \eta\chi)} - \frac{(1 - \alpha) \bar{r}}{\kappa} \right] \eta \frac{(\phi + 1)}{\phi} \hat{z}, \quad (27)$$

where the parameters are defined as:

$$\begin{aligned} \xi_1 &= \frac{(1 - \alpha) (1 - \bar{r}\eta) + \frac{1}{\nu - \rho} (\phi (1 - \nu) - \nu)}{\phi \kappa} + 1 \\ \xi_2 &= \frac{(1 - \alpha) (1 + n - \eta \bar{r})}{\kappa} + \frac{\eta \left(\chi - \beta \frac{1 + \bar{r}}{1 + n} \frac{\phi + 1}{\phi} \right)}{(1 - \eta\chi)} \\ \varepsilon &= (\nu - \rho) \left[\frac{[\phi (1 - \rho) - \rho] \left(\frac{1 - \nu}{\nu - \rho} \right)^2}{\kappa} - \nu \xi_1 + (1 - \nu) \xi_2 \right]^{-1} \end{aligned}$$

with $\phi = [1 - \beta + \eta (1 - \beta \frac{n - \bar{r}}{1 + n})] / [1 - \eta (1 - \beta \frac{n - \bar{r}}{1 + n})]$, $\kappa = \left[\frac{1 - \nu}{\nu - \rho} \right]^2 (\phi (1 - \rho) - \rho) + (1 - \alpha) (n - \eta \bar{r})$ and $\chi = 1 - \beta \frac{n - \bar{r}}{1 + n}$.

We can then express (27) in log-levels to obtain an equation for the equilibrium level of R that we can estimate. Note that, since b/y can be negative, we cannot take its log for

²⁰We focus on comparing alternative steady states with different values of the fundamentals determining RER, but we do not empirically model the fundamentals themselves. Econometric estimation, however, considers the possibility of endogenous regressors.

²¹A full derivation of the linearization procedure is available from the authors on request.

estimation. A convenient way of expressing the log-level equation is then in terms of the b/y ratio:

$$\log R^C = \Psi + [1 + \varepsilon (\xi_1 + \xi_2)] \log a_T - \log a_N + \varepsilon \left[\frac{\chi}{(1 - \eta\chi)} - \frac{(1 - \alpha) \bar{r}}{\kappa} \right] \eta \frac{(\phi + 1)}{\phi} \frac{y_0^*}{b_0^*} \frac{b}{y}, \quad (28)$$

where Ψ is a constant.

For the unconstrained steady state, the log-linearized expression (in levels) is simply:

$$\log R^{UC} = \Theta + (\log a_T - \log a_N), \quad (29)$$

where Θ is a constant.

Using these linear expressions, we can then confront the implications of model with data. Since we want to analyze the restrictions implied by (28) and (29) on the long-run equilibrium exchange rate, especially the effect of b/y , we use a common specification for both groups. Also, because one of the two datasets used below does not allow us to separate proxies for a_T and a_N , we assume common coefficients for both variables. Section 4.3.4 below, however, presents results when these two variables are allowed different coefficients for the constrained case using our second dataset. Our empirical specification is then:

$$\log R_{it} = \gamma_i + \gamma_t + \gamma_1 (\log a_T - \log a_N)_{it} + \gamma_2 \frac{b_{it}}{y_{it}} + \epsilon_{it}, \quad (30)$$

where γ_i and γ_t are country-specific effects and time effects respectively, and ϵ_{it} is an error term. Note that γ_2 is not an elasticity but a semi-elasticity. By multiplying γ_2 times the average (absolute) value of b_{it}/y_{it} , we then obtain the value of the elasticity corresponding to the coefficient multiplying \hat{z} in equation (27).

The coefficients (γ 's) in (30) are then estimated for a panel of countries i using a panel-modified version of the Dynamic-OLS (DOLS) estimator which controls for endogeneity by including leads and lags of the differenced regressors. Following Phillips and Loretan (1991), we also augmented the regression with lags of the residuals. This estimator, which behaves equivalently to a Maximum Likelihood estimator, is not only efficient but ensures that the parameters are normally distributed. In our application, given the yearly nature of the data, we used one lag (and lead) augmentation²². As discussed below, we then compare the results for the group of constrained and unconstrained economies and analyze their correspondence with (28) and (29). The error correction model (ECM) for each variable is then estimated using a system GMM estimator as discussed below.

²²The results from using a DOLS estimator as proposed in Kao and Chiang (2001) are very similar.

4.1 Data

We use two datasets for the empirical analysis. The first is from Lane and Milesi-Ferretti (2004,2007) [LMF (2004)] which we use for comparison reasons to benchmark against a related study. The cross-sectional dimension of this dataset also allows us to split the sample formally. Because we match it with the Chinn-Ito (2007) index of financial openness ($KOPEN_t$), the LMF (2004) data we use comprises 55 countries for the period 1970-1998.²³

In this first dataset, the measure of the RER we use is the trade-weighted CPI-based RER.²⁴ From the point of view of the theory definition of the RER (R), considering fixed foreign prices, this measure would be a proxy for $\log(\pi)$, so that $LRE R_t = \log RER_t = \xi + (1 - \alpha) \log R$ and $\xi = \log(\phi(\alpha)) = \text{ctant}$. This obviously assumes that there are no deviations of the price of traded goods from PPP (see Engel, 1999). Betts and Kehoe (2008) find that the correlation between bilateral CPI-based RERs and the relative price of nontraded goods for 50 countries is high, with an average correlation of 60% in levels. Nevertheless, their sample of countries and period is different from ours. This is one of the reasons we use a second dataset with direct relationship with the theory definitions.

Relative productivity is proxied by (log) GDP per capita relative to trading partners constructed using Summers and Hestons data on GDP per capita at constant 1985 PPP international dollars (LYD_t). The weights used are the same as for $LRE R_t$. This, again, is an imperfect proxy for the relative total factor productivity (TFP) of traded to nontraded sectors (a_t^T/a_t^N). Usually, sectoral data availability on output and employment for large samples of countries is limited. We use this proxy for comparison reasons with LMF (2004). However, Ricci *et al.* (2008) report no correlation between GDP *per worker* and relative productivity of traded and non-traded sectors.²⁵ This limitation of the productivity proxy is the other key reason for using a second dataset which is, nevertheless, more limited in terms of country coverage. Hence, for this dataset, the econometric specification used is:²⁶

$$LRE R_{it} = \gamma_i + \gamma_t + \gamma_1 LYD_{it} + \gamma_2 \frac{NFA_{it}}{Y_{it}} + \epsilon_{it}. \quad (31)$$

The second dataset measures directly the variables of interest from the theory model.

²³A list of countries is provided in Appendix A.

²⁴See Lane and Milesi-Ferretti (2004) for further details.

²⁵They also report that the difference between traded and non-traded sector productivity growth has widened precisely for the countries in their sample with higher *per capita* income growth such as Asia and transition economies.

²⁶Because we benchmark against LMF (2004) results, we also add the (log) terms of trade (LTT_t) to the basic specification. This is also because the transfer effect can have an impact on the RER through terms of trade adjustment [as in Keynes (1929)]. For this to be possible, however, the countries considered must be large enough. The terms of trade are measured as the ratio between export and import unit values in US dollars from IMF's World Economic Outlook.

We constructed data on R_t and relative productivity between traded and non-traded sectors using the 10-sectors data provided by the Groningen Growth and Development Center (GGDC).²⁷ This source allowed us to build data for 21 countries for the 1974-2004 period.²⁸ The cross-sectional coverage is much smaller than in LMF (2004), but there is a clear advantage in terms of its match with the theory definitions. The (log) RER (LR_t) is defined as the ratio between the non-traded and traded value added deflators.²⁹ These, in turn, are weighted averages of value added deflators for the sectors in each group. The weights correspond to the value added share of each sector within its group. We followed de Gregorio *et al.* (1994) and Ricci *et al.* (2008) to classify sectors into the two categories. We hence considered tradable sectors Agriculture, Mining, Manufacturing and Transport, Storage and Communication. Non-tradable sectors are: Public Utilities, Construction, Wholesale and Retail Trade, Finance, Insurance, and Real Estate, Community, Social and Personal Services, and Government Services. Given the lack of data on capital stocks, we proxied TFP by labor productivity. The (log) relative productivity (LRP_t) is then defined as the (value added) weighted sum of tradable productivities relative to the weighted sum on non-tradable productivities. The econometric specification here is:

$$LR_{it} = \gamma_i + \gamma_t + \gamma_1 LRP_{it} + \gamma_2 \frac{NFA_{it}}{Y_{it}} + \epsilon_{it}. \quad (32)$$

4.2 Sample splitting

Given our interest on the impact of external financial access on the determination of the RER, we split the sample into constrained and unconstrained economies according to an observable indicator. We pay special attention to this issue because of its relevance to interpret the empirical results. In principle, a variety of variables could be used as indicators of the degree of financial access of countries in international markets. One such variable is the level of income. However, this is a very imperfect proxy for financial access as we can have rich countries with restrictive capital account practices and vice versa. This would affect the sample splitting exercise precisely for countries close to the splitting threshold. Another such measure is the ratio of NFA (raw or in absolute value) to GDP. This is a *de facto* measure that shows the exposure of a country to capital flows. Although observable and directly related to capital flows, this measure also presents some disadvantages. Our interest is on whether the country is *a priori* restricted by the international capital markets. Countries that are unconstrained could have very different levels of external indebtedness depending on whether their relative prices and domestic interest rates are close to the world ones.

²⁷See Timmer *et al.* (2009).

²⁸See also Appendix A for the list of countries.

²⁹No data was available for output deflators.

We could hence observe countries with low NFA to GDP ratios due to either fundamental economic reasons or financial constraints.

Price variables could be used to separate constrained and unconstrained countries such as the real interest rate. A clear implication of financial constraints, as discussed in Section 2.3, is that it introduces a wedge between domestic and world returns to capital. However, reliable data on nominal interest rates and inflation for instruments with similar maturities is not available for our sample of countries.³⁰ The problems with these data are multiple. For many countries, data are not reported or are available only for a few years of the sample (or, in some cases, discontinued). This makes it impossible to compare real rates across countries for similar sample periods and debt maturities. Another important problem is that real interest rates for some developing countries are extremely volatile due to periods of hyperinflation.

For this reason, we also look at alternative measures of access to international capital flows based on *de jure* classifications. One such measure is the capital openness index ($KOPEN_t$) developed by Chinn and Ito (2007). This is an index that measures the extent of openness in capital account transactions of an economy. It is based on the first standardized principal component of a series of binary variables accounting for the presence of multiple exchange rates, capital account transaction restrictions, current account transactions restrictions and the appropriation of export proceeds. Low values indicate high capital account restrictions and hence constraints on the access to international finance. The higher the $KOPEN_t$ index, the more open the country is to international capital flows. Quinn and Toyoda (2008) discuss different measures of capital account liberalization and also develop their own indexes based on Quinn (1997). Both of their measures are highly correlated with $KOPEN_t$ and produce similar country rankings. Given that $KOPEN_t$ comprises a larger number of countries matching the Lane and Milesi-Ferretti dataset, we prefer to use $KOPEN_t$ for our sample splitting.

In order to obtain an optimal sample split, we used the methodology developed by Hansen (2000) based on threshold estimation. It would be desirable to obtain a sample split for the whole panel data. However, threshold sample splitting techniques for nonstationary variables are not available in the literature. For this reason we applied the sample splitting method on a cross-sectional estimate. Given the limited cross-sectional sample size of the GGDC database, we only apply formal sample splitting methods to the LMF (2004) data. For the cross-sectional estimate, we regress the first difference of $LRER$ on the first difference of the independent variables in equation (31). To avoid problems of initial and final anomalous observations, the first difference is defined as the difference between the average value of the

³⁰Reliable data are usually available precisely after periods of internal and external financial liberalization, which would obviously introduce a sample selection bias if we were to use only countries where comparable real interest rate data are available.

variable for 1985-1998 and the average for 1970-1984.

According to the discussion above, we use several observable threshold variables. These are Chinn and Ito's $KOPEN_t$, LYD_t , NFA_t/GDP_t , and its absolute value ($|NFA_t|/GDP_t$). In all cases we used the average value of the threshold variable throughout the sample period for each country.³¹ The results from the sample splitting tests are reported in Table 2. We report the value of the estimated threshold for each variable, the LM test for the null of no threshold (no sample split) and its bootstrapped p-value, and the number of countries in each regime. The results show that only NFA_t/GDP_t and $KOPEN_t$ appear to be statistically significant threshold variables. In the case of $KOPEN_t$, this is so at all conventional critical values. For NFA_t/GDP_t the LM test only marginally rejects the null of no threshold. The sample split with the latter variable is also more unbalanced than with $KOPEN_t$. The results hence point to $KOPEN_t$ as a statistically preferable splitting variable. The split point is at a value of -0.53. Figure 3 shows the recursive Likelihood Ratio test as a function of the threshold variable, which is minimized at -0.53. It is worth noting, though, that splitting the sample arbitrarily between countries with positive and negative average $KOPEN_t$ values gave similar results. Since the cross sectional component of the GGDC data does not allow us to apply these sample splitting methods, we split this dataset between those with positive and negative $KOPEN_t$. The list of countries in each group for both datasets is reported in Appendix A.³²

[Table 2]

[Figure 3]

³¹We also used the initial value of $KOPEN_t$ as a threshold variable. However, it was only marginally significant and delivered a very uneven split between countries. Using the average value of $KOPEN_t$ for 1970-1984, though, resulted in very similar results to those reported in the paper in terms of the countries comprising the group of constrained and unconstrained economies.

³²We also analyzed further the use price variables such as the real interest rate. We calculated sample averages and standard deviations of real interest rates for the countries and periods available from IMF's IFS database. These real rates are not reliable as they include different instruments and maturities, they were only available for 41 countries and, for most of them, the series are incomplete. The data, available on request, show that the average real rate for the group of constrained economies is much higher than that of unconstrained ones classified using the $KOPEN_t$ index. If we drop Argentina and Brazil from the sample, due to their unusually high nominal and real interest rates during some hyperinflation periods, the real interest rate continues to be higher than in the unconstrained group, albeit the difference is much smaller. However, the average standard deviation (standard deviation for each country averaged across countries within the group) is much higher regardless of whether we drop Argentina and Brazil from the sample. This indicates that the classification based on $KOPEN_t$ may also be correlated with the level and volatility of real interest rates in this group of countries.

4.3 Results

4.3.1 LMF (2004) data

We then proceed to the estimation of the long-run cointegration vector for both sub-samples of countries. Following standard procedure, all variables were checked for stationarity using the IPS and Maddala-Wu panel unit root tests, and the null $I(1)$ specification could not be rejected. Cointegration tests were performed using $LRER_t$, NFA_t/Y_t , and LYD_t as dependent variables in the cointegration vector. Table 3 presents the results from the group-ADF test of Pedroni (1999).³³ Throughout this section, we present the results with both the specification based solely on (31) and one that includes the terms of trade (LTT) as mentioned above. The results in Table 3 show that only the equations using $LRER_t$ as dependent variable constitute long-run equilibrium relations.

[Table 3]

Tables 4 to 6 present the estimated long-run cointegration vectors for $LRER_t$. We also show the Error Correction Term (ECT) from the estimation of the short-run Error Correction Model (ECM) for each variable. Given the well known bias of the OLS estimator for dynamic stationary panels, we estimated the ECMs by system GMM. We used the lagged levels and the lagged first differences of the series as instruments. For this reason, we present J-tests for over-identifying restrictions for the ECMs.

[Table 4]

[Table 5]

[Table 6]

In all cases, the ECTs are only significant for the RER equation, with the RER adjusting to the long-run equilibrium relation at a slow but significant speed ranging from almost 12% to almost 16% per year. The slow adjustment of the RER is a common feature found in the literature. In all cases, the J-test indicated that the ECM system is over-identified.

Regarding the long-run coefficients of interest, the results for the whole sample (Table 4) show a positive relationship between the three variables involved. However, the impact of NFA is not significant at standard significance levels. When, for comparison with LMF (2004), we include the terms of trade in the regression, it is relative income that becomes insignificant, and an increase in NFA now significantly appreciates the RER . Lane and

³³We also checked for cointegration using the panel ADF test and the group and panel PP tests proposed in Pedroni (1999). The results are also invariant to extracting group means to account for cross-sectional correlation.

Milesi-Ferreti (2004) report similar coefficient values but, in our case, relative income appears to have an insignificant effect. The results, though, are not directly comparable due to differences in the sample of countries.

The results from the sample splitting are displayed in Tables 5 and 6. The theory model predicts that, for financially open economies, only productivity determines the *RER*, whereas for financially constrained economies both productivity and NFA would determine the equilibrium *RER*. These predictions find qualified support from our results. For unconstrained economies, the productivity effect is positive and strong. The NFA effect is only marginally significant and small. When the terms of trade are included in the regression, the coefficient on NFA becomes insignificant. For the constrained economies, in all cases, the transfer effect is positive and highly significant as expected even after the introduction of LTT_t . The relative income effect is significant but substantially smaller than in the unconstrained sample. Surprisingly, however, the effect appears to be negative. This finding is also reported in LMF (2004) for closed and low income economies. One could argue that, according to the discussion in theory model above, the Balassa-Samuelson effect may be reversed in these economies. However, it is likely that this is the result of relative income being a poor proxy for relative productivity, and the REER measure a poor proxy for the relative price of non-tradables. We hence look at the results obtained from the GGDC database.

4.3.2 GGDC data

Tables 7 to 10 present the results for the GGDC data corresponding to the results from the LMF (2004) data in Tables 3 to 6. Variables LR_t and LRP_t were first tested for the order of integration and the I(1) specification could not be rejected. Table 7 presents the panel-cointegration tests. As with the LMF (2004) data, we could only find cointegration when the RER was used as the dependent variable for all country groupings.

[Table 7]

The results from the modified DOLS estimation of the long-run equilibrium relationships and the estimation of the error correction models are reported in Tables 8 to 10. We can observe that, in all cases, and in line with the results in Table 7, only the ECT's for the RER equation are significant. The speed of convergence to equilibrium is slightly lower than that found for the $LRER_t$ model, ranging from 7% to 17% per year. All system ECM estimates are over-identified according to the J-test.

[Table 8]

[Table 9]

[Table 10]

For the whole sample, relative productivity has a strongly significant and positive effect on the relative price of non-traded goods. This is supportive of a significant Balassa-Samuelson effect. The transfer effect, however, is not significant. The results are invariant to the inclusion of LTT_t . For the unconstrained economies, the productivity effect is strong and significant. The impact of NFA, however, is very small in magnitude and, although statistically significant, takes a negative value. For the constrained economies, both effects are positive and statistically significant as expected from the theory model. The NFA effect is also larger in magnitude. The coefficients on these two variables are not sensitive to the inclusion of the terms of trade.

4.3.3 Robustness

We analyzed further the results to check for the possibility that they are sensitive to the inclusion of some countries in the sample. The robustness of our findings was tested using a cross-validation approach. We assume a function:

$$\Phi_{it}(x_{it}, z_{it}, \gamma) = \mathbf{u}_{it} \quad i \in [1, N], t \in [1, T] \quad (33)$$

where x_{it} is the vector of endogenous variables; z_{it} is the vector of exogenous variables; Φ_{it} is a vector function representing the estimated cointegration functional form or the ECM; γ is the vector of estimated parameters, and \mathbf{u}_{it} is the error term. Denote by $\tilde{\gamma}_{(i-1)}$ the estimate of γ obtained when we omit country $i \in [1, N]$ from the sample. In this case, $\tilde{\gamma}_{(i-1)}$ is the cross-validated estimate of γ when we omit country $i = 1, \dots, N$. This procedure allows us to check for correct statistical inference, especially when the number of cross-sections is small.

We analyzed the robustness of all the long-run estimated coefficients in both (constrained and unconstrained) panels and datasets as well as the robustness of the error correction term in the ECM. The estimates remained remarkably stable throughout, which further confirms the advantages of our sample split as no further parameter instability arising from the cross-section appears to be present in the model. Figures 4-1 and 4-2 present the analysis for the LMF (2004) data and Figures 4-3 and 4-4 for the GGDC data respectively. They display the estimated coefficient (denoted by a diamond) for the panel when we drop each one of the countries plus-minus one standard error (denoted by the vertical bar).

[Figure 4-1]

[Figure 4-2]

For reasons of space we only present the coefficients of the long-run vector for NFA_{it} and LYD_{it} (or LRP_t), but the other coefficients, including the one for the ECM, also show the

same stable pattern. We can easily see that dropping any of the countries does not produce a substantial change in the estimated coefficients and their significance. Any changes are of a small order of magnitude, both statistically and economically, and do not change the basic properties of the estimates of our equilibrium RER equation.

4.3.4 Comparison with theory

The linearized expressions for the RER, equations (28) and (29), provide a benchmark for comparison of our econometric estimates with the model. We can hence calibrate the model and obtain coefficient values for expression (28). Using the same calibration values and functional forms as in section 3.1.3, we obtain:

$$\log R = 1.393 \log a_T - \log a_N + 0.036 \frac{b}{y}. \quad (34)$$

In the case of unconstrained economies, equation (29) provides the benchmark. In order to compare the constrained estimation with the theory results, we also estimated a version of (32) where we allow different coefficients for a_T and a_N . This version yields the following results:

$$LR_{it} = 0.592 LPT_{it} - 0.506 LPN_{it} + 0.058 (NFA/Y)_{it},$$

[0.001]
[0.001]
[0.038]

where LPT_{it} and LPN_{it} are the (logs) of traded and non-traded sector productivity respectively.

When compared with the calibrated values, the productivity coefficients, although significant and with the right sign, tend to be smaller for both groups of countries. This is, however, not unusual when using labor productivity as a proxy for TFP (see, for instance, Canzoneri *et al*, 1999). When using the specification with different coefficients for the two sectors, the one on tradable sector productivity is about 17% larger than that for non-tradables. The coefficients on NFA/GDP , however, are very close to the calibrated value. Overall, estimated coefficients are satisfactory when compared with calibrated values.

Another way of testing for congruence between theory and estimation results is to analyze whether (34) and (29) constitute cointegration relations for constrained and unconstrained countries respectively. That is, whether RER data simulated from the model around the steady state, for given exogenous values of productivity and NFA, do not deviate systematically from observed RER data. In order to do so, we hence impose the coefficients implied by (34) and (29) and test for (panel) cointegration. The econometric test is then carried out as follows. Denote $\omega_{it} = LR_{it} - \check{LR}_{it}$, where \check{LR}_{it} is the calibrated value of the RER given by (34) and (29). To run the panel unit-root on ω_{it} , we apply a two-stage procedure. First, we run a separate ADF regression for each country:

$$\Delta\omega_{it} = \alpha_i + \beta_i\omega_{it-1} + \sum_{j=1}^k \gamma_{ij}\Delta\omega_{it-j} + e_{it}, \quad (35)$$

where e_{it} is a normally distributed *iid* error term with zero mean and constant variance. The null unit root hypothesis $H_0 : \beta_i = 0 \forall i$ is tested against the alternative $H_1 : \beta_i < 0$ for at least one i by combining the N p -values (p_i) of the individual ADF tests, as follows (see Choi, 2001):

$$P = -2 \sum_{i=1}^N p_i. \quad (36)$$

This test is distributed as a χ^2 with degrees of freedom twice the number of cross section units under the null hypothesis. However, since the co-integration vector is imposed rather than estimated, we approximate the empirical distribution following the bootstrapping procedure suggested by Psaradakis (2001). The computed P value for the unconstrained case is 42.31 while for the constrained case it is 32.34. The corresponding critical values at the 5% significance level are 33.92 and 31.40. The test, hence, rejects the null unit root hypothesis. That is, the calibrated long-run value of the RER does not deviate systematically from the observed value of R .

Overall, our estimates of the equilibrium RER equations appear to be supportive of the predictions of the theory model. This happens both, in terms of the expected sign and significance of the variables, and how they match the predicted values from a calibrated version of the linearized model for the real exchange rate.

5 Conclusions

Empirical evidence suggests that real exchange rate (RER) determinants change as we vary periods and countries considered. We argue that access to international credit markets can explain, at least partly, differences in the determinants of the RER. We develop an overlapping generations two-factor two-sector model of a small open economy in which the way the RER is determined varies with the country's capacity to borrow on international markets. We assume that the country faces a constraint on capital inflows. A special feature of the model, and in contrast to the existing literature, is that an economy can converge to a steady state that can either be constrained or unconstrained. The way capital, net foreign assets (NFA), and the RER are determined depends on the nature of the steady state. In the unconstrained steady state, the RER only depends on productivity spread between sectors - a Balassa-Samuelson effect. In the capital inflows constrained steady state, the RER does

not only depend on productivity but also on the determinants of savings and net foreign assets (the so-called transfer effect).

We then estimate a RER equation derived from the linearized version of the model for financially constrained and unconstrained economies. We split the sample using the Chinn and Ito (2007) capital account openness variable as an index of external financial constraints. Our results lend support for the theoretical implications of the model: the RER appears to be mainly driven by productivity and NFA in countries that face external constraints and exclusively by productivity in countries with perfect access to international capital markets. The estimation results are in line with the coefficient values obtained from a calibrated version of the model.

Our results point to the importance of institutional factors, creditworthiness, and capital market imperfections for the analysis of equilibrium RERs. This is of special relevance for emerging markets with scope to improve their access to capital markets, and during a process of global external wealth re-adjustments.

Tables

Table 1: Calibration

	Constrained steady state	Unconstrained steady state
k / k_T	0.7547	0.7643
l_T	0.3924	0.3770
y_T / y	0.4351	0.4162
R	0.5898	0.6053

Table 2: Sample splitting results using sample averages of variables

Threshold variable	KOPEN	YD	NFA	NFA
Threshold estimate	-0.53	-0.14	-0.001	0.25
95% Interval	[-0.75 -0.06]	[-0.31 -0.10]	[-0.24 0.17]	[0.09 0.75]
LM test	11.62	8.21	9.69	7.58
Bootstrap p-value	0.006	0.317	0.09	0.161
No. countries Reg 1 (var >threshold)	21	40	17	30
No. countries Reg 2 (var <threshold)	33	14	37	24

Notes: The table shows the results from the Hansen (2000) threshold method for sample splitting for different threshold variables. The bootstrapped CVs were obtained using 1,500 bootstrap draws.

Table 3: Panel cointegration tests, Group-ADF statistics. LMF (2004) dataset.

	Model without ToT	Model with ToT
Dep. Variable	Whole sample	
LRER _t	-3.68***	-2.63***
LYD _t	-1.42	-0.51
NFA _t	1.25	0.65
Panel A (KOPEN>-0.53)		
LRER _t	-3.23***	-1.84*
LYD _t	0.56	0.54
NFA _t	2.90	3.88
Panel B (KOPEN<-0.53)		
LRER _t	-3.12***	-1.97**
LYD _t	0.69	-0.74
NFA _t	2.74	-1.58

Note: (***), (**) and (*) show rejection of the null hypothesis of no cointegration at 1%, 5% and 10% statistical level respectively.

Table 4: Long-run cointegration vector and ECM terms. Whole sample.

LMF (2004) dataset. Dependent variable: LRER		
Variable	Model without ToT	Model with ToT
LYD	0.321 [0.000]	0.044 [.265]
NFA	0.060 [0.129]	0.320 [.000]
LTT	-	0.070 [.005]
ECT _{RER}	-0.118 [0.001]	-0.151 [.000]
ECT _{YD}	0.015 [0.291]	0.018 [.191]
ECT _{NFA}	0.022 [0.710]	0.003 [.617]
R ²	0.882	0.883
Obs.	1,320	1,320
J-test [p-val]	17.579 [0.129]	18.87 [0.22]

Notes: numbers in brackets [.] are p-values of the coefficients. The J-test is a test for over-identification restrictions for the system of equations of the ECM model estimated by GMM.

Table 5: Long-run cointegration vector and ECM terms. Unconstrained economies.

LMF (2004) dataset. Dependent variable: LRER		
Variable	Model without ToT	Model with ToT
LYD	0.606 [0.000]	0.477 [.000]
NFA	0.049 [0.080]	0.021 [.549]
LTT	-	0.218 [.000]
ECT _{RER}	-0.157 [0.001]	-0.159 [.000]
ECT _{YD}	-0.011 [0.638]	-0.009 [.754]
ECT _{NFA}	-0.0019 [0.844]	0.002 [.872]
R ²	0.901	0.887
Obs.	528	528
J-test [p-val]	9.042 [0.699]	18.99 [0.21]

Notes: see Table 4.

Table 6: Long-run cointegration vector and ECM terms. Constrained economies.

LMF (2004) dataset. Dependent variable: LRER		
Variable	Model without ToT	Model with ToT
LYD	-0.236 [0.000]	-0.177 [.000]
NFA	0.458 [0.000]	0.482 [.000]
LTT	-	-0.001 [.819]
ECT _{RER}	-0.140 [0.001]	-0.159 [.000]
ECT _{YD}	0.033 [0.091]	0.027 [.128]
ECT _{NFA}	0.0029 [0.717]	0.004 [.616]
R ²	0.901	0.865
Obs.	528	792
J-test [p-val]	16.48 [0.189]	15.95 [0.38]

Notes: see Table 4.

Table 7: Panel cointegration tests, Group-ADF statistics. GGDC dataset.

Dep. Variable	Model without ToT	Model with ToT
	Whole sample	
LR _t	-3.656***	-3.622***
LRP _t	-1.60	-1.363
NFA _t	-1.19	-1.512
Panel A (KOPEN>0)		
LR _t	-4.76***	-5.145***
LRP _t	-1.32	-1.44
NFA _t	-1.45	-1.62
Panel B (KOPEN<0)		
LR _t	-4.406***	-2.93***
LRP _t	0.306	-1.64
NFA _t	0.851	-1.07

Note: (***), (**) and (*) show rejection of the null hypothesis of no cointegration at 1%, 5% and 10% statistical level respectively.

**Table 8: Long-run cointegration vector and ECM terms. Whole sample.
GGDC dataset. Dependent variable: LR**

Variable	Model without ToT	Model with ToT
LRP	0.545 [0.001]	0.548 [0.001]
NFA	-0.021 [0.890]	-0.007 [0.824]
LTT	-	0.093 [0.001]
ECT _R	-0.110 [0.001]	-0.106 [0.001]
ECT _{RP}	-0.033 [0.664]	0.027 [0.513]
ECT _{NFA}	0.028 [0.566]	-0.049 [0.467]
R ²	0.949	0.945
Obs.	651	651
J-test [p-val]	14.78 [0.254]	16.23 [0.265]

Notes: see Table 4.

**Table 9: Long-run cointegration vector and ECM terms. Unconstrained economies.
GGDC dataset. Dependent variable: LR**

Variable	Model without ToT	Model with ToT
LRP	0.502 [0.000]	0.495 [0.000]
NFA	-0.027 [0.004]	-0.027 [0.011]
LTT	-	-0.084 [0.002]
ECT _R	-0.174 [0.030]	-0.071 [0.001]
ECT _{RP}	0.0168 [0.944]	0.011 [0.821]
ECT _{NFA}	0.084 [0.904]	-0.030 [0.707]
R ²	0.951	0.952
Obs.	341	341
J-test [p-val]	2.151 [0.542]	5.12 [0.387]

Notes: see Table 4.

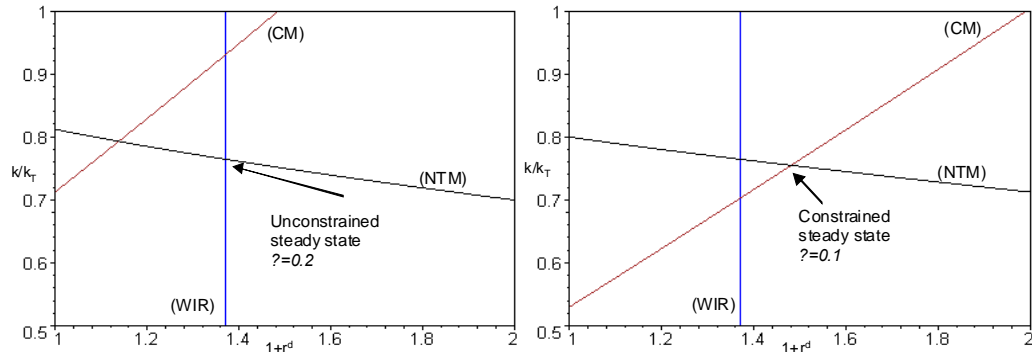
Table 10: Long-run cointegration vector and ECM terms. Constrained economies.

GGDC dataset. Dependent variable: LR		
Variable	Model without ToT	Model with ToT
LRP	0.617 [0.000]	0.603 [0.000]
NFA	0.101 [0.010]	0.094 [0.009]
LTT	-	0.313 [0.001]
ECT_R	-0.145 [0.001]	-0.128 [0.002]
ECT_{RP}	0.157 [0.114]	0.024 [0.664]
ECT_{NFA}	0.039 [0.465]	0.068 [0.175]
R^2	0.942	0.942
Obs.	310	310
J-test [p-val]	10.19 [0.335]	14.65 [0.341]

Notes: see Table 4.

Figures

Figure 1: Calibration of Steady-State

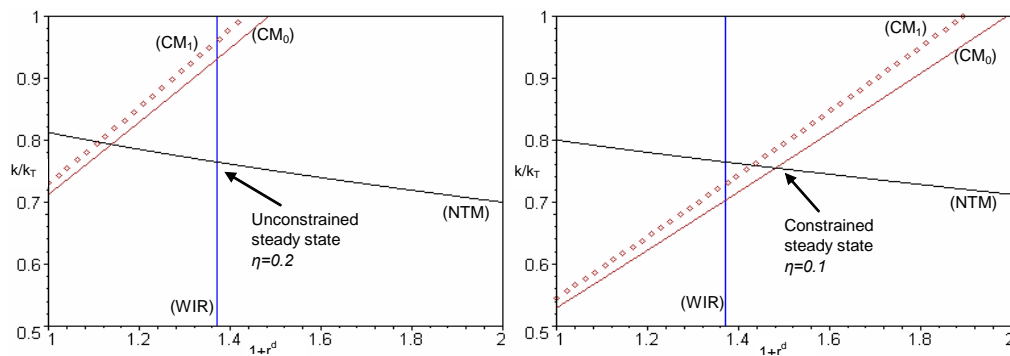


The loci (CM) and (NTM) depict, respectively, the capital market [equations (19) and (23)] and non-traded good market [equations (20) and (22)] equilibria. The locus (WIR) is the world interest factor.

If (CM) intersects (NTM) below (WIR), the steady state is the unconstrained one.

$\nu = 0.4, \rho = 0.2, \beta = 0.6, \alpha = 0.5, \bar{r} = 0.37, \pi = 0.6$

Figure 2: The transfer effect



The loci (CM₀) and (NTM) depict, respectively, the initial capital market and non-traded good market equilibria.

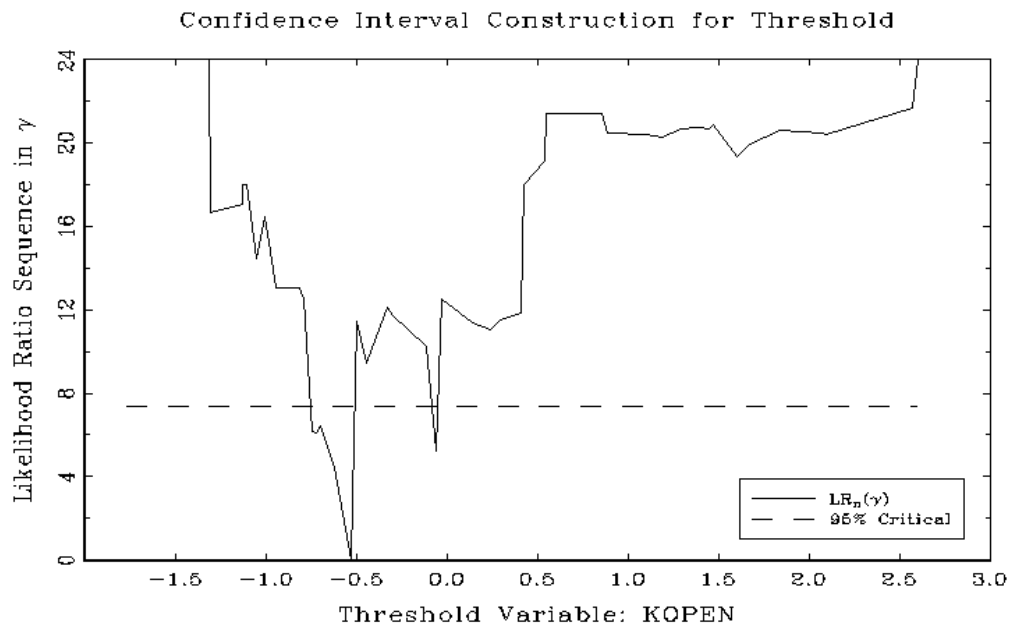
The locus (CM₁) depicts the capital market equilibrium after a 0.5% rise in the Transfer.

The locus (WIR) is the world interest factor.

If (CM₀) intersects (NTM) below (WIR), the steady state is the unconstrained one.

$\nu = 0.4, \rho = 0.2, \beta = 0.6, \alpha = 0.5, F = 0.37, n = 0.6$

Figure 3: Confidence interval for the threshold test



Figures 4: sensitivity analysis.

Figure 4-1: Coefficients sensitivity analysis, LMF (2004) data, high KOPEN

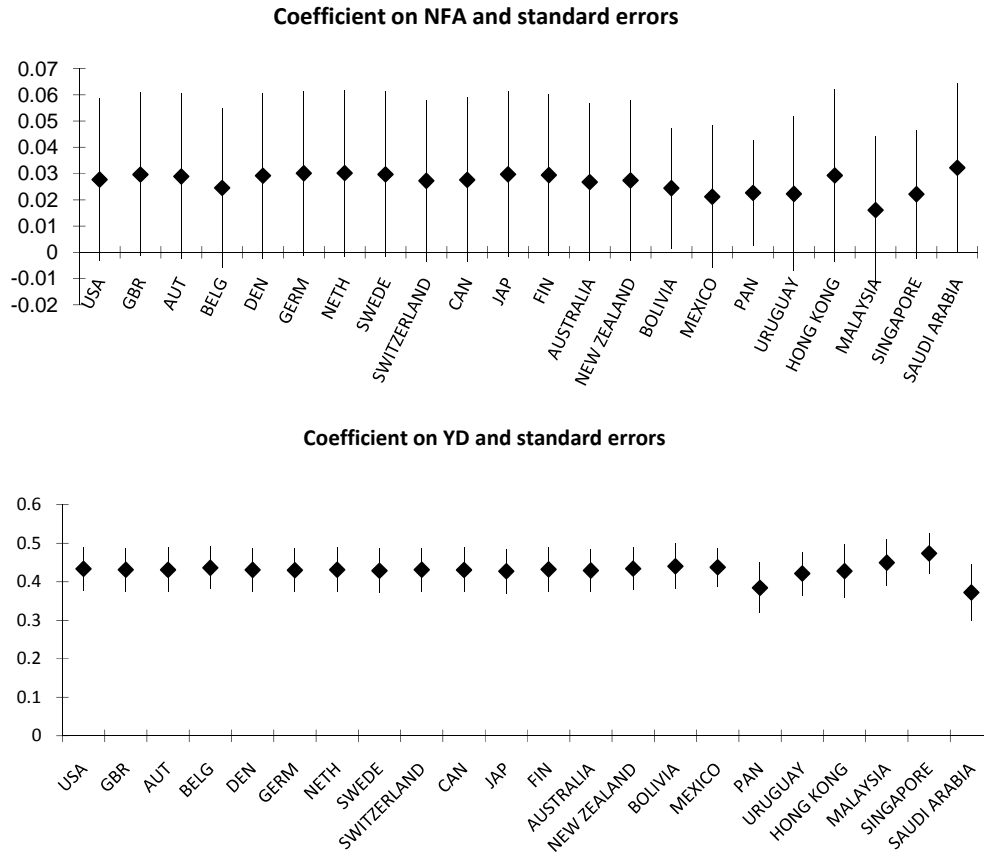
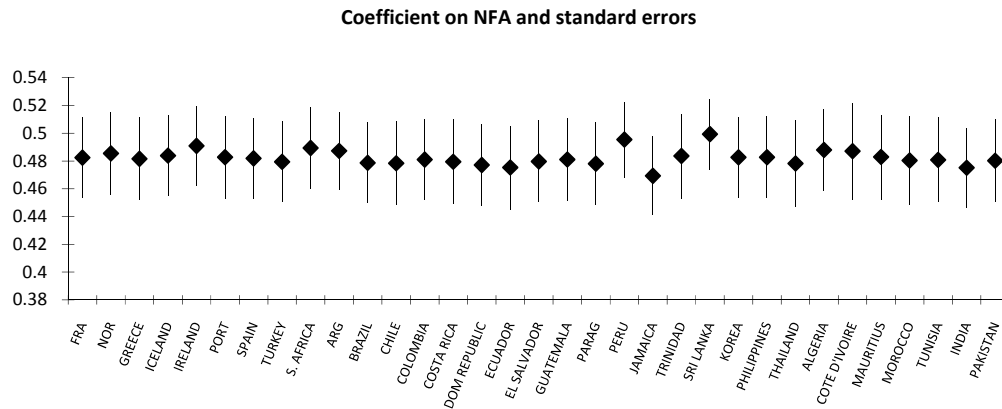


Figure 4-2: Coefficients sensitivity analysis, LMF (2004) data, low KOPEN



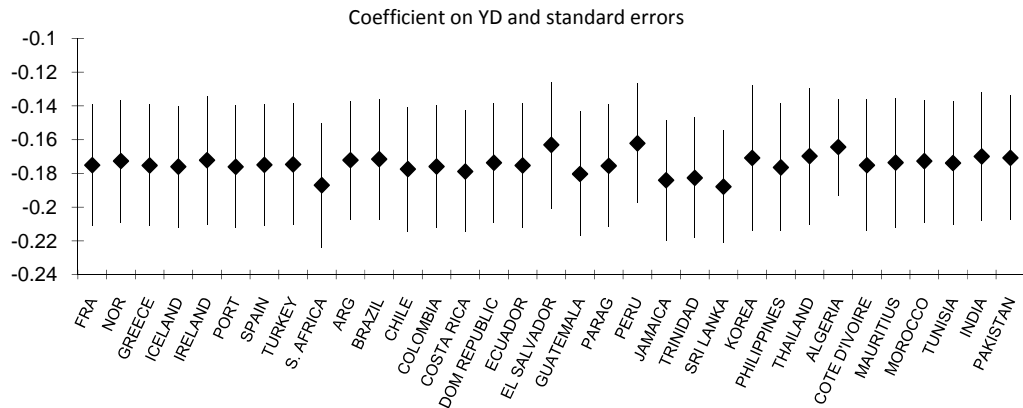


Figure 4-3: Coefficients sensitivity analysis, GGDC data, high KOPEN

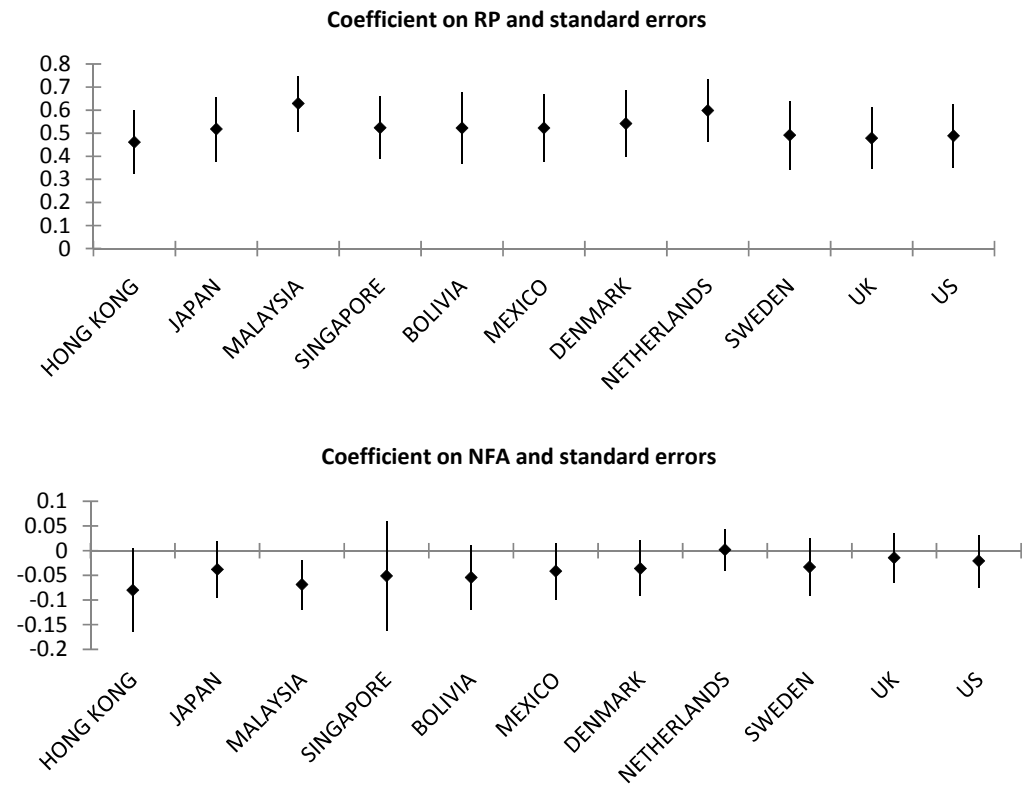
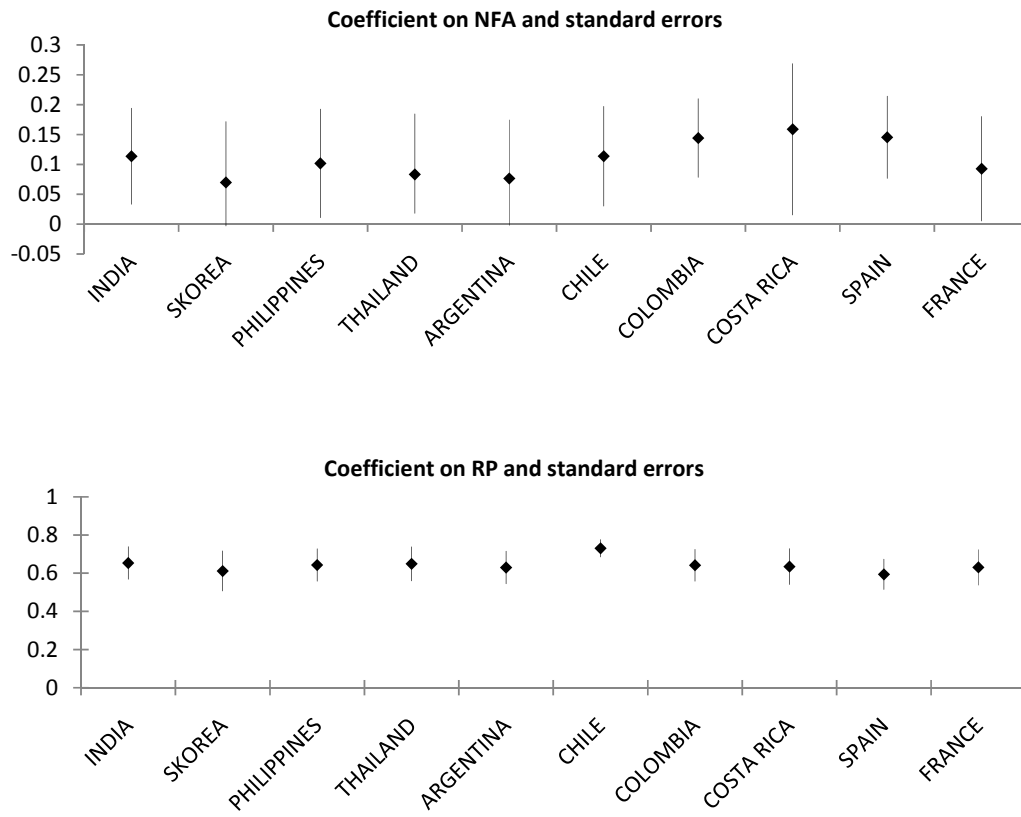


Figure 4-4: Coefficients sensitivity analysis, GGDC data, low KOPEN



APPENDIX

A Samples

The country sample split for the LMF (2004) dataset is as follows:

- Low $KOPEN_t$: France, Norway, Greece, Iceland, Ireland, Portugal, Spain, Turkey, South Africa, Argentina, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Paraguay, Peru, Jamaica, Trinidad and Tobago, Sri Lanka, Korea, Philippines, Thailand, Algeria, Ivory Coast, Mauritius, Morocco, Tunisia, India, Pakistan.
- High $KOPEN_t$: USA, UK, Austria, Belgium, Denmark, Germany, Netherlands, Sweden, Switzerland, Canada, Japan, Australia, New Zealand, Bolivia, Mexico, Panama, Uruguay, Hong Kong, Malaysia, Singapore, Saudi Arabia.

For the GGDC dataset, the two groups are:

- Low $KOPEN_t$: India, Korea, Philippines, Thailand, Argentina, Chile, Colombia, Costa Rica, Spain, France.
- High $KOPEN_t$: Bolivia, Denmark, Hong-Kong, Japan, Malaysia, Mexico, Netherlands, Singapore, Sweden, UK, United States.

B Calculation of $\tilde{\eta}$

Under what conditions will the domestic interest rate r^d converge to the world one? Will domestic saving be enough to drive k^* to \bar{k} given the borrowing constraint?

Let \tilde{k}^* denote the steady state capital per capita obtained in the constrained steady state (see equation (20)) in which $R = \bar{R}$

$$\tilde{k}^* = \frac{w(\bar{R})}{1+n} \frac{1-\beta+\eta}{1-\eta^{\frac{1+\bar{r}}{1+n}}} \quad (37)$$

since $\Gamma(\bar{R}) = 0$. Then the critical level of the constrained $\tilde{\eta}$ is such that $\tilde{k}^* = \bar{k}$. Let the production functions be

$$f(k_T) = k_T^\nu, \quad 0 < \nu < 1 \quad (38)$$

$$h(k_N) = k_N^\rho, \quad 0 < \rho < 1 \quad (39)$$

Let $\Psi = (1 - \alpha) [\beta + (1 - \beta) (1 + \bar{r}) / (1 + n)]$ denote the aggregate propensity to consume the non-traded good. Then, using $k = (1 - l_N) k_T + l_N k_N$, the convenient Cobb-Douglas specification and equations (23) and (37) the critical level of the constraint $\tilde{\eta}$ is given by

$$\tilde{\eta} = \frac{\frac{1+n}{1+\bar{r}} [\nu + \Psi (\rho - \nu)] - (1 - \beta) (1 - \nu)}{1 + \Psi (\rho - \nu)} \quad (40)$$

We can also calculate $\tilde{\eta}$ when there is a transfer in the long-run. The temporary equilibrium in the constrained case becomes, with the transfer,

$$k_{t+1} = [1 - \beta + \eta - \beta \Gamma (R_{t+1})] \frac{w (R_t)}{1 + n} + (\eta - \beta \Gamma (R_{t+1})) \frac{1 + r^d (R_t)}{1 + n} k_t + \frac{T}{1 + n}$$

with T a constant per-period per-capita transfer.

The constrained steady state is

$$k^* = \frac{1}{1 + n} \frac{[1 - \beta - \beta \Gamma (R^*) + \eta] w (R^*) + T^*}{1 - \frac{1+r^d(R^*)}{1+n} (\eta - \beta \Gamma (R^*))}$$

which gives

$$\tilde{k}^* = \frac{1}{1 + n} \frac{[1 - \beta + \eta] w (R^*) + T^*}{1 - \frac{1+\bar{r}}{1+n} \eta}$$

The unconstrained steady state capital stock \bar{k} is unchanged and then we can calculate $\tilde{\eta}$ such that $\tilde{k}^* = \bar{k}$

$$\tilde{\eta} = \frac{\frac{1+n}{1+\bar{r}} [\nu + \Psi (\rho - \nu)] - T^* \left(\frac{1+\bar{r}}{a_T \nu} \right)^{\frac{\nu}{1-\nu}} - (1 - \beta) (1 - \nu)}{(\rho - \nu) \Psi + 1}$$

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