MAGYAR NEMZETI BANK

# MNB WORKING PAPERS

## 2009/4

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# Capital liberalization and the US external imbalance

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# December 2009

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# Abstract

Differences in financial systems are often named as a prime candidate for the current state of global imbalances. This paper argues that the process of capital liberalization can explain a substantial fraction of the US net external liabilities. We present a simple two-country model with an internationally traded bond, in which capital controls are reflected in the presence of borrowing and lending constraints on that bond. In a US versus the rest of the world (RoW) scenario, we perform experiments that are largely consistent with countries' liberalization experiences. A reduction in the RoW's controls on capital outflows and/or a tightening in the RoW's borrowing constraint enables the US economy to better insure against consumption risk relative to the rest of the world, and therefore decreases its motives for precautionary asset holdings relative to the rest of the world. As a result of these asymmetric shifts in countries' barriers to capital mobility, the US runs a long run external deficit.

# Összefoglalás

A pénzügyi közvetítő rendszerek különbözősége sokak szerint a jelenlegi globális egyensúlytalanságok kialakulásának egyik fő oka. A tanulmány bemutatja, hogy a tőkepiaci liberalizáció folyamata miként magyarázhatja az USA külső adósságállománya alakulásának jelentős részét. Egy egyszerű, két országos modellt vizsgálunk, amelyben az egyetlen nemzetközileg forgalmazott pénzügyi eszköz egy kockázatmentes kötvény. Ennek kereskedelme azonban szabályozott, amelyet a hitelezés és a hitelfelvétel elé állított korlátokkal ragadunk meg. Az USA és a világ többi része (VTR) közötti kapcsolatot vizsgáló szimulációnk eredménye konzisztens a különböző országok tőkepiaci liberalizáció során szerzett tapasztalataival. Ha a VTR-ben csökkennek a külföldi hitelezés és hitelfelvétel elé állított korlátok, ez lehetővé teszi az USA számára, hogy a VTR-hez képest hatékonyabban biztosítsa magát a fogyasztási kockázatokkal szemben. Ez csökkenti az USA óvatossági megtakarítási hajlandóságát. A tőkemozgások elé állított korlátok aszimmetrikus csökkenésének hatása tehát az USA hosszú távú külső deficitje.

# 1  Introduction

In recent years the US net external liabilities stand at close to 20% of its GDP, the current account has been in deficit for most of the last 25 years. The fact that the US is an external borrower, and the size and persistence of its net external position is challenging to the conventional wisdom of standard economic theory and has led to a large debate, among academics and policy makers alike. Contents of this debate are the sustainability of these imbalances, whether and when adjustment needs to take place or how painful it is going to be for the world economy. A number of authors have argued that major policy actions need to be taken to avoid a painful worldwide rebalancing process (e.g. Obstfeld and Rogoff (2004), Roubini and Setser (2005), Blanchard et al. (2005)). On the other hand, a number of papers have emphasized that before policy advice can be given as to how adjustment of the current global imbalance should take place, it is important to understand how these imbalances have arrived in the first place.

We suggest that part of the US imbalance can be rationalized by differences in the degree of financial openness across countries, and, in particular, the effects of asymmetric changes in barriers to capital mobility that are a result of the process of capital liberalization. Arguably, the US is the economy that has had the most liberalized financial account already in the 1980s while in most other regions of the world capital controls were much more prevalent. In the rest of the world the process of capital liberalization has, over the last decades, led on the one hand to a reduction of controls on capital outflows, as a result of the catching up of other advanced and emerging market economies in terms of capital account openness. On the other hand, many emerging market economies that have experienced crises after the initial liberalization of their capital accounts, have faced increased limitations in their ability to borrow internationally. We argue that, over these two channels, capital liberalization has led to asymmetric changes in countries' ability to borrow and lend internationally, which has brought about differences in their ability to manage consumption uncertainty. In particular, it has improved, relative to the rest of the world (RoW), the US's ability to better smooth their consumption and therefore has lowered their motives for precautionary asset holdings relative to RoW. As a result, the US runs an external deficit.

We address this question in a stylized two-country one good model of consumption and saving choice. We consider an endowment economy, where outputs arrive stochastically each period. The home economy is taken to be the US while the foreign economy stands for the rest of the world. We assume that the representative agent in each country can trade a non-contingent bond to smooth consumption in response to country specific shocks, but that she cannot do so unrestrictedly. In particular, in each country agents have limited access to borrow and lend in international financial markets; there are limits beyond which capital cannot flow in or out. We think of the presence of capital controls as being reflected in the tightness of these borrowing and lending constraints. When the limits are set to zero, such that the bond holdings are not only constrained but cannot be used at all, the economies are in financial autarky. As the constraints get more and more relaxed, it becomes increasingly easier to smooth consumption.

The setup of the model provides us with a structured way to analyze the effect of changes in the degree of financial openness, resulting from the process of capital liberalization. In particular, we use the model to perform two experiments: The catching up of the rest of the world's financial openness is modeled as a one-time permanent relaxation of the upper limit of capital outflows of the foreign economy. On the other hand, the limitations that some emerging market countries faced in their ability to borrow internationally in response to crisis experiences is modeled as tightening in the RoW's borrowing constraint. Effectively, both these channels improve the US ability to borrow *relative* to the rest of the world. For any given level of risk it faces it can now better use the international bond for consumption smoothing purposes, and the implied drop in consumption volatility means that it has less of a motive to hold assets as a buffer for times of low consumption. It is this drop in the (relative) importance of the precautionary savings motive that endogenously makes the US hold long run negative net foreign assets as it transitions to a new implied steady state.

We conduct extensive sensitivity analysis for crucial parameters, in particular, for the initial level of financial openness and the extent of liberalization assumed, as well as for the functional form of preferences. We also consider a model with production and capital accumulation, thereby allowing for an additional (internal) asset that the change in precautionary asset demand can fall on. The model allowing for capital accumulation is similar to the model of Backus et al. (1992), which is a standard workhorse model of international macroeconomics. In all specifications, we show, that our model framework implies that differences in financial openness and the process of capital liberalization can contribute to rationalizing the sizeable observed imbalances and help explain the puzzle of the direction of net flows, within a standard neoclassical model.

There are several contributions in the recent literature that our paper connects to, that emphasize the role of cross-country differences in financial factors as a potential driving force behind the imbalances (Mendoza et al. (2007), Caballero et al. (2006), Caballero (2006)). Mendoza et al. (2007) emphasize the heterogeneity of financial systems within countries, such as a country's credit markets and differences in the ability to borrow from collateral. In their model agents face idiosyncratic risk from both endowments and investment technology, which has to be managed differently. In this relatively rich model setup, differences in financial development between countries matter when economies open up to trade in international financial markets. The accompanied process of factor equalization -less developed economies face an increase in the interest rate relative to its autarky interest rate, therefore an incentive to save- leads to capital flows from less developed financial markets into the US economy. Contrary to Mendoza et al. (2007) we do not focus on differences in how well financial markets are developed within a country. We show, in a comparably much simpler model setup, that a sizeable part of imbalances can come from differences solely in how easily countries can access *international* financial markets, irrespective of a comparison of the state of financial development within a country. The process of capital liberalization has changed the ease with which countries can demand assets in the international financial market, and as a result changed their motives for precautionary asset holdings.

Caballero et al. (2006) argue that for emerging market economies, the development of local financial markets has not kept pace with the growth experiences of their economies which results in an inability to supply high quality financial assets. In our model imbalances derive not from differences in the ability to supply assets, but rather from differences in the demand for assets that have been induced by the process of capital liberalization.

In another recent paper, Fogli and Perri (2006) argue that the 'great moderation' in business cycle volatility in the US (compared to the rest of the world) has led to a decrease in consumption volatility, and as a result to a decrease in the US precautionary savings motive relative to the rest of the world. Similarly to Fogli and Perri (2006), in rationalizing the US external deficit, our paper emphasizes the importance of lower precautionary savings motives relative to RoW as a result of its lower relative consumption volatility. However, in our model it is the opening up of countries' capital accounts which allows the US to better smooth its consumption and endogenously achieve a lower consumption volatility.

Durdu et al. (2007) use a small open economy model to suggest that the motive for emerging market economies' precautionary asset holdings may stem from either changes in business cycle volatility, from financial globalization, or from self-insurance against sudden stops. In the line of thought of a self-insurance motive, we obtain similar effects from our experiment of modeling the increased difficulty to borrow internationally.

The rest of the paper is organized as follows. Section 2 discusses how financial openness and capital liberalization is measured in the data. In section 3 we present the model framework, a simple two country endowment model that allows for constraints on capital in- and outflows. Section 3 explains in detail how financial openness and capital liberalization is modeled. Subsections 3 and 3 briefly describe the solution technique and discusses parametrization. In section 4 we present the results of our 'capital liberalization' exercise for the simple model. together with extensive sensitivity analysis. Section 5 concludes.

# 2 Empirical Motivation

## THE US EXTERNAL POSITION

Figure 1 plots the development of the US current account and its net foreign asset (NFA) position. As can be seen the gradual decline in the US net external position begins in the mid 1980s, and was actually positive before. As we will show in the next section, the beginning of this downward trend in the US NFA position coincides with major liberalization periods in terms capital account openness in the rest of the world.

**Figure 1**

**US current account and net foreign assets as percentage of GDP**
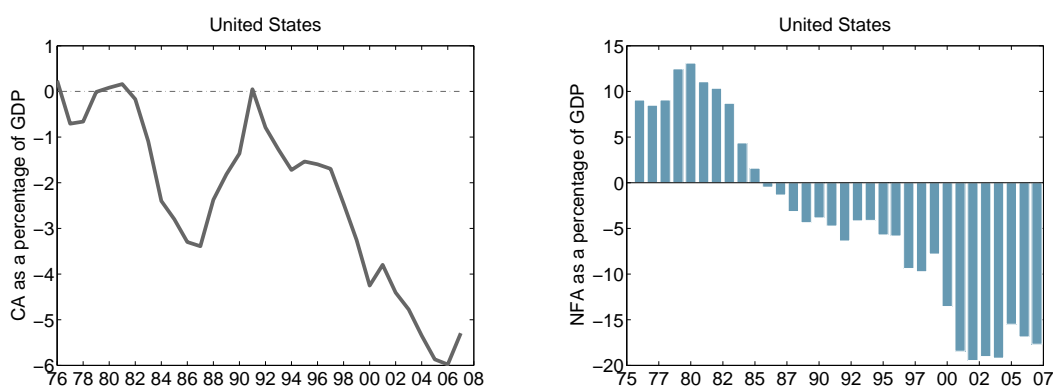


Source: Bureau of Economic Analysis

## MEASUREMENT OF FINANCIAL OPENNESS AND CAPITAL LIBERALIZATION

A large literature has studied the effect of financial integration on growth and volatility, with mixed conclusions. While the focus of this paper is a different one - in particular, we focus on the effect of capital liberalization on countries' net foreign asset positions -, we draw from this literature in terms of how it treats the measurement of financial openness. In general, one can distinguish two types of measures of financial openness, *de jure* and *de facto* measures.

The majority of the papers studying the effects of capital account liberalization rely on 'de jure' measures, which reflect legal restrictions on capital movements (or lack thereof). These are rule-based indices on various types of capital controls, in the largest number of cases based on the IMF's *Annual Reports on Exchange Rate Arrangements and Exchange Restrictions* (AREAER).[1] A shortcoming of de jure measures is the fact that they just capture whether there are controls or not, but not how stringent these controls are. In addition to the problem of measuring the intensity of legal capital controls, there is generally also a lack of systematic information on how strongly these legal restrictions are enforced.

De facto measures of financial integration typically look at actual data on cross-country capital flows (or interest rate differentials) to draw conclusions about the degree of capital mobility. Observed flows do, however, not necessarily capture the correct degree of capital mobility. In practise it is difficult to distinguish whether capital does not flow across countries because of actual restrictions or because of other factors unrelated to the level of capital restrictions.

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[1] Among others, de-jure measures based on information on the AREAER have been developed by Quinn (1997), Johnston and Tamirisa (1998), Miniane (2004), Glick and Hutchison (2005) and Chinn and Ito (2005). There are also a number of surveys of the literature, see e.g Dooley (1996), Eichengreen (2001) and Edison et al. (2002).

Figure 2 documents the evolution of three types of de jure indices for the United States, for the group of industrial countries other than the US, and for emerging economies, over the period of 1983-2004.[2,3] The black line with diamond-signs displays the evolution of a country-average over a binary indicator on 'restrictions on payments for capital account transactions' published in the pre-1996 editions of the IMF's AREAER, which takes on value 1 if there are restrictions or value 0 if there are no restrictions. As noted by Eichengreen (2001) this simple dummy accounts only for controls on capital outflows. Because of the obvious limitations of a dichotomic dummy the IMF changed reporting procedures starting with the 1996 edition of the AREAER. In the category of restrictions on payments for capital account transactions, the "new" AREAER provides dummies in not one but 13 subcategories of transactions, some of which are even further disaggregated. Miniane (2004) uses the post-1996 disaggregated capital account information and extends the indices back to 1983 for a representative sample of countries. This index is given by the purple line with circle-signs in figure 2. While the disaggregated indices generally do a better job than the pre-1996 single dummy in reflecting global trends toward capital account liberalization, the index unfortunately does not distinguish between controls on capital inflows and outflows.[4] Finally, figure 2 plots the inverse of an index of financial openness developed by Chinn and Ito (2005), which is given by the blue line with crosses.[5] Chinn and Ito's index is a broader measure in the sense that it incorporates information not only on countries' restrictions on capital account transactions, but also on restrictions on current account transactions, the presence of multiple exchange rates within that country or requirements for the surrender of export proceeds.

As can be seen from these indices, the US has always been financially open over the last three decades, and most other regions have been liberalizing gradually since the beginning of the 1980s. The IMF dummy indicates that the US were not imposing any restrictions on it capital outflows over the entire period. The Chinn and Ito index also appraises the US the highest financial openness over the entire period. Only Miniane's index indicates that the US has also been liberalizing its financial account, however, starting from a low level of restrictions already in the mid 1980s.

The indices for the group of industrial countries other that the US also paint a clear picture. Initially, in the mid 1980s, because of controls on capital inflows and especially on outflows in many industrial countries world capital markets were far from complete. While for many countries capital was not being prevented from flowing into the country, controls on capital outflows often were much tighter. The evolution of the IMF dummy indicates that starting in the mid 1980s controls on capital outflows have been largely eliminated. Also the other indices suggest that industrial countries have largely caught up with the US in terms of capital account openness.

For the group of emerging countries the picture is somewhat less clear. One thing to point out is the general higher level of restrictions on capital flows to begin with, when compared to industrial countries. On the other hand liberalization seems to have occurred at also at a lower pace. For the IMF index we observe, after an initial spike, a steady reduction of restrictions on capital outflows. The Miniane index displays a lesser degree of liberalization. This may be partly due to the fact that after recurrent crisis that some of the emerging market economies have faced during the end of the 1990s, they suffered limitations in their ability to borrow internationally.

It is important to note that the measurement of the existence and intensity of capital controls is empirically very challenging, and as a result the effect of restrictions to capital mobility on economic variables is some-

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[2] The group of industrial countries except US consists of Canada, Japan, Austria, Australia, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Netherlands, New Zealand, Norway, Portugal, Spain and the UK. The group of emerging countries consists of Argentina, Bolivia, Brazil, Chile, China, Colombia, Ecuador, Guatemala, Honduras, Hong Kong, Hungary, India, Indonesia, Korea, Malaysia, Mexico, Peru, Philippines, Romania, Singapore, Thailand, Turkey, Venezuela.

[3] We focus on de jure indices since these most closely reflect the prevailing level and evolution of *restrictions* on capital flows, that we will be interested in for our theoretical model.

[4] While the "new" AREAER editions after 1996 now makes a distinction between capital inflows and capital outflows, this information is not available for earlier periods.

[5] As the original index is an index of openness we plot the inverse of it (and rescale the index to the 0 to 1 interval) to make it comparable with the other measures of capital *restrictions*.

**Figure 2**
**Indices of Capital Restrictions**
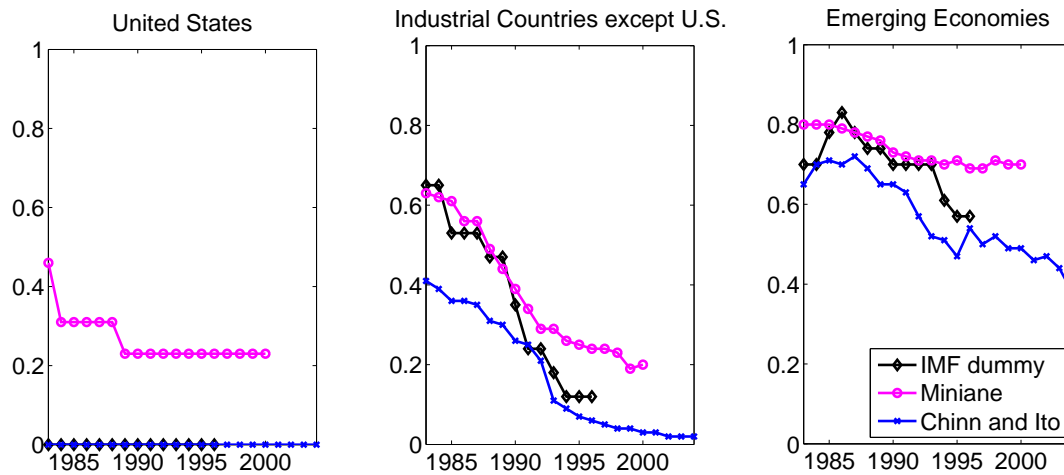


Sources: AREAER (IMF, various editions), Miniane (2004), Chinn and Ito (2005)

times difficult to establish. We believe that even more so we need a theory for how financial flows relate to the presence of capital controls in a framework of the models we use in modern macroeconomics.

We make use of the stylized facts just presented in that they inspire the experiments we perform in our theoretical model: on the one hand we will analyze the effects of a reduction on capital outflows in the RoW, which can be thought of stemming mostly from the group of other industrial countries. On the other hand, we will consider an experiment of increased difficulties in borrowing for the RoW, incorporating the experiences of some emerging economies.

# 3   The model

## MODEL SETUP

The world economy consists of two countries, Home and Foreign, which are taken to be the US and the rest of the world respectively. We will assume that all idiosyncratic risk is perfectly insured among residents of a country, i.e. within-country financial markets are complete. We can therefore think of a representative consumer in each country that maximizes the expected sum of future discounted utilities from consumption, $c_t$:

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t), \tag{1}$$

where $\beta$ is the discount factor. The utility function $u(c)$ is assumed to be constant relative risk aversion $u(c) = (1/(1-\sigma))\left[c^{1-\sigma} - 1\right]$, where $\sigma$ is the coefficient of relative risk aversion. The foreign representative agent faces an equivalent problem, where foreign variables are denoted with an asterisk. Agents of each country receive an exogenous endowment $y_t$ or $y_t^*$ respectively in every period $t$. Exogenous outputs are assumed to follow a bivariate autoregressive process of order 1:

$$\begin{pmatrix} \ln(y_t) - \ln(\overline{y}) \\ \ln(y_t^*) - \ln(\overline{y}^*) \end{pmatrix} = A \begin{pmatrix} \ln(y_{t-1}) - \ln(\overline{y}) \\ \ln(y_{t-1}^*) - \ln(\overline{y}^*) \end{pmatrix} + \begin{pmatrix} \varepsilon_t \\ \varepsilon_t^* \end{pmatrix}, \tag{2}$$

where $\overline{y}$ is mean income, $A$ is a 2x2 matrix of coefficients describing the autocorrelation properties of the process, and $\mathbf{e} = \left(\varepsilon_t, \varepsilon_t^*\right)'$ is a vector of shocks from a bivariate normal distribution with mean zero and variance-covariance matrix $V(\mathbf{e})$, i.e. $\mathbf{e}_t \sim N(0, V(\mathbf{e}))$.

Asset markets are incomplete in the sense that countries are only allowed to trade in a one-period risk-free bond, $b_t$, which promises one unit of consumption the next period and trades at price $\frac{1}{r_t}$, where $r_t$ is the gross real interest rate. We can then write the home country's budget constraint as:

$$\frac{b_{t+1}}{r_t} = b_t + y_t - c_t, b_0 \, given. \tag{3}$$

Even though agents are assumed to be able to trade a risk-free bond in order to smooth their consumption, they cannot do so unrestrictedly. In particular, we assume that the home country's debt level cannot exceed some fraction $\underline{B}$ of the level of its steady state output:[6]

$$\frac{b_{t+1}}{\overline{y}} \geq -\underline{B} \tag{4}$$

Due to capital controls international asset holdings are also limited by an upper bound.

$$\frac{b_{t+1}}{\overline{y}} \leq \overline{B} \tag{5}$$

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[6] In principle, there is also a 'natural debt' limit as in Aiyagari (1994) according to which both countries will not borrow more than the minimum value that the endowment can take at period t+1 discounted to period t prices. To compute the natural debt limit in a two country model, where the interest rate is endogenous, is more difficult than in a partial equilibrium model where the interest rate is exogenous. In addition if one the constraint binds for one of the economies the interest rate generally differs for each agent (for a detailed discussion see Anagnostopoulos (2006)). However, the debt limits we impose here are generally stricter than the natural debt limit.

The foreign country's budget constraint and the borrowing and lending constraints are equivalent versions of equations (3), (4) and (5), replacing all variables with starred ones. The borrowing limit for the foreign country is therefore given by $\frac{b^*_{t+1}}{\overline{y}^*} \geq -\underline{B}^*$ and the lending limit is given by $\frac{b^*_{t+1}}{\overline{y}^*} \leq \overline{B}^*$.[7]

Due to symmetry and the fact that bond holdings must be in zero net supply, only two of the four constraints on borrowing and lending effectively matter. More precisely, the limit that is imposed on up to how much one country can borrow is determined by either its own borrowing constraint or by the other country's lending constraint - whichever of the two is stricter. Formally, the range over which the international bond can effectively be traded is given by the interval $[\mathbf{B}, \mathbf{B}^*]$, where $\mathbf{B} = \max\left(-\underline{B}\overline{y}, -\overline{B}^*\overline{y}^*\right)$ denotes the home country's *effective* borrowing constraint. Similarly, $\mathbf{B}^* = \min\left(\overline{B}\overline{y}, \underline{B}^*\overline{y}^*\right)$ denotes the foreign country's *effective* borrowing constraint.

The equilibrium of this economy is defined as a path of interest rates $\{r_t\}_{t=0}^{\infty}$ together with consumption plans $\{c_t\}_{t=0}^{\infty}$ and $\{c^*_t\}_{t=0}^{\infty}$ and debt plans $\{b_t\}_{t=0}^{\infty}$ and $\{b^*_t\}_{t=0}^{\infty}$ such that:

1. $c_t$ and $b_{t+1}$ maximize (1) subject to (3)-(4)-(5), for all $t$, and $b_0$ given,

2. $c^*_t$ and $b^*_{t+1}$ maximize the foreign version of (1) s.t. the foreign versions of (3)-(4)-(5), for all $t$, and $b^*_0$ given,

3. the real interest rate clears the bond market, $b_t + b^*_t = 0$, for all $t$,

4. the goods market also clears (due to Walras' Law), $c_t + c^*_t = y_t + y^*_t$, for all $t$.

The equilibrium conditions can then be summarized as:[8]

$$c_t^{-\sigma} - r_t\lambda_t^{\underline{B}} + r_t\lambda_t^{\overline{B}} = \beta r_t E_t\left[c_{t+1}^{-\sigma}\right] \tag{6}$$

$$c_t^{*-\sigma} - r_t\lambda_t^{\underline{B}^*} + r_t\lambda_t^{\overline{B}^*} = \beta r_t E_t\left[c_{t+1}^{*-\sigma}\right] \tag{7}$$

$$\frac{b_{t+1}}{r_t} = b_t + y_t - c_t \tag{8}$$

$$-\frac{b_{t+1}}{r_t} = -b_t + y^*_t - c^*_t \tag{9}$$

$$\lambda_t^{\underline{B}}\left[\frac{b_{t+1}}{\overline{y}} + \underline{B}\right] = 0 \tag{10}$$

$$\lambda_t^{\underline{B}^*}\left[-\frac{b_{t+1}}{\overline{y}^*} + \underline{B}^*\right] = 0 \tag{11}$$

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[7] In equilibrium, since bonds are held in zero net supply, $b^*_t = -b_t$, the foreign country's borrowing constraint reads $\frac{b_{t+1}}{\overline{y}^*} \leq \underline{B}^*$ and the lending constraint reads $\frac{b_{t+1}}{\overline{y}^*} \geq -\overline{B}^*$.

[8] Where we have used the bond market clearing condition to substitute out $b^*_t$.

$$\lambda_t^{\overline{B}} \left[ \bar{B} - \frac{b_{t+1}}{\bar{y}} \right] = 0 \qquad (12)$$

$$\lambda_t^{\overline{B}^*} \left[ \bar{B}^* + \frac{b_{t+1}}{\bar{y}^*} \right] = 0 \qquad (13)$$

We can distinguish five cases that are summarized by equilibrium conditions (6)-(13):

1. The case where no borrowing or lending constraint is binding for either country. In this case the Lagrange multipliers associated to the borrowing and lending limits are equal to zero, i.e. $\lambda_t^{\underline{B}} = \lambda_t^{\underline{B}^*} = 0$ and $\lambda_t^{\overline{B}} = \lambda_t^{\overline{B}^*} = 0$, and the Euler equations (6)-(7) reduce to their standard expressions.

2. The borrowing constraint binds for the home country, i.e. $\frac{b_{t+1}}{\bar{y}} = -\underline{B}$. The Lagrange multiplier of the home borrowing constraint, $\lambda_t^{\underline{B}}$, which reflects the shadow value of relaxing the constraint marginally, is therefore positive.

3. The lending constraint binds for the home country, that is $\frac{b_{t+1}}{\bar{y}} = \overline{B}$, and $\lambda_t^{\overline{B}^*} > 0$.

4. The borrowing constraint binds for the foreign country, $\frac{b_{t+1}}{\bar{y}^*} = \overline{B}^*$ and $\lambda_t^{\overline{B}} > 0$.

5. The lending constraint binds for the foreign economy, $\frac{b_{t+1}}{\bar{y}^*} = -\bar{B}^*$, and $\lambda_t^{\overline{B}^*} > 0$.

## THE INTERPRETATION OF FINANCIAL OPENNESS AND CAPITAL LIBERALIZATION IN THE MODEL

In the framework of the model we think of financial market openness as being reflected in the tightness of the respective borrowing and lending constraints the countries are facing. Therefore, a relaxation of a country's lending or borrowing constraints can be interpreted as a reduction of capital controls on that country's capital outflows or inflows. Before we discuss the choice of these constraints in our model, let us first consider two special cases that are nested in our model setup and correspond to the more standard cases analyzed previously in the literature, known as the 'financial autarky' case and as the incomplete markets 'bond economy' case.

First, if $\overline{B} = \overline{B}^* = \underline{B} = \underline{B}^* = 0$ then the world is in financial autarky. In this case there is no international consumption risk sharing - the bond cannot be used at all to insure against idiosyncratic (country) risk.[9]

Second, $\overline{B}$, $\overline{B}^*$, $\underline{B}$ and $\underline{B}^*$ are sufficiently high, such that effectively none of the constraints ever binds, and the bond can be very freely traded across countries.[10] This case coincides with the standard case of what is known as the incomplete markets 'bond economy' case. It is well known that under this case, even though markets are incomplete, the outcome is very close to the perfect risk sharing case under complete markets, where consumption in both economies perfectly co-moves (see, e.g., Baxter and Crucini (1995)).

We interpret intermediate cases between financial autarky and no limits in borrowing and lending as reflecting intermediate stages of capital account openness, with the state of liberalization being more advanced as

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[9] In the endowment case therefore volatility of the exogenous endowment process directly translates into the volatility of consumption. In a later extension of the model that includes capital accumulation, the home country can even under financial autarky engage in at least some consumption smoothing through increasing or running down its capital stock.

[10] However, there still is a 'natural debt limit' and a 'No Ponzi' condition that needs to be satisfied.

$\overline{B}$ and $\overline{B}^*$, and $\underline{B}$ and $\underline{B}^*$ increase. The presence of limits in bond holdings in these intermediate cases makes it hard for the countries' economic agents to perfectly insure against country specific shocks. Since agents dislike the possibility of being left without any consumption at any point in time, they have an incentive to build up a buffer stock of savings to facilitate consumption smoothing, that is they have precautionary savings motives. This will be the crucial mechanism with which the model is able to generate external imbalances. As long as borrowing constraints are not 'too' relaxed, such that consumption smoothing is not too close to perfect risk sharing, precautionary savings motives have a significant impact on the equilibrium bond holding policy functions.[11]

The experiments we undertake are the following. The initial borrowing constraints, denoted $\underline{B}^{BL}$ and $\underline{B}^{*BL}$ (BL stands for 'before liberalization') for the home and foreign country, and capital outflow limits, $\overline{B}^{BL}$ and $\overline{B}^{*BL}$, are initially set to some constant fraction of bond holding to the countries' steady state output, i.e. $\underline{B} = \frac{b}{y}$ and $\underline{B}^* = \frac{b^*}{y^*}$ and similarly for the capital outflow limit, $\overline{B} = \frac{b}{y}$ and $\overline{B}^* = \frac{b^*}{y^*}$. From the evidence given in section 2 it is safe to assume that the US' constraints have always been looser than the RoW's constraints. Effectively, this means that the RoW's constraints determine how easily both countries can access international financial markets and make use of the bond for their consumption smoothing purposes.
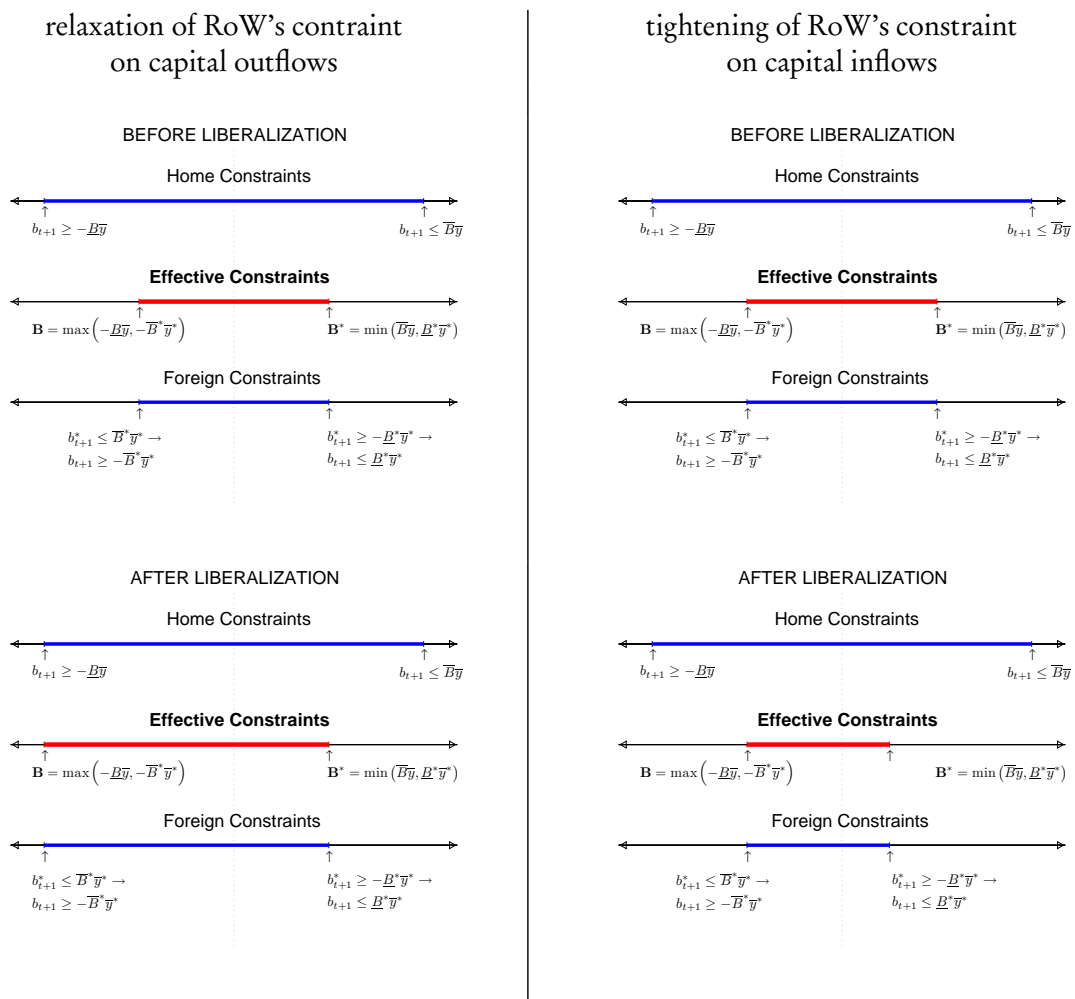
In particular, we can use the model to perform two experiments. In the first experiment, the catching up of the rest of the world's financial openness in the RoW is modeled as a one-time permanent relaxation of the upper limit of capital outflows of the foreign economy. This reflects the dismantling of restrictions on controls on capital outflows especially in industrial countries, but to some degree also in emerging economies. We model the RoW's reduction of controls on capital outflows as a relaxation of the lending constraint to a new level $\overline{B}^{*AL}$ (AL stands for 'after liberalization'), with $\overline{B}^{*AL} > \overline{B}^{*BL}$. This is depicted in the left column of figure 3. The upper left panel describes the initial level of openness to international financial markets, before liberalization. It can be seen that the US constraints ('Home constraints') are looser than the RoW's constraints ('Foreign constraints'), and as a result the permissible region over which the internationally traded bond can be used is pinned down by the latter, given by what we call 'effective constraints'. Liberalization relaxes the RoW's constraint on capital outflows and, as a result, also implies an outward shift of the effective constraint, $\mathbf{B} = \max\left(-\underline{B}\overline{y}, -\overline{B}^*\overline{y}^*\right)$. After liberalization, the permissable region over which the bond can be held has become larger, international financial markets have become more accessible. As a result both countries are now able to better use the internationally traded bond for their consumption smoothing purposes and achieve, for any given output volatility, a lower consumption volatility. This reduces the incentives for precautionary savings in both countries. However, because the reduction in the RoW's controls on capital outflows has led to a relaxation of the *effective* US borrowing constraint, and countries care more about smoothing out the downside risk of consumption uncertainty, the US' precautionary savings motives will fall by more than the precautionary savings motives in the RoW.

In a second experiment, we can capture the limitations that some emerging market countries faced in their ability to borrow internationally in response to crisis experiences by modeling it as a tightening in the RoW's borrowing constraint. This may reflect the responses of some emerging market economies to financial turbulence and their associated difficulties to borrow in international markets. This shift is displayed graphically in the right column of figure 3. Such a shift would decrease the permissible region over which the bond can be held in response to shocks to income. While this implies that the precautionary savings motives of both countries are going to increase, it is important to emphasize that the precautionary savings motives of the US increase by less than those of the RoW, such that the precautionary savings motive of the US *relative* to the RoW actually goes down.

In our experiments we make two simplifying assumptions. One, rather than modeling the process of liberalization as something that took place gradually over time, we make the simplifying assumption that it

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[11] As shown by Anagnostopoulos (2006) a global solution when there are relatively restrictive borrowing limits instead of a local approximation solution avoids the well-known problem of non-stationarity of bonds in the model.

**Figure 3**

**Changes in capital controls and permissible region of bond holding**

relaxation of RoW's contraint
on capital outflows

BEFORE LIBERALIZATION

Home Constraints

$b_{t+1} \geq -\underline{B}\overline{y}$ $\qquad$ $b_{t+1} \leq \overline{B}\overline{y}$

**Effective Constraints**

$\mathbf{B} = \max\left(-\underline{B}\overline{y}, -\overline{B}^*\overline{y}^*\right)$ $\qquad$ $\mathbf{B}^* = \min\left(\overline{B}\overline{y}, \underline{B}^*\overline{y}^*\right)$

Foreign Constraints

$b^*_{t+1} \leq \overline{B}^*\overline{y}^* \rightarrow$
$b_{t+1} \geq -\overline{B}^*\overline{y}^*$ $\qquad$ $b^*_{t+1} \geq -\underline{B}^*\overline{y}^* \rightarrow$
$b_{t+1} \leq \underline{B}^*\overline{y}^*$

AFTER LIBERALIZATION

Home Constraints

$b_{t+1} \geq -\underline{B}\overline{y}$ $\qquad$ $b_{t+1} \leq \overline{B}\overline{y}$

**Effective Constraints**

$\mathbf{B} = \max\left(-\underline{B}\overline{y}, -\overline{B}^*\overline{y}^*\right)$ $\qquad$ $\mathbf{B}^* = \min\left(\overline{B}\overline{y}, \underline{B}^*\overline{y}^*\right)$

Foreign Constraints

$b^*_{t+1} \leq \overline{B}^*\overline{y}^* \rightarrow$
$b_{t+1} \geq -\overline{B}^*\overline{y}^*$ $\qquad$ $b^*_{t+1} \geq -\underline{B}^*\overline{y}^* \rightarrow$
$b_{t+1} \leq \underline{B}^*\overline{y}^*$

tightening of RoW's constraint
on capital inflows

BEFORE LIBERALIZATION

Home Constraints

$b_{t+1} \geq -\underline{B}\overline{y}$ $\qquad$ $b_{t+1} \leq \overline{B}\overline{y}$

**Effective Constraints**

$\mathbf{B} = \max\left(-\underline{B}\overline{y}, -\overline{B}^*\overline{y}^*\right)$ $\qquad$ $\mathbf{B}^* = \min\left(\overline{B}\overline{y}, \underline{B}^*\overline{y}^*\right)$

Foreign Constraints

$b^*_{t+1} \leq \overline{B}^*\overline{y}^* \rightarrow$
$b_{t+1} \geq -\overline{B}^*\overline{y}^*$ $\qquad$ $b^*_{t+1} \geq -\underline{B}^*\overline{y}^* \rightarrow$
$b_{t+1} \leq \underline{B}^*\overline{y}^*$

AFTER LIBERALIZATION

Home Constraints

$b_{t+1} \geq -\underline{B}\overline{y}$ $\qquad$ $b_{t+1} \leq \overline{B}\overline{y}$

**Effective Constraints**

$\mathbf{B} = \max\left(-\underline{B}\overline{y}, -\overline{B}^*\overline{y}^*\right)$ $\qquad$ $\mathbf{B}^* = \min\left(\overline{B}\overline{y}, \underline{B}^*\overline{y}^*\right)$

Foreign Constraints

$b^*_{t+1} \leq \overline{B}^*\overline{y}^* \rightarrow$
$b_{t+1} \geq -\overline{B}^*\overline{y}^*$ $\qquad$ $b^*_{t+1} \geq -\underline{B}^*\overline{y}^* \rightarrow$
$b_{t+1} \leq \underline{B}^*\overline{y}^*$

occurs at once. And two, the modeling of financial markets, that is, the assumption that there only exists one internationally traded bond, is clearly overly simplistic. In particular, it cannot address questions of portfolio choice or give any rationale to why gross asset and liability positions have risen drastically, but focuses entirely on the effect of capital liberalization on countries' net positions. We however also see the simplicity of our model and the fact that a standard model of consumption and saving choice is nested in our setup as an advantage. We show that even in a simple setup and with only aggregate (country specific) risk we can explain a sizable portion of the US net external deficits through effects of capital liberalization.

## MODEL SOLUTION

To address the questions we are interested in, local approximation techniques like loglinearization around the non-stochastic steady state cannot be used. Instead, we need to use a global solution technique that can explicitly account for the influence of second moments on agent's policy functions and that also allows treatment of occasionally binding inequality constraints.

We use time iteration techniques as described by Coleman (1990) and increased its speed by using the endogenous grid points method developed by Carroll (2006) which reduces the number of non-linear equations the algorithm needs to solve. Time iteration has several advantages as compared to standard dynamic programming as it preserves the continuous nature of the state space since it relies on interpolation techniques, and it easily allows to take into account inequality constraints. In particular, we make guesses on the policy rules as functions of the economy's state variables. In the endowment economy we obtain policy rules for bond holdings and the interest rate as functions of last period bond holdings and the two endowment processes, $b''(b'; y', y^{*'})$ and $r'(b'; y', y^{*'})$. Further details about the solution technique are provided in the appendix.

## PARAMETERIZATION

Table 1 presents our baseline parameter values for the experiments of our model economy, chosen such as to match US quarterly data versus the rest of the world. Most parameter choices are relatively standard in the literature, which we briefly outline first. We then discuss the choice of the borrowing and lending constraints, for which there is no previous (nor obvious) choice.

The coefficient of risk aversion $\sigma$ is set to 2, a common choice in macroeconomics. The discount factor $\beta$ is set such as to match a 4% annual interest rate in the non-stochastic steady state. The exogenous process follows a bivariate AR(1) with a coefficient of autocorrelation $\rho$ of 0.98 (and no spillovers). The standard deviation of the exogenous process $\sigma_\varepsilon$ is set to 0.0075, its cross-country correlation $\rho_\varepsilon$ is set to 0.4, as estimated by Fogli and Perri (2006) for the US economy. We focus on a setup in which both economies are completely symmetric, apart from the parameterization of the constraints reflecting the different degrees of financial openness. This way, the predictions of our model can be understood as stemming entirely from changes in countries degree of financial openness.

The parameter choice for the level of the constraints on capital in- and outflows is more challenging. Unfortunately, there is no empirical counterpart that tells us what exactly the choice of these constraints should be. We do not know how to relate regulatory measures such as the de jure indices presented in section 2 to the quantitative measures we have in our model, where constraints are expressed as a fraction of NFA to a country's output. On the other hand, neither can we use actual observed capital flows as a guideline in setting the parameter of our constraints, as we would like to explain actual flows as resulting from changes in the constraints. We thus start with some initial parameters for the constraints, but perform extensive sensitivity analysis on a) the level of initial constraints and b) the size of the relaxation of the constraints.

We set the initial ('before liberalization') constraints for the home economy to 100 percent of its steady state output ($\underline{B}^{BL} = \overline{B}^{BL} = 1$), reflecting the fact that the US economy was very little constrained already in the 1980s. The initial constraints for the RoW are set such that the RoW is initially much less financially

**Table 1**

**Baseline parameter values**

| | | |
|---|---|---:|
| coefficient of relative risk aversion | $\sigma$ | 2 |
| discount factor | $\beta$ | 0.9895 |
| steady state level of output | $\overline{y}, \overline{y}^*$ | 1 |
| persistence of exogenous processes | $\rho$ | 0.98 |
| standard deviation of exogenous shock | $\sigma_\varepsilon$ | 0.0075 |
| shock correlation | $\rho_\varepsilon$ | 0.4 |

open that the US. We set the constraint on both inflows and outflows to 50 percent of output initially $(\underline{B}^{*BL} = \overline{B}^{*BL} = 0.5)$.[12]

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[12] As argued in section 2, the initial constraint on capital outflows is likely to have been stricter, as many economies did not restrict capital from flowing into the economy as much as they prevented it from flowing out of their economies. We could have incorporated this by parameterizing the initial constraints as $\underline{B}^{*BL} > \overline{B}^{*BL}$. To clearly lay out the mechanism of how the presence of international liquidity constraints affect the model variables, we instead focus on a setup of initially equal controls on capital inflows and outflows.

# 4 Results

## BASELINE MODEL

This section outlines our main results. Before discussing the experiment of the relaxation in the home country's borrowing constraint we comment on the general effect of borrowing constraints in a stochastic environment. The presence of borrowing constraints give the agents of both countries an incentive to engage in precautionary saving, to store away some extra assets in the 'good' states of nature for the 'bad' states in which the constraint may bind and and in which they may not be able to borrow as much as they would desire in world markets. In our endowment economy the only asset available to be used as a buffer is the bond. Because initial constraints are such that the both countries can borrow and lend up to the same amount (and the parameterization is symmetric otherwise), and because the bond must be held in zero net supply, this means that none of two countries can actually have positive holdings of the international bond. As first observed by Aiyagari (1994), as a result of these motives to hold precautionary buffer assets, when the (gross) real interest rate would be at their certainty equivalent level, $\frac{1}{\beta}$, there would be an excess demand for savings.

Under uncertainty, therefore, the asset price needs to be higher relative to its non-stochastic level to clear the bond market, or, equivalently, the real interest rate needs to be lower than in a non-stochastic world.

We now turn to our experiments of how the process of capital liberalization affects the economic variables of our model, and in particular, how it affects the US net foreign asset position. Rather than modeling the process of liberalization as something that took place gradually over time, we make the simplifying assumption that liberalization occurs at once. In particular, we model the catching up of the RoW in terms of its financial openness, that is, the dismantling of controls on its capital outflows as a one-time permanent relaxation of $\overline{B}^{*BL}$ from 0.5 to $\overline{B}^{*AL} = 1$. Because the US are initially more financially open (such that $\overline{B}^{*BL} < \underline{B}^{BL}$), the relaxation of the RoW's constraint on capital outflows translates also into a relaxation of the US' *effective* borrowing constraint from 50% of its current output level to 100% of its output. This means that before capital liberalization the effective borrowing constraints are $\mathbf{B}^{BL} = \mathbf{B}^{*BL} = 0.5$, but are equal to $\mathbf{B}^{*AL} = 0.5$ and $\mathbf{B}^{AL} = 1.0$ after liberalization. We choose the mid 1980 as the date for the experiment which coincides with the start of the decline in the US net foreign asset position and the start of a major liberalization period. With the relaxation of the US' effective borrowing constraint the probability that the constraint binds at any moment in time decreases. Both regions are now able to better smooth consumption in response to shocks and to achieve a lower consumption volatility, and as a result, the motives to hold precautionary assets in both countries decreases. The drop in the US consumption demand for precautionary assets is larger, however, since home agents can now better insure against times when their consumption is rather low.[13] Accordingly, the US motive to hold precautionary assets decreases by more than the RoW's motive for buffer assets.

The left column of figure 4 shows the response of main macroeconomic variables in the face of the US' increased ability to borrow in international markets in comparison to RoW. As a result of the fact that the RoW's desire for precautionary savings is now stronger relative to the US, we observe (in the first and second left panel of figure 4) a US current account deficit and a gradual decline in the US net foreign asset position as the economy transitions to a new steady state.[14] At the end of 2006, our experiment implies US net foreign liabilities to output of 4.3%, which means that our proposed channel could explain roughly one fifth of the empirically observed US external position. The decrease in the importance of US' precautionary savings also

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[13] That is, with utility is concave, marginal utility of consumption is higher for low levels of consumption. Therefore agents benefit more from being able to smooth consumption through borrowing when their consumption is low than from lending when their consumption is high.

[14] In principle the responses shown in figure 4 need to be derived from averages over a large number of simulations, such that the stochastic behavior of the economy can be 'aggregated away' and only the deterministic change in the policy functions -that reflects the change in the importance of precautionary savings- is left over. To save computational time we instead feed $\sigma_\varepsilon = 0$ in the 'simulation' (the policy functions themselves have, of course, been obtained from a stochastic setting with $\sigma_\varepsilon$ as indicated in section 3).

**Figure 4**

**Response to a) a relaxation in the RoW's constraint on capital outflows, and b) to a tightening in the RoW's borrowing constraint**



relaxation of RoW's contraint on capital outflows

tightening of RoW's constraint on capital inflows
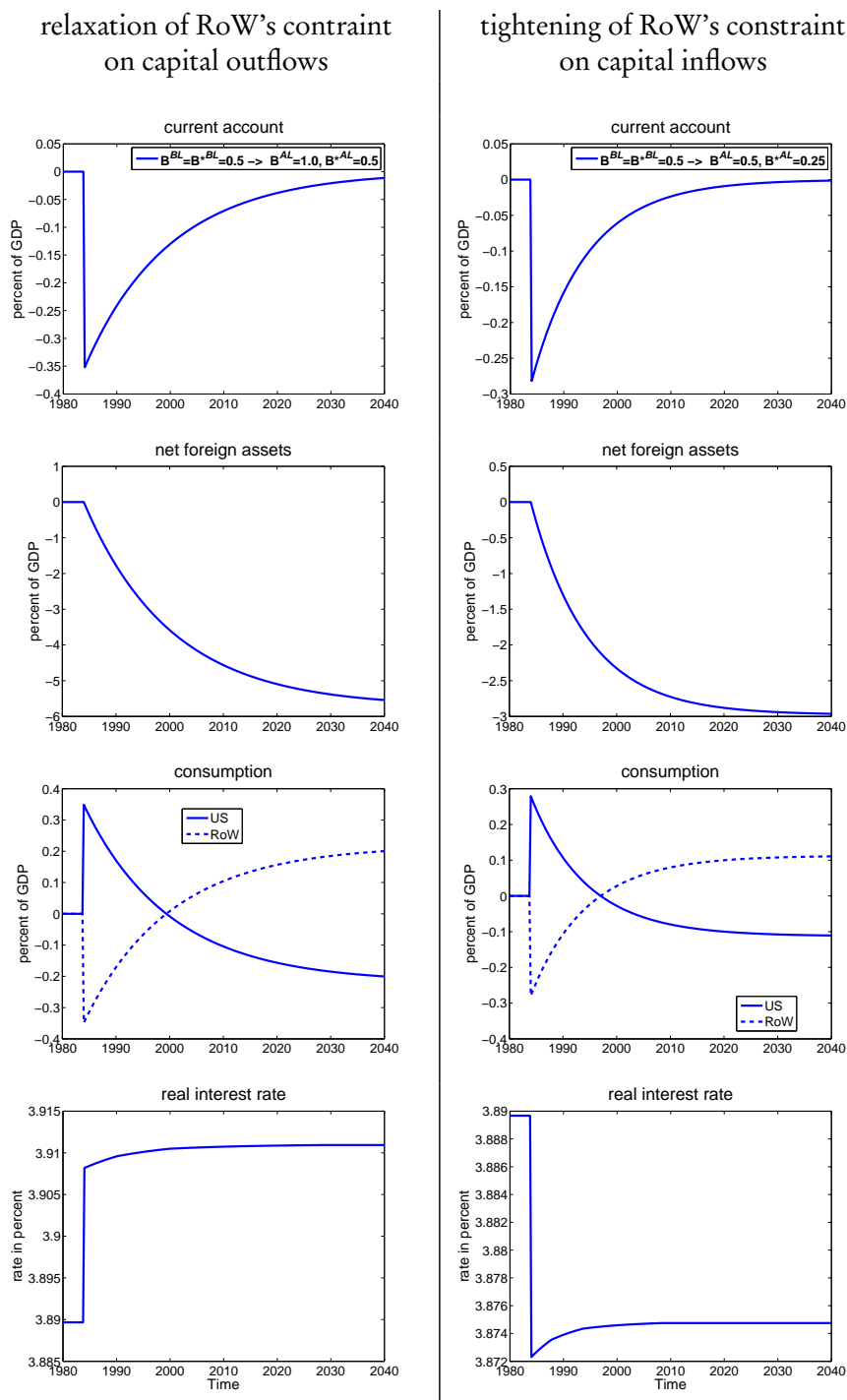
lowers its demand for the asset and, as a consequence, pushes up the interest rate (panel 4 of figure 4) which gives the RoW a motive to forgo consumption today. As interest rates increase the RoW finds it optimal to save and enjoy higher consumption only in the future. The consumption responses in panel 3 of figure 4 show that home consumers implicitly become relatively more impatient. The drop in the precautionary savings motive leads them to consume more relative early on at the expense of consumption in future periods, such that the long run value of US consumption at the new steady state is at a lower level permanently.

The right column of figure 4 shows the evolution of the model's variables in response to the second experiment we perform, a tightening of the RoW's constraint on capital inflows. As outlined before, this can be thought of as modeling the fact that many emerging countries in practice continue to have limitations in the ability of obtaining external finance, and, after the recurrent crises that some of the emerging markets have faced during the end of the 1990s, have suffered limitations in their ability to borrow internationally. We observe that the responses of the current account, the net foreign asset position and consumption resemble, at least qualitatively, the case of the first experiment. This again is due to a shift in the relative importance of precautionary assets across countries: in particular, it results in a higher precautionary savings motive in the RoW relative to the US. The crucial difference is, however, that the tightening in the RoW's effective borrowing constraint has led to a lower ability to use the bond for consumption smoothing, which increases demand for precautionary assets. As precautionary asset demand increase relatively more in the RoW, we observe net flows from the RoW to the US. The higher worldwide asset demand and as a result decreases the interest rate.[15]

It is important to note that figure 4 does not plot the responses to a particular shock, nor did we assume that the mean or variance of the endowment processes has changed at any point in time. The response in figure 4 is entirely due to the decrease in the importance of the precautionary savings motive for the US economy as coming from the shift in international liquidity constraints, and plots the expected path as the economy transitions to the new implied steady state.

## SENSITIVITY ANALYSIS WITH RESPECT TO PARAMETER VALUES

Figure 5 presents some sensitivity analysis. Given the difficulty to parameterize the borrowing limits, we consider it especially important to do sensitivity analysis on different values of the effective borrowing constraints. The quantitative response of net foreign assets to a relaxation depends on two things: one, on the degree to which the constraints where initially restricting asset trade, and two, on the amount by which the effective constraints are relaxed. The panels in the first and second columns therefore show variations in the assumptions on these constraints either before or after capital liberalization.

We plot the first set of sensitivity experiments with respect to the borrowing constraints in column 1 of figure 5 under varying degrees of 'initial financial market openness'. We keep the size of the relaxation of the home effective borrowing constraint constant at 0.5 (that is, $\mathbf{B}^{AL} - \mathbf{B}^{BL} = 0.5$), and show the responses of the economic variables for three different initial parameterizations. The first set of responses repeat the baseline case, the second assumes that initially international financial markets were very closed (the constraints change from $\mathbf{B}^{BL} = \mathbf{B}^{*BL} = 0.01$ to $\mathbf{B}^{*AL} = 0.01$ and $\mathbf{B}^{AL} = 0.5$)[16], and the third starts out in a situation where international financial markets were (relatively) open to begin with (from $\mathbf{B}^{BL} = \mathbf{B}^{*BL} = 1.0$ to $\mathbf{B}^{*AL} = 1.0$ and $\mathbf{B}^{AL} = 1.5$). Since precautionary motives are highest when financial markets can hardly be accessed as a means to engage in consumption smoothing, the drop in the net foreign asset position is strongest in the case where international financial markets are initially very closed. In this case the implied NFA response at the

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[15] It is interesting to note, that within the framework of the model, the relaxation of the RoW's outflow constraint (thought to have been taking place in mainly the industrial countries and to only some degree in emerging economies) and the tightening of the RoW's borrowing constraint (in emerging economies) may also have interesting implication for the relation of financial openness to consumption volatilities. In particular, it may give a rationale to the empirical finding that industrial countries' consumption volatilities typically have decreased with increasing financial openness while emerging countries' consumption volatilities have increased.

[16] For displaying the results of our sensitivity analysis we focus throughout on *effective* constraints, $\mathbf{B}$ and $\mathbf{B}^*$.

**Figure 5**
**Sensitivity analysis for responses to a relaxation in the US effective borrowing constraint**
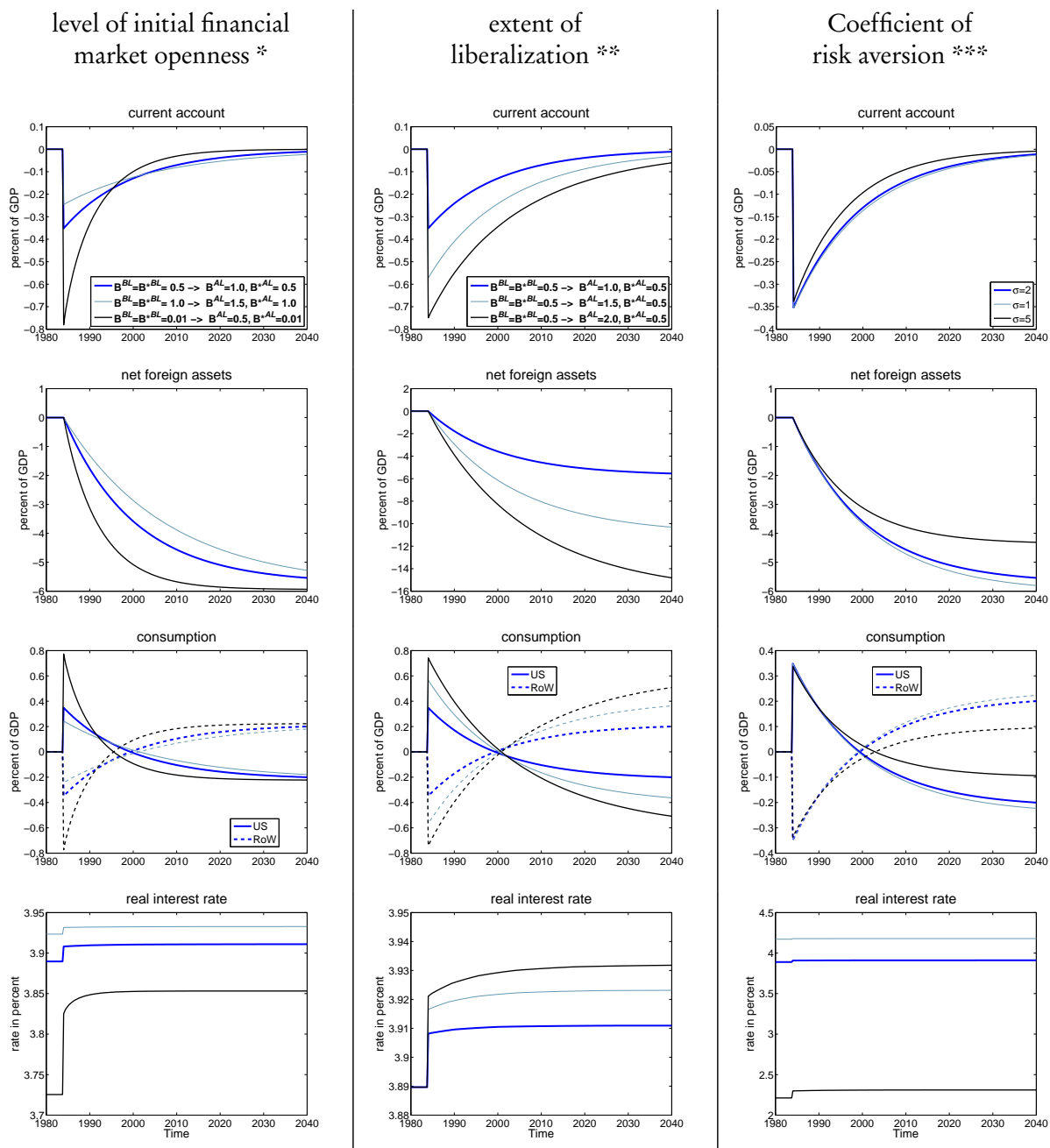


* different initial tightness of debt limits
** and different extents of relaxation
*** different degrees of risk aversion

end of 2006 is -5.6% in comparison to -4.3% in the baseline case, while it is only -3.6% in the case of initially rather open international financial markets.

The second column of figure 5 shows different cases for 'the extent of liberalization', that is, for different assumptions on by how much the effective borrowing constraint is relaxed. We show the baseline case, and the changes in the constraints from $\mathbf{B}^{BL} = \mathbf{B}^{*BL} = 0.5$ to $\mathbf{B}^{*AL} = 0.5$ and $\mathbf{B}^{AL} = 1.5$, and from $\mathbf{B}^{BL} = \mathbf{B}^{*BL} = 0.5$ to $\mathbf{B}^{*AL} = 0.5$ and $\mathbf{B}^{AL} = 2.5$. Not surprisingly, the decline in the net foreign asset position is more pronounced the higher the extent of the relaxation, in which US net foreign assets in year 2006 stand at -7.6% (in case 2) or -10.4% (in case 3) respectively.

Finally, the last column of figure 5 presents the equilibrium response of our baseline parameterization for values of the coefficient of relative risk aversion $\sigma$ equal to 1, 2 (baseline) and 5, respectively. As can be seen, the higher is the degree of risk aversion, the smaller is the reduction of the importance of US' precautionary motives and therefore, the smaller is the accumulation of net foreign debt.

## SENSITIVITY ANALYSIS WITH RESPECT TO THE FUNCTIONAL FORM OF PREFERENCES

Carroll and Kimball (2006) distinguish between incentives for buffer asset holdings that derive from uncertainty and those that derive from liquidity constraints - both of which have similar effects because they lead to a concave consumption function. Since our paper concentrates on the effects of buffer asset holdings that derive from (changes in) liquidity constraint, we now turn to a further sensitivity experiment and use quadratic instead of CRRA utility. Through the use of quadratic utility, which has no inherent precautionary savings motive, we are able to isolate the role of precautionary savings motive as coming from international liquidity constraints. Column 1 of figure 6 plots the equilibrium responses to our baseline experiment and contrasts it with the case of quadratic utility. We find that regardless of the assumption of preferences the equilibrium responses are very similar.

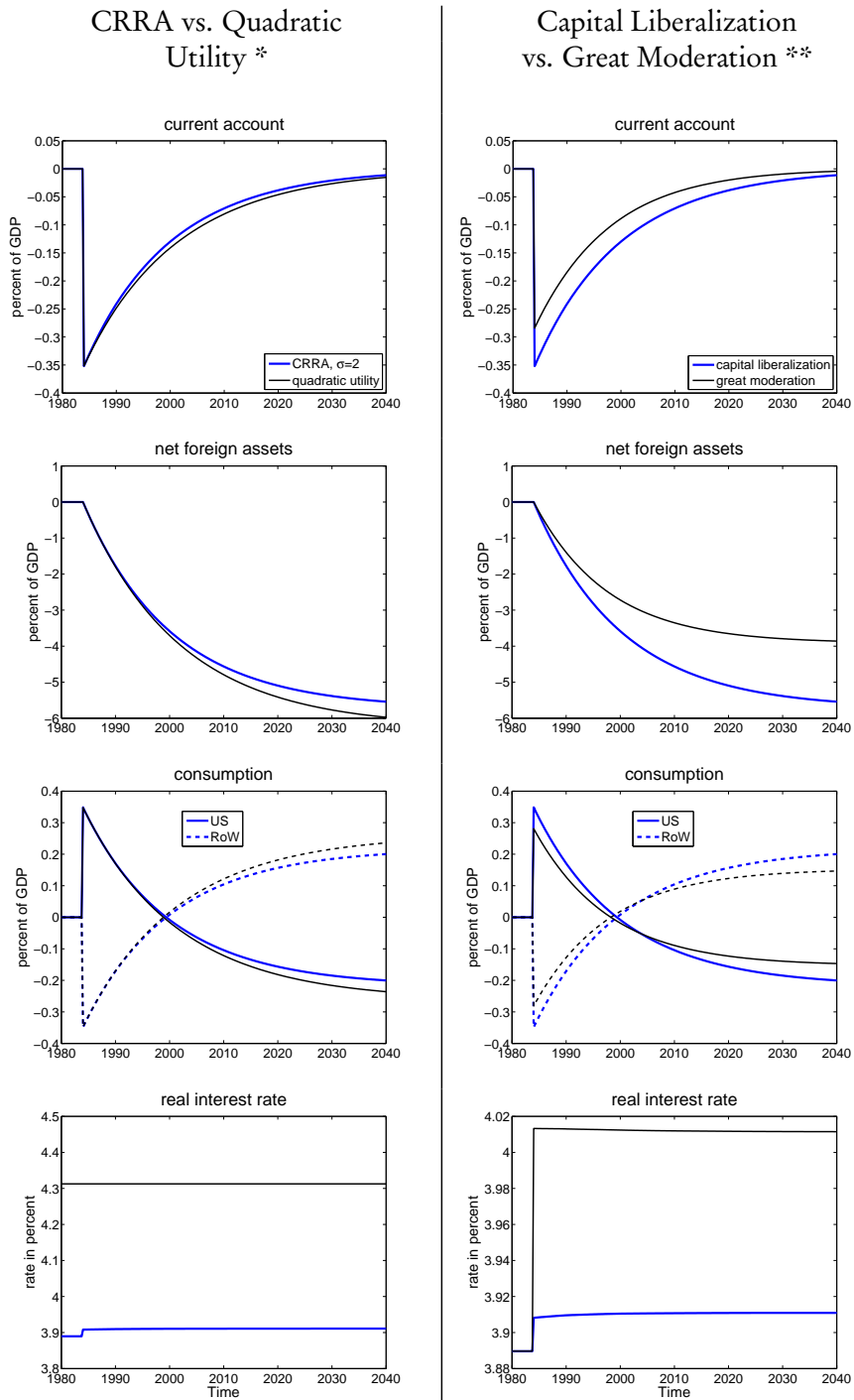## COMPARISON WITH THE "GREAT MODERATION" EXPERIMENT

In order to compare the results obtained with our approach with the recent contribution of Fogli and Perri (2006) we also run the experiment of the 'great moderation' in US business cycle volatility. In their experiment they consider a decrease in the volatility of US aggregate productivity of one third. Column 2 of figure 6 plots the results of the 'great moderation' experiment.[17] We find that both capital liberalization in the RoW and the great moderation of business cycle volatility can contribute to explaining the US net foreign asset position. At the end of 2006, the process of capital has led to a net foreign asset position of -4.3% of output, while the great moderation can contribute to explaining another 3.2%.

## A MODEL WITH PRODUCTION AND CAPITAL ACCUMULATION

It can be argued that in a setup in which agents' only option to save and to smooth consumption intertemporally is through the use of the international bond, that the effects of changes in the strength of precautionary savings motives across countries have an unrealistically strong impact on the external position. We therefore now turn to a model setup in which the representative agents in both countries are also owners of the economy's capital stock which is used in production. This gives the agents another asset that can be used to smooth intertemporal consumption and to hold savings for precautionary reasons. Now, the home representative agent maximizes eq. (1) with respect to borrowing constraint (4) and lending limit (5). As in the endowment economy, international asset markets can therefore be used only incompletely for consumption

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[17] Note that the model used by Fogli and Perri (2006) is different as they include capital accumulation in their model. We also include an additional asset in the next section.

**Figure 6**
**Further experiments on the baseline model**



CRRA vs. Quadratic Utility *

Capital Liberalization vs. Great Moderation **

* sensitivity analysis for assumption of preferences: CRRA utility vs. quadratic utility.
** comparison of capital liberalization with great moderation experiment.

smoothing purposes. The budget constraint under this set-up and the law of motion for capital are:

$$c_t + x_t + \frac{b_{t+1}}{r_t} = \omega_t n + r_t^k k_t + b_t \tag{14}$$

$$k_{t+1} = (1-\delta)k_t + x_t - \frac{\phi}{2}\left[\frac{k_{t+1}-k_t}{k_t}\right]^2 \tag{15}$$

where $k_t$ is capital, $n$ is labor, which is supplied inelastically, and $w_t$ and $r_t^k$ refer to the wage rate and the return of capital respectively. To avoid a counterfactual volatile investment, $x_t$, there are adjustment costs to install new capital. Households are assumed to supply their labor inelastically.

Firms produce output according to a Cobb-Douglas production function and face a country specific productivity. They are assumed to be competitive such that profit maximization leads to factors being paid their marginal products.

Technologies are modeled as exogenous processes which follow a bivariate autoregressive process of order 1.[18]

$$\begin{pmatrix} \ln(z_t)-\ln(\overline{z}) \\ \ln(z_t^*)-\ln(\overline{z}^*) \end{pmatrix} = A \begin{pmatrix} \ln(z_{t-1})-\ln(\overline{z}) \\ \ln(z_{t-1}^*)-\ln(\overline{z}^*) \end{pmatrix} + \begin{pmatrix} \varepsilon_t \\ \varepsilon_t^* \end{pmatrix} \tag{16}$$

where $\overline{z}$ is a parameter reflecting the mean productivity, $A$ is a 2x2 matrix of coefficients describing the autocorrelation properties of the process, and $\mathbf{e} = \left(\varepsilon_t \varepsilon_t^*\right)'$ is a vector of shocks from a bivariate normal distribution with mean zero and variance-covariance matrix $V(\mathbf{e})$, i.e. $\mathbf{e}_t \sim N(0, V(\mathbf{e}))$.

The equilibrium of this economy is defined as a path of interest rates $\{r_t\}_{t=0}^{\infty}$ and input prices $\{w_t\}_{t=0}^{\infty}$ and $\{r_t^k\}_{t=0}^{\infty}$ together with consumption plans $\{c_t\}_{t=0}^{\infty}$ and $\{c_t^*\}_{t=0}^{\infty}$, capital accumulation plans $\{k_t\}_{t=0}^{\infty}$ and $\{k_t^*\}_{t=0}^{\infty}$, and debt plans $\{b_t\}_{t=0}^{\infty}$ and $\{b_t^*\}_{t=0}^{\infty}$ such that households and firms solve their optimization problem and markets for bonds, consumption and capital clear.

The equilibrium conditions of the full model are given by the set of equilibrium conditions of the endowment model, equations (6)-(13) -where the budget constraints are replaced by their versions of equation (14) - plus the additional Euler equations with respect to the choice of the optimal capital stock, given by equation 17 and its foreign equivalent:

$$\left(1+\frac{\phi}{k_t}\left(\frac{k_{t+1}}{k_t}-1\right)\right)c_t^{-\sigma} = \beta E_t\left\{c_{t+1}^{-\sigma}\left[\begin{array}{c}(1-\delta)+\alpha z_{t+1}\left(\frac{k_{t+1}}{n}\right)^{\alpha-1}\\+\frac{\phi}{k_{t+1}}\left(\frac{k_{t+2}}{k_{t+1}}-1\right)\frac{k_{t+2}}{k_{t+1}}\end{array}\right]\right\} \tag{17}$$

**Solution method and parameters values**

The model is solved with the same technique as in the endowment economy model. In the full model with production we iterate on policy function guesses of $b'', k'', k^{*''}$ and $r'$ as functions of $(b', k', k^{*'}; z', z^{*'})$. In the model with capital we have a number of additional parameters. The capital share $\alpha$ is set equal to 0.36. The quarterly depreciation rate, $\delta$, is set to 2.5%. In order to avoid counterfactual volatile investment, we include quadratic capital adjustment costs with parameter $\phi$ equal to 8. The AR(1) process for our exogenous variables is unchanged, with the only difference that the interpretation of these variables is now technology not output endowments.

**Figure 7**

**Response to an relaxation of controls on capital outflows in the RoW**
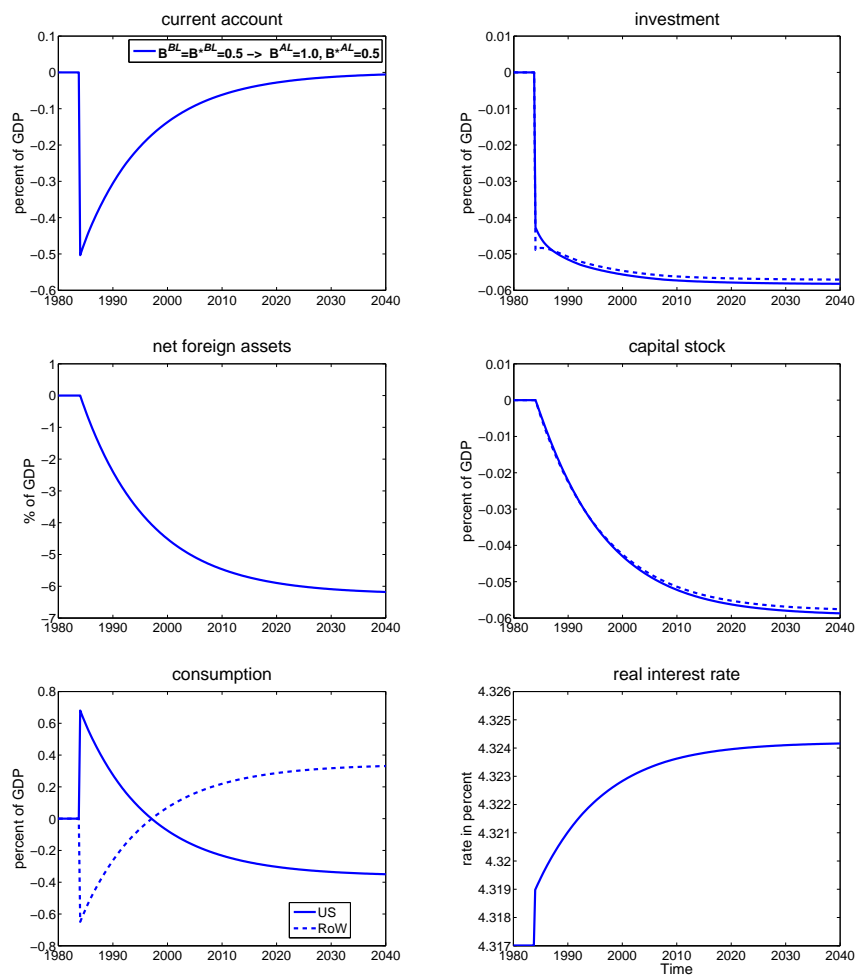
**Responses to capital liberalization in the full model with capital**

Figure 7 presents the equilibrium responses when the RoW is initially facing a high level of capital controls. We continue to perform our experiment of relaxing the RoW's constraint on capital outflows from $\overline{B}^{*BL} = 0.5$ to $\overline{B}^{*AL} = 1$. After capital liberalization takes place in the RoW, the foreign lending constraint softens which also relaxes the US' effective borrowing constraint. As in the endowment model, we can observe that the US net foreign asset position before the onset of capital liberalization in the rest of the world is initially zero, and then starts its subsequent decline. As figure 7 shows, the drop in the US net foreign asset position remains substantial in the capital model, despite the fact that part of the decrease of buffer stock holdings that result from lower precautionary motives of the US is expressed by lowering investment, and therefore, by a decrease in the economy's long-run capital stock level. While the drop in home variables (investment, capital stock) are relatively small quantitatively, the effects on the external position are quite substantial -a model prediction that is in line with the experience of the US economy.

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[18] This is the same assumption we made for the endowment model, just that the exogenous processes describe productivity instead of output.

# 5 Conclusions

Since the mid 1980's we have observed a persistent decline in the US net foreign asset position and continues to be the main world net borrower. Not only is the size and persistence of the US NFA position puzzling, it is contrary to the conventional wisdom of neoclassical theory, which predicts that capital would flow from rich to poor countries. Among the most notable changes in the world between the mid 1980s and today is the rapid process of dismantling of controls on international capital flows. In this paper we have explored the role of the process of capital liberalization in driving the US net foreign asset position into deficit. For doing so, we used a stylized model of consumption and savings choice across countries, enriched with borrowing and lending constraints that proxy for the presence of controls on capital in- and outflows. In an extension we also considered a model with capital accumulation, which is very close to the two-country one model good of Backus et al. (1992), a workhorse model in international macroeconomics.

In all cases, we have shown that the current US net external imbalance can be a natural outcome of the catching up process of other advanced and emerging economies in terms of their financial openness in the last 25 years.

# Appendices

# A   Appendix

The endowment model of section 3 as well as the model with capital accumulation of section 4 are solved by making policy function guesses combined with the method of endogenous grid points. Below we briefly outline the steps of the algorithm used:

- We follow the methodology of Tauchen and Hussey (1991) to discretize the exogenous processes. In the following, we denote t+1 variables with a prime, that is, $b'$ is $b_{t+1}$ (and accordingly, $b''$ is $b_{t+2}$). We construct a grid of endogenous state variables at time $t+1$. For the endowment economy we therefore have, for each combination of $y'$ and $y^{*'}$, a one-dimensional grid in $b'$ which consists of $n_b$ grid points and ranges from $\min(-\underline{B}\overline{y}, \overline{B^*y^*})$ to $\max(\overline{B}\overline{y}, -\underline{B^*y^*})$. For the capital economy we construct, for each combination of $z'$ and $z^{*'}$, a 3-dimensional grid in $k', k^{*'}, b'$ consisting of $n_k n_{k^*} n_b$ grid points. The range for $k'$ and $k^{*'}$ is set from .6 to 1.4 times the non-stochastic steady state level of the capital stock. The number of gridpoints was chosen to be $n_b = 25$ and $n_y = n_{y^*} = 15$. For the full model with capital, we used $n_b = 21$, $n_k = n_{k^*} = 13$ and $n_z = n_{z^*} = 5$.

- Set counter equal to 1. We make initial policy function guesses using the log-linear solution as starting point. In the endowment economy guesses are made for $b''(b'; y', y^{*'})$ and $r'(b'; y', y^{*'})$. In the capital economy initial guesses are made for $b''(k', k^{*'}, b'; z', z^{*'})$, $k''(k', k^{*'}, b'; z', z^{*'})$, $k^{*''}(k', k^{*'}, b'; z', z^{*'})$, and $r'(k', k^{*'}, b'; z', z^{*'})$.

- Using these initial policy function guesses, and using the discretized states and transition matrix for the exogenous processes, the conditional expectations in the Euler Equations can be computed. In particular, in the endowment model we compute $E\left[c'^{-\sigma}\right]$ and $E\left[c^{*'-\sigma}\right]$ from equations (6)-(7). For the capital economy we derive an expression for $E\left[c'^{-\sigma}\left(f_{k'} + 1 - \delta + \Phi_{k'}\right)\right]$ and its foreign counterpart from equation (17).

- Using the so computed expressions for the conditional expectations, the values of $b$ (or, respectively, the values of $k, k^*$ and $b$) are found for each grid-point $b'$ (combination of grid-points $k', k^{*'}$ and $b'$) by using a nonlinear equations solver.

- Finally, the policy function guesses are updated using interpolation methods. As the function $b'(b; y, y^*)$ and $r(b; y, y^*)$ (or, in the capital economy, $k'(k, k^*, b; z, z^*)$, $b'(k, k^*, b; z, z^*)$ and $r(k, k^*, b; z, z^*)$) are known, one can obtain the updated guesses by interpolating $b''$ and $r'$ at points $(b'; y', y^{*'})$ (or, in the capital economy, $k'', k^{*''}, b''$ and $r'$ at points $(k', k^{*'}, b'; z', z^{*'})$).

- The above steps are repeated until convergence is achieved.

# References

Aiyagari, R. (1994). Uninsured idiosyncratic risk and aggregate savings. *Quarterly Journal of Economics*, 59:659–84.

Anagnostopoulos, A. (2006). Consumption and debt dynamics with (rarely binding) borrowing constraints. *mimeo*.

Backus, D., Kehoe, P., and Kydland, F. (1992). International real business cycles. *Journal of Political Economy*, 100:745–775.

Baxter, M. and Crucini, M. (1995). Business cycles and the asset structure of foreign trade. *International Economic Review*, 36.

Blanchard, O., Giavazzi, F., and Sa, F. (2005). The U.S. current account and the dollar. *NBER Working Paper*, (11137).

Caballero, R. (2006). On the macroeconomics of asset shortages. *NBER Working Paper*, (12753).

Caballero, R., Farhi, E., and Gourinchas, P.-O. (2006). An equilibrium model of 'global imbalances' and low interest rates. *American Economic Review*, 98:358–93.

Carroll, C. D. (2006). The method of endogenous gridpoints for solving dynamic stochastic optimization problems. *Economics Letters*, 91:312–320.

Carroll, C. D. and Kimball, M. S. (2006). Liquidity constraints and precautionary savings. *NBER Working Papers*, (8496).

Chinn, M. and Ito, H. (2005). A new measure of financial openness. *University of Wisconsin mimeo*.

Coleman, W. J. (1990). Solving the stochastic growth model by policy-function iteration. *Journal of Business and Economic Statistics*.

Dooley, M. (1996). A survey of literature on controls over international capital transactions. *IMF Staff Papers*, 43 (December):639–87.

Durdu, C. B., Mendoza, E. G., and Terrones, M. E. (2007). Precautionary demand for foreign assets in sudden stop economies: An assessment of the New Merchantilism. *NBER Working Papers*, (13123).

Edison, H. J., Klein, M. W., Ricci, L. A., and Slok, T. (2002). Capital account liberalizations and economic performance: Survey and synthesis. *IMF Working Paper*, (02/120).

Eichengreen, B. (2001). Capital account liberalizations: What do cross-country studies tell us? *World Bank Economic Review*, 15:341–65.

Fogli, A. and Perri, F. (2006). The 'great moderation' and the U.S. external imbalance. *Monetary and Economic Studies*, 24:209–225.

Glick, R. and Hutchison, M. (2005). Capital controls and exchange rate instability in developing countries. *Journal of International Money and Finance*, 24.

Johnston, B. R. and Tamirisa, N. T. (1998). Why do countries use capital controls? *IMF Working Paper*, pages 98–181.

Mendoza, E., Quadrini, V., and Rios-Rull, J. V. (2007). Financial integration, financial deepness and global imbalances. *NBER Working Paper*, (12909).

Miniane, J. (2004). A new set of measures on capital account restrictions. *IMF Staff Papers*, (276-308).

Obstfeld, M. and Rogoff, K. (2004). The unsustainable US current account position revisited. *NBER Working Paper*, (10869).

Quinn, D. P. (1997). The correlates of change in international financial regulation. *American Political Science Review*, 91:531–551.

Roubini, N. and Setser, B. (2005). Will the Bretton Woods 2 regime unravel soon? the risk of a hard landing in 2005-2006. *Unpublished Manuscript*.

Tauchen, G. and Hussey, R. (1991). Quadrature-based methods for obtaining approximate solutions to non-linear asset pricing models. *Econometrica*, 59:371–396.