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On the solvency of nations: Cross-country evidence on the dynamics of external adjustment☆

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We test the hypothesis that net foreign asset positions are consistent with external solvency and examine the dynamics of external adjustment using data for 50 countries over the 1970–2006 period. Our analysis adapts Bohn's (2007) error-correction reaction function approach – which tests for a negative long-run relationship between net exports (NX) and net foreign assets (NFA) as a sufficiency condition for the intertemporal budget constraint to hold – to a dynamic panel framework. Pooled Mean Group (PMG) and Mean Group error-correction estimation yield evidence of a statistically significant, negative response of NX to NFA. Moreover, we cannot reject the hypothesis that the response is largely homogeneous across countries. Our sensitivity analysis shows that the countries with relatively weaker fundamentals need to respond more strongly to the changes in NFA to keep their NFAs on a sustainable path.

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1. Introduction

One of the most significant developments in international finance over the past decade was the emergence of large imbalances in current accounts and net foreign asset positions. Fig. 1a and b shows the evolution of these "global imbalances" since 1997. The U.S. current account deficit rose sharply in this period, reaching a record 1.6 percent of world GDP in 2006 (see Fig. 1a), while current account surpluses grew to record levels in Emerging Asia, oil exporting countries, and Japan. In line with these developments, the dispersion of NFA positions widened substantially (see Fig. 1b). The NFA position of the United States declined markedly, while those of Japan, Emerging Asia, and the oil exporting countries rose. Recent economic turmoil has reduced the U.S. current account deficit somewhat, but the nation's large negative NFA position has changed little, and this "stock imbalance" is very likely to persist.

Large and persistent imbalances in the NFA positions of nations pose three central questions that this paper aims to address: First, are the net exports and net foreign asset positions observed in the last few decades consistent with external solvency conditions (e.g., the expected intertemporal budget constraint (IBC) or the no-Ponzi game condition)? Second, if they are, what dynamic pattern of adjustment do net exports and net foreign assets follow in the process to attain external solvency? Third, how does this pattern of adjustment differ depending on country characteristics, such as income levels, institutional quality, leverage levels, trade openness, etc.?

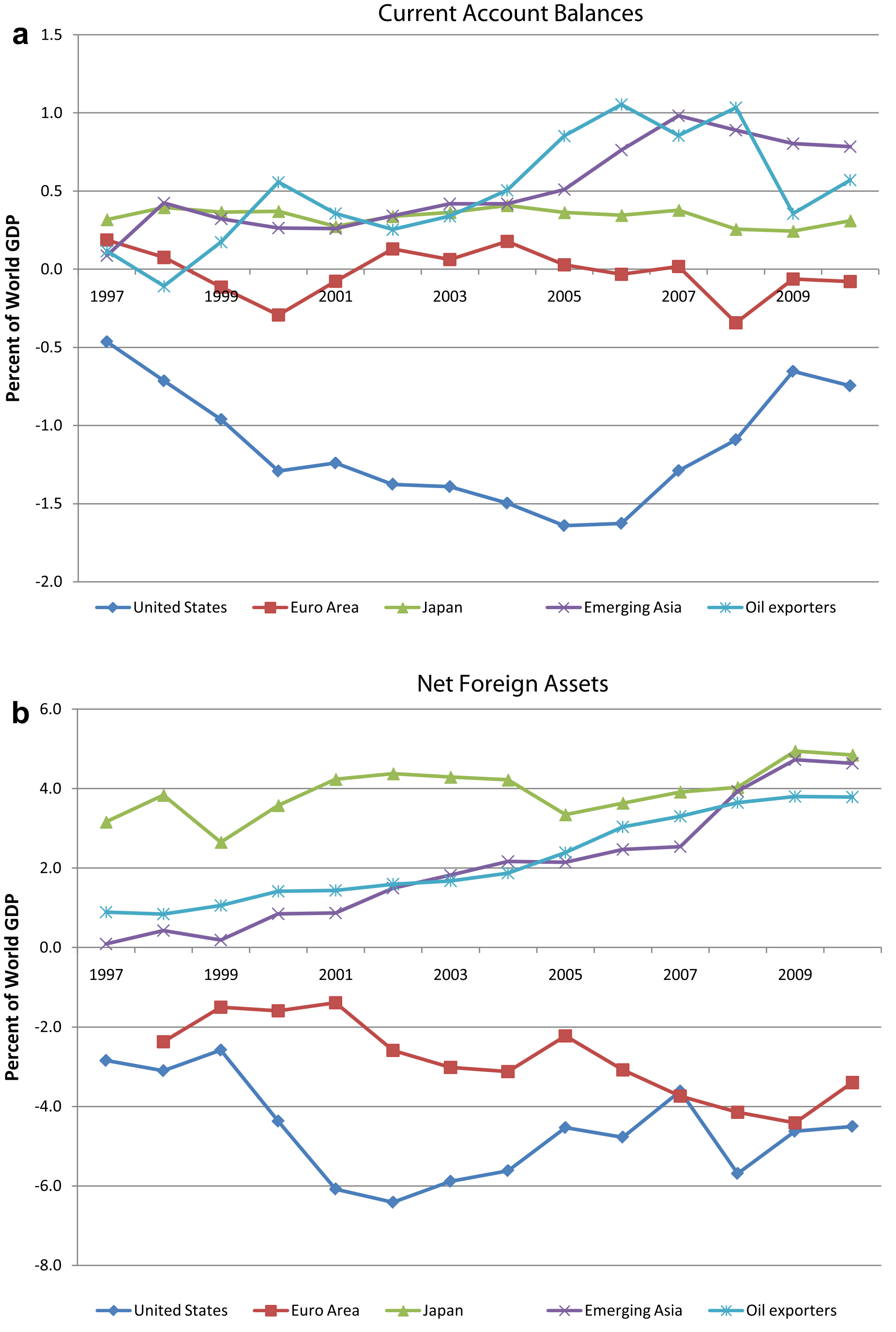
To answer these questions, we implement a dynamic framework for evaluating external solvency based on recent theoretical results derived by Bohn (2007). In particular, we adapt his error-correction reaction function approach to a cross-country dynamic panel environment.

Bohn's Proposition 3 (henceforth, PB3) establishes a sufficiency condition for solvency according to which, if NX and NFA satisfy an error-correction specification of the form $\mathrm{NX}_t - \rho\mathrm{NFA}_{t-1} = z_t$, and z_t is integrated of order m for some $\rho < 0$ such that $|\rho| \in (0, 1 + r]$, where r is a constant interest rate, then the IBC holds. This proposition implies that we can study the dynamics of external solvency by estimating an error-correction "reaction function" between NX and NFA testing for a negative, statistically significant relationship between the two. Evidence that this reaction function exists indicates that NX reacts in the long run to changes in NFA in such a way that NFA grows slower than what a Ponzi scheme implies. Moreover, the magnitude of ρ drives the speed of the adjustment process by which trade surpluses or deficits adjust to larger or smaller NFA positions, and it becomes a key determinant of the long-run average of NFA.

The rationale for following this reaction function approach is that, as Bohn's Proposition 1 (henceforth, PB1) shows, all what is required for the IBC to hold is that the NFA series be integrated of order m for any finite $m \geq 0$. Thus, testing for solvency per se is not very interesting, because it is very unlikely that NFA (just like any other macroeconomic time series) is not integrated of low order. Hence, shedding light on the characteristics of the adjustment process that sustains solvency is a more important task, and for this purpose Bohn proposed the reaction function approach behind PB3.

In this paper, we use the reaction function approach to study the predictions of the data as to the nature of the dynamic process by which solvency is expected to be attained. To do so, we conduct panel error-correction estimation of a model of the NFA–GDP ratio (*nfa*) and the NX–GDP ratio (*nx*), using a panel dataset covering 50 countries for the period 1970–2006. We estimate Pesaran et al. (1999) Pooled Mean Group (PMG) and Mean Group (MG) estimators, and find evidence in favor of the homogeneity conditions of the former vis-à-vis the latter. PMG models the dynamic *nx* and *nfa* relationship as a long-run reaction function common to all countries in the sample, with homogeneity tests to validate this assumption (against the alternative MG estimator that uses country-specific long-run relationships). Despite this homogeneity restriction, PMG still allows for country-specific short-run deviations from the long-run relationship.

The PMG results show that there is a statistically significant error-correction relation between *nx* and *nfa* both for the full sample of countries and for sub-samples separating emerging from industrial countries, and creditor from debtor countries. The systematic long-run component of *nx* responds negatively to movements in *nfa*, in line with Bohn's PB3, and homogeneity tests cannot reject the hypothesis that this response coefficient is similar across countries (vs. the null of country-specific response coefficients produced by MG estimation).



Notes: Emerging Asia comprises of China, Hong Kong, Indonesia, Korea, Malaysia, Philippines, Singapore, Taiwan and Thailand. Oil exporters comprise of Algeria, Angola, Azerbaijan, Bahrain, Rep. of Congo, Ecuador, Equatorial Guinea, Gabon, Iran, Kuwait, Libya, Nigeria, Norway, Oman, Qatar, Russia, Saudi Arabia, Syria, Turkmenistan, UAE, Venezuela and Yemen

Fig. 1. a) Current account balances, (b) Net foreign assets.

The long-run response coefficient is estimated at −0.07, which indicates that a one percentage point drop in *nfa* leads to a 0.07 percentage points increase in *nx* in the long run. This result also implies that, assuming realistic growth-adjusted real interest rates (below 7 percent), both *nx* and *nfa* are stationary processes.[1] The error correction coefficient is estimated at −0.27, which implies that the adjustment of *nx* to a given change in *nfa* has an average half-life of over 2.2 years.

Does the response coefficient of NX to NFA vary with the level of development? To examine this issue, we split the sample into two groups of countries: industrial and emerging market countries. The PMG results show that *nx* is more responsive to movements in *nfa* in emerging markets than in industrial countries. The response coefficient in emerging markets is about twice as large as in industrial countries. Keeping other factors constant (i.e., country-specific fixed effects), this difference implies that industrial countries converge to higher long-run averages of *nfa* that are consistent with external solvency.

We also explore the importance of institutional quality, financial sector development, capital account openness, and exchange rate regime. Our results show that the countries with relatively weaker fundamentals (i.e., less institutional quality, less financial sector development, less open to capital, and less flexible exchange rate regime) need to respond more strongly to the changes in NFA to keep them on a sustainable path. Our baseline findings regarding the sustainability of imbalances are preserved in all these cases.

Our work is related to the large empirical literature on tests of fiscal and external solvency and estimation of reaction functions. Studies in this literature include Mendoza and Ostry (2007), Trehan and Walsh (1991), Uctum and Wickens (1993), Ahmed and Rogers (1995), Liu and Tanner (1996), Engel and Rogers (2006), and Nason and Rogers (2006), among others. The tests we conduct here differ from several of the tests conducted in this literature, and in the related literature testing for fiscal solvency, which generally test for unit roots in the foreign debt-GDP (or public debt-GDP) and NX–GDP (or primary balance-GDP) ratios; for cointegration between exports and imports (or between fiscal revenues and outlays); or for specific orders of integration in debt (public or external). Bohn (1998, 2005, 2007) showed that failure of these tests cannot be relied on to evaluate solvency because the tests consider only sufficiency conditions that are not necessary for the IBC to hold, and hence can indicate that observed debt dynamics violate solvency, when in fact they do not.

Our tests are in line with the literature on fiscal reaction functions pioneered by Bohn (1998) with an application to U.S. data, and extended to a cross-country fiscal panel by Mendoza and Ostry (2007).[2] However, these reaction functions were estimated using fiscal datasets in which public debt and fiscal balances are stationary as shares of GDP. In contrast, the hypothesis of unit roots cannot be rejected in our external accounts data (in levels or in shares of GDP), and hence we cannot implement Bohn's (1998) reaction function specification for stationary variables. Instead, we use the more general error-correction formulation characterized in PB3, which applies even when the relevant debt stock and net revenue flow variables are not stationary.[3]

Our work is also related to the large and growing literature on global imbalances. This literature presents opposing views about the sustainability of the global imbalances, along with explanations of why the observed NFA dynamics may be consistent or inconsistent with solvency.[4] In this context, our

[1] With growth-adjusted interest rate lower than the long-run response coefficient, the increases (decreases) in initially positive (initially negative) *nfa* due to interest earnings (payments) will be offset by decreases (increases) in *nx* so that *nfa* would not continue to increase (decrease), e.g., would remain stationary.

[2] Engel and Rogers (2006) tested for external solvency in the United States using Bohn's (1998) test. They estimated a conditional linear reaction function for *nx* and the *negative* of the net external financial position-to-GDP ratio over the 1791–2004 period. They obtained a negative and statistically significant response coefficient, which indicates failure of the sufficiency condition for external solvency.

[3] We also conduct the *m*th-order-difference stationarity tests implied by PB1. Results for this exercise can be found in Section 3.4.

[4] One group of studies (e.g., Summers, 2004; Obstfeld and Rogoff, 2004; Roubini and Setser, 2005; Blanchard et al., 2005; Krugman, 2006) argues that these imbalances are not sustainable. On the other hand, other studies (e.g., Backus et al., 2005; Bernanke, 2005; Croke et al., 2005; Durdu et al., 2009; Gourinchas and Rey, 2005; Hausman and Sturzenegger, 2005; Henriksen, 2004; Mendoza and Ostry, 2007; Lane and Milesi-Ferretti, 2005; Caballero et al., 2006; Cavallo and Tille, 2006; Engel and Rogers, 2006; Fogli and Perri, 2006; Ghironi et al., 2006), argue that the imbalances are an equilibrium outcome of various developments such as differences in business cycle volatility, financial development, demographic dynamics, a 'global savings glut', self insurance against financial crises, or valuation effects.

results suggest that global imbalances are consistent with external solvency, inasmuch as using an international dataset that includes about a decade of observations of the global imbalances era we find a well-behaved reaction function that is sufficient for the expected IBC to hold. Moreover, in our setup it is possible for the IBC to hold even if *nfa* is not stationary, but as long as the growth of *nfa* and the predicted response of *nx* is such that net foreign liabilities grow at a slower pace than the one implied by a Ponzi scheme. As PB3 shows, this only requires $\rho < 0$.

The rest of the paper is organized as follows: Section 2 describes the analytical foundations of our empirical methodology. Section 3 presents the results of the empirical tests. Section 4 concludes.

2. Methodology

Our methodology for testing external solvency adapts Bohn's (2007) theoretical findings to a dynamic panel cross-country environment. Consider an open economy with the following standard period-by-period resource constraint:

$$\mathrm{NFA}_t = X_t - M_t + (1 + r_t)\mathrm{NFA}_{t-1}, \tag{1}$$

where M denotes imports, X exports, and r the interest rate on external assets and liabilities. These variables could be expressed in nominal terms, real terms, or as a ratio to GDP as long as r is adjusted accordingly (i.e., if the variables are in nominal terms, r is the nominal interest rate; if the variables are in real terms, r is the real interest rate; if the variables are ratios to GDP, $1 + r$ is the growth-adjusted real interest rate that follows from dividing the gross real interest rate by the gross rate of output growth).

Under alternative standard simplifying assumptions about the nature of the r_t process, the resource constraint implies[5]:

$$\mathrm{NFA}_t = -\psi E_t[X_{t+1} - M_{t+1} - \mathrm{NFA}_{t+1}], \tag{2}$$

where $\psi = 1/(1 + r) < 1$, and $r = E[r_t + 1]$. The above expectational difference equation, together with the transversality condition,

$$\lim_{n \to \infty} \psi^n E_t[\mathrm{NFA}_{t+n}] = 0, \tag{3}$$

implies the following intertemporal budget constraint:

$$\mathrm{NFA}_t = -\sum_{t=1}^{\infty} \psi^i E_t(X_{t+i} - M_{t+i}). \tag{4}$$

In what follows, we review Bohn's PB3, which establishes testable predictions about the time-series behavior of NFA and NX that characterize economies for which (3) and (4) hold.

2.1. The error-correction reaction function approach

Our framework to study external solvency looks for a systematic negative response of NX to NFA in the form of an error-correction specification. In particular, Bohn (2007) established the following result:

Proposition 1. ***PB3***. If $\mathrm{NX}_t - \rho\mathrm{NFA}_{t-1} = z_t \sim I(m)$ for some $\rho < 0$, such that $|\rho| \in (0, 1 + r]$, and $r_t = r$ is constant, then NFA satisfies condition (3).

Proof. See p. 1844 in Bohn (2007).

[5] Bohn (2007) reviews three possible assumptions that deliver this outcome: (1) r positive and constant, (2) r i.i.d with a positive and constant conditional expectation, or (3) r is any stationary stochastic process with mean $r > 0$, and subject to implicit restrictions that may be required so that the process of "interest adjusted imports" ($M_t^* = M_t - (r_t - r)\mathrm{NFA}_{t-1}$) has similar statistical properties as M_t.

This proposition states that if a country's NX and NFA positions are linked through an error–correction relationship with a ρ coefficient that satisfies the stated conditions, then IBC and the transversality condition hold. Existence of such a reaction function implies that, implicitly, households, firms and the government adjust their savings and investment plans over time in a manner that is in line with the financing requirements implied by changes in the economy's NFA position. With this response in place, the economy's external liabilities grow at a slower pace than what a Ponzi scheme implies, so that external positions are consistent with the IBC. For countries with more negative ρ, the response of net exports to changes in net foreign assets is stronger. In turn, more negative ρ's are likely to reflect limitations affecting the financial markets that those countries can access, in terms of the level of financial development and/or the presence of financial frictions.

It is important to keep in mind that the above results establish only a sufficiency condition for the IBC to hold. Thus, it is possible that countries might not display a negative response coefficient and still display NFA data that are stationary of a finite order, so that IBC holds. For example, in abnormal situations, like when a country is in default with its external creditors, the reaction function relationship may break but the IBC is maintained because by lowering its net external debt via restructuring the country brings closer to balance its existing debt with the expected present value of its net exports. Hence, evidence of a systematic reaction function consistent with solvency is not inconsistent with the observation that countries may default. The reaction function describes the normal dynamic adjustment of net exports to changes in debt, while default events reflect discrete adjustments.

Efficient estimation of country-specific error-correction reaction functions linking NX and NFA requires large datasets that are generally not available for a large number of countries. The best data available for NFA positions, which is the dataset constructed by Lane and Milesi-Ferretti (2010), covers only the 1970–2008 period. The alternative, therefore, is to exploit the cross-sectional, time-series structure of the data to estimate a panel error-correction specification of the following form:

$$nx_{it} - \rho nfa_{it-1} = \eta_{it}, \tag{5}$$

where η is an $I(0)$ process. This is an error-correction specification in the class of those allowed by PB3.

Following Pesaran et al. (1999), we can nest the above relationship in an auto-regressive distributed lag (ARDL) model. In this model, lagged dependent and independent variables enter the right-hand-side of the model with lags of order p and q, respectively:

$$nx_{i,t} = \mu_i + \sum_{j=1}^{p} \lambda_{i,j} nx_{i,t-j} + \sum_{l=0}^{q} \delta'_{i,l} nfa_{i,t-l} + \varepsilon_{i,t}, \tag{6}$$

where $nx_{i,t}$ and $nfa_{i,t}$ denote the net exports-GDP and NFA–GDP ratios in country i at time t respectively, and μ_i denotes country-specific fixed effects. ε is a set of normally distributed error terms with country-specific variances, $\mathrm{var}(\varepsilon_{it}) = \sigma_i^2$.

The above equation can be expressed in terms of a linear combination of variables in levels and first differences, as follows:

$$\Delta nx_{i,t} = \mu_i + \phi_i nx_{i,t-1} + \varphi_i nfa_{i,t} + \sum_{j=1}^{p-1} \lambda^*_{i,j} \Delta nx_{i,t-j} + \sum_{l=0}^{q-1} \delta^*_{i,l} \Delta nfa_{i,t-l} + \varepsilon_{i,t},$$

where $\phi_i = -(1 - \sum_{j=1}^{p} \lambda_{i,h})$, $\varphi_i = \sum_{j=0}^{p} \delta_{i,j}$, $\lambda^*_{i,j} = -\sum_{m=j+1}^{p} \lambda_{i,m}$, $\delta^*_{i,l} = -\sum_{m=l+1}^{q} \delta_{i,m}$, with $j = 1,2,\ldots,p-1$, and $l = 1,2,\ldots,q-1$.

To highlight the long-run relationship, the above equation can be rearranged as:

$$\Delta nx_{i,t} = \mu_i + \phi_i \left[nx_{i,t-1} - \rho_i nfa_{i,t} \right] + \sum_{j=1}^{p-1} \lambda^*_{i,j} \Delta nx_{i,t-j} + \sum_{l=0}^{q-1} \delta^*_{i,l} \Delta nfa_{i,t-l} + \varepsilon_{i,t}, \tag{7}$$

where $\rho_i = -\phi_i^{-1} \varphi_i$ denotes the long-run reaction function relationship between nx and nfa, and ϕ_i denotes the speed at which NX adjusts towards that long-run relationship following a change in NFA.

As shown earlier, a negative and statistically significant response coefficient ρ is sufficient to guarantee that IBC in Eq. (4) holds.

We estimate the dynamic panel Eq. (7) using MG and PMG estimators. MG estimates independent error-correction equations for each country and computes the mean of the country-specific error-correction coefficients and its relevant statistics (see Pesaran and Smith (1995)). This approach produces consistent estimates of the average of the coefficients as long as the country-specific coefficients are independently distributed and the regressors are exogenous. If some of the coefficients are the same for all countries, however, the MG estimates are inefficient. In this case, PMG is efficient (see, Pesaran, et al., 1999). The PMG estimator imposes the restriction that the long-run coefficients are the same across countries, but the intercept, short-term coefficients and error variances still can differ. Pesaran et al. (1999) suggest as the criterion for choosing whether the PMG estimator should be preferred to the MG estimator a standard Hausman test on the homogeneity restriction that the long-run coefficient is the same for all countries.

Using the results from PMG or MG estimation, we can derive estimates of the long-run average *nfa* positions to which each country converges. For the long-run average of *nfa* to exist, *nfa* must be stationary, and this requires that the estimation results satisfy three conditions: $\phi < 0$, $\rho < 0$ and $|\rho| > r$. The first condition is required for the error-correction specification to be well-defined, and the last two follow from PB3. Note that if $\rho < 0$ but $|\rho| \leq r$, PB3 still applies and IBC still holds, but *nfa* and *nx* are not stationary (see Bohn, 2007).

If *nfa* is stationary, Eq. (7) and the resource constraint imply that each country's *nfa* position converges to the following long-run average:

$$E[nfa_i] = \frac{\mu_i}{\phi_i(\rho_i + r)}. \tag{8}$$

If we use the PMG estimator, ρ_i is the same for all countries in the estimation panel, but there can still be significant heterogeneity in the predicted values of $E[nfa_i]$ because PMG still allows for country-specific estimates of ϕ_i and μ_i.

Since the stationarity conditions imply $\phi_i < 0$ and $(\rho_i + r) < 0$, the denominator of the right-hand-side of the above expression is positive, and therefore $\text{sign}(E[nfa_i]) = \text{sign}(\mu_i)$. The intuition for this result is straightforward: if μ_i is positive (negative), the country's long-run trade balance converges to a deficit (surplus), and the resource constraint dictates that in the long run $E[nfa_i] = -\mathrm{E}[nx_i]/r$ (i.e., net foreign assets are equal to the negative of the annuity value of the trade balance).

It is important to note that $\text{sign}(\mu_i)$ also determines whether $E[nfa_i]$ is a positive or negative function of the parameters that determine it. $E[nfa_i]$ is a positive (negative) function of ρ_i, ϕ_i or r if μ_i is positive (negative). This result has an important implication: everything else constant, countries with lower *s* result has an important implicit converge to higher (lower) mean *nfa* positions if μ_i is negative (positive). This result is also intuitive. Comparing two net debtor countries (each with $\mu_i < 0$), the one with a stronger response coefficient responds to temporary declines in its *nfa* by adjusting its trade surplus relatively more, vis-à-vis the alternative of widening more the current account deficit, and the larger surpluses imply a higher (less negative) long-run average of *nfa*. A similar intuition applies to a comparison of two creditor countries. This suggests that stronger response coefficients can be viewed as evidence that the corresponding countries have more limited access to financial markets, either to borrow or to save, than those that display weaker response coefficients.

2.2. General equilibrium representation

The derivation of the IBC in Eq. (4) followed from a generic setup that applies to a variety of intertemporal open-economy models, as long as condition (3), and the assumptions about the *r* process that support the expectational difference equation for NFA_t hold. The latter can be particularly restrictive, however, because they effectively imply that the expected future stream of trade balances in the right-hand-side of (4) can be discounted at a time- and state-invariant average interest rate. This simplification is very useful for the proof of PB3, but it is important to note that the key implications of PB3 still hold in more general environments that do not restrict discount rates in the same way. In particular, we show below that this is the case in a canonical general equilibrium model of a small open economy with complete markets of state contingent claims traded at exogenous world-determined prices.

Domestic output (y) in this economy is an exogenous random process, and there are similar processes driving the output of a large number of identical countries. The world-wide state of nature s (i.e., the vector of all country output realizations) follows a stochastic process with the Markov transition density function $f(s_{t+1}, s_t)$. Since agents have access to complete international markets of state-contingent claims $b_t(s_{t+1})$, the small open economy's period-by-period budget constraint is:

$$\int Q_1(s_{t+1}|s_t)b_t(s_{t+1})ds_{t+1} = b_{t-1}(s_t) + y(s_t) - c(s_t), \tag{9}$$

where $Q_1(s_{t+1}|s_t)$ is the period-t world-determined price of a state-contingent claim that pays one unit of good in state s_{t+1} at period $t+1$. At equilibrium, these prices are equal to the corresponding stochastic marginal rates of substitution in consumption across time and states of nature. Given these prices, and if the appropriate transversality condition holds, the above budget constraint implies the following IBC:

$$b_{t-1}(s_t) = \mathrm{NX}_t + \sum_{j=1}^{\infty} E_t\left[\frac{\beta^j u'\left(y_{t+j} - \mathrm{NX}_{t+j}\right)}{u'(y_t - \mathrm{NX}_t)} NX_{t+j}\right], \tag{10}$$

where $u'(\cdot)$ denotes the marginal utility of consumption, β denotes the subjective discount factor, and $\beta^j u'(y_{t+j} - \mathrm{NX}_{t+j})/u'(y_t - \mathrm{NX}_t)$ is the stochastic discount factor. If we denote by R_{jt} the rate of return of a j-period-ahead risk-free asset, we can rewrite the IBC as follows[6]:

$$b_{t-1}(s_t) = \mathrm{NX}_t + \sum_{j=1}^{\infty}\left\{[R_{jt}]^{-1}E_t(\mathrm{NX}_{t+j}) + cov_t\left[\frac{\beta^j u'\left(y_{t+j} - \mathrm{NX}_{t+j}\right)}{u'(y_t - \mathrm{NX}_t)},\ \mathrm{NX}_{t+j}\right]\right\}. \tag{11}$$

If the economy's output process represents purely diversifiable country-specific risk (e.g., if the country-specific output processes are i.i.d. and aggregated into a non-stochastic world-wide income), domestic agents would attain a perfectly smooth consumption path constant across time and states, and the compounded risk-free rate would be $[R_{jt}]^{-1} = \beta^j$. In this case, the small open economy's IBC simplifies to the same expression in (4), and proposition PB3 obviously apply.

If domestic agents cannot attain perfectly smooth consumption (which could happen for a variety of reasons, such as a global component in country output fluctuations, the existence of nontradable goods, country-specific government purchases, incomplete markets, etc.), the expressions of the IBC in (4) and (11) are not equivalent. In particular, the co-variance terms in the right-hand side of (11) are not zero, and as a result a constant discount factor equal to the unconditional expectation of the interest rate, as assumed in (4), is not the appropriate discount factor that is consistent with the true solvency condition (11). The correct discount factor is given by the equilibrium asset pricing kernel.

The intuition for why the risk-free rate is not the appropriate discount factor is that, depending on the shocks hitting the economy, the NFA stocks that result from the resource constraint can vary over a wide range and be correlated with sources of risk such as terms-of-trade shocks, foreign demand shocks, etc. As a result, NFA, NX, and asset prices and returns implied by the equilibrium pricing kernel are likely to follow very different stochastic processes, and therefore risk-free interest rates are not appropriate discount rates. As Bohn (2005) puts it: “not just technically wrong, but also providing a misleading economic intuition”.

Equation (11) also implies an interesting relationship between the economy's initial NFA position and the sequence of conditional covariances of stochastic discount factors and NX. In particular, given the same expected present discounted value of net exports, a Country A with lower covariances than a Country B should display a lower initial NFA position. In turn, assuming a standard isoelastic utility

[6] At equilibrium, this interest rate satisfies $[R_{jt}]^{-1} = \beta^j E_t[u'(y_{t+j} - \mathrm{NX}_{t+j})/u'(y_t - \mathrm{NX}_t)]$.

function, the covariances can be re-interpreted as covariances between inverse consumption growth rates and net exports, which can then be related to observed co-movements between these variables (see Section 3.2 below).

A second important implication of Eq. (11) is that, as Bohn (1998, 2005) showed, it again implies that a reaction function with a negative, linear response of NX to NFA is sufficient to guarantee that external solvency holds. Thus, this sufficiency condition for solvency holds here even with an interest rate that is generally *not* time- and state-invariant as assumed in PB3.

3. Estimation results

3.1. Data

Our analysis is based on annual data for the period 1970–2006 covering 21 industrial countries (IC) and 29 emerging markets (EM). The IC mainly comprise the core OECD countries while the EM are those listed in Appendix 1. NFA data in U.S. dollars are from Lane and Milesi-Ferretti (2010).[7] Data for NX and GDP in U.S. dollars are from the International Monetary Fund's *International Financial Statistics*. Summary statistics are provided in Table 1.

Our sample selection is simply based on data quality and availability. The sample includes all the countries, which satisfy two criteria: first, NX and NFA data start at least as of 1990 and second, if the first holds, go as far back as possible up to 1970. Overall, the sample consists of 1765 observations for both the NX and NFA positions – of which 754 observations correspond to IC group and 1011 observations to EM group.

3.2. Panel error-correction estimation

We test PB3 by estimating the dynamic panel equation derived in the previous Section using PMG and MG estimators. Table 2 reports results for the full sample combining ICs and EMs and for subsamples separating ICs from EMs. The table is divided into two blocks. Block 1 shows our baseline results, and Block 2 shows results obtained with the data expressed as ratios of world gdp.[8] We selected the ARDL lag structure for each country using the Schwartz Bayesian criterion. For the majority of countries, the criterion rejected specifications without lagged dependent variables at conventional levels of statistical significance. Throughout this section, we examine the null hypothesis that there is no error-correction relation between *nfa* and *nx* under both the PMG and MG estimators, and use *t*-statistics to test this hypothesis.

The Full Sample panel in Block 1 shows the main results combining all the countries in our sample. The Hausman *h*-statistic test cannot reject the slope homogeneity restriction, indicating that the PMG estimator is preferred to the MG estimator (see the *p*-value, which is above the critical threshold of 0.10). The PMG estimates of the long-run response coefficient show a negative and statistically significant response of *nx* to *nfa*. A reduction (increase) of one percentage point in *nfa* raises (lowers) *nx* by 0.07 percentage points. The estimated error correction coefficient of 0.27 (in absolute value) indicates that the adjustment of *nx* to a given change in *nfa* has an average half-life of just over 2.25 years.[9] Overall, these results for the full sample indicate that PB3 and the external solvency condition hold.

The IC and EM panels of Block 1 show that the results of MG and PMG estimation splitting the sample according to whether countries are industrialized or emerging economies also support the hypothesis that PB3 holds. The null hypothesis of no error-correction relation between *nx* and *nfa* is rejected in both the IC and EM groups, and the *h*-test indicates that PMG dominates MG for both the IC and EM groups. What is more important is that now, comparing across the two groups, we find that the

[7] Lane and Milesi-Ferretti report data up to 2008 but the observations for 2007 and 2008 are preliminary and subject to revisions that are likely to be large in light of the large fluctuations observed during the global financial crisis.

[8] We also studied the results where only those countries with statistically significant EC coefficients and intercept terms (as reported in Table 3) are kept in the sample. We found that the results are robust to this sample selection.

[9] The half-life is calculated as $\log(0.5)/\log(1-|EC|)$, where *EC* denotes the error correction coefficient. The higher is the $|EC|$, the lower is the half-life and the faster is the adjustment.

Table 1
Sample statistics period 1970–2006.

	All	Industrial countries	Emerging market economies
1. Net exports (% of GDP)			
Mean	−0.7	0.2	−1.4
Median	−0.4	0.2	−1.3
Bottom quartile	−3.5	−1.9	−4.9
Top quartile	2.6	2.7	2.6
Standard deviation	8.6	4.9	10.4
Number of observations	1844.0	777.0	1067.0
Number of countries	50.0	21.0	29.0
2. Net foreign assets (% of GDP)			
Mean	−17.9	−10.5	−23.3
Median	−20.0	−11.5	−28.8
Bottom quartile	−39.7	−26.8	−44.4
Top quartile	−4.8	4.6	−12.7
Standard deviation	42.2	34.2	46.5
Number of observations	1765.0	754.0	1011.0
Number of countries	50.0	21.0	29.0

long-run response coefficient is higher in EMs than in ICs (−0.092 vs. −0.047). Both of these estimates are statistically significant at a 1 percent significance level. The error-correction coefficients imply that the adjustment of *nx* to changes in *nfa* is more protracted in ICs, for which the average half-life is about 3.1 years, than in EM, for which the average half-life is 1.8 years.

The result indicating that the long-run response coefficient of EMs is about twice larger than that for ICs implies that net exports in EMs need to respond more to changes in net foreign assets in order to support external solvency. As suggested earlier, this difference can be attributed to the under-development of financial markets or the severity of the financial frictions that EMs face compared to ICs.

Table 3 shows the long-run *nfa* positions that each country group converges to. In this table, we report the estimates for a selected small group of countries to illustrate potential country-specific variations. The *nfa* estimates reported in column 5 are calculated using the formula in (8). The column labeled "*nfa*

Table 2
Dynamic panel estimates of net exports on net foreign assets (1970–2006 period).

	Full sample		Industrial countries		Emerging markets	
	MG	PMG	MG	PMG	MG	PMG
1. As a percent of country GDP						
LR coefficient	−0.124	−0.070***	−0.077	−0.047***	−0.157***	−0.092***
	[0.036]	[0.010]	[0.058]	[0.013]	[0.045]	[0.015]
EC coefficient	−0.314***	−0.265***	−0.279***	−0.201***	−0.339***	−0.316***
	[0.030]	[0.030]	[0.042]	[0.039]	[0.042]	[0.043]
Hausman statistics		2.38		0.28		2.35
p-value		[0.12]		[0.60]		[0.13]
Number of countries	50	50	21	21	29	29
2. As a percent of world GDP[a]						
LR coefficient	−0.134	−0.077***	−0.443	−0.063***	0.083	−0.079***
	[0.200]	[0.010]	[0.337]	[0.016]	[0.243]	[0.013]
EC coefficient	−0.330***	−0.271***	−0.286***	−0.197***	−0.361***	−0.326***
	[0.034]	[0.037]	[0.041]	[0.038]	[0.050]	[0.055]
Hausman statistics		0.08		1.27		0.45
p-value		[0.78]		[0.26]		[0.50]
Number of countries	51	51	21	21	30	30

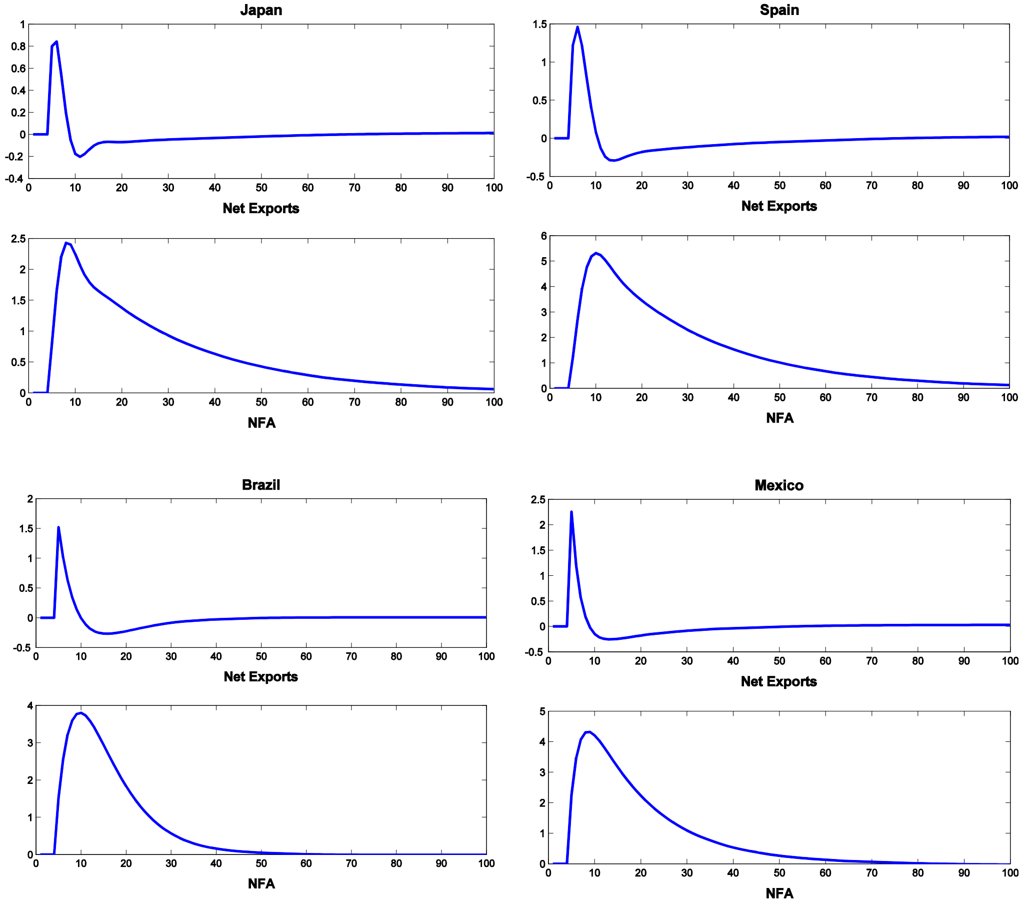
Note: The symbols *, *** and *** indicate statistical significance at the 10%, 5% and 1%, levels, respectively. Standard errors are reported in brackets. The Hausman statistic refers to the test statistic on the long-run homogeneity restriction. The maximum number of lags considered in the estimation is 2.

[a] Includes the Rest of the World, which is created as the negative of the global external imbalances. The World Output is the sum of the outputs of industrial and emerging market countries in our sample.

Table 3
Long-run NFA.

Countries	ρ	ϕ	μ	*nfa*	*nfa* for constant μ	*nfa* for constant ϕ
Brazil	−0.0917***	−0.305***	−0.7071**	−28.740	−46.457	−27.740
India	−0.0917***	−0.3415***	−1.0257***	−32.904	−36.667	−35.560
Japan	−0.0469***	−0.344***	0.6869***	42.960	−13.259	73.524
Mexico	−0.0917***	−0.3301***	−1.2124**	−48.225	−45.465	−50.377
Spain	−0.0469***	−0.2223**	−0.625**	−42.787	−14.513	−47.321
Venezuela	−0.0917***	−0.4967***	2.9557**	74.189	−28.690	116.613
EM all	−0.0917***	−0.316***	−1.143**	−41.792	−41.792	−41.792
Industrial all	−0.0469***	−0.201***	−0.212	−25.263	−25.263	−25.263

Note: The table shows the long-run NFA positions that the PMG model converges to for the countries with significant ϕ and μ. The last two columns illustrate the respective implied NFA positions if the EC coefficient and intercept terms were kept constant at the value estimated for the whole sample for the EM or IC group.



Notes: This figure illustrates the impulse responses functions of NFA and NX to a one-standard-deviation noise shock These impulse responses are calculated using the PMG estimates reported in Table 2, and setting the initial conditions to the long-run values the model predicts they converge to. The main finding is that although NX can converge back to its long-run equilibrium faster, the adjustment of NFA (i.e., the stock imbalance) can persist much longer.

Fig. 2. Impulse responses to a one-standard-deviation. Noise shock: selected industrial countries.

Table 4
Dynamic panel estimates of net exports on net foreign assets (as percent of GDP, 1970–2006 period).

	1. External leverage				2. Trade openness				3. Institutional quality			
	Low leverage		High leverage		Less open economies		More open economies		More institutional quality		Less institutional quality	
	MG	PMG	MG	PMG	MG	PMG	MG	PMG	MG	PMG	MG	PMG
LR coefficient	−0.093*** [0.053]	−0.124*** [0.021]	−0.147 [0.049]	−0.064 [0.011]	−0.081* [0.043]	−0.060*** [0.014]	−0.167*** [0.057]	−0.076*** [0.014]	−0.083 [0.051]	−0.048*** [0.012]	−0.168*** [0.050]	−0.097*** [0.016]
EC coefficient	−0.344*** [0.044]	−0.280*** [0.046]	−0.290*** [0.042]	−0.240*** [0.042]	−0.375*** [0.048]	−0.327*** [0.049]	−0.253*** [0.033]	−0.204*** [0.031]	−0.287*** [0.036]	−0.216*** [0.035]	−0.343*** [0.049]	−0.327*** [0.050]
Hausman statistics		0.38		3.10		0.27		2.67		0.49		2.26 [0.13]
p-value		[0.54]		[0.08]		[0.60]		[0.10]		[0.49]		
Number of countries	25	25	25	25	25	25	25	25	25	25	25	25

Note: The symbols *, ** and *** indicate statistical significance at the 10%, 5% and 1%, levels, respectively. Standard errors are reported in brackets. The Hausman statistic refers to the test statistic on the long-run homogeneity restriction. The maximum number of lags considered in the estimation is 2.

for constant μ" calculates the implied estimate for *nfa* in the formula where the intercept term (μ) is set to the value estimated for the whole sample (All). The purpose of this exercise is to illustrate the potential changes in estimated *nfa* driven solely by the changes in the EC term (ϕ). Likewise, the last column shows the estimates for *nfa* when the EC coefficient is fixed at the estimate for the whole sample to illustrate the importance of the intercept term. The results show that even if the long-run coefficient (ρ) is kept the same for both country groups, there are marked variations in long-run *nfa* estimates that each group converges to. The large changes in these estimates are driven by differences in the EC and intercept terms, which, in turn, is affected by the structural differences across countries.

In order to study further the dynamic pattern of adjustment of net foreign assets and net exports implied by our estimates, Fig. 2 illustrate the impulse responses functions of *nfa* and *nx* for a selected group of countries when those economies are subject to a one-standard-deviation noise shock (figures are shown for only a selected set of countries due to space limitations but results for other countries are available upon request). These impulse responses are calculated using the PMG estimates reported in Table 2, and setting the initial *nfa* and *nx* positions to the long-run values the model predicts they converge to. The main finding is that although *nx* can converge back to its long-run equilibrium faster, the adjustment of *nfa* (i.e., the stock imbalance) can persist much longer. The convergence of the *nfa* positions to their long-run values in our sample takes from about 10 years to up to 50 years. Our exercise also illustrates that, although the long-run coefficients are common across EMs and ICs, there is marked variation among countries in their convergence.

3.3. Robustness analysis

We study next the robustness of our results to several interesting modifications. First, we implement a reformulation of the data in which the NX and NFA series are normalized using world GDP instead of country-specific GDPs (Block 2, Table 2). For this purpose, the world GDP is simply the sum of the respective GDPs of the countries in the sample, each expressed in U.S. dollars. In addition, we impose global market clearing by requiring NFAs and NXs to sum to zero across the world. This is done by introducing a residual country with NFA and NX positions equal to negative of the sum of the NFA and NX positions for all countries in our sample. This exercise aims to explore if the baseline results are altered by relative country size or by restrictions that force global market clearing.

In Block 2, the results for the Full Sample panel show that again the Hausman *h*-test indicates that the cross-country slope homogeneity restriction cannot be rejected, and that the PMG estimate of the response coefficient (−0.077) must be chosen over the MG estimator. The average half-life of adjustment to the long-run relationship in this scenario is 2.2 years. These results are very similar to those obtained using the standard *nx* and *nfa* measures based on country GDPs.

4. Financial Sector Development				5. Capital Account Openness				6. Exchange Rate Flexibility			
More financial sector dev.		Less Financial sector dev.		More open to capital		Less open to capital		More flexible		Less flexible	
MG	PMG	MG	PMG	MG	PMG	MG	PMG	MG	PMG	MG	PMG
−0.112*	−0.063***	−0.136***	−0.078***	−0.082*	−0.047***	−0.159***	−0.133***	−0.077*	−0.062***	−0.222***	−0.114***
[0.060]	[0.013]	[0.040]	[0.015]	[0.048]	[0.011]	[0.052]	[0.020]	[0.043]	[0.010]	[0.061]	[0.028]
−0.273***	−0.203***	−0.354***	−0.326***	−0.316***	−0.254***	−0.312***	−0.259***	−0.344***	−0.285***	−0.250***	−0.220***
[0.034]	[0.034]	[0.049]	[0.048]	[0.051]	[0.052]	[0.037]	[0.038]	[0.041]	[0.042]	[0.035]	[0.032]
	0.68		2.35		0.55		0.30		0.13		3.95
	[0.41]		[0.12]		[0.46]		[0.58]		[0.71]		[0.05]
25	25	25	25	25	25	25	25	25	25	25	25

The results for the IC and EM panels with world gdp ratios are also similar to those obtained with country gdp ratios. The Hausman h-test cannot reject the long-run homogeneity condition for ICs, which implies that the PMG estimate of −0.063 is preferred to the MG estimator. And the average half life for this country group is 3.16 years. Both of these estimates are very similar to ones reported using country gdp ratios. Also for EMs, the Hausman h-test suggests that the hypothesis of long-run homogeneity cannot be rejected and that the PMG estimate of −0.079 should be chosen. And the average half-life is estimated at 1.8 years, which is very close to the one reported earlier.

The next robustness test explores the implications of splitting the sample into high vs. low leverage countries (leverage is defined as the ratio of total assets relative to equity liabilities, see Gourinchas and Obstfeld, 2011, for details). High (low) leverage countries are defined as those with above (below) median leverage level.[10] The results of the dynamic panel estimation are shown in Panel 1 of Table 4. For low leverage countries, the Hausman h-test cannot reject the cross-country homogeneity restriction and, thus, indicates that the PMG estimate of −0.124 should be preferred. The average half-life for this group is estimated at 2.11 years. For high leverage countries, the Hausman h-test indicates that the cross-country homogeneity restriction can be rejected and that the MG estimate of −0.147 is preferred. The average half-life for this group of countries is estimated at 2 years. In summary, these findings suggest that in terms of its implications for sustainability, there is no significant behavioral difference between high or low leverage countries.

Next, we explore the importance of trade openness (panel 2, Table 4). Those countries with a volume of trade as a share of GDP higher than the volume for the median country are treated as more open economies, and the rest is treated as less open economies. For both groups, the long-run homogeneity restriction cannot be rejected. The implied PMG estimates are −0.070 (with half life 2.8 years) and −0.065 (with half life 1.4 years) for more open and less open economies, respectively, suggesting that there is no significant difference between these two groups.

We also explore the importance of institutional quality, financial sector development, capital account openness, and exchange rate regime as shown in panels 3–6, respectively. In all these cases with the exception of panel 6, the Hausman test cannot reject the long-run homogeneity restriction so that the PMG should be the preferred method.[11] These results mainly show that the countries with relatively weaker fundamentals (i.e., less institutional quality, less financial sector development, less open to capital, and less flexible exchange rate regime) need to respond more strongly to the changes in NFA to keep them on a sustainable path (notice that implied PMG estimates for the long-run coefficient is more negative for these groups compared to their counterparts with stronger fundamentals). However, our baseline findings regarding the sustainability of imbalances are preserved in all these cases.

[10] The list of countries pertaining to each group is available on request.

[11] Note that both the PMG and MG estimators provide evidence of external solvency. Thus, whether the Hausman test selects the PMG over the MG estimator or vice versa does not change the main findings of the paper.

3.4. Testing solvency with NFA integration tests

As explained earlier, proposition PB1 in Bohn (2007) established that a stochastic time series of debt or assets is consistent with its corresponding IBC if the series is stationary at *any* finite order of differencing.[12]

In our context, this proposition indicates that as long as any finite difference of NFA is stationary, the NFA positions are consistent with solvency. The intuition, as pointed out by Bohn (2007), is that if NFA is mth-order integrated, its n-period-ahead conditional expectation is a polynomial that is *at most* of order m. The discount factor in the transversality condition, however, grows exponentially with n. Since exponential growth dominates polynomial growth of any order, NFA grows slower than the discount factor in the transversality condition as long as NFA is integrated of any finite order.

Following the above proposition, we proceed now to establish, using the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests, that indeed the degree of integration of *nfa* is finite, and in fact quite low, for each country in our sample. As discussed before, however, this confirms that the solvency condition cannot be rejected by the data, but is otherwise uninformative about the nature of the external adjustment process.

We use both ADF and PP tests because, although they are asymptotically equivalent, they can differ significantly in small samples (see Hamilton, 1994). We first test the null hypothesis that *nfa* is integrated of order 1 ($H(0)$: $nfa \sim I(1)$) against the alternative that it is stationary ($H(1)$: $nfa \sim I(0)$). Second, if the null is accepted, we test the null hypothesis that the first difference of *nfa* is integrated of order 1 (i.e., $H(0)$: $\Delta nfa \sim I(1)$) against the alternative that it is stationary ($H(1)$: $\Delta nfa \sim I(0)$). We continue on this procedure until we arrive at stationarity at a finite order of differencing. As detailed, we arrive at stationarity in the first order of differencing on most cases.

Fig. 3 summarizes our main findings. The top panel of the Figure shows that ADF and PP tests cannot reject the null hypothesis of a unit root in *nfa* at commonly used significance levels for all countries in the sample. The bottom panel shows that when we perform the tests for the first difference of *nfa*, however, we reject the null hypothesis of a unit root in favor of the alternative of stationarity for almost all of the countries. This means that in most countries *nfa* is integrated of order 1. Only for very few countries (e.g., Belgium, Germany, Portugal, Colombia, India), we cannot reject the hypothesis of unit roots present in the first differences of *nfa*.[13] These results do not change significantly when we allow for the possibility of structural breaks, intercepts and trend components in the time-series processes.

To examine the robustness of the above findings, we also conducted tests using the KPSS stationarity test, developed by Kwiatkowski et al. (1992). In contrast with the ADF and PP unit root tests, KPSS tests the null that *nfa* is stationary ($H(0)$: $nfa \sim I(0)$) against the alternative that it is integrated of order 1 ($H(1)$: $nfa \sim I(1)$). In the event the null hypothesis is rejected, we next proceed to check if the first difference of *nfa* is stationary (i.e., $H(0)$: $\Delta nfa \sim I(0)$) against the alternative that it is integrated of order 1 ($H(1)$: $\Delta nfa \sim I(1)$). As in the case of the ADF and PP tests, the results of the KPPS test indicate that *nfa* is integrated of finite order.[14]

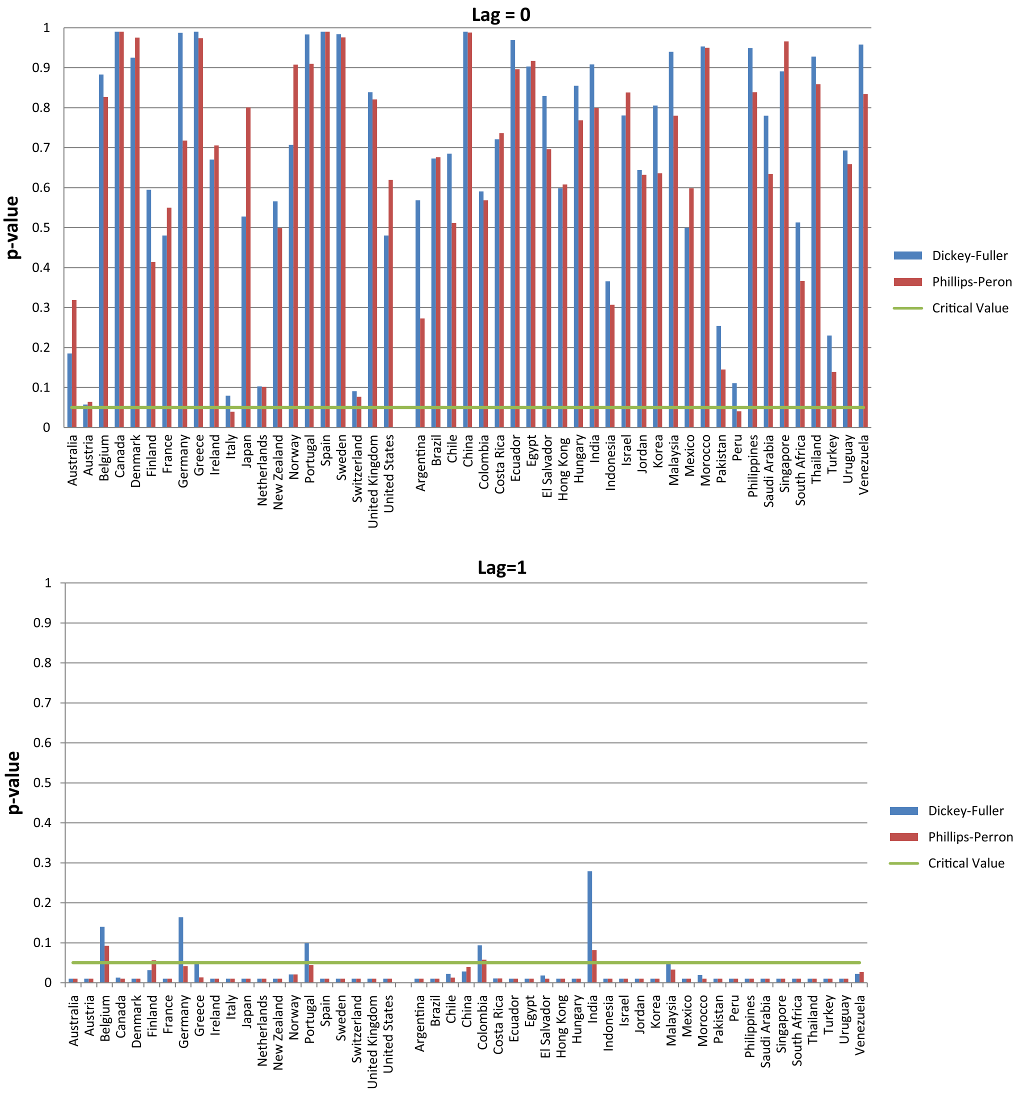
We performed additional robustness tests using historical data for the United States. The U.S. has a large weight in our analysis because of its large share of global imbalances. For this exercise, we performed the aforementioned unit root tests using a long time series data of *nfa* covering 1790–2004 from Engel and Rogers (2006), and data from Curcuru et al. (2008), which is corrected for valuation changes. We find that our main findings are preserved in both datasets, i.e., *nfa* is nonstationary in levels but stationary in first differences.

It is important to keep in mind that the usual caveats about inference problems in short samples due to limited power of the tests are relevant for our sample. In particular, it is well known that the ADF and

[12] A common test used to evaluate external solvency is to test if NFA is difference-stationary (integrated of order 1). Rejection of this hypothesis was commonly taken as evidence against external solvency, but PB1 demonstrates that this interpretation is incorrect.

[13] For those countries, the second difference of *nfa* passes the unit root tests.

[14] The results for KPSS tests are available upon request.



Notes: This figure shows unit root tests for NFA using Dickey-Fuller and Phillips-Perron tests. The top panel shows that our tests cannot reject cannot reject the null hypothesis of a unit root at commonly used significance levels. The bottom panel shows that when we perform the tests for the first difference, however, we reject the null hypothesis of a unit root for almost all of the countries.

Fig. 3. The order of Integration of net foreign assets positions.

PP tests do not have the power to distinguish between a unit root or a near unit root process or between a drifting or trend stationary process. In fact, when we examine the individual AR(1) coefficients for each country (see Fig. 4), we find that they span a wide range from 0.59 to 1.06, and that their standard errors are relatively large (ranging from 0.065 to 0.146). Thus, although we could not reject the hypothesis of unit roots in *nfa*, the possibility remains that due to the low power of the tests the true data generating process is in fact stationary in levels. This, however, would not affect our finding that the data support the hypothesis that the solvency condition holds, since stationarity in levels is also consistent with PB1.

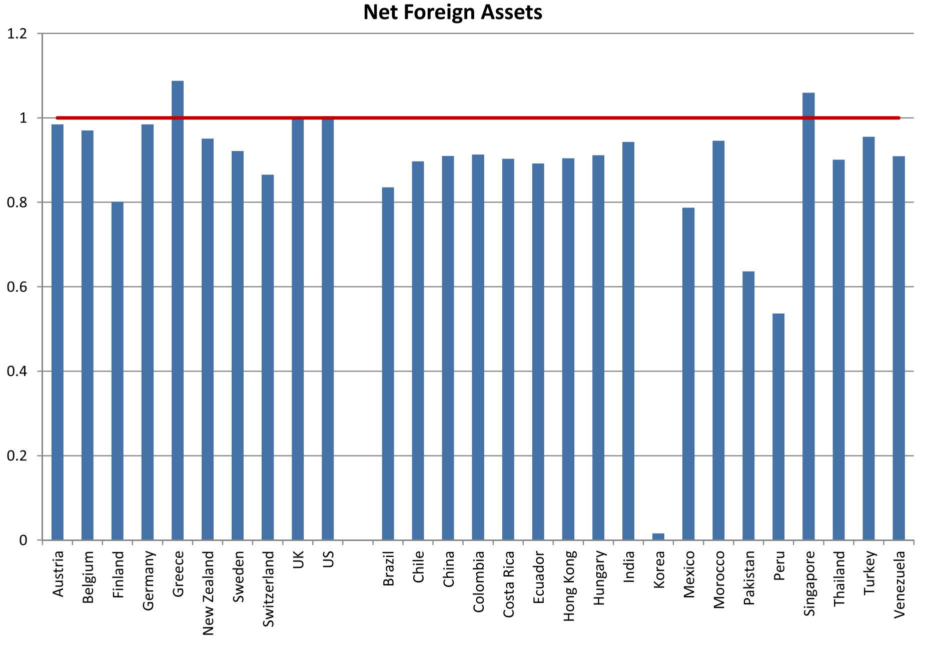


Fig. 4. The estimated AR(1) coefficients.

4. Conclusion

This paper conducts an empirical investigation of external solvency and the dynamics of adjustment of net foreign assets using a dynamic panel framework with data for 21 industrial and 29 emerging economies for the 1970–2006 period.

Following the theoretical results established by Bohn (2007), we use an error-correction reaction function approach to test for a sufficiency condition that ensures that the intertemporal budget constraint linking net exports and net foreign assets holds. This condition requires a negative, statistically significant coefficient of response of net exports to increases in net foreign assets. We provide the first set of empirical results in which this approach to study external solvency has been applied in a cross-country dynamic panel setting.

We estimate panel error-correction models using PMG and MG estimators. In these models, the reaction function is postulated as a long-run relationship that can differ country by country (in the MG model) or homogeneous across countries (in the PMG). Both estimators produced strong evidence of a negative, statistically significant response coefficient, but homogeneity tests favor the PMG estimates over the MG estimates. We also provide results of stationarity of net foreign assets at a low order of integration, which are in line with Bohn's (2007) necessary condition for solvency that simply requires net foreign assets to be stationary at any finite order of integration. As Bohn argued, however, this approach to study solvency is not very informative, given that stationarity of any finite order is a very weak condition. In contrast, the reaction function approach allows us to characterize the dynamic adjustment process of net foreign assets that is consistent with solvency, and also allows to study how that adjustment process differs according to country characteristics.

Our results indicate that the statistically significant error-correction relation between *nx* and *nfa* holds both for the full sample as well as for the subsamples. Simulations based on PMG estimates show that *nx* can converge back to its long-run equilibrium faster, but the adjustment of *nfa* (i.e., the stock imbalance) can persist much longer. The convergence of the *nfa* positions to their long-run values in our sample takes from about 10 years to up to 50 years. We also found that the response coefficient of emerging markets is higher than industrial countries, and that as a result emerging economies converge to higher long-run averages of *nfa* than industrial countries. Finally, the countries with relatively weaker fundamentals (i.e., less institutional quality, less financial sector development, less open to capital, and less flexible exchange rate regime) need to respond more strongly to the changes in NFA to keep them on a sustainable path.

Our analysis has important implications for the ongoing debate on global imbalances. Inasmuch as we found robust evidence in support of the reaction function sufficiency condition for solvency using a database with 50 countries over 1970–2006, which includes more than a decade of data from the global imbalances era, our findings suggest that observed global imbalances are not inconsistent with external solvency. On the other hand, the reaction function provides only a sufficiency condition for solvency, and hence does not preclude instances in which adjusting net foreign assets to restore a path consistent with solvency may be done by means such as sovereign default and debt restructuring. Still, the robust empirical evidence in favor of the reaction function suggests that in "normal times" the dynamics driven by the gradual adjustment of net exports in response to net foreign assets are the centerpiece of the process that maintains solvency. Moreover, the evidence also indicates that there is a surprisingly high degree of homogeneity across countries in the response coefficient governing these dynamics.

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Appendix I. Derivation of the PMG equation

Following Pesaran et al. (1999), we can nest the relationship in Eq. (5) in an auto-regressive distributed lag (ARDL) model in which dependent and independent variables enter the right-hand-side of the model with lags of order p and q, respectively:

$$nx_{i,t} = \mu_i + \sum_{j=1}^{p} \lambda_{i,j} nx_{i,t-j} + \sum_{l=0}^{q} \delta'_{i,l} nfa_{i,t-l} + \varepsilon_{i,t},$$

where $nx_{i,t}$ and $nfa_{i,t}$ denote the net exports-GDP and NFA–GDP ratios in country i at time t respectively, and μ_i denotes country-specific fixed effects. ε is a set of normally distributed error terms with country-specific variances, $\text{var}(\varepsilon_{it}) = \sigma_i^2$.

Using the following identity in the left-hand side of the equation $nx_{i,t} = nx_{i,t-1} + \Delta nx_{i,t}$; and the following identities in the right-hand side of the equation $nx_{i,t-1} = nx_{i,t} - \Delta nx_{i,t}$ and $r > 0$ the above equation can be rewritten as follows:

$$\begin{aligned} nx_{i,t-1} + \Delta nx_{i,t} &= \mu_i + \lambda_{i,1} nx_{i,t-1} + \delta_{i,0} nfa_{i,t} + \sum_{j=2}^{p} \lambda_{i,j}\left[nx_{i,t-j+1} - \Delta nx_{i,t-j+1}\right] \\ &\quad + \sum_{l=1}^{q} \delta_{i,l}\left[nfa_{i,t-l+1} - \Delta nfa_{i,t-l+1}\right] + \varepsilon_{i,t}, \end{aligned}$$

or

$$\begin{aligned} \Delta nx_{i,t} &= \mu_i - \left(1 - \lambda_{i,1} - \lambda_{i,2}\ldots\right) nx_{i,t-1} + \left(\delta_{i,0} + \delta_{i,1} + \ldots\right) nfa_{i,t} \\ &\quad - \left(\lambda_{i,2} + \lambda_{i,3} + \ldots\right)\Delta nx_{i,t-1} - \left(\lambda_{i,3} + \lambda_{i,4} + \ldots\right)\Delta nx_{i,t-2} - \ldots \\ &\quad - \left(\delta_{i,2} + \delta_{i,3} + \ldots\right)\Delta nfa_{i,t-1} - \left(\delta_{i,3} + \delta_{i,4} + \ldots\right)\Delta nfa_{i,t-2} - \ldots + \varepsilon_{i,t}, \end{aligned}$$

or

$$\Delta nx_{i,t} = \mu_i + \phi_i nx_{i,t-1} + \varphi_i nfa_{i,t} + \sum_{j=1}^{p-1} \lambda_{i,j}^* \Delta nx_{i,t-j} + \sum_{l=0}^{q-1} \delta_{i,l}^* \Delta nfa_{i,t-l} + \varepsilon_{i,t},$$

where $\phi_i = -(1 - \sum_{j=1}^{p} \lambda_{i,h})$, $\varphi_i = \sum_{j=0}^{p} \delta_{i,j}$, $\lambda_{i,j}^* = -\sum_{m=j+1}^{p} \lambda_{i,m}$, $\delta_{i,l}^* = -\sum_{m=l+1}^{q} \delta_{i,m}$, with $j = 1,2,\ldots,p-1$, and $l = 1,2,\ldots,q-1$.

To highlight the long-run relationship, the above equation can be rearranged as:

$$\Delta nx_{i,t} = \mu_i + \phi_i \left[nx_{i,t-1} - \rho_i nfa_{i,t} \right] + \sum_{j=1}^{p-1} \lambda_{i,j}^* \Delta nx_{i,t-j} + \sum_{l=0}^{q-1} \delta_{i,l}^* \Delta nfa_{i,t-l} + \varepsilon_{i,t},$$

where $\rho_i = -\phi_i^{-1} \varphi_i$ denotes the long-run equilibrium relationship between *nx* and *nfa*, and ϕ_i denotes the speed at which NX adjust toward their long-run equilibrium following a change in NFA.

Appendix II. Sample of countries

The sample comprises 21 industrial countries and 29 emerging markets.

Industrial Countries: Australia (AUS), Austria (AUT), Belgium (BEL), Canada (CAN), Denmark (DNK), Finland (FIN), France (FRA), Germany (DEU), Greece (GRC), Ireland (IRL), Italy (ITA), Japan (JPN), Netherlands (NLD), New Zealand (NZL), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), United Kingdom (GBR), United States (USA).

Emerging Markets: Argentina (ARG), Brazil (BRA), Chile (CHL), China (CHN), Colombia (COL), Costa Rica (CRI), Ecuador (ECU), Egypt (EGY), El Salvador (SLV), Hong Kong (HKG), Hungary (HUN), India (IND), Indonesia (IDN), Israel (ISR), Jordan (JOR), Korea (KOR), Malaysia (MYS), Mexico (MEX), Morocco (MAR), Pakistan (PAK), Peru (PER), Philippines (PHL), Saudi Arabia (SAU), Singapore (SGP), South Africa (ZAF), Thailand (THA), Turkey (TUR), Uruguay (URY), Venezuela (VEN).

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