Macroeconomic Volatility and External Imbalances*

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Abstract

This paper studies the impact of macroeconomic volatility/uncertainty on the accumulation of net foreign assets of a country. We first show that in OECD economies over the period 1970-2012 increases in country specific macroeconomic volatility are, after controlling for wide array of factors, significantly positively associated with accumulation of net foreign assets. We show that this relation arises naturally in the context of a standard open economy consumption/saving/investment model. Changes in country specific macroeconomic volatility act as observable changes to the country specific rate of time preference which increase the gains from international inter-temporal trade, and hence make external imbalances more likely. We conclude that time varying macroeconomic volatility is a quantitatively important factor to understand the causes and forecast the medium/long run evolution of external imbalances across OECD countries.

JEL CODES: F32, F34, F41

KEY WORDS: Business cycles, Current account, Global Imbalances, Precautionary saving, Uncertainty

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1 Introduction

This paper argues that time varying uncertainty about macroeconomic conditions (which throughout the paper we'll measure as realized macro volatility) is a quantitatively important determinant of domestic consumption/saving decisions and through those, on the medium long run evolution of net foreign asset positions of countries.

We first show that, for OECD countries over the last 40 years, medium run changes in macroeconomic volatility are significantly positively associated with changes in net foreign asset position. In order to understand these patterns we introduce time varying macroeconomic uncertainty in a standard open economy model and show that the model can account for this relationship well, both in the short and in the long run. The intuition is simple: in response to increases in domestic uncertainty agents increase their precautionary saving balances. Decreasing returns in domestic capital, increasing risk of domestic capital (due to the increase in uncertainty) and the assumption of open economy imply that the bulk of the additional precautionary saving will go into foreign assets. If changes in uncertainty are persistent, the accumulation of foreign assets continues through time and can lead to sizeable changes in medium/long run net foreign asset positions, thus generating persistent "global imbalances".

Our findings suggest that time varying uncertainty, which many authors are recently putting at the center stage of macroeconomic analysis, is an important factor to understand macroeconomic outcomes, but especially in the context of open economies. To give a more precise example many countries in our sample experiences changes in volatility (relative to the one of their partners) in excess of 50 basis points. Our data and theory together suggest that such a change can lead, over the span of 10 years, to a change in the net foreign asset position of that country of around 8% of GDP . We also find the model useful to precisely understand and quantify the channels through which uncertainty affects agents' decision and to understand how the effects of uncertainty depend on structural aspects of the economy such as preferences, persistence of shocks, the development of international financial markets.

This paper is related to two strands of literature. The first is the one which studies the recent phenomenon of "global imbalances" and search for causes of the growing dispersion of external imbalances in various countries.[1] Our study suggests that, in a world with integrated capital markets and persistent differences in country specific volatilities, large

[1]See, among others, Fogli and Perri (2006), Blanchard (2007), Caballero, Fahri and Gourinchas (2008), Mendoza, Quadrini and Rios-Rull (2009) and Chang, Kim and Lee (2013)

imbalances are bound to emerge as differences in volatility act as (observable) differences in rate of time preferences and hence create a strong motives for intertemporal trade. The second strand is the literature that studies the effect of changes in macroeconomic uncertainty on aggregagate outcomes [2]. Most of the literature focuses on the importance of shocks to uncertainty in generating business cycle fluctuations, while our work focuses on global imbalances and show that even in the case where shocks to uncertainty have modest business cycle impact, they can have a sizeable impact on external positions of countries. The work is also connected to the literature that studies how the optimal level of external reserves of a country depends on aggregate risk. [3]

The paper is organized as follows. Section 2 provides empirical evidence on the relationship between volatility of output growth and external imbalances. Section 3 presents the model. In section 4 we describe how we use the model to understand the data. Section 5 analyzes the importance of different structural factors in how uncertainty affects the economy and Section 6 concludes.

2 Empirical evidence

This section first establishes that for developed countries changes in (relative) macroeconomic volatility are positively associated with changes in net foreign asset position. This relationship constitutes our key piece of evidence about the role of precautionary motives in determining inter-temporal trade patterns across countries.

Our sample consist of the set of all OECD countries for which we could obtain comparable (across time and countries) macroeconomic data starting at least in the early 1980s. The final dataset is an unbalanced panel which includes 21 countries and spans from the first quarter of 1970 to the last quarter of 2012. [4]. Our benchmark measure of relative macroeconomic volatility for a country in a given time interval is the standard deviation of quarterly real GDP growth over the interval minus the average (across the other countries) standard deviation of quarterly real GDP growth over the interval. Our benchmark measure of net foreign asset position is total gross foreign assets minus total gross foreign liabilities over GDP, averaged over the same interval. Figure 1 provides a comprehensive summary of

[2]See, among others, Barlevy (2004), Justiniano and Primiceri (2008), Bloom (2009), Fernández-Villaverde et al. (2011), Bloom et al. (2012) and Arellano, Bai and Kehoe (2012)

[3]See, for example, Durdu, Mendoza and Terrones (2009) and Jeanne and Ranciere (2011)

[4]All the national accounts data is from the OECD Quarterly National Accounts. The foreign asset position data up to 2007 is from Lane and Milesi-Ferretti (2006), while figures in post 2007 years are derived from the IMF international investment position statistics

our dataset, plotting trends of net foreign asset position and volatility of GDP growth in each year for all countries in our sample. Both measures are computed in each year using 10 years rolling windows (always using quarterly data for volatility and yearly data for NFA position), where the time indicator in each graph represents the mid year of the window.

The figure reveals that for many countries there is the strong association between changes in their relative volatility. Countries who have experienced a permanent reduction of their relative volatility/uncertainty (such Australia, Austria, Great Britain and Greece) have also permanently reduced their external asset position. Countries who have instead experienced an increase in their relative volatility (such as Belgium, Switzerland or Japan) have accumulated foreign assets. Obviously the relation does not hold perfectly for every country, suggesting that there are other factors driving the accumulation/decumlation of foreign assets, but the figures suggest that changes in volatility can play a major role in foreign asset dynamics.

Figure 2 provides evidence that the relation between volatility and net foreign assets is not dependent on our long run measure of volatility. We first measure volatility of GDP growth estimating a GARCH(1,1) for GDP growth in each country and in the figure we report the annual averages of the estimated conditional volatility of GDP growth in each country, together with annual averages of net foreign assets over GDP. Although volatility measured in this way is more noisy, the figure still reveal association between the two variables.

The association between the variables that appear in figures 1 and 2 might be driven by any common factor that drives, at the same time, volatility and net foreign asset position. In order to control for these we next turn to linear regression analysis. Table 1 reports the coefficients obtained regressing the benchmark measure of net foreign assets (averaged over 10 years windows) on volatility (computed as the standard deviation of GDP growth over the same window) and on a set of controls. In all regressions we include include country and year fixed effects. Country fixed effects control for the possibility that some unobserved characteristic of a country (for example institutional quality) drives at the same time long run volatility and external imbalances. Time fixed effects capture events that might affect the net foreign assets of countries at the same time, such as, for example, the emergence of China. Another important control we include is average GDP growth over the window. If high growth periods are also low volatility periods, and high growth induce countries to borrow on international markets to finance investment, then a positive relation between volatility and net foreign asset position would arise but not for precautionary reasons.

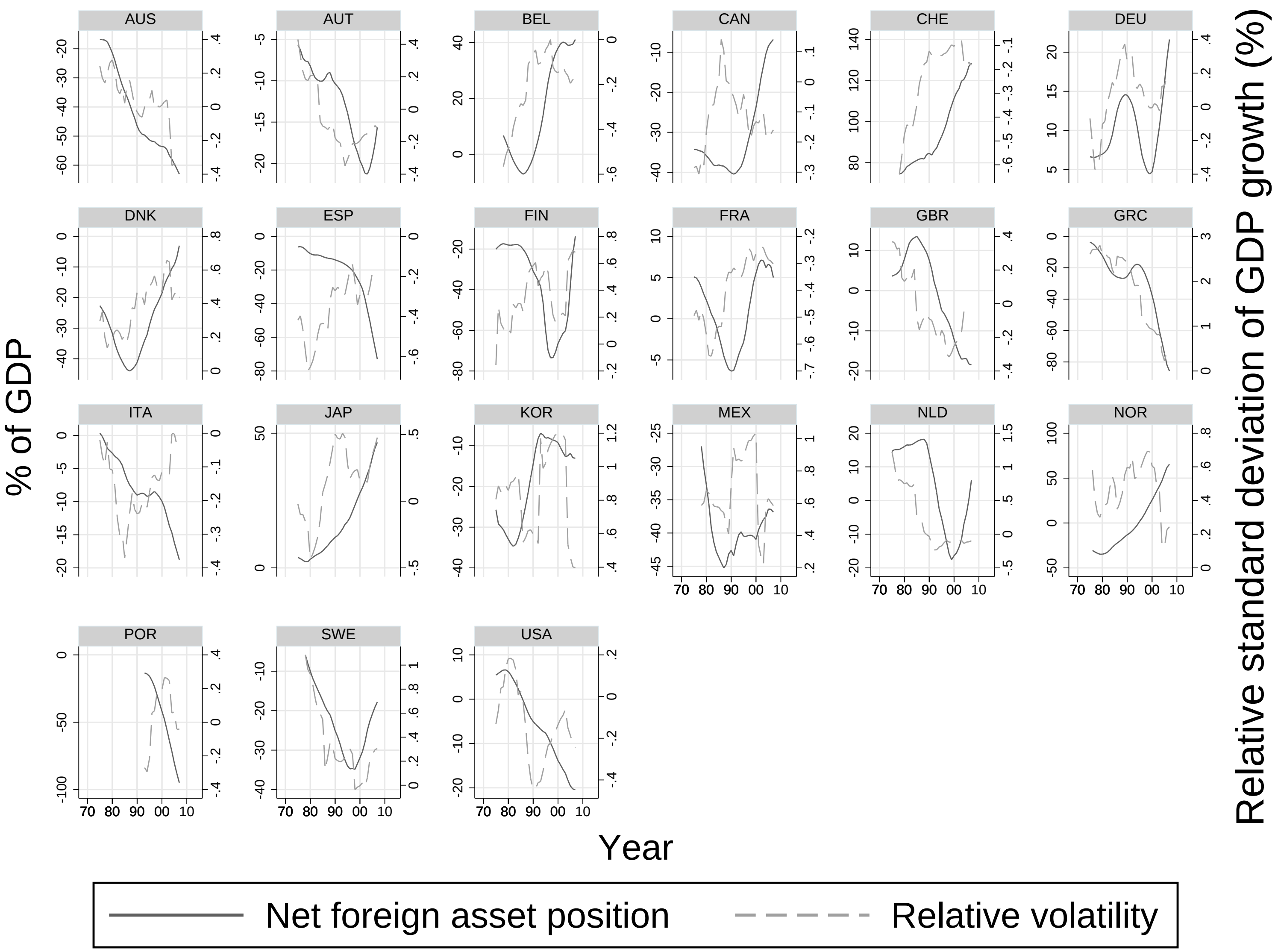

Figure 1: Relative volatility and net foreign asset positions

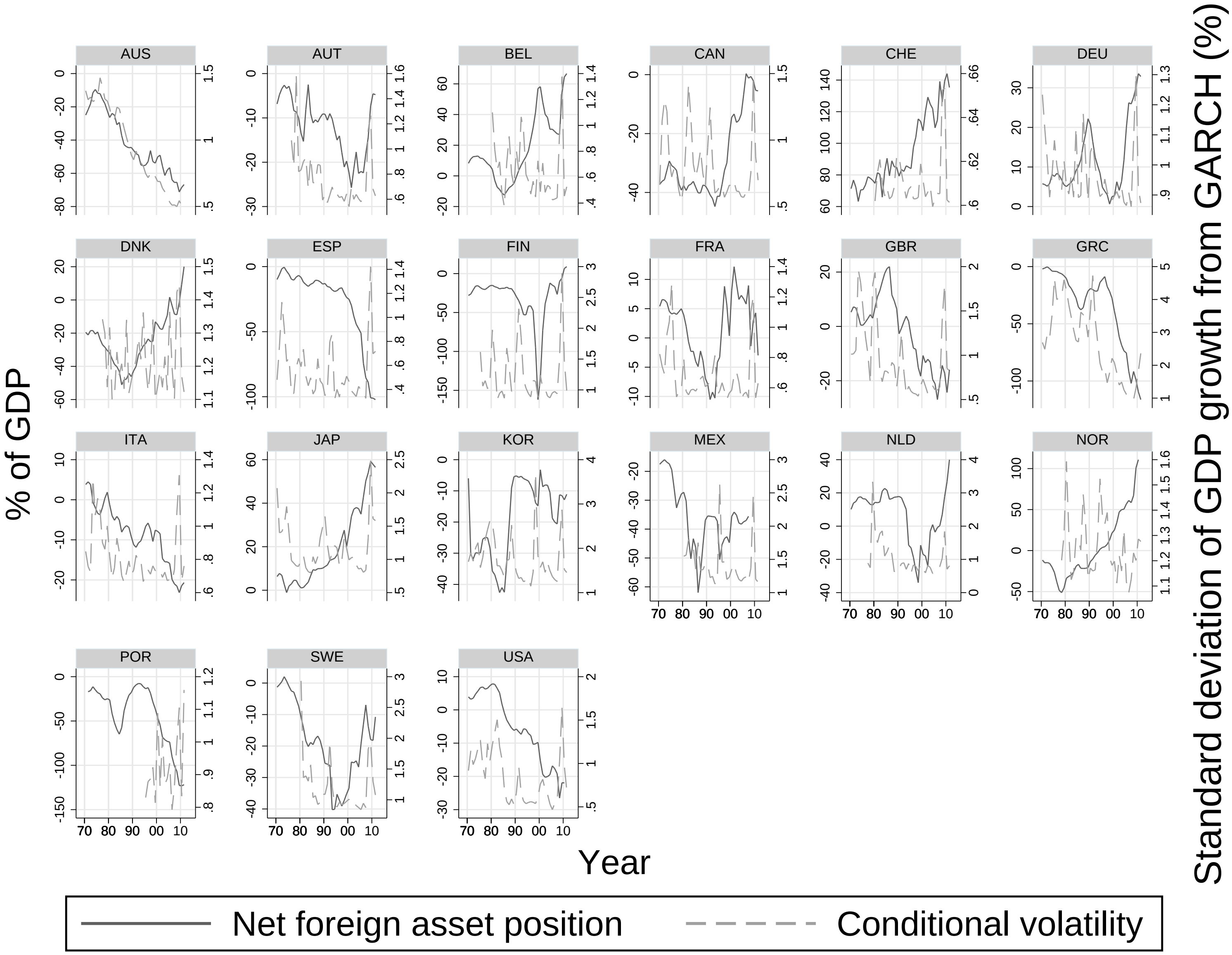

Figure 2: Conditional volatility and net foreign asset positions

Additional controls include average inflation, standard deviation of inflation, and two measures of financial openness. The first measure is gross international financial diversification (foreign assets plus foreign liabilities over GDP) while the second measure is the Chinn-Ito index of financial openness. All the controls are also computed using the 10 year window. Table 1 reports the results obtained for four different specifications of the regression. The results in the first column are those obtained in the baseline regression that only includes volatility as a control, together with country and time fixed effects. We then add progressively more controls. Specifically, we add average GDP growth in column (ii), our two measures of inflation over the period in column (iii) and the two measures of financial openness in column (iv). We find that the volatility of GDP growth is significant at the 1% level in all specifications, even when standard errors are estimated in the most conservative fashion, i.e. allowing for arbitrary correlation structure for the errors at the country level.[5]

The magnitude of the coefficient is stable across specifications and economically relevant, as, for example, a 0.5% change in relative volatility (experienced by many countries in our sample) is associated with a change in the ratio of net foreign asset position to GDP of about 8% Both country and time dummies are also strongly significant reflecting the importance of country specific factors and of common time trends (such as financial globalization or the growing importance of new industrial nations such China or India) in explaining trends in net foreign assets. The rationale for including the additional variables in the regression is to control for potential changes in policy which would at the same time affect country volatility and external imbalances. We first control for policies indirectly by including average GDP growth over the period as, for example, good macroeconomic policies might lead to higher growth (and hence higher international borrowing) and at the same time lower volatility. We also control for policies directly by including two commonly used measures of monetary policy (average and standard deviation of inflation) and two measures of financial integration. We find it remarkable that none of these measures is significant in explaining the changes in net foreign assets.

[5]OLS and robust (without accounting for clustering) standard errors are sizeably smaller.

Table 1: Volatility and External Imbalances

	Dependent variable is Net Foreign Assets						
	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)
Volatility of GDP Growth	18.62***	17.22***	17.22***	17.33***	15.14***	15.59***	
	(3.812)	(4.876)	(4.471)	(5.757)	(5.023)	(4.848)	
Average GDP Growth		-5.790	-4.745	-5.810	-6.924	-2.569	-10.72
		(9.336)	(9.523)	(9.777)	(10.96)	(11.35)	(11.26)
Average Inflation			1.802	3.710*	4.030*	3.225	2.544
			(1.686)	(2.028)	(2.300)	(2.270)	(2.595)
Volatility of Inflation			-0.904	-2.299	-2.000	-1.698	-0.699
			(3.540)	(3.528)	(3.207)	(3.232)	(3.344)
Volatility of Govm. Cons. Growth				-4.893	-6.824	-7.008	-8.003
				(4.419)	(4.960)	(5.102)	(5.502)
Financial Openness 1					-0.698	-0.101	0.551
					(4.003)	(4.200)	(4.542)
Financial Openness 2					2.123	1.148	1.729
					(4.386)	(3.843)	(3.833)
Trade Openness						-54.06	-50.56
						(66.78)	(67.79)
N	662	662	662	646	633	633	633
adj. R^2	0.814	0.814	0.815	0.820	0.796	0.801	0.790

Robust standard errors in parentheses account for clustering at the country level.

All regressions include a constant, country and year fixed effects.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In table 2 we investigate the robustness of our results to alternative way of computing volatility of GDP growth and to changes in the sample. In columns (i) and (ii) we report results when we compute all our variables (including volatility) over 5, as opposed to 10, years windows. Notice how the coefficient on volatility is lower but remains strongly significant. In the theoretical section we will show how a reduction of the size of the coefficient with the length of the window is consistent with the mechanism we propose. In columns (iii) and (iv) we compute the volatility of GDP growth by estimating a univariate GARCH(1,1) on quarterly data from our sample and then take yearly averages of the quarterly series of conditional standard deviation resulting from the GARCH. Notice that volatility is still significant, although less so than in previous specifications. We believe that this is due to the presence of high frequency variation in the volatility estimated from the GARCH, which is not associated with high frequency variation in net foreign asset position. So this result suggests that most of the association between volatility and net foreign asset positions happens at medium low frequencies. In the last 2 columns we restrict the sample to include only the 1985-2005 which is a period of lower business cycles volatility and higher financial integration.

For the sake of brevity we do not report all the additional controls included in table 1 but for none of the specifications reported in table 2 they are significant.

Table 2: Volatility and External Imbalances - Alternative Measures and Sample

	Dependent variable is Net Foreign Assets[a]							
	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)
Vol. GDP Growth (5 yrs)	14.83***	14.41***						
	(4.395)	(4.753)						
Av. GDP Growth (5 yrs)		-2.613						
		(5.737)						
Vol. GDP Growth (7 yrs)			16.65***	15.73***				
			(4.105)	(4.627)				
Av. GDP Growth (7 yrs)				-5.171				
				(7.222)				
Vol. GDP Growth (from GARCH)					14.02***	14.61***		
					(4.841)	(4.858)		
Av. GDP Growth (1 yr)						1.966		
						(2.198)		
Vol. GDP Growth (1985-2012)							16.46***	16.67**
							(5.609)	(6.386)
Av. GDP Growth (1985-2012)								0.626
								(12.05)
N	720	720	698	698	764	764	475	475
adj. R^2	0.756	0.756	0.779	0.780	0.710	0.710	0.845	0.844

a) Net foreign asset position in each specification is computed on the same window used for computing volatility.

Robust standard errors in parentheses account for clustering at the country level.

All regressions include a constant, country and year fixed effects.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The main result of this section is that for OECD countries there is a robust, economically and statistically significant and robust positive association between relative changes, over thee medium/long run, in volatility and changes in net foreign asset position. Quantitatively a change in the relative volatility of a given country of the order of 0.5% (which many countries in our sample have experienced) over a ten year period is associated with a change in net foreign assets for that that country of the order of 8% of GDP. In the next section we will show how such a link arises naturally in a simple open economy model of consumption/saving/investment decisions, and we will assess whether the link generated by the model is quantitatively consistent with the link measured in the data.

3 Model

We consider a version of the standard one-good two-country business cycle model (as Backus, Kehoe Kydland, 1992 or Baxter and Crucini, 1995) with a variety of assumptions about international asset trade and with time varying business cycle volatility. In the model agents face persistent country specific productivity shocks and in general international financial markets do not allow perfect insurance of country specific risk: this implies that agents in both countries have a precautionary saving motive. If the volatility of shocks changes over time and across countries, the precautionary motive also changes and this naturally generates, in a open economy equilibrium, external imbalances, with the more volatile country accumulating a net positive external position vis-a-vis the with the less volatile one. So this model has a natural link between changes in volatility and changes in imbalances and is a good laboratory to check whether precautionary saving motive can account for the observed link between volatilities and imbalances.

The world economy consists of two equal size countries, $i = 1, 2$, each inhabited by a large number of infinitely-lived consumers and endowed with a constant returns to scale production technology operated by competitive firms. Time is discrete and each period is a quarter. The countries produce a single good, and their preferences and technology have the same structure and parameter values. The labor input consists only of domestic labor, and production is subject to country-specific technology shocks.

In each period t, the economy experiences one of finitely many events $s_{t.}$ We denote by $s^t = (s_0, \ldots, s_t)$ the history of events up through and including period t. The probability, as of period zero, of any particular history s^t is $\pi(s^t)$. We assume that idiosyncratic risk within each country is perfectly insured among residents so we can consider a representative consumer in each country who has preferences of the form

$$\sum_{t=1}^{\infty}\sum_{s^t}\beta^t\pi(s^t)U(c_i(s^t),l_i(s^t)) \tag{1}$$

where $c_i(s^t)$ and $l_i(s^t)$ denote consumption and labor of the representative consumer in country i after history s^t, $U(c,l)$ is a standard utility function and $\beta > 0$ is a positive parameter capturing their rate of time preference. The representative agents in the two countries are endowed with one unit of time and they supply labor to domestic firms in exchange for a wage $w_i(s^t)$, own and (possibly) trade share in domestic and foreign firms, trade internationally an uncontingent default-free bond $b_i(s^t)$ which pays a gross interest $R(s^t)$ and choose consumption in each state of the world to maximize their expected lifetime utilities, given in (1) subject to the following budget constraints:

$$\begin{aligned} & c_1(s^t)+b_1(s^t)+\lambda_1(s^t)p_1(s^t)+\lambda_1^F(s^t)p_2(s^t) && (2)\\ \leq\ & l_1(s^t)w_1(s^t)+\lambda_1(s^{t-1})(d_1(s^t)+p_1(s^t))+(\lambda_1^F(s^{t-1}))(d_2(s^t)+p_2(s^t))+b_1(s^{t-1})R(s^{t-1}) \\ & c_2(s^t)+b_2(s^t)+\lambda_2(s^t)p_2(s^t)+\lambda_2^F(s^t)p_1(s^t) && (3)\\ \leq\ & l_2(s^t)w_2(s^t)+\lambda_2(s^{t-1})(d_2(s^t)+p_2(s^t))+(\lambda_2^F(s^{t-1}))(d_1(s^t)+p_1(s^t))+b_2(s^{t-1})R(s^{t-1}) \end{aligned}$$

and initial conditions

$$\lambda_i(s^0),\lambda_i^F(s^0),b_i(s^0) \text{ given}$$

In (2) and (3) $d_i(s^t)$ denote dividend paid by firms in country i, $\lambda_i(s^t)$ and $\lambda_i^F(s^t)$ denote holdings of shares of domestic and foreign firms, and $p_i(s^t)$ denote the price of shares of domestic and foreign firms. In the case in which we exogenously restrict

$$\begin{aligned} \lambda_1(s^t) &= \lambda_2(s^t)=1 \text{ for every } s^t \\ \lambda_1^F(s^t) &= \lambda_2^F(s^t)=0 \text{ for every } s^t \end{aligned}$$

our setup reduces exactly to the Baxter and Crucini model in which the only asset that is trade internationally is a single non contingent bond. Competitive firms own the capital stock installed in each country $k_i(s^t)$ and hire labor to operate a Cobb-Douglas technology and solve the following problem

$$
\begin{aligned}
& \max_{l_i(s^t),k_i(s^t),x_i(s^t)} \sum_{t=1}^{\infty}\sum_{s^t} d_i(s^t)Q_i(s^t) \\
& s.t. \\
d_i(s^t) &= A_i(s^t)l_i^{1-\alpha}(s^t)k_i^{\alpha}(s^{t-1}) - w_i(s^t)l_i(s^t) - x_i(s^t) \\
k_i(s^t) &= (1-\delta)k_i(s^{t-1}) + x_i(s^t) - \phi k_i(s^{t-1})\left[\frac{x_i(s^t)}{k_i(s^{t-1})} - \delta\right]^2 \\
& k_i(s^0) \text{ given}
\end{aligned}
$$

where $Q_i(s^t)$ are state contingent prices used by firms to evaluate dividend payments in state s^t, $A_i(s^t)$ is a country-specific total factor productivity shock which follows an exogenous process with time varying volatility (the process will be specified in the next section), α is a constant parameter determining the relative importance of capital and labor in production, $x_i(s^t)$ represent investment, δ and ϕ are fixed parameters that determine the rate of capital depreciation and the size of capital adjustment costs, respectively. .Notice how the state-contingent consumption prices $Q_i(s^t)$ affect firms decisions regarding how to divide earnings between investment and dividend payments. In the reminder of the paper we assume that domestic firms use the stochastic discount factor of the representative domestic household to price the marginal cost of foregoing current dividends in favor of extra investment[6], i.e.

$$Q_i(s^t) = \beta^t \pi(s^t) U_c(c_i(s^t), l_i(s^t))$$

An equilibrium for this economy is defined as a collection of mappings for prices $w_i(s^t), r_i(s^t), p_i(s^t), R(s^t), Q_i(s^t)$, exogenous processes $A_i(s^t)$ quantities $c_i(s^t), x_i(s^t), k_i(s^t)$, and portfolio choices $b_i(s^t), \lambda_i(s^t), \lambda_i^F(s^t)$ such that, when consumers and firms take prices and exogenous processes as given, the quantities and portfolio choices solve their optimization problems, and such that the markets for consumption/investment goods, capital, labor, bonds and stocks clear in each country, in each date t and in each state s^t.

4 Results

We will now use the model just described to answer the following questions:

[6]When ownership of the domestic firm is internationally dispersed it is possible to make different assumption about $Q_i(s^t)$ as foreign and domestic consumers may value differently dividend payments in a given state.

i) What are the effects of a change in volatility of business cycle shocks in a particular country?

ii) How does the relation between volatility and net foreign asset position implied by the model compares (quantitatively) with the relationship measured in the data.

iii) How does the importance of volatility changes depend on structural features of the economy?

To answer these questions, we first choose parameter values and then characterize the numerical solution of the model.

4.1 Parameters and computation

We need to set a functional form for the utility function $U(c, l)$, values for the discount factor β, for the technology parameters α, δ and ϕ and most importantly for the process for TFP shocks $A_i(s^t)$. The discount factor β, the capital depreciation rate δ, the share of capital in production α and the capital adjustment costs ϕ are set so that a symmetric equilibrium in the model (i.e. an equilibrium in which both countries face equally volatile shocks) displays an average return to capital of 4%, a yearly average capital to GDP ratio of 2.5, an average share of GDP going to labor equal to 64% and an investment series which is 2.5 times as volatile as the GDP series. These values are typical for the US and other major world economies and the structure of the model allow us to easily and precisely identify the parameters. The functional form and the parameters describing preferences of the representative agents in both countries are obviously important. In the benchmark case we assume a standard Cobb Douglas utility

$$U(c, l) = \frac{1}{1-\gamma}\left[c^{\mu}(1-l)^{1-\mu}\right]^{1-\gamma}$$

and we set the parameter μ in order to match a fraction of time spent working equal to 1/3 and the curvature parameter to 2. In section 6 below we will explore more the role of the curvature parameter and of the functional form for utility. The last important input of the model is the stochastic process for TFP shocks. We specify it as a bi-variate autoregressive process of the form

$$\begin{array}{c} \log(A_1(s^t)) \\ \log(A_2(s^t)) \end{array} = \begin{bmatrix} \rho & \psi \\ \psi & \rho \end{bmatrix} \begin{array}{c} \log(A_1(s^{t-1})) \\ \log(A_2(s^{t-1})) \end{array} + \begin{array}{c} V_1(s^t)\varepsilon_1(s^t) \\ V_2(s^t)\varepsilon_2(s^t) \end{array} \quad (4)$$

$$\begin{array}{c} V_1(s^t) = (1-\rho_V) + \rho_V V_1(s^{t-1}) + \eta_1(s^t) \\ V_2(s^t) = (1-\rho_V) + \rho_V V_2(s^{t-1}) + \eta_2(s^t) \end{array} \quad (5)$$

where ρ, ψ and ρ_V are fixed parameters and $\varepsilon_i(s^t), \eta_i(s^t)$ are jointly, un-correlated, normal shocks with zero mean, and variance σ_ε^2 and σ_η^2 respectively. Note that $\varepsilon_i(s^t)$ are the standard innovations to TFP, while $\eta_i(s^t)$ are innovations to the standard deviation of TFP innovations, which is time varying and equal to $V_i(s^t)\sigma_\varepsilon^2$. We first set the parameters $\rho = 1$, $\psi = 0$. As discussed by Baxter and Crucini (1995), this choice of parameters is not inconsistent with data and allows a model like the one discussed above to better match the international cross correlations of output and consumption. Table 2 summarizes our benchmark choices of parameter values.

Table 3: Parameter Values

Name	Symbol	Value
Preferences and Technology		
Discount Factor	β	0.99
Utility function	$\frac{1}{1-\gamma}\left[c^\mu(1-l)^{1-\mu}\right]^{1-\gamma}$	
Consumption share	μ	0.32
Curvature	γ	2
Capital share	α	0.36
Depreciation rate	δ	0.025
Capital Adjustment Cost	ϕ_k	1.8
TFP Shocks		
Persistence of Productivity	ρ_A	0.998
Std. Dev. of productivity innovations	σ_ε	1.1%
Spillover	ψ	0
Persistence of Volatility shocks	ρ_V	0.95
Std. Dev. of Volatility shocks	σ_η	7%

Table 2: Calibration Targets

Name	Data	Model
Business Cycle Statistics[a]		
St. Dev. of GDP Growth	1.1300%	1.1460%
Relative St. Dev. of Consumption to GDP Growth	0.9460	0.9208
Relative St. Dev. of Investment to GDP Growth	3.2744	1.6062
St. Dev. of Change in Net-Exports-to-GDP Ratio	1.1158%	0.1552%
Other Moments[b]		
St. Dev. of Relative Volatility (de-meaned)	0.2976%	0.2986%
Persistence of Relative Volatility	0.8667	0.9603
St. Dev. of NFA (de-meaned)	14.4518%	14.7125%

a) Each standard deviation is computed as average standard deviation on quarterly data across countries. b) Recall that relative volatility and net foreign asset position are computed at yearly frequency. Moreover we consider 10 year windows. County-specific effects are purged by subtracting average relative volatility and net foreign assets by country in the de-meaned statistics. Persistence in turn is computed by estimating an AR(1) on relative volatility with country fixed effects.

Note finally that, since we are interested in capturing the effect of changes in volatilities, we do not numerically compute equilibria of this model using standard linearization based methods, as, using such methods, individuals' and firms' decision rules are independent from second moments of the shocks. We instead compute decision rules using third order approximation methods, as the third order is necessary to capture the impact of changes of variance on agents decsion rules.

4.2 The impact of volatility changes

As a benchmark case we consider the economy parameterized above and in which the only assets traded is a non contingent bond. In Figure 3 below we show the 30 years expected responses of key variables to a permanent unanticipated increase in volatility in country 1. In particular (see panel a) we start both countries with equal standard deviation of volatilities (equal to 0.8% which is the unconditional mean of the volatility of productivity shocks in all countries in our sample) and with other state variables equal to their long run average. [7] We then increase the volatility of innovation to productivity shocks of country 1 by 1% so that it is easy to compare the association between volatility and imbalances in the model and in the data.

Notice in panel (b) how the increase in relative volatility leads to a sizeable net foreign asset accumulation from country 1 and a corresponding imbalance in country 2. The magnitude of the response of external imbalance to a volatility shock predicted by the model is a bit smaller but of the same order of magnitude of the response measured in section 2. The data suggests that over a period of 10 years a 1% increase in volatility is associated with about a 18% increase in net foreign assets. Panel (b) suggests that the 10 year effect of a 1% increase in volatility on net foreign assets is about 10%. Also interestingly the model predicts that the response of net foreign assets to a given change in volatility increases with the duration of the volatility change and the evidence we presented in table 2 suggests that a similar phenomenon is observed in the data.

In order to understand the dynamics leading up to the imbalance, in panels c through f we report the expected paths of labor, consumption, capital stock, investment, current account and real interest rate. Since consumers in country 1 hold all claims to country 1 GDP, an increase in volatility increases their risk and their precautionary saving motive. This effect makes them more "patient" by effectively changing the "risk adjusted" rate of time preference in country 1. Since there is no similar effect in country 2 the equilibrium interest rate on international bonds (which before the shock was equal to the reciprocal of the common "risk adjusted" discount factor) falls now in between the the reciprocal of the two different discount factors; as a consequence consumption of agents in country 1 will fall on impact but drift upward after and consumption in country 2 will raise on impact and drift downward in subsequent periods. The preferences imply that households desired path of leisure mimics the path of consumption and thus labor supply in country 1 increases on impact, increasing returns to capital in country 1 and leading to additional capital in country 1 while the opposite happens in country 2. In the long run though the increase in consumption in country 1 is associated with an increase in leisure which eventually leads to reduction in capital invested in country 1 and to the opposite in country 2. Note that, as long as differences in volatility are permanent are permanent, the imbalance continue to grow. This is because an ever increasing consumption path and and an ever falling labor and capital path in country 1 can only be financed by accumulating a growing amounts of foreign assets.

[7] Note in this economy certainty equivalent does not hold hence the long run expected value o of variables are in general different from the value of the variables in the deterministic steady state.

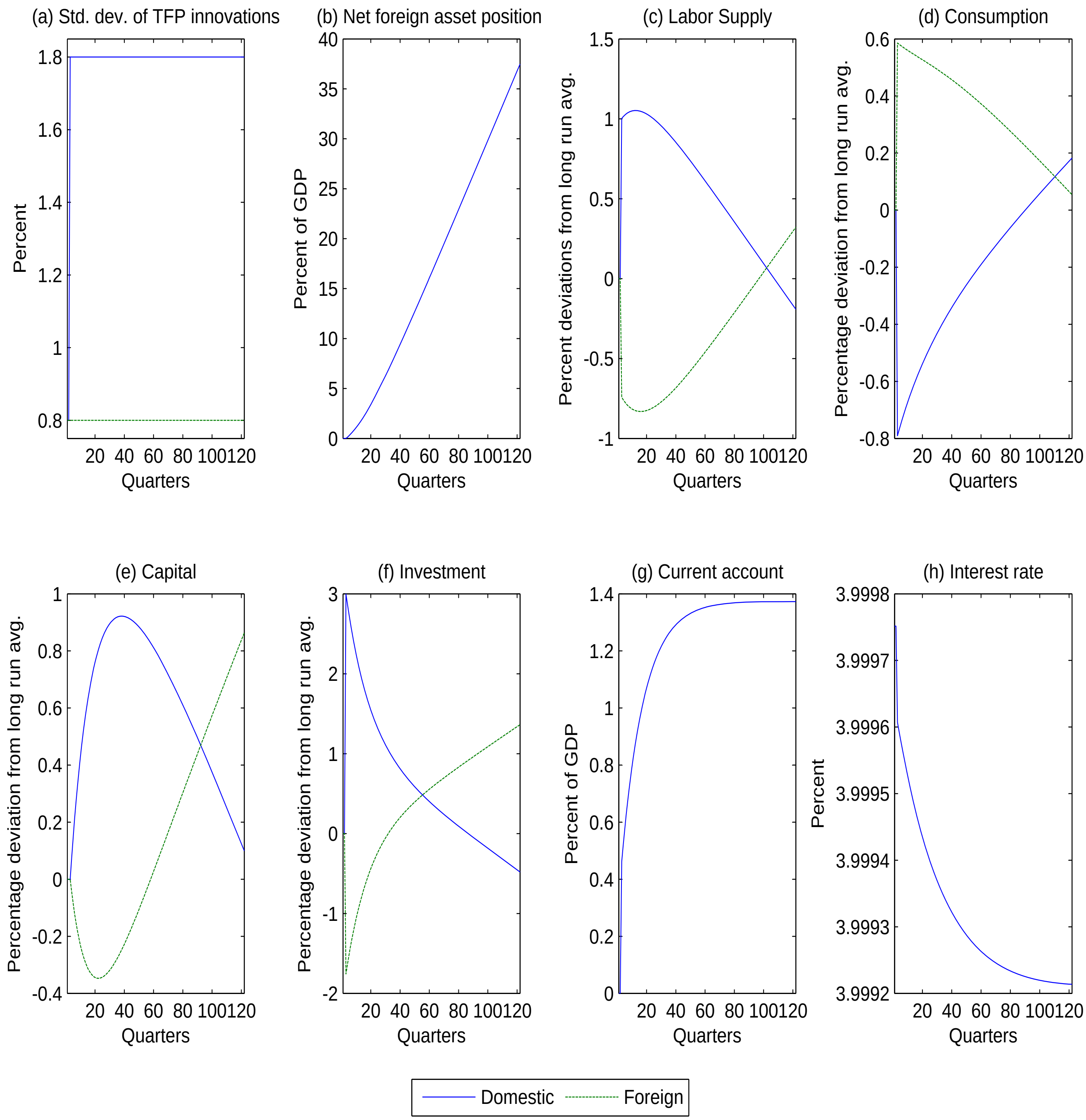

Figure 3: Response to a volatility shock (Standard preferences)

Note also how all variables (i.e. investment, consumption, capital, labor) except net foreign assets have a small and non monotone response to a change in volatility, thus explaining why in our empirical exercise the change in foreign assets and the changes in volatility were so strongly associated.

One aspect that might puzzle the reader is the allocation of capital. Panels (e) and (f) show that when capital in country 1 becomes more risky (with the same return) more capital is allocated (in the short run) to country 1. As discussed above this is due to the change in precautionary saving motive and to the assumption about preferences which induce a tilt in the time path for leisure. In figure 4 below we show that if we change preferences so to eliminate wealth effect from labor/leisure decision (i.e. if we assume that preferences have the following functional form $U(c,l) = (\frac{1}{1-\gamma}(c-\mu\frac{l^{1+\xi}}{(1+\xi)})^{1-\gamma})$ the responses for investment and capital are different. In particular with these preferences labor is independent from the path of consumption and hence the increase in risk in country 1 reduces the risk adjusted relative return of investing in country 1 and induces a reallocation of capital from country 1 to country 2. Notice though that the overall impact of volatility shock on external imbalances is very similar for both specification of preferences.

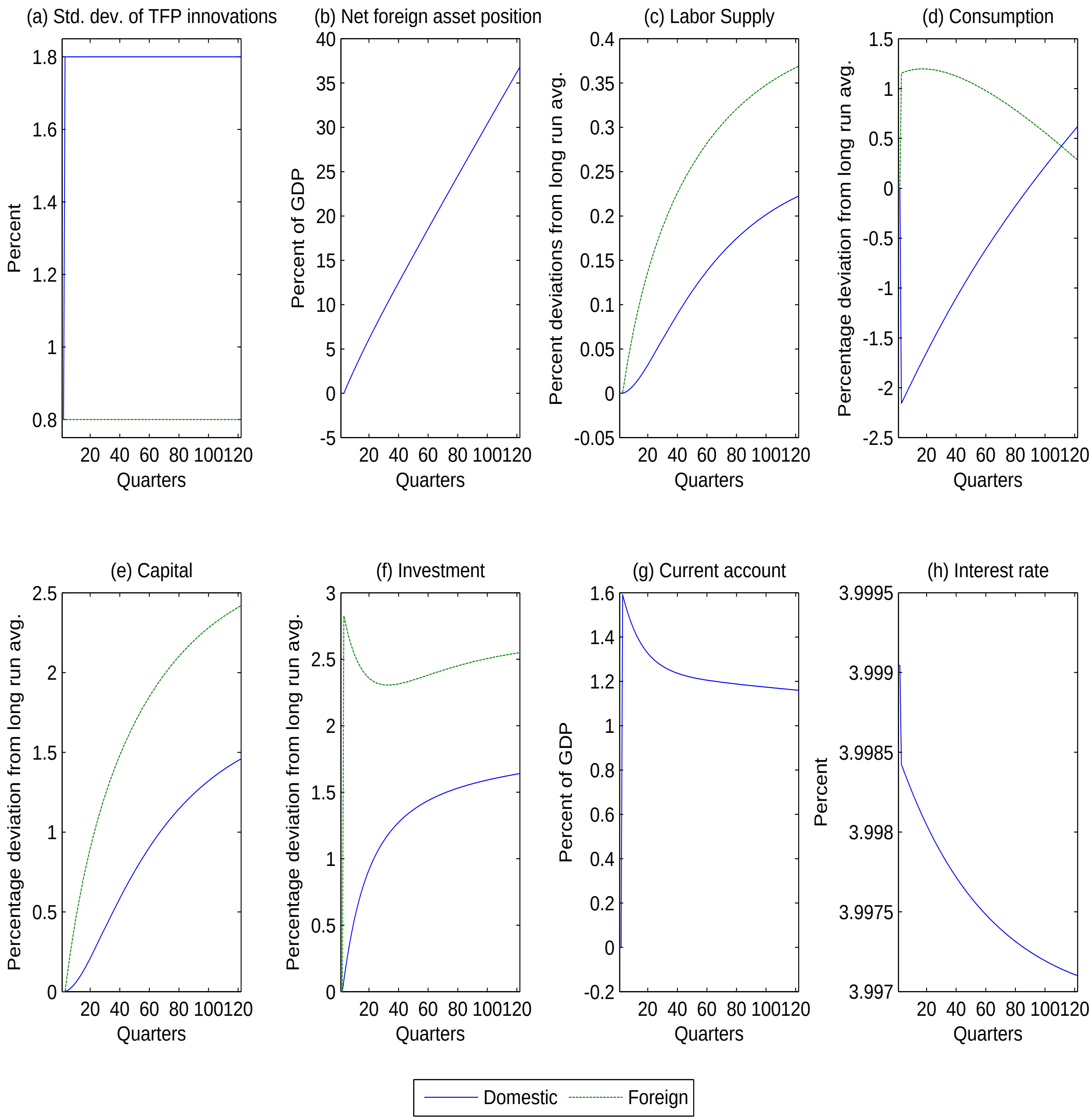

Figure 4: Response to a volatility shock (No wealth effect preferences)

4.3 Numerical results

The simulation procedure is as follows. Once the approximate solution to the 2-country model has been computed, we repeatedly simulate the 2-country model for 212 periods (the maximum length of the actual series in the dataset) generating 10 groups of simulations, each comprising 20 simulations of the model. Innovations hitting country 2 remain the same across simulations of the 2-country model. For country 1, histories of innovations change at each simulation. For each simulation, we compute the relative volatility of GDP growth as the difference between the standard deviation of GDP growth in country 1 and country 2 (over the fixed window width). Then all series concerning country 2 are dropped, so that we are left with 10 groups of simulations, each containing 20 simulations of country 1. We consider a group a 20 simulations of country 1 as the model analogue to the group of OECD countries considered in the empirical analysis. Therefore we are left with 10 simulations of this artificial "world" economy. All simulation statistics are computed as averages of the corresponding statistics across the 10 simulations of the "world" economy.

- Result 1. We simulate the model with both shocks to productivity and to the volatility of productivity and then run on data generated by the model the same regressions we run in the data, to evaluate whether the impact that changes in risk have on net foreign asset position in the model can generate the relation we see in the data. The key result is that the model captures a substantial part of the medium run co-movement between volatility and net foreign asset position.

Table 3: Coefficients, Data and Model

Dependent variable is Net Foreign Assets

	Data		Model 1		Model 2	
Window	V	VG	V	VG	V	VG
20 years	21.82*** (5.938)	19.05*** (6.610)	19.11	20.14	29.20	29.19
		-12.06 (9.964)		27.92		-9.79
15 years	20.62*** (4.868)	18.12*** (5.899)	18.21	19.39	28.17	28.13
		-9.75 (9.130)		27.22		-0.81
10 years	18.62*** (3.812)	17.22*** (4.876)	17.02	18.15	27.55	27.53
		-5.79 (9.336)		23.50		2.01
5 years	14.83*** (4.395)	14.41*** (4.753)	13.52	14.29	23.73	23.83
		-2.61 (5.737)		15.64		4.81

"V" denotes regressions of net foreign asset position on volatility of GDP growth, "VG" denotes regressions on volatility and average GDP growth. All regressions on the real world data include a constant, country and year fixed effects. All regressions on simulated data include a constant and country fixed effects. The regressor in this case is relative volatility of GDP growth, which delivers results comparable to including year fixed effects and using plain volatility of GDP growth at the same time.

- Result 2. First we compute the cross sectional standard deviation of net foreign asset position (after controlling for country and time fixed effects) in the data and then we assess how much of this cross sectional dispersion can be reproduced by the model.

Table 4: Importance of Uncertainty Shocks

	Model	
Uncertainty Shocks	NO	YES
St. Dev. of GDP Growth	1.1460%	1.1460%
St. Dev. of Consumption Growth	1.0541%	1.0552%
St. Dev. of Investment Growth	1.8322%	1.8407%
St. Dev. of Change in Net-Exports-to-GDP Ratio	0.1475%	0.1552%
St. Dev. of Relative Volatility (de-meaned)	0.1489%	0.2986%
St. Dev. of NFA (de-meaned)	12.7414%	14.7125%

TO BE COMPLETED

4.4 Role of Preferences and International Risk Sharing

Table 5a: Sensitivity Analysis

Name	Data	$\gamma = 2$	$\gamma = 5$	$\gamma = 10$	GHH	Stocks
St. Dev. of GDP Growth	1.1300%	1.2667%	1.1460%	1.0766%	1.4024%	1.1289%
Relative St. Dev. of Consumption to GDP Growth	0.9460	0.7214	0.9208	1.0574	1.1737	0.9557
Relative St. Dev. of Investment to GDP Growth	3.2744	2.1122	1.6062	1.2918	1.0454	2.4932
St. Dev. of Change in Net-Exports-to-GDP Ratio	1.1158%	0.1328%	0.1552%	0.1719%	0.2373%	0.4982%
St. Dev. of Relative Volatility (de-meaned)	0.2976%	0.3297%	0.2986%	0.2796%	0.3671%	0.2936%
St. Dev. of NFA (de-meaned)	14.4518%	9.8976%	14.7125%	18.5602%	31.5537%	7.1500%

All statistics are computed using 10 year rolling windows. With Greenwood-Hercowitz-Huffman preferences, the inverse Frish elasticity of labor supply ξ is set equal to 2 and the utility weight of labor $\mu = 21.7$, which yields a steady state value for the labor supply of approximately 0.33. In the stock economy, we set holdings of shares of domestic as well as foreign firms by country 1 equal to 0.5. All the remaining parameters are left as in the baseline calibration 1.

Dependent variable is Net Foreign Assets

	Data		$\gamma = 2$		$\gamma = 5$		$\gamma = 10$		GHH		Stocks	
	V	VG	V	VG	V	VG	V	VG	V	VG	V	VG
Vol. GDP Growth	18.62***	17.22***	10.75	11.39	17.02	18.15	18.86	20.59	25.36	27.95	7.61	7.83
	(3.812)	(4.876)										
Av. GDP Growth		-5.79		13.30		23.50		32.48		40.88		8.01
		(9.336)										

With simulated data, the regressor is the relative volatility of GDP growth.

TO BE COMPLETED

5 Conclusions

The main result of the paper is that changes in country specific uncertainty are quantitatively important drivers of foreign asset accumulation. One conclusion we can draw from this is that macro uncertainty and its evolution should be a major factor to consider when discussing the causes and the sustainability of global imbalances.

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