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# CURRENT ACCOUNT THEORY AND THE DYNAMICS OF US NET FOREIGN LIABILITIES

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# ABSTRACT

## Current Account Theory and the Dynamics of US Net Foreign Liabilities*

This paper provides empirical evidence on the adjustment dynamics of US net foreign liabilities, net output and consumption. We use empirical techniques that allow us to quantify the relative importance of permanent and transitory innovations. We find that transitory shocks contribute considerably to the variation in all three variables for a horizon up to a year, and their contribution remains significant for a horizon up to five years. A permanent shock – that we interpret as a technological shock – dominates the variation of all variables at longer horizons. In response to this shock, net foreign liabilities, net output and consumption all increase -- consistent with the effect of productivity gains raising domestic return to capital and thus generating an inflow of foreign capital. Conversely, shocks that cause net output and consumption to increase temporarily are accompanied by short-run accumulation of net foreign assets -- in contrast with the traditional model predicting procyclical current account deficits in response to temporary output fluctuations. Instead, our results are qualitatively consistent with predictions of the intertemporal approach to the current account.

JEL Classification: C32, E21, F32 and F41
Keywords: consumption smoothing, current account, international adjustment mechanism, intertemporal approach to the current account, net foreign wealth and permanent-transitory decomposition

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# 1 Introduction

Modern textbooks in international macroeconomics stress that, since the current account is the difference between national saving and investment, external deficits or surpluses result from intertemporal investment and consumption decisions by firms, households and the government. Thus, when international markets provide limited insurance opportunities, borrowing and lending enable economic agents to smooth consumption through intertemporal trade, enhancing economic efficiency. Namely, in response to positive temporary shocks to net output, domestic households can increase both current and future consumption by lending internationally, either directly or through financial institutions. Conversely, in response to permanent shocks that raise net output in the long run by more than in the short run, domestic households can optimally smooth consumption by borrowing in the international financial markets. To the extent that the permanent increase in net output is driven by shocks to productivity, borrowing in international financial markets allow the domestic economy to sustain higher rates of domestic investment without cutting current consumption.

For more than a decade, these basic propositions have been tested using variants of the present-value model originally conceived by Campbell [1987] and Campbell and Shiller [1987]. Test results are mixed. The model is successful in some cases, unsuccessful in others. The extent to which the model performance is driven by the empirical failure of the auxiliary assumptions commonly adopted to make the model testable (without being necessary to the main theoretical proposition) is unclear. In addition, present-value tests do not distinguish between shocks that drive the dynamics of net foreign liabilities of a country, i.e. whether these shocks are temporary or permanent. Recent literature is addressing these issues theoretically and numerically using DSGE models (see e.g. Nason and Rogers [2003]).

In this paper we take a different and less structured approach to the empirical analysis of the current account dynamics. Building upon Campbell and Mankiw [1989] and Lettau and Ludvigson [2001, 2004], we provide an empirical characterization of the link between net output, consumption and the accumulation of net foreign liabilities, with the goal of detecting whether the data support — if only qualitatively — the most basic propositions of current account theory. We focus our study on the dynamics of U.S. net foreign liabilities. For this country, we find that in the short run (for a horizon of up to 4 quarters), the dynamics of U.S. net foreign liabilities is strongly influenced by temporary disturbances that raise U.S. output and consumption together with U.S. net foreign assets — a pattern implied by the basic textbook model of the current account. Over longer horizons, permanent shocks take over: the dynamic behavior of net liabilities is dominated by shocks that increase net output and consumption in the long run associated with large accumulation of net foreign liabilities. As these shocks have a natural interpretation as technology innovations, this pattern is consistent with capital inflows in response to permanent innovations to productivity.

Relative to the traditional model (e.g. Mundell-Fleming), the dynamic response of the system to temporary shocks does not provide support to the hypothesis of a pro-cyclical deterioration of the current account. According to our empirical results, temporary output expansions are associated with external surpluses (not with deficits) in a quite robust way. Net external liabilities grow with output, instead, in response to permanent shocks to the system.

The largest share of the variance of U.S. net liabilities is explained by the permanent shock with long-run impact on net output at all horizons. According to our interpretation of this shock as a permanent productivity innovation, variance decomposition supports the view that, quantitatively, the current account is dominated by investment dynamics. Yet we are also providing evidence that consumption smoothing in response to temporary fluctuations of net output is non negligible, especially over horizons between one and four quarters.

Relative to present value and DSGE models in the literature, we derive our empirical framework by imposing a smaller set of equilibrium restrictions, namely, we make use of transversality conditions but not of the Euler equations from the representative national consumer's problem. So, we do not need to impose restrictive assumptions on preferences, i.e. specific functional forms for the utility function of the national representative consumer, thereby making our results consistent with a wide range of theoretical structures. By the same token, we do not need impose a constant interest rate — it is well understood that allowing for stochastic real interest rates improves the match between the model and the data (see for instance Bergin and Sheffrin [2000] and Nason and Rogers [2003]). In our analysis, the pattern of the impulse responses to permanent and temporary shocks for the U.S. is qualitatively consistent with basic predictions of the intertemporal approach to the current account: our results thus corroborate the view that the discouraging empirical performance of present-value models might well be due to auxiliary assumptions on preferences or asset returns.

We proceed as follows. As a preliminary step, we test a (weak) implication of the intertemporal budget constraint for the U.S.: under the plausible assumption that real rates of return are stationary, the budget constraint implies that consumption, net output and the stock of net foreign liabilities be cointegrated — a condition for which we find support in the data.

We then make use of the long-run restrictions implied by cointegration to identify empirically trend and cyclical components,[1] and relate these components to aggregate consumption, net output and foreign assets. As mentioned above, we find that in response to temporary shocks that raise U.S. net output, consumption also increases temporarily, but less than output. Hence, the economy runs a surplus and accumulates net foreign assets. Instead, a permanent shock that raises long-run per-capita net output leads to permanently higher per-capita consumption, but also raises net foreign liabilities. This is qualitatively in line with the effects of a permanent shock to productivity that raises U.S. returns above world level, thus raising domestic investment

[1] There are several studies that employ the restrictions implied by cointegration to identify specific innovations in a range of structural models (e.g. King et al. [1991], Melander et al. [1992]).

and attracting capital from abroad.

When using our full sample, for a horizon of four quarters, the transitory shock accounts for roughly 60 percent of the variance in net output, 35 percent of the variance in consumption and 15 percent of the variance in net foreign liabilities. At a horizon of twenty quarters ahead, the transitory shock keeps contributing a non negligible amount to the forecast error variance of these three variables. But at longer horizons the system is dominated by the two permanent shocks we identify in our analysis. At a horizon of forty quarters, the first of these permanent shocks accounts for roughly 80 percent of the variance in net output, 75 percent of the variance in consumption and 90 percent of the variance in net foreign liabilities. While these figures may vary depending on sample and model specification, we find that the order of magnitude of these shares remain stable across all our experiments.

The shocks that move the variables in our systems in either a permanent or a temporary fashion correspond to a variety of structural disturbances hitting the economy at either national or international level — the methodology employed in our paper does not allow identification of structural disturbances. But in some sense this strengthens the central message of our paper: shocks that result into temporary innovations in current output also raise current consumption and induce net foreign asset accumulation; permanent innovations that raise net output in long-run (by more than in the short run) are associated with current account deficits. However, our study does not distinguish between country-specific and global shocks. This distinction would be crucial in the analysis of small open economies. But since our case study is the U.S., we claim that such limitation of our analysis is not too consequential for our results. Because of the economic size of this country, most domestic shocks have global repercussions, but still have a clear asymmetric component relative to the rest of the world.[2]

The methodology we adopt in this paper proves useful in many promising areas of research in international finance. Notably, Gourinchas and Rey [2004] also build an open-economy empirical model following Campbell and Mankiw [1989] and Lettau and Ludvigson [2001, 2004]. Whereas we examine the adjustment of the capital account (current account) in response to shocks that hit the economy and focus on quantity adjustments, Gourinchas and Rey [2004] analyze the adjustment of the financial account towards the equilibrium through the adjustment of asset prices rather than quantities. Their results raise issues in the role of exchange rate movements in correcting external imbalances through valuation effects in the assets market.

The rest of the paper is organized as follows. Section 2 provides a theoretical motivation for our work. Section 3 lays out our empirical methodology. Section 4 presents our empirical results. Section 5 concludes.

[2] For an analysis of global vs. country-specific shocks see Glick and Rogoff [1995], and Iscan [2000]. Hoffmann [2001, 2003] is amongst the first contributions that exploits cointegration and the stationarity of the current account, in order to identify permanent and transitory global and country-specific shocks.

## 2 Intertemporal Budget Constraint and Common Trends in Consumption, Net Output and Foreign Debt

In our analysis, as in Campbell and Mankiw [1989] and Bergin and Sheffrin [2000], we derive an approximate expression for the budget constraint of a country by taking a first-order Taylor approximation of the intertemporal budget constraint, imposing the appropriate transversality conditions and taking expectations. In doing so, we assume that the portfolio share of foreign wealth in domestic private wealth is stationary — so that the expected value of this share exists.

Consider an open-economy in which all goods are traded. Domestic agents can borrow and lend in the international bond market at a time-varying (stochastic) real interest rate. The sequence of current account surpluses can be written as

$$B_{t+i+1} - B_{t+i} = Z_{t+i} - C_{t+i} + r_{t+i}B_{t+i}, \qquad i = 0, 1, ...; \; B_t : given \tag{1}$$

where $B_{t+i}$ is the stock of net foreign assets at the beginning of period $t+i$ and $r_{t+i}$ is the world real interest rate, which may vary over time. Define $R_{t,s}$ as the market discount factor for date $s$ consumption, so that

$$R_{t,s} = \left[ \prod_{j=t+1}^{s} (1 + r_j) \right]^{-1} \tag{2}$$

with $R_{t,t} = 1$. With optimizing national consumers, consumption plans will obey the following transversality condition:

$$\lim_{k \to \infty} E_t \left( R_{t,t+k} B_{t+k+1} \right) = 0. \tag{3}$$

Summing up the current account over all periods and using this optimality condition we then write an intertemporal budget constraint as:

$$\sum_{i=0}^{\infty} R_{t,t+i}C_{t+i} = B_t + \sum_{i=0}^{\infty} R_{t,t+i}Z_{t+i} \tag{4}$$

It is convenient to denote the present discounted value of consumption and net output as

$$\begin{aligned} \Phi_t &\equiv \textstyle\sum_{i=1}^{\infty} R_{t,t+i}C_{t+i} \\ \Psi_t &\equiv \textstyle\sum_{i=0}^{\infty} R_{t,t+i}Z_{t+i} \end{aligned}$$

Since the current account and the capital account satisfy the identity

$$CA_t + KA_t \equiv 0,$$

we can define $D_t = -B_t$ as the stock of net foreign liabilities, and write the intertemporal budget constraint as:

$$\Psi_t = D_t + \Phi_t. \tag{5}$$

It is then possible to derive an approximate expression for the above intertemporal budget constraint, by taking a first-order Taylor approximation of (5), imposing two transversality conditions and taking expectations.[3] Throughout this paper we use lower case letters to denote log variables (e.g., $c_t \equiv \ln(C_t)$ and $\phi_t \equiv \ln \Phi_t$) and define $r_t \approx \ln(1 + r_t)$. We obtain:

$$c_t - \frac{1}{\rho_{D\Psi}} z_t + \left(\frac{1}{\rho_{D\Psi}} - 1\right) d_t \approx$$
$$E_t \left\{ -\sum_{i=1}^{\infty} \rho_{C\Phi}^i \Delta c_{t+i} + \frac{1}{\rho_{D\Psi}} \sum_{i=1}^{\infty} \rho_{Z\Psi}^i \Delta z_{t+i} + \sum_{i=1}^{\infty} \rho_{C\Phi}^i r_{t+i} - \frac{1}{\rho_{D\Psi}} \sum_{i=1}^{\infty} \rho_{Z\Psi}^i r_{t+i} \right\}, \tag{6}$$

where $\rho_{D\Psi} \equiv 1 - \exp\left(\overline{d_t - \psi_t}\right)$, $\rho_{C\Phi} \equiv 1 - \exp\left(\overline{c_t - \phi_t}\right)$ and $\rho_{Z\Psi} \equiv 1 - \exp\left(\overline{z_t - \psi_t}\right)$. Let $KA_t^*$ denote the left-hand side of (6), i.e.

$$KA_t^* \equiv c_t - \varphi_z z_t + (\varphi_z - 1) d_t, \tag{7}$$

where $\varphi_z \equiv \frac{1}{\rho_{D\Psi}}$, or more generally

$$KA_t^* \equiv c_t + \beta_z z_t + \beta_d d_t.$$

Then we can write

$$KA_t^* = E_t \left\{ -\sum_{i=1}^{\infty} \rho_{C\Phi}^i \Delta c_{t+i} + \frac{1}{\rho_{D\Psi}} \sum_{i=1}^{\infty} \rho_{Z\Psi}^i \Delta z_{t+i} + \left( \sum_{i=1}^{\infty} \rho_{C\Phi}^i r_{t+i} - \frac{1}{\rho_{D\Psi}} \sum_{i=1}^{\infty} \rho_{Z\Psi}^i r_{t+i} \right) \right\}. \tag{8}$$

This expression shows that $KA_t^*$ embodies rational forecasts of interest rates (returns), consumption growth and net output growth. This is intuitively appealing, and expressions similar to (8) have been extensively examined in the literature, especially for testing present value relations of the current account (Bergin and Sheffrin, [2000]; Sheffrin and Woo [1990a], [1990b] - *inter alia*).

A few features of (8) need to be discussed. First, under the weak maintained hypothesis that the real rate of return $r_t$, $\Delta z_t$ and $\Delta c_t$ are covariance stationary, the budget constraint implies that the logs of consumption, net output and net foreign liabilities must be cointegrated. Even if net foreign wealth is non-stationary in levels (as predicted by standard infinite-horizon intertemporal model), the transversality condition (3) prevents it to wander away from net output and consumption.

Using a well known result by Campbell and Shiller [1987] in the framework of present-value models, if $Z_t$ is well characterized as an integrated process, then current account as the

[3] The two transversality conditions are:

$$\lim_{T\to\infty} \rho_{C\Phi}^T \left(c_{t+T} - \phi_{t+T}\right) \quad \to \quad 0$$
$$\lim_{T\to\infty} \rho_{Z\Psi}^T \left(z_{t+T} - \psi_{t+T}\right) \quad \to \quad 0$$

where $\phi_t \equiv \ln \Phi_t$ and $\psi_t \equiv \ln \Psi_t$. Details of the derivation and discussion are provided in Corsetti and Konstantinou [2005] — which is a complete technical appendix to accompany this paper.

discounted sum of expected changes in $Z_t$ will be stationary — this follows from the Wiener-Kolmogorov formula (see Sargent [1987]).[4] Essentially, we make use of this property of the current account in deriving empirical implications of the intertemporal budget constraint via a log-linear approximation of the present value relation in terms of $KA_t^*$. In line with the literature, $KA_t^*$ is stationary.

Second, the cointegrating residual is $c_t + \beta_d z_t + \beta_d d_t$, and the cointegrating parameters $\beta_z$ and $\beta_d$ are equal to the theoretical parameters $-\varphi_z$ and $(\varphi_z - 1)$. Observe that $\varphi_z$ is a function of the expected ratio of net foreign debt to domestic *private* wealth, defined as the present discounted value of output net of (private and public) gross investment and government consumption. In other words, $\varphi_z$ is a function of the average portfolio share of net foreign assets in domestic private wealth. When we log-linearize the intertemporal budget constraint, we assume that $\varphi_z$ (essentially $\exp\left(\overline{d_t - \psi_t}\right)$) is constant. This is in line with recent work by Kraay and Ventura [2000, 2002] and Ventura [2003], who advocate models of the current account allowing for international portfolio diversification in which the portfolio share of foreign wealth is constant. In these models, a constant $\varphi_z$ follows from a time-invariant $D_t/\Psi_t$. But we note that our methodology is valid under a much weaker condition: all we need is a well defined expected value of the ratio of net foreign debt to domestic *private* wealth. For instance, $\varphi_z$ is also constant when $D_t/\Psi_t$ varies over time following a stationary distribution.

In our econometric study below we are unable to reject the hypothesis that $\varphi_z$ is constant — which may correspond to a portfolio share of foreign assets in wealth that is either time-invariant, or (more plausibly) follows some stationary distribution. With a time varying $D_t/\Psi_t$, however, it is possible that a country switches its international net position during the sample period. Since in deriving our log-linear approximation we have assumed that no variable switches sign, a technical issue in applying our methodology to the U.S. is that this country is a net creditor in the first part of our sample, and becomes a net debtor during the 1980s.

Third, if the cointegrating relation on the left-hand-side of (8) is not constant, it must forecast either changes in rates of return, net output or consumption growth, or some combination of the three. In particular, (8) implies that the cointegrating residual $c_t + \beta_z z_t + \beta_d d_t$ should summarize expectations of future rates of return, net output and consumption growth, and provide a rational forecast of them. Strong versions of such predictive ability have been tested in the literature by means of the present value test of the current account.

The empirical approach we describe below simply exploits the above cointegrating relation — without imposing additional structure. As long as budget constraints hold, which is implied by the transversality conditions of the problem of the national representative consumer, a country's net output, consumption and net foreign debt should commove in the long run and therefore be

[4] The Wiener-Kolmogorov formula essentially states that for a covariance stationary process $Y_t$, with a Wold MA representation, $Y_t = \Upsilon(L)\, v_t$ and $\delta \in (0,1)$, then the MA representation for $X_t = \sum_{i=1}^{\infty} \delta^i \mathrm{E}_t Y_{t+i}$ is given by $X_t = \delta\left[\left(\Upsilon(L) - \Upsilon(\delta)\right)/(L-\delta)\right] v_t$.

cointegrated. In fact, as we discuss shortly, our empirical findings support this hypothesis.

# 3 Econometric Framework

A contribution of this paper consists of using cointegration to identify permanent and transitory components of consumption, net output and net foreign liabilities. To detail our approach, this section describes how we work towards isolating the permanent and transitory shocks of a $n$-dimensional cointegrated vector $\mathbf{x}_t$. In our application, $\mathbf{x}_t = (c_t, z_t, d_t)'$.

## 3.1 Data and Preliminary Analysis

In our empirical analysis, consumption, $C_t$, is real per-capita expenditure on nondurables and services.[5] Net output, $Z_t$, is gross domestic product net of investment, durable goods and government expenditure, expressed in real, per-capita terms. The stock of net foreign liabilities, $D_t$, is also expressed in real, per-capita terms. The variable $D_t$ is derived by cumulating the current account deficits over the sample period. We stress here that $D_t$ records more than bonds — as it includes the whole array of assets and liabilities traded internationally. Data limitations do not allow us to use series of net foreign liabilities allowing for capital gains and losses on a wide array of assets — as proposed by Lane and Milesi-Ferretti [2001]. Namely, the series built in this study is at a lower frequency (annual), and for a smaller sample than the one we adopt in our work. Yet we should note here that our series and the Lane & Milesi-Ferretti series are quite correlated.[6] A full description of the data is provided in the appendix.

Table 1 reports the summary statistics of the data. We carry out our analysis using variables in logs, i.e., $c_t$, $z_t$ and $d_t$, whereas we rescale the original series of net liabilities $D$ so that it becomes positive throughout the sample. The standard deviation of the quarterly net foreign liabilities growth is over ten times as high as that of consumption growth, and over four times as high as that of net output growth. The correlation between consumption and net output growth rate is roughly 0.4, while the growth rate of net liabilities is positively correlated with consumption growth and negatively correlated with net output growth — the correlation coefficient being equal to 0.05 and -0.08, respectively.

[Insert Table 1]

[5] Since we are mainly interested in the dynamics generated by consumption smoothing, we prefer to exclude expenditure on durables expenditure — as they replace (or add to) capital stock rather than buying a service flow from the existing capital stock. We include durable expenditure in investment.

[6] The correlation between our measure of net foreign liabilities and that reported in Lane and Milesi-Ferretti [2001] (based on adjusted cumulative current account) is 0.987.

### 3.2 Cointegration Analysis

We make use of the restrictions implied by cointegration to identify the permanent and transitory components of the three variable system, $\mathbf{x}_t$. Identification is possible because cointegration places restrictions on the long-run multipliers of the shocks in a model where innovations are distinguished by their degree of persistence, as shown, for example, in Gonzalo and Granger [1995], Johansen [1995], King *et al.* [1991], and Mellander *et al.* [1992]. While this approach does not identify structural shocks,[7] it will yield results that have some natural structural interpretation.

The procedure we follow takes several steps. We first estimate the VEqCM, then use the estimated parameters to back out the long-run restrictions. To obtain a correctly specified VEqCM, we test for the presence and the number of cointegrating relations in $\mathbf{x}_t$. Results are presented in Appendix B (Table 4). Based on standard unit root tests,[8] we assume that all the variables contained in $\mathbf{x}_t$ are at most integrated of order one, i.e. $I(1)$. The results in Appendix B (Table 4) suggest the presence of one cointegrating relation in the data. We therefore impose one cointegrating relation in our VEqCM specification.[9] Normalizing the cointegrating coefficient on consumption to one, we denote the single cointegrating vector for $\mathbf{x}_t$ as $\boldsymbol{\beta} = [1, \beta_z, \beta_d]'$. We obtain estimates of the cointegrating parameters $\boldsymbol{\beta} = (1, \beta_z, \beta_d)'$ using maximum likelihood (Johansen, [1995]), which generates "superconsistent" estimates of $\beta_z$ and $\beta_d$. Using "hats" to denote estimated values of parameters, we have $\widehat{\beta}_z = -1.759$ and $\widehat{\beta}_d$=0.097 — with associated $t$-statistics equal to -9.88 and 2.85 respectively.

Observe that the coefficients $\hat{\boldsymbol{\beta}}$ have the right sign and satisfy an important inequality. The estimated coefficient on $z_t$ is negative and larger than one; similarly, the coefficient of $d_t$ is positive and larger than zero. Both estimated coefficients thus imply that $\rho_{D\Psi} = 1 - \overline{(D_t/\sum_{i=0}^{\infty} R_{t,t+i}Z_{t+i})} < 1$. That is, on average, the value of net foreign debt is strictly smaller than the present value of net output. From our theoretical discussion in section 2, $\widehat{\beta}_z$ should be equal to $(1/\rho_{D\Psi})$, and $\widehat{\beta}_d$ to $(1/\rho_{D\Psi} - 1)$. Hence, the log-linearized budget constraint in section 2 implies that these coefficients should sum to minus one. In our sample this (over-identifying) restriction is rejected at conventional significance levels, as we obtain $Q(1) = 9.20$ distributed as a $\chi^2(1)$ with asymptotic $p$-value of [0.002] and bootstrap $p$-value of [0.028] (see also Panels B and C of table 2). Lettau and Ludvigson [2001, 2004] argue that testing such restrictions in empirical implementations of similar models is sensitive to measurement errors. Specifically,

[7] Strictly speaking, cointegration allows us to find a suitable rotation that maps reduced form shocks $\mathbf{u}_t$ into shocks $\mathbf{e}_t$, such that $n - r$ of them have permanent effects on $\mathbf{x}_t$ and the rest $r$ have only a transitory effect on $\mathbf{x}_t$. But as explained in King *et al.* [1991] and Mellander *et al.* [1992], if some structural shocks are assumed to be permanent and some transitory, then cointegration can considerably reduce the number of restrictions that need to be imposed to identify the shocks.

[8] Results are available upon request.

[9] The Johansen [1995] cointegration tests are based on a VAR with two lags selected using standard information criteria and likelihood ratio tests.

nondurable consumption flows are not directly observable and need to be proxied; by the same token, our measure of net foreign liabilities is a rough proxy of the true variable. In our case study, it turns out that tests result are sensitive to sample specification — the restriction is not rejected when we exclude the last few observations (see our discussion of robustness checks in Section 4 below). Yet when we test for parameter instability in the cointegrating relation, we cannot detect signs of parameters instability in our sample.[10]

Under the cointegrating restrictions one can estimate a VEqCM representation for $\mathbf{x}_t$ which takes the form

$$\boldsymbol{\Gamma}(L)\,\boldsymbol{\Delta}\mathbf{x}_t = \boldsymbol{\delta} + \boldsymbol{\alpha}\hat{\boldsymbol{\beta}}'\mathbf{x}_{t-1} + \mathbf{u}_t, \tag{9}$$

where $\boldsymbol{\Delta}\mathbf{x}_t$ is the vector of log first differences, $(\Delta c_t, \Delta z_t, \Delta d_t)'$, $\boldsymbol{\delta}$ and $\boldsymbol{\alpha} \equiv (\alpha_c, \alpha_z, \alpha_d)'$ are $(3 \times 1)$ vectors, $\hat{\boldsymbol{\beta}} \equiv (1, \beta_z, \beta_d)'$ is the $(3 \times 1)$ vector of the cointegrating coefficients discussed above, and $\boldsymbol{\Gamma}(L)$ is a finite matrix polynomial in the lag operator.

The term $\hat{\boldsymbol{\beta}}'\mathbf{x}_{t-1}$ gives the previous period equilibrium error; $\boldsymbol{\alpha}$ is the vector of "adjustment" coefficients (or loadings) that tells us which of the variables react to the previous periods' equilibrium error (cointegrating residual); that is, which of the variables, and by how much, adjust to restore the equilibrium relation $\boldsymbol{\beta}'\mathbf{x}_{t-1}$ back to its mean when a deviation occurs. By virtue of the Granger Representation Theorem (see Engle and Granger [1987]), if a vector of variables $\mathbf{x}_t$ is cointegrated, then at least one of the adjustment parameters in the $(3 \times 1)$ vector $\boldsymbol{\alpha}$ must be non-zero in the VEqCM representation (9). Thus if $x_i$ does at least some of the adjusting needed to restore the long-run equilibrium subsequent to a shock that distorts this equilibrium, then the parameter $\alpha_i$ should be different from zero in the equation for $\Delta x_i$ in the VEqCM representation (9).

The results from estimating the first-order specification (9) are presented in table 2. Panel A of table 2 shows the estimated VEqCM, with the associated $t$-statistics, adjusted $R^2$ and a set of misspecification statistics for each equation. Panel B shows the estimated unrestricted cointegrating vector and the associated standard errors. Panel C shows the estimated (restricted) cointegrating vector, the relevant standard errors for the coefficients as well as the likelihood ratio test statistic for the restriction on $\hat{\boldsymbol{\beta}}$. Note first that all variables show evidence of strong equilibrium correction, with log net foreign liabilities displaying the largest (in absolute value) adjustment to the disequilibrium error. Specifically all variables do much of the adjustment following a shock that caused them to deviate from their long-run stochastic trends. Second, consumption growth is predictable by lagged consumption growth, and the equilibrium error; net output growth is predictable by lagged net foreign liabilities growth and the equilibrium error; finally, net liabilities growth is predictable by its own growth rate and the cointegrating error term. These results imply that there is short-run predictability of all the variables in the system and much of it is attributable to the fact that all variables adjust to restore the equilibrium

[10] In order to conserve space, cointegrating parameter stability tests and short-run parameter stability test are presented in Corsetti and Konstantinou [2005].

error, $\hat{\boldsymbol{\beta}}'\mathbf{x}_t$, back to its mean. Furthermore, this short-run predictability suggests that there are important transitory components in all three variables in our system. We further explore this issue below.

`[Insert Table 2 about here]`

### 3.3 Permanent and Transitory Decomposition

Cointegration between the variables in our system may be used to decompose $\mathbf{x}_t$ into shocks that are very persistent (permanent) and shocks that are transitory. Since $\mathbf{x}_t$ has three elements, and we find a single cointegrating vector, this implies that there are two common stochastic trends (Stock and Watson [1988]), or, alternatively, that there are two permanent shocks and one transitory shock. Our identification is achieved in two steps. Specifically, cointegration restricts the matrix of long-run multipliers of shocks in the system, which identifies the permanent components. The transitory components are identified in a 'residual' manner. In order to study the dynamic impact of the transitory innovations, it is assumed that they are orthogonal to the permanent innovations.

It is useful to review our methodology in some detail, and explain how it is related to our application. From the Granger Representation Theorem it follows that, under the maintained hypothesis that the growth rates in $\mathbf{x}_t$ are covariance stationary, there exists a multivariate Wold representation of the form

$$\boldsymbol{\Delta}\mathbf{x}_t = \boldsymbol{\kappa} + \mathbf{C}(L)\,\mathbf{u}_t, \tag{10}$$

where $\mathbf{C}(L)$ is a $3\times3$ matrix polynomial in the lag operator. We want to map these $n = 3$ reduced form innovations, $\mathbf{u}_t$, into transformed innovations $\mathbf{e}_t$ that are distinguished by whether they have permanent or transitory effects. Without loss of generality the shocks $\mathbf{e}_t$ are ordered so that the first $n-r$ of them have permanent effects; and the last $r$ of them have transitory effects. Following Gonzalo and Granger [1995], we define a shock $\mathbf{e}_t^P$ as permanent if $\lim_{h\to\infty} \partial E(\mathbf{x}_{t+h})/\partial\mathbf{e}_t^P \neq 0$, and a shock $\mathbf{e}_t^T$ as transitory if $\lim_{h\to\infty} \partial E(\mathbf{x}_{t+h})/\partial\mathbf{e}_t^T = 0$.

Applying the methodology of King *et al.* [1991], as extended by Mellander *et al.* [1992], the permanent and transitory innovations may be identified using the estimated parameters of the VEqCM representation (9) of a cointegrated system. Essentially, cointegration implies that the matrices $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are each of dimension $n\times r$ and have full rank $r < n$, (here they are just vectors since $r = 1$). Let $\boldsymbol{\alpha}_\perp$ and $\boldsymbol{\beta}_\perp$ be $n \times (n-r)$ matrices orthogonal to $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ respectively (that is $\boldsymbol{\alpha}'_\perp\boldsymbol{\alpha} = \mathbf{0}$ and $\boldsymbol{\beta}'_\perp\boldsymbol{\beta} = \mathbf{0}$ respectively). From the Granger Representation Theorem, it follows that $\boldsymbol{\beta}'\mathbf{C}(1) = \mathbf{0}$ and $\mathbf{C}(1)\,\boldsymbol{\alpha} = \mathbf{0}$. In particular, as explained in Johansen [1995], the matrix $\mathbf{C}(1)$ of the Wold representation (10), admits a closed-form solution in terms of the parameters of the VEqCM (9), namely:

$$\mathbf{C}(1) = \boldsymbol{\beta}_\perp \left(\boldsymbol{\alpha}'_\perp \boldsymbol{\Gamma}(1)\,\boldsymbol{\beta}_\perp\right)^{-1} \boldsymbol{\alpha}'_\perp. \tag{11}$$

Note that the structure of this matrix is such that it maps reduced-form disturbances $\mathbf{u}_t$ into the space spanned by the columns of $\boldsymbol{\alpha}_\perp$ i.e. $sp(\boldsymbol{\alpha}_\perp)$. The disturbances $\boldsymbol{\alpha}'_\perp \mathbf{u}_t$ accumulate to the permanent component of $\mathbf{x}_t$, whereas transitory disturbances will be in the null-space of $\mathbf{C}(1)$. We can therefore define the permanent disturbances (permanent shocks) as:

$$\mathbf{e}_t^P = \boldsymbol{\alpha}'_\perp \mathbf{u}_t. \tag{12}$$

Then by requiring that the permanent and transitory shocks be orthogonal to each other, we can define the transitory shocks as:[11]

$$\mathbf{e}_t^T = \boldsymbol{\alpha}'\boldsymbol{\Omega}^{-1}\mathbf{u}_t. \tag{13}$$

Denoting

$$\mathbf{P} = \begin{bmatrix} \boldsymbol{\alpha}'_\perp \\ \boldsymbol{\alpha}'\boldsymbol{\Omega}^{-1} \end{bmatrix} \tag{14}$$

the transformed (permanent and transitory) shocks are given by

$$\mathbf{e}'_t = \begin{bmatrix} \mathbf{e}_t^{P\prime} & \mathbf{e}_t^{T\prime} \end{bmatrix} = \mathbf{P}\mathbf{u}_t. \tag{15}$$

It follows that

$$Var(\mathbf{e}_t) = diag\left\{Var\left(\mathbf{e}_t^P\right), Var\left(\mathbf{e}_t^T\right)\right\} = \begin{bmatrix} \boldsymbol{\alpha}'_\perp \boldsymbol{\Omega} \boldsymbol{\alpha}_{\perp\ (n-r)\times(n-r)} & \mathbf{0}_{(n-r)\times r} \\ \mathbf{0}_{r\times(n-r)} & \boldsymbol{\alpha}'\boldsymbol{\Omega}^{-1}\boldsymbol{\alpha}_{\ r\times r} \end{bmatrix} = \mathbf{P}\boldsymbol{\Omega}\mathbf{P}'. \tag{16}$$

Observe that we have achieved both a rotation from reduced-form shocks to permanent and transitory shocks, and orthogonalization.[12] Letting $\mathbf{D}(L) = \mathbf{C}(L)\mathbf{P}^{-1}$, and $\mathbf{e}_t = \mathbf{P}\mathbf{u}_t$, the transformed Wold representation is

$$\boldsymbol{\Delta}\mathbf{x}_t = \boldsymbol{\kappa} + \mathbf{C}(L)\mathbf{P}^{-1}\mathbf{P}\mathbf{u}_t = \boldsymbol{\kappa} + \mathbf{D}(L)\mathbf{e}_t. \tag{17}$$

Thus each element of $\boldsymbol{\Delta}\mathbf{x}_t$ has been decomposed into a function of $n-r=2$ permanent and $r=1$ transitory shocks. With this decomposition, the level of $\mathbf{x}_t$ can be written as the sum of $n-r$ I(1) common factors (permanent component), and $r$ I(0) transitory components.[13]

[11] This is a rather innocuous assumption. See Quah [1992] for a discussion.

[12] An alternative scheme for identifying permanent and transitory shocks is due to Gonzalo and Ng [2001]. A problem with this approach is that the matrix that achieves the permanent-transitory decomposition is

$$\mathbf{G} = \begin{bmatrix} \boldsymbol{\alpha}'_\perp \\ \boldsymbol{\beta}' \end{bmatrix},$$

which is not guaranteed to have full rank in all cases. See Johansen [1995], exercise 4.3, for a counter-example. In contrast, the matrix $\mathbf{P}$ that we employ is always guaranteed to have full rank.

[13] The $n-r$ common factors in the Granger-Gonzalo/ Gonzalo-Ng decomposition described above are determined by $\boldsymbol{\alpha}'_\perp \mathbf{x}_t$. This permanent component may contain serial correlation around the random walk component given by the multivariate Beveridge-Nelson decomposition. Alternatively, as explained in Proietti [1997] taking into

# 4 Dynamic Analysis of Temporary and Permanent Shocks

## 4.1 Permanent and Transitory Shocks on Consumption, Net Output and Net Foreign Debt

Using the permanent-transitory decomposition discussed in section 3, it is straightforward to investigate how each of the variables in our system is related to permanent and transitory shocks. This decomposition can be understood by looking at the properties of the matrix $\mathbf{P}$ in (14) that achieves the rotation from the reduced form to permanent and transitory shocks. Intuitively, any variable $x_j$ participates little in the equilibrium correction when $\alpha_j$ is small in absolute value, so that the element of $\boldsymbol{\alpha}'_{\perp}$ that multiplies $u_{jt}$ is large in absolute value. In this case $x_j$ has a large weight in the permanent and a small weight in the transitory innovations. Conversely, $x_j$ has a small weight in the permanent innovations and a large weight in the transitory innovations when $\alpha_j$ is large — implying that the element of $\boldsymbol{\alpha}'_{\perp}$ that multiplies $u_{jt}$ is small in absolute value. Recall that variables have a large transitory component when they do much of the adjustment needed to restore equilibrium back to its mean. This is an intuitively appealing property because any variable that does at least some of the adjustment required to bring the equilibrium relation back to its mean must have deviated from its trend, hence contains a transitory component. In our application, the elements of the adjustment vector $\boldsymbol{\alpha}$ are all relatively large and statistically significant (see Table 2), implying that all the variables have a non-negligible weight in the transitory innovations.

Cointegration and the identification of permanent and transitory shocks impose the restriction that the last column of the $\mathbf{D}(1) = \mathbf{C}(1)\mathbf{P}^{-1}$ matrix is a zero vector. The assumption of orthogonality between permanent and transitory shocks is sufficient to identify the single transitory shock. Hence, we need an extra restriction to identify econometrically the shocks in our three-variable system.[14]

We adopt the following long-run restriction to identify the two permanent shocks — denoted $\eta^P_{1t}$ and $\eta^P_{2t}$. The first permanent shock is the only disturbance that is allowed to have a long-run effect on net output per capita, $z_t$. Hence, it has a natural interpretation as a *permanent technology shock*. More generally, this shock can be read as a linear combination of structural shocks that result into a permanent change in net output. The second permanent shock in our baseline model structure has long-run impact on consumption and net foreign wealth, but no

account the short-run dynamics of the systems, as these are captured by the lag polynomial $\mathbf{\Gamma}(L)$, one may use the identity

$$\mathbf{x}_t = \mathbf{C}(1)\mathbf{\Gamma}(1)\mathbf{x}_t + \{\mathbf{I}_n - \mathbf{C}(1)\mathbf{\Gamma}(1)\}\mathbf{x}_t,$$

where the $n-r$ common factors are given by $\mathbf{C}(1)\mathbf{\Gamma}(1)\mathbf{x}_t$.

[14] Essentially, taking advantage of the assumption of orthogonality among structural shocks, one needs $(n-r)\times((n-r)-1)/2 = (3-1)\times((3-1)-1)/2 = 1$ restriction to identify the permanent shocks and $r(r-1)/2 = 0$ restrictions to identify the transitory shocks, relative to the total of $n(n-1)/2$ usually needed in structural VAR (SVAR) applications.

persistent effect on output. Note that $\eta^P_{1t}$ and $\eta^P_{2t}$ are identified by imposing a single restriction on $\mathbf{D}(1)$. The transitory shock — denoted by $\eta^T_{3t}$ — only affects net output in the short run, and can therefore be read as a linear combination of structural shocks that lead to transitory changes in $z_t$ — including *temporary technology shocks and demand shocks*. Recall that the transitory shock is orthogonal to the other two shocks.[15]

## 4.2 Variance decompositions

Table 3 reports the fraction of the total variance in the forecast error of $\Delta z_t$, $\Delta c_t$, and $\Delta d_t$ that is attributable to the two permanent shocks $\eta^P_{1t}$ and $\eta^P_{2t}$, and the transitory shock $\eta^T_{3t}$. We report variance decompositions and impulse responses. To quantify sampling uncertainty we use a bootstrap Monte Carlo procedure. Specifically, Table 3 displays the fraction of the $h$-step ahead forecast-error variance in net output, consumption and net foreign debt that is attributable to the two permanent shocks and to the single transitory shock. For $h = 1, 2, ...$ and $h \rightarrow \infty$ we compute the portion of the total variance of each variable that is attributable to each disturbance.

For a horizon of one to four quarters ahead, the transitory shock accounts for a portion between 74 and 63 percent of the variance in net output, between 45 and 33 percent of the variance in consumption and between 29 and 15 percent of the variance in net foreign liabilities. At a horizon of eight to twenty quarters ahead, the transitory shock continues to contribute a considerable amount to the forecast error variance of the three variables in the system (respectively, between 52 and 28 percent, between 24 and 11 percent, and between 10 and 6 percent). However, it is the two permanent shocks that now account for the largest portion of variance. At a horizon of forty quarters, the first permanent shock accounts for 79 percent of the variance of net output, 73 percent of the variance of consumption and 87 percent of the variance of net foreign liabilities. The second permanent shock accounts for 23 percent of the variance of consumption, whereas it has a negligible contribution to the variance of the other two variables (roughly 9 percent). Notably, at a horizon of forty quarters, the transitory shock still contributes between 4 and 12 percent to the variance of the three variables, although the point estimates are insignificant. Finally, the two permanent shocks account for the total of the long-run error variance in all variables,[16] with the first permanent shock accounting for 74 and 71 percent of the variance of consumption and net foreign liabilities, respectively.

The finding that transitory shocks accounts for a non negligible share of the total variation in all the variables at relatively short horizons should be appropriately emphasized. Namely, temporary shocks account for most output movements for a horizon up to 8 quarters. Their

[15] By construction the third identified shock of the system is the transitory shock, i.e. $\eta^T_{3t} \equiv e^T_{3t}$.

[16] The property that only permanent shocks affect the variables in the long-run, whereas transitory do not, follows from cointegration and is not specific to the rotation of the shocks we have chosen. See also Gonzalo and Ng [2001] for a discussion.

impact is also sizeable, but less pronounced, on consumption. As a result, the temporary shocks explain a non-negligible share of the variance of net liabilities, especially in the very short run. However, the importance of temporary shocks in driving net liabilities tends to decline rapidly, from 29 percent over a one-quarter horizon down to 15 percent over a one year horizon, and to 10 percent over a two-year horizon.

The largest share of the variance of net liabilities is explained by the first permanent shock at all horizons. Consistent with our interpretation of this shock, variance decomposition supports the view that, quantitatively, the current account is dominated by investment dynamics. Yet we are also providing evidence that consumption smoothing in response to temporary fluctuations of net output is non negligible, especially over short horizons between one and four quarters. Moreover, in line with the incomplete-market model of the current account (predicting lasting changes in the net asset position in response to temporary shocks), relatively small effects of consumption smoothing are to be found over very long horizons, up to 20 or 40 quarters.

[Insert Table 3 about here]

### 4.3 Impulse responses

Impulse responses are shown in figures 1 to 3. In each figure we plot the accumulated impulse response of $\Delta z_t, \Delta c_t$ and $\Delta d_t$ and the associated bootstrap confidence bands.[17]

Before delving into a discussion of our results, we should stress an important difference between our analysis and present value models of the current account. These models are usually derived by adopting some particular specification of the preferences of the national representative consumer. Thus they lead to empirical frameworks that test whether consumption and current account movements are quantitatively consistent with theory, conditional on tastes specification. As we do not specify preferences, we limit ourselves to verify whether the impulse responses in figure 1 to 3 are *qualitatively* consistent with the prediction of the current account models. We will therefore focus our discussion on the sign and shape of the impulse response functions.

#### 4.3.1 Transitory shocks

Figure 1 shows the response of all the variables to a positive transitory shock raising net output temporarily. Both consumption and net output rise on impact, but consumption rises by less than net output. Correspondingly, the country runs a current account surplus and accumulates foreign assets: net foreign liabilities jump down on impact and remain negative for at least ten years.[18]

[17] In our plots we employ Hall's [1992] percentile intervals as explained in Benkwitz et al. [2001], which in has certain theoretical advantages relative to the standard percentile interval that is commonly employed.

[18] Moreover, as a check on our results, we have used alternative methodologies to calculate confidence intervals around our estimates. The confidence bands, if anything, become smaller.

The sign of these impulse-responses is consistent with the prediction of the simplest intertemporal models of the current account, in which national agents use foreign borrowing and lending to smooth consumption in the face of temporary shocks to their net output — see e.g. Obstfeld and Rogoff [1996], chapter 2 and chapter 3, whereas in overlapping generation models the effect on foreign assets and consumption disappears over time. While most of the analysis is developed in highly stylized models of a small open economy, the same principle also applies in the case of a large economy such as the U.S. economy.

Strikingly, Figure 1 does not lend support to procyclical current account deficits in response to temporary shocks. Temporary output expansions are not associated with a widening of the external imbalance, as implied by traditional models stressing the role of demand shocks (e.g. government spending) in generating business cycle fluctuations.

Observe that, in light of our evidence on cointegration and our assumption of orthogonality between permanent and transitory shocks, our conclusions regarding the effects of the transitory shock are invariant to alternative ways to identify the two permanent shocks in the system, shown in Figures 4 and 5 below.

`[Insert Figure 1 about here]`

#### 4.3.2 Permanent shocks

Figure 2 shows the impulse responses to the first permanent shock — that, we argued above, has a natural interpretation as a technology shock. Consumption increases on impact and keeps increasing over time. Net output also increases on impact, but by less than consumption; it then grows faster, increasing by at least as much in the long-run as consumption. The permanent shock raises net foreign liabilities on impact. These keep increasing for a period of four years after the shock, then revert to a lower level in the long run, but strictly above zero.

According to the standard intertemporal model, permanent productivity shocks that raise per capita output in the long run also raise the stock of net foreign liabilities: high returns to domestic capital raise domestic investment, while higher permanent income tends to reduce domestic saving, creating a current account deficit.[19] The higher rate of return to domestic capital also attracts foreign investment, corresponding to the accumulation of net foreign liabilities. The impulse responses in Figure 2 are qualitatively consistent with this prediction.

It is well known that if net output growth can be adequately described by an autoregressive process, a positive shock $\epsilon_t$ to net output (resulting in future net output levels that rise by more than $\epsilon_t$) will increase permanent output more than current output. Consumption smoothing then implies that consumption should increase by more than current output. As a result, a

[19] Although not reported in the paper, we have experimented with an empirical model that allows for explicit investment dynamics, by modelling the vector of variables $\tilde{\mathbf{x}}_t = [\log(Y_t - G_t), \log(I_t), \log(C_t), \log(D_t)]'$. See our discussion bellow.

positive output innovation implies a current account deficit, rather than a surplus as predicted by the model conditional on stationary output shocks (e.g., see Obstfeld and Rogoff, 1996, p. 84). Our impulse responses in Figure 2 are strikingly consistent with this interpretation. For the first permanent shock hitting the system, $c_t$ increases by more than net output over many quarters, thereby opening current account deficits.

Moreover, given that the U.S. is large in the world economy, a shock raising U.S. productivity and/or U.S. demand (i.e. reducing U.S. net saving) would put upward pressure on the world real interest rate. To the extent that the upsurge in the U.S. demand translates into a temporary higher real rate of return, the consumption Euler equation implies that the marginal utility of U.S. consumption should fall gradually along the transition path. Consistent with this view, as shown by the figure the U.S. consumption increases gradually in response to the shock.

Figure 3 shows the responses of our variables to the second permanent shock. This shock leads to a temporary small decrease in net output, which goes back to its initial level — allowing for sampling uncertainty — after six years, whereas consumption increases gradually to a new higher long-run level. Net foreign liabilities fall, although the response to the shock is not significant for a period of about three years. Eventually, however, they become negative, implying accumulation of net foreign assets.

The impulse responses in Figure 3 are puzzling. One could observe that the impulse-responses are qualitatively consistent with terms of trade appreciation and/or asset valuation shocks, raising consumption in the long run, while having a transitory negative effect on domestic output. In deriving our empirical model, however, we do not explicitly account for terms of trade and relative price effects and, as discussed above, our constructed proxy for the time series of net foreign liabilities, $d_t$, does not account for capital gains or losses. Relative goods and asset prices clearly impact the intertemporal decisions by domestic and international agents, and our result may in part capture these effects despite the empirical limitations of our variables. We conclude by noting that the second permanent shock in our baseline model explains a fairly small portion of the variance of consumption, output and net debt.

[Insert Figure 2 and 3 about here]

#### 4.3.3 Alternative identification assumptions

Relative to our baseline model, there are other ways to identify permanent shocks in our system. In what follows we will briefly discuss alternative identification assumptions. It is worth mentioning once again that, since the temporary shock is orthogonal to the other two shocks, the system's response to the temporary shock is independent of the changes in identification studied below. So, we will not need to comment on the results regarding this shock.

A first alternative to the identification scheme in our benchmark consists of assuming that the first permanent shock is the only shock that has a long-run effect on $d_t$ — this shock could be dubbed as a 'portfolio shift' shock —, while the second permanent shock has only a long-run effect on $z_t$ and $c_t$. Results are shown by Figure 4.

The effects of the first permanent shock — the portfolio shift shock — are similar to the effects of permanent technology shock discussed in the previous section. Net output grows gradually towards a new higher level. Consumption rises on impact and keeps growing, although its long-run level appears not to be significantly different from its initial level. Net foreign debt grows until it reaches its new steady state in five years; it seems to decline gently afterwards (see figure 4, first column). As discussed above, these impulse responses are qualitatively consistent with permanent productivity shocks that increase long-run output, raising consumption and domestic investment, corresponding to current account deficit.

The impulse responses for the second permanent shock depict a somewhat similar picture. Net output drops in the short run but then rises above zero, becoming significantly positive after four years. Consumption rises significantly both in the short run and in the long run, with gradual increments over time. The stock of net foreign liabilities rises reaching a peak after two years, then gradually decreases converging slowly to its initial level. Using the new identification scheme, the effects of the second permanent shock are also qualitatively similar to the effects of the first permanent shock — although this shock does not seem to have a long-run impact on foreign wealth.

A second possible alternative to the identification scheme in our benchmark consists of assuming that the first permanent shock is the only shock that has a long-term effect on $c_t$, while the second permanent shock has only a long-run effect on $z_t$ and $d_t$. Note that it is quite difficult to give an economic interpretation to the second permanent shock. The first one, instead, could still be interpreted as a permanent productivity shock, affecting positively the three variables in the system. Indeed, the impulse responses for this shock shown in Figure 5 are broadly in line with the corresponding impulse responses discussed above. The second permanent shock produces significant upward movements in net output and liabilities for an unchanged consumption level.

[Figures 4 and 5 about here]

Overall, these results suggest that the effects of the first permanent shock are quite robust to changes in identification schemes — a conclusion that is confirmed in a number of additional experiments we have conducted.

### 4.3.4 Additional robustness experiments

To check robustness, we have carried out two sets of experiments — analyzed in detail in Corsetti and Konstantinou [2005]. A first set of experiments consists of verifying the robustness of our results to changes in the sample size. In particular, many analysts argue that the second half of the 1990s is characterized by an asset pricing bubble driving the boom of assets markets in the

U.S. and elsewhere. A bubble has strong implications for the intertemporal budget constraint — as deficits are at least in part financed by issuing ultimately worthless assets. This consideration raises the important issue of whether our results are sensitive to the inclusion of the last part of our sample into the analysis. To address this issue, we have run our model on a sample truncated in 1995, i.e. the new sample runs from the first quarter of 1963 to the fourth quarter of 1995.[20] The pattern of impulse responses for the three shocks is virtually identical to the ones shown by Figures 1 to 3, although the exact magnitudes of the responses differ especially regarding the second permanent shock. The role of the first shock is somewhat less pronounced in variance decomposition exercise at long horizons as far as net output and net foreign liabilities are concerned. In Corsetti and Konstantinou [2005] we also run the model by measuring net foreign liabilities in deviations from mean, rather than rescaling the variable and taking logs.

An important conclusion emerging from this set of experiments is that our main results regarding the response of the system to the first permanent shock and the temporary shock are virtually unaffected by using a shorter sample, and measuring net foreign liabilities in deviations from its sample mean rather than in logs.[21] We interpret this as empirical evidence that qualitatively lends support to the intertemporal approach to the current account.

A second set of experiments consists of carrying out our analysis by using a four-variable model, including investment as a separate variable. The question is whether investment behavior will be in accord to our interpretation of the first permanent shock as a permanent technology innovation. While the econometric framework of a four-variable model differs from the above in a number of dimensions, in Corsetti and Konstantinou [2005] we find that permanent shocks that raise consumption and output net of government spending also raise net foreign liabilities and investment. Investment increases immediately, and reaches a peak after approximately one year; afterwards it declines towards a higher long-run level, consistent with a stationary 'great ratio' between investment and the level of output. Relative to our results using a three-variable model, the valuable additional information is that investment behavior is indeed consistent with our interpretation of the shock as a domestic technology shock, and in accord to standard open economy models.

## 5 Conclusion

This paper explores the empirical link between consumption, net output and net foreign liabilities/assets. The literature has shown that such link cannot be understood without distinguishing between trend and cycles. In this paper, we use the intertemporal budget constraint for a country to derive a linear model in the three variables above, and take an empirical approach to

[20] As mentioned in Section 3, we cannot reject the over-identifying restriction that $\beta_z + \beta_d = -1$.

[21] Another question is whether results may be sensitive to the degree of financial liberalization. Splitting the sample in the 1980s (results available upon request) does not substantially affect our results.

identifying transitory and permanent shocks.

Focusing our study on the U.S., we find that the data appear to support the most basic propositions of current account theory. First, in response to a permanent shock that raises per capita net output permanently, per-capita consumption and the stock of net foreign liabilities also increase permanently. This dynamic behavior is qualitatively consistent with permanent shocks to productivity that drive U.S. returns above world level, increasing both domestic investment and consumption, and attracting capital from abroad. Conversely, temporary output gains in the U.S. are associated with foreign asset accumulation.

Overall, our empirical characterization of the response to shocks of U.S. consumption, net output and net foreign liabilities are qualitative consistent with consumption smoothing via intertemporal trade. It is instead at odds with models associating temporary output expansions with pro-cyclical deterioration of the external balance.

Looking at variance decomposition, we find that long-run movements in net output, consumption and net foreign liabilities are mostly driven by permanent shocks over long horizons. But short-term changes in net foreign liabilities with transitory nature also seem to play a significant role in consumption smoothing. A contribution of this paper is to document the total quantity of variation in net foreign liabilities that is transitory, specifying the extent to which this follows from transitory variations of macroeconomic aggregates such as consumption and net output.

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## Tables

Table 1: **Summary Statistics**

| | $\Delta c_t$ | $\Delta z_t$ | $\Delta d_t$ |
|---|---|---|---|
| Univariate Summary Statistics | | | |
| Mean ($\times$100) | 0.550 | 0.536 | 1.688 |
| Standard Deviation ($\times$100) | 0.452 | 1.007 | 4.618 |
| Correlation Matrix | | | |
| $\Delta c_t$ | 1.000 | 0.433 | 0.050 |
| $\Delta z_t$ | | 1.000 | -0.081 |
| $\Delta d_t$ | | | 1.000 |

NOTES for Table 1: This table reports summary statistics for quarterly growth of consumption $\Delta c_t$, net output $\Delta z_t$, and the net foreign liabilities growth rate $\Delta d_t$, where all variables are expressed in real, per-capita terms. The sample spans the first quarter of 1963 to the fourth quarter of 2002.

Table 2: **Estimates from a Cointegrated VAR(2)**

**Panel A: Cointegrated VAR**

| | Equation | | |
|---|---|---|---|
| | $\Delta c_t$ | $\Delta z_t$ | $\Delta d_t$ |
| Dependent Variable | | | |
| $\Delta c_{t-1}$ | **0.326** | -0.256 | 1.540 |
| $(t-stat.)$ | [3.904] | [−1.297] | [3.469] |
| $\Delta z_{t-1}$ | -0.011 | -0.114 | -0.241 |
| $(t-stat.)$ | [−0.323] | [−1.371] | [−1.290] |
| $\Delta d_{t-1}$ | 0.008 | **0.040** | **0.832** |
| $(t-stat.)$ | [1.076] | [2.351] | [21.579] |
| $\hat{\boldsymbol{\beta}}'\mathbf{x}_{t-1}$ | **0.013** | **0.039** | **-0.055** |
| $(t-stat.)$ | [3.765] | [4.862] | [−3.050] |
| $\delta$ | **0.086** | **0.257** | **-0.359** |
| $(t-stat.)$ | [3.891] | [4.938] | [−3.064] |
| $\bar{R}^2$ | 0.225 | 0.124 | 0.789 |
| $\hat{\sigma}_\varepsilon \times 100$ | 0.401 | 0.944 | 2.127 |
| $LM_{HET-SQ.}$ | 1.791 | 1.430 | 1.802 |
| $LM_{ARCH(2)}$ | 0.016 | 0.831 | 5.157** |
| $LM_{AR(1-12)}$ | 1.962* | 1.517 | 1.528 |

**Panel B: Cointegrating Coefficients**

$$\hat{\boldsymbol{\beta}}'\mathbf{x}_t = c_t + \hat{\beta}_z z_t + \hat{\beta}_d d_t$$

$$\hat{\boldsymbol{\beta}}' = \begin{bmatrix} 1 & \mathbf{-1.759} & \mathbf{0.097} \end{bmatrix}$$

$$S.E.(\hat{\boldsymbol{\beta}}') = \begin{bmatrix} - & 0.178 & 0.034 \end{bmatrix}$$

**Panel C: Restricted Cointegrating Coefficients**

$$\hat{\boldsymbol{\beta}}'_R\mathbf{x}_t = c_t + \hat{\beta}_z z_t + \left(-\hat{\beta}_z - 1\right) d_t$$

$$\hat{\boldsymbol{\beta}}'_R = \begin{bmatrix} 1 & \mathbf{-0.9848} & \mathbf{-0.0152} \end{bmatrix}$$

$$S.E.(\hat{\boldsymbol{\beta}}'_R) = \begin{bmatrix} - & 0.0056 & 0.0056 \end{bmatrix}$$

$\mathcal{LR}$-test: $Q(1) = \mathbf{9.200}$

| Asymptotic $p$-value | Bootstrap $p$-value |
|---|---|
| [0.002] | [0.028] |

NOTES for Table 2: Panel A of the table reports the estimated coefficients from a cointegrated vector autoregressive (VAR) model of the column variable on the row variable; $t$-statistics are given in square brackets. Estimated coefficients that are significant at the 10 percent level are highlighted in bold face. For each equation the adjusted $\bar{R}^2$, the estimated standard error, a $LM_{AR(1-12)}$ test for first to twelfth order autocorrelation (F(12,141)-distributed), a $LM_{ARCH(2)}$ test for second order autoregressive conditional heteroscedasticity (F(2,149)-distributed) and a $LM_{HET-SQ.}$ test for heteroscedasticity (F(8,144)-distributed) are reported. The term $\hat{\boldsymbol{\beta}}'\mathbf{x}_t \equiv c_t + \hat{\beta}_z z_t + \hat{\beta}_d d_t$ is the estimated equilibrium error (cointegrating residual) without the "symmetry" restriction imposed on the parameters. Panel B reports the unrestricted cointegrating coefficients and their associated standard errors, while Panel C reports the restricted cointegrating coefficients, their standard errors, as well as the likelihood ratio test ($\chi^2(1)$-distributed) and the associated $p$-value. The sample spans the first quarter of 1963 to the fourth quarter of 2002.

Table 3: **Forecast Error variance Decomposition (Orthogonalized Shocks)**

| | $\Delta z_{t+h} - E_t\Delta z_{t+h}$ | | | $\Delta c_{t+h} - E_t\Delta c_{t+h}$ | | | $\Delta d_{t+h} - E_t\Delta d_{t+h}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| Horizon $h$ | $\eta_{1t}^P$ | $\eta_{2t}^P$ | $\eta_{3t}^T$ | $\eta_{1t}^P$ | $\eta_{2t}^P$ | $\eta_{3t}^T$ | $\eta_{1t}^P$ | $\eta_{2t}^P$ | $\eta_{3t}^T$ |
| 1 | 0.004 | 0.258 | 0.739 | 0.430 | 0.125 | 0.445 | 0.621 | 0.086 | 0.293 |
| SE | (0.283) | (0.194) | (0.130) | (0.221) | (0.248) | (0.064) | (0.206) | (0.179) | (0.128) |
| 2 | 0.005 | 0.308 | 0.687 | 0.464 | 0.138 | 0.399 | 0.718 | 0.055 | 0.228 |
| SE | (0.284) | (0.195) | (0.121) | (0.225) | (0.255) | (0.053) | (0.214) | (0.183) | (0.113) |
| 3 | 0.013 | 0.334 | 0.653 | 0.492 | 0.146 | 0.362 | 0.775 | 0.042 | 0.183 |
| SE | (0.290) | (0.196) | (0.125) | (0.233) | (0.260) | (0.047) | (0.219) | (0.189) | (0.108) |
| 4 | 0.027 | 0.348 | 0.625 | 0.516 | 0.153 | 0.331 | 0.810 | 0.035 | 0.154 |
| SE | (0.294) | (0.197) | (0.127) | (0.239) | (0.263) | (0.042) | (0.222) | (0.193) | (0.105) |
| 8 | 0.140 | 0.339 | 0.521 | 0.591 | 0.173 | 0.236 | 0.870 | 0.029 | 0.102 |
| SE | (0.301) | (0.196) | (0.135) | (0.257) | (0.267) | (0.030) | (0.233) | (0.210) | (0.096) |
| 12 | 0.283 | 0.294 | 0.423 | 0.638 | 0.188 | 0.174 | 0.888 | 0.032 | 0.080 |
| SE | (0.296) | (0.189) | (0.134) | (0.267) | (0.268) | (0.023) | (0.242) | (0.225) | (0.088) |
| 16 | 0.414 | 0.245 | 0.341 | 0.669 | 0.198 | 0.133 | 0.894 | 0.038 | 0.067 |
| SE | (0.283) | (0.179) | (0.127) | (0.272) | (0.269) | (0.020) | (0.249) | (0.237) | (0.082) |
| 20 | 0.520 | 0.204 | 0.276 | 0.689 | 0.207 | 0.105 | 0.895 | 0.046 | 0.059 |
| SE | (0.265) | (0.167) | (0.116) | (0.275) | (0.269) | (0.017) | (0.256) | (0.248) | (0.076) |
| 40 | 0.786 | 0.093 | 0.121 | 0.727 | 0.229 | 0.044 | 0.872 | 0.093 | 0.035 |
| SE | (0.172) | (0.111) | (0.067) | (0.277) | (0.270) | (0.010) | (0.281) | (0.282) | (0.054) |
| $\infty$ | 1.000 | 0.000 | 0.000 | 0.744 | 0.256 | 0.000 | 0.705 | 0.295 | 0.000 |
| SE | | | | (0.272) | (0.273) | | (0.352) | (0.352) | |

NOTES for Table 3: The table reports the fraction of the variance in the $h$ step-ahead forecast error of the variable listed at the head of each column that is attributable to innovations in the permanent shocks, $\eta_{1t}^P$ and $\eta_{2t}^P$, the transitory shock, $\eta_{3t}^T$. Horizons are in quarters, and the underlying VEqCM is of order 1. Each row below the reported FEVD shows the estimate of the fraction due to each shock, and the associated bootstrap standard errors. The sample spans the first quarter of 1963 to the fourth quarter of 2002.

The reported standard errors were computed using a bootstrap Monte Carlo procedure. Specifically, we have constructed 10000 time series of the vector $\mathbf{x}_t$ as follows. Let $\{\hat{\mathbf{u}}_t\}_{t=1}^T$ denote the vector of residuals from the estimated VEqCM. We constructed 10000 sets of new time series residuals, $\{\hat{\mathbf{u}}_t(j)\}_{t=1}^T$, $j = 1, ..., 10000$. The $t^{th}$ element of $\{\hat{\mathbf{u}}_t(j)\}_{t=1}^T$ was selected by drawing randomly, with replacement, from the set of fitted residual vectors $\{\hat{\mathbf{u}}_t\}_{t=1}^T$. For each $\{\hat{\mathbf{u}}_t(j)\}_{t=1}^T$, we have constructed a synthetic time series $\tilde{\mathbf{x}}_t$, denoted $\{\tilde{\mathbf{x}}_t(j)\}_{t=1}^T$, using the estimated VEqCM and the historical initial conditions on $\mathbf{x}_t$. We the re-estimated the VEqCM using $\{\tilde{\mathbf{x}}_t(j)\}_{t=1}^T$ and calculated the implied forecast error variance decompositions for $j = 1, ..., 10000$.

# Appendix

## A Data Description

This appendix briefly describes the variables employed in the analysis. For all variables except net foreign liabilities, our source is the FRED II Database of the Federal Reserve Bank of the Saint Louis.

- CONSUMPTION $C_t$

Consumption is measured as expenditure on non-durables (PCNDGC96) and services (PCESVC96). The quarterly series are seasonally adjusted at annual rates, in billions of chain-weighted 1996 dollars.

- NET OUTPUT $Z_t$

Net Output is defined as $Z_t \equiv Y_t - I_t - G_t$, whereas $Y_t$ is the real gross domestic product (GDPC1), $I_t$ is real gross private domestic investment (GPDIC1) + real change in private inventories (CBIC1) + real personal consumption expenditure on durable goods (PCDGCC96); finally, $G_t$ is real government consumption expenditures & gross investment (GCEC1). All series are seasonally adjusted at annual rates, in billions of chain-weighted 1996 dollars.

- NET FOREIGN DEBT $D_t$

We build our series of net foreign liabilities by cumulating the negative of the U.S. current account (BOPBCA). We scale the resulting series by 1.000, so that the series become positive throughout our sample. In the cumulated current account series, the minimum observation (largest negative in absolute value) is -699.77. So we have experimented using different additive constants (750, 800, 900, 1000, 1100), verifying the absence of any qualitative difference in our results.

- POPULATION

Our measure of population was obtained by sampling at the end of each quarter the monthly population series.

- PRICE DEFLATOR

To deflate net foreign liabilities, we employ the personal consumption expenditure chain-type deflator (1996=100), seasonally adjusted (PCECTPI), as a proxy of the unobserved price deflator corresponding to our measure of consumption.

# B Tests for Cointegration

Table 4: **Trace (Cointegration) Statistics**

| Panel A: Trace Statistics | | | | Panel B: Bartlett-Corrected Trace Statistics | | | |
|---|---|---|---|---|---|---|---|
| $H_0 : r$ | $r = 0$ | $r \leq 1$ | $r \leq 2$ | $H_0 : r$ | $r = 0$ | $r \leq 1$ | $r \leq 2$ |
| $n - r$ | 3 | 2 | 1 | $n - r$ | 3 | 2 | 1 |
| $Q\left(r\vert\, n\right)$ | **37.998** | 9.130 | 0.096 | $Q_{b-corr}\left(r\vert\, n\right)$ | **32.848** | 6.189 | 0.057 |
| Asymptotic $p$-val. | [0.004] | [0.353] | [0.757] | Asymptotic $p$-val. | [0.002] | [0.673] | [0.811] |
| Simulated $p$-val. | [0.002] | [0.336] | [0.745] | Simulated $p$-val. | [0.015] | [0.658] | [0.808] |
| Bootstrapped $p$-val. | [0.011] | [0.613] | [0.848] | Bootstrapped $p$-val. | [0.015] | [0.658] | [0.861] |
| $Q_{corr}\left(r\vert\, n\right)$ | **36.56** | 8.78 | 0.09 | | | | |
| Asymptotic $p$-val. | [0.006] | [0.393] | [0.762] | | | | |
| $Q_{95}\left(r\vert\, n\right)$ | 29.68 | 15.41 | 3.76 | $Q_{95}\left(r\vert\, n\right)$ | 29.68 | 15.41 | 3.76 |
| $Q_{95}^{sim}\left(r\vert\, n\right)$ | 28.591 | 14.961 | 3.801 | $Q_{95}^{sim}\left(r\vert\, n\right)$ | 28.471 | 14.998 | 3.864 |
| $Q_{95}^{boot}\left(r\vert\, n\right)$ | 32.481 | 19.522 | 9.051 | $Q_{95}^{boot}\left(r\vert\, n\right)$ | 28.906 | 14.428 | 5.526 |

NOTES for Table 4: $Q\left(r\vert\, n\right)$ denotes the trace statistic as defined in Johansen [1995], i.e. $Q(r\vert\, n) = -T\sum_{i=r+1}^{n} \ln\left(1-\hat{\lambda}_i\right)$ and the $Q_{corr}\left(r\vert\, n\right)$ is the trace statistic with the small sample correction proposed by Reinsel and Ahn [1992] i.e. $Q_{corr}(r\vert\, n) = -\left(T - nk\right)\sum_{i=r+1}^{n} \ln\left(1-\hat{\lambda}_i\right)$. The asymptotic p-values reported are calculated using the methods in Doornik [1998], while the asymptotic critical values are taken from Osterwald-Lenum [1992]. The simulated critical values and $p$-values are based on a Monte Carlo Simulation for T=200 with 10.000 replications. The bootstrap critical values and bootstrap $p$-values are based on a Bootstrap Monte Carlo with 10.000 replications. The Bartlett-corrected trace statistics $Q_{b-corr}\left(r\vert\, n\right)$ use the finite sample correction reported in Johansen [2002], and the asymptotic and bootstrap critical values have been obtained by 10.000 replication of the empirical model used. The sample spans the first quarter of 1963 to the fourth quarter of 2002.