Modelling Global Trade Flows: Results from a GVAR Model*

Matthieu Bussière[†] Alexander Chudik[‡] Giulia Sestieri[§]

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Abstract

This paper uses a Global Vector Auto-Regression (GVAR) model to investigate the factors behind global trade flows, with a particular view on the issue of global trade imbalances and on the conditions of their unwinding. Using a panel of 21 emerging market and advanced economies, we focus on the effect on real trade flows of shocks to the real effective exchange rate and to domestic and foreign demand. The GVAR approach enables us to make two key contributions: first, to model international linkages among a large number of countries, which is a key asset given the diversity of countries and regions involved in global imbalances, and second, to model exports and imports jointly, in contrast to the existing literature, which considers them separately. The model can be used for a variety of simulation scenarios. The main results suggest that a (negative) shock to US output would have a significantly larger impact on the US trade balance than a depreciation of the US dollar. However, this would also have a large effect on foreign output and on global trade.

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[†]European Central Bank. Email: matthieu.bussiere@ecb.int.

[‡]European Central Bank. Email: alexander.chudik@ecb.int.

[§]University of Rome Tor Vergata. Email: giuliasestieri@hotmail.com.

Non-technical Summary

The question of what drives exports ans imports at the country level is one of the longest standing themes in international macroeconomics. Fluctuations in net exports represent indeed a substantial component of output growth volatility, while changes in the trade balance are closely monitored in policy circles. More specifically, two mechanisms have received a lot of attention. The first one is the effect of nominal exchange rate changes on exports and imports (in particular, whether a given depreciation can successfully stimulate exports and trigger an expenditure-switching effect away from imported goods). The second key mechanism is the role of domestic and foreign demand: to what extent will a fall in domestic demand in a given country affect the magnitude of this country's imports? And what effect will this have of this country's trading partners?

Such questions have received renewed interest in recent years, with the emergence of global trade imbalances: to the extent that the US trade deficits recorded since the early 2000s were deemed unsustainable, one important policy question was to study the conditions of an unwinding of such imbalances. Studies on the issue have focused in particular on the magnitude of the dollar depreciation that would accompany an adjustment in the US trade balance (Obstfeld and Rogoff, 2005, 2006, Blanchard, Giavazzi and Sa, 2006). Since the intensification of the financial crisis at the end of 2008, the question of what are the determinants of global trade flows has become even more pressing, with global trade flows literally collapsing in all regions of the world.

The aim of the present paper is to introduce a new tool to analyse trade flows, using the so-called Global Vector Auto-Regression (GVAR) model developed originally by Pesaran, Schuermann and Weiner (2004). This model is applied for the first time to study the issue of international trade adjustment. Two specific characteristics of the model make it particularly appealing for this issue, compared to the existing literature. The first one is that GVAR models are specifically designed to account for the interaction between a large number of countries. This is a crucial feature given that global imbalances cannot be subsumed to any bilateral deficit; in particular, in contrast to previous historical episodes of global imbalances, the number of surplus countries is very high and includes very heterogeneous economies and regions (see Bracke et al., 2008, for statistical measures and a discussion along these lines). Having many countries allows to answer questions that could not be tackled previously in studies with just three or four main countries/regions. For instance, it provides estimates of the impact of a US slow-down not only on US imports, but also on trade flows and output growth in European countries and in Asia. Such estimates represent an important input in the debate on the possible "decoupling" of some regions of the world.

The second feature of our model that significantly differs from the existing literature is that, instead of estimating equations for exports and imports separately, we are able to model them jointly. We find that this innovation is important. Exports and imports appear indeed to comove substantially for a variety of countries. Such comovement can come in particular from the strong import content of exports: with globalization and the internationalization of production, the production of exported goods and services tends to use a substantial amount of imported components. This stylized fact has important implications for the transmission of shocks across countries: if foreign demand addressed to a given country falls, negatively impacting this country's exports, its imports are also likely to be affected, in turn impacting exports from other trading partners.

Concretely, our GVAR model is estimated with a sample of 21 countries, including 14 advanced countries and 7 emerging market economies. We use quarterly data starting in 1980 and ending in 2007. The selection of this particular country sample followed two considerations: on the one hand, the objective to include all systemically relevant countries and work with sufficiently long time series to estimate the model properly, and on the other hand data availability issues, which led to the exclusion of specific countries and time periods. The data appendix presents the detail of the dataset.

The GVAR approach can be briefly described in two steps. In the first step, country-specific small-dimensional models are consistently estimated, which include domestic variables and cross section averages of foreign variables. Particular importance is given in our modelling strategy to the identification of the long-run (cointegrating) relations among the variables. In the second step, the estimated coefficients from the country-specific models are stacked and solved in one big system (global VAR), which can be used for different purposes, such as the analysis of impulse-response functions.

We use the results from our GVAR model to simulate the effect of various shocks. Specifically, we consider three main scenarios: a shock to the US real effective exchange rate, a shock to US domestic output, and shocks to foreign output. Our estimated elasticities appear to be broadly in line with the existing literature for the demand shocks. For the exchange rate shock, we find a higher response of exports than imports in the US. The main results suggest in particular that a (negative) shock to US output would have a larger impact on the US trade balance than a depreciation of the US dollar (when shocks are scaled to one standard deviation of the variables). This comes in particular from the low reaction of US imports to a depreciation of the dollar, which itself is consistent with low pass-through to US import prices (as reported, e.g. in Marazzi et al., 2005). However, a shock to US output would also have a large effect on output abroad and on world trade.

1 Introduction

The question of what drives exports ans imports at the country level has a very long history in the field of international economics. Nearly a quarter of a century ago, Goldstein and Kahn (1985) could write *"Few areas in all of economics, and probably none within international economics itself, have been subject to as much empirical investigation over the past thirty five years as the behavior of foreign trade flows"*. More recently, the reasons behind the emergence of global trade imbalances in the early 2000s, as well as the conditions of their unwinding in the wake of the 2008 financial crisis, have attracted a lot of attention among academics and policy-makers, triggering in particular renewed interest in the role of the exchange rate and of relative demand terms in the adjustment of international trade flows. Studies on the issue have focused in particular on the magnitude of the dollar depreciation that would accompany a reduction in the US trade deficit (Obstfeld and Rogoff, 2005, 2006, Blanchard, Giavazzi and Sa, 2006). Similarly, the debate on what caused the sharp contraction in world trade towards the end of 2008 underlines the importance of carefully estimating the elasticity of exports to a change in foreign demand.

One specific aspect of the above questions that calls for particular attention - and largely motivates the approach that we follow in this paper - is the multilateral nature of international trade and of global imbalances. Indeed, the notion of global imbalances cannot be subsumed to one country, or even to one country pair. Rather, it involves a large number of countries, as can be seen through key stylised facts. Among the countries with an external deficit, the United States of course stands prominently: the United States has run large current account deficits for most of the past two decades, reaching a peak in 2006 at nearly $790 bn, or 6% of GDP. However, just as the US current account balance started to adjust in 2006 and 2007, other countries went on to register sizeable trade deficits and participated in the adjustment process by importing more from abroad (noticeably the United Kingdom and Australia, whose deficits reached around 5% and 6% of GDP in 2007, respectively). On the surplus side, one distinguishing feature is the diversity of the countries involved: the world's largest surpluses include emerging market countries (China, Singapore), advanced economies (Japan, Germany[1], Switzerland) and oil exporting countries (Saudi Arabia, Russia, Norway).[2] This aspect of global imbalances was fully acknowledged in G7 communiqués[3], which recognized that global imbalances are a "shared responsibility" for the international community, rather than the sole responsibility of the United States. Unsurprisingly therefore, the unwinding that took place at the end of 2008 affected a large number of countries and continents. Looking at gross flows instead of net balances also confirms the fact that world trade is accounted for by a variety of countries: although the United States certainly is a large importer and exporter of goods, US trade flows only account for less than 15% of world trade.

Unfortunately, the multi-country dimension of the problem at stake is generally overlooked, as existing papers focus on a small subset of countries. In papers using panel regressions, the countries that compose the panel are often treated as independent units and cross-country spillovers are ignored. The present paper aims to fill this gap by using a Global Vector Auto-Regression approach (GVAR). This model features vector error correction models for the individual countries included in the panel, which are linked to each other by including foreign variables in each country-specific VAR. This makes the GVAR approach particularly useful for the analysis of global imbalances. For example, it enables to model the complex effects of a slow-down in domestic demand in the United States on the global economy, i.e. not only the direct impact of lower US demand on US imports, but also the indirect effect on demand from foreign countries and, in turn, on US exports.

This paper is related to two main strands of the literature: the econometric literature on GVAR models and the empirical literature on trade and open economy macroeconomics, which aims to estimate trade elasticities. Starting with the former, the present paper builds on previous contributions to the GVAR literature, in particular Pesaran, Schuermann and Weiner (2004), Pesaran and Smith (2006), as well as Dées et al. (2007a, 2007b). The GVAR framework was applied in the past to a variety of questions; to our knowledge this paper

[1] Individual euro area countries are here considered individually in order to enable comparisons across different time periods. Taken as an aggregate, the euro area current account was close to balance in recent years.

[2] In the mid-1980s, when the United States already recorded a sizeable deficit, only three countries accounted for 50% of the world's current account surpluses: Germany, Japan and the Netherlands. See also Bracke et al. (2008), who report statistical indicators of dispersion.

[3] See e.g. the Annex on Global Imbalances from the G7 meeting on April 21, 2006.

presents the first application of the GVAR methodology to the issue of international trade and global imbalances. Turning to the trade literature, if one abstracts from the foreign variables featured in the GVAR model, the equations we estimate for individual countries are similar to the models used in other policy institutions for forecasting and simulation purposes, such as the New OECD International Trade Model (Pain et al., 2005), the ECB's Area Wide Model (Fagan, Henry and Mestre, 2001), the Fed's FRB Global and USIT models (see e.g. Bertaut, Kamin and Thomas, 2008), research work at the Federal Reserve Board on trade elasticities (Hooper, Johnson and Marquez, 1998, 2000), etc. This family of models itself follows the contribution of Goldstein and Kahn (1985) and the literature reviewed within.

Compared to existing trade models, the present paper makes two main contributions. The first one is to link for the first time individual country trade models together using the GVAR framework. This allows us to specifically model cross-country spillovers. It also allows for considerable modelling opportunities, as we are able to study the impact of a shock to any of the four variables among our 21 countries on any of the other 20 countries. The second main contribution that we make is that, instead of estimating export and import equations separately, we estimate them jointly in one system. This proves to be very important because of substantial comovements between exports and imports, which appear to cointegrate with each other for several countries.[4] This may come from the fact that the trade balance is expected to be stationary in the long-run, and also from the fragmentation of production across borders (e.g., exporting firms typically import components, inducing comovements between exports and imports). To our knowledge, this crucial point has been overlooked in the existing literature, which typically models exports and imports separately. In addition to these two main contributions, we also address a methodological point: whereas most existing trade models used for forecasting and monitoring rely on single equations (making the assumption that the right-hand side variables are exogenous), we estimate the model in a vector error correction form, which enables a richer (and more accurate) specification of the relation between the economic variables. We also discuss

[4] Exports and imports cointegrate with each other with coefficients [1,-1] only for one country; for other countries the coefficients are different from unity and other variables are part of the cointegrating vector.

the interpretation of "trade elasticities" in the context of a vector-error correction model (whereas many authors interpret the coefficients of the cointegrating relation as elasticities, we rely predominantly on impulse-response functions).

We use the results from our GVAR model to simulate the effect of various shocks. Specifically, we consider three main scenarios: a shock to the US real effective exchange rate, a shock to US domestic output, and to foreign output. Our estimated elasticities appear to be broadly in line with the existing literature for the demand shocks. For the exchange rate shock, we find a higher response of exports than imports in the US. The main results suggest in particular that a (negative) shock to US output would have a larger impact on the US trade balance than a depreciation of the US dollar (when shocks are scaled to one standard deviation of the variables). This comes in particular from the low reaction of US imports to a depreciation of the dollar, which itself is consistent with low pass-through to US import prices (as reported, e.g. in Marazzi et al., 2005). However, a shock to US output would also have a large effect on output abroad and on world trade.

The rest of the paper is organized as follows. Section 2 reviews the related economic literature and compares our approach to previous papers on the topic; it also motivates our main modeling choices. Section 3 outlines the main features of the GVAR model. Section 4 reports the estimation results, Section 5 turns to our simulation results, focusing on specific adjustment scenarios, while Section 6 concludes. Finally, Appendix A presents the data, Appendix B the tables and Appendix C the figures.

2 Review of the Literature

This paper is related to two main research areas: empirical trade modelling and the econometric estimation of global VAR models. The aim of this section is to contrast our approach with previous papers on these subjects.

2.1 Empirical Trade Modelling

To begin with, the equations we estimate for individual countries are similar to most empirical trade models, if one abstracts from the foreign variables that characterize the GVAR approach. In particular, our empirical strategy is close to the ECB's Area Wide Model and to the models used in other policy institutions for forecasting and simulation purposes. This family of models itself follows the framework presented in Goldstein and Kahn (1985).[5] Thus, the New OECD International Trade Model (Pain et al., 2005) presents single equation estimates for 24 OECD countries, where the models are estimated in error correction form. In this model, real exports depend on relative export prices and on foreign demand, while real imports depend on relative import prices and domestic demand. In the Area Wide Model (Fagan, Henry and Mestre, 2001), euro area exports and imports are not modeled within an error correction framework. Rather, the ratio of euro area exports to world demand (export market share) is a function of its own lags and of a competitiveness indicator, the ratio of export prices to world prices. On the import side, euro area imports are explained by domestic demand and by relative import prices (the ratio of import prices to the GDP deflator). For the US economy, the updated version of the USIT[6] model presented in Bertaut, Kamin and Thomas (2008) follows a very similar logic; one noticeable aspect of USIT is that the estimation is done at a disaggregated level. The appropriate level of disaggregation is an important and recurrent issue in the context of trade equations; clearly, with 21 countries and 9 variables, and given the strong constraints imposed regarding the data coverage for emerging market economies, we carry out the analysis at an aggregate level. Research at the Federal Reserve Board is actually not limited to the US economy: a similar model is estimated for export and import volumes in all G7 countries in Hooper, Johnson and Marquez (1998, 2000). Finally, another celebrated model using a similar approach is the IMF MULTIMOD model (Laxton et al., 1998).

Compared to these models, the main contribution of the present paper is therefore to link individual country models together through the foreign variables.[7] Country specific foreign variables capture unobserved common factors in the spirit of Pesaran's (2006) Common Correlated Effects estimators (see Dees et. al. 2007a for a related discussion). In addition,

[5] The empirical trade literature has a long history. Noticeable contributions include Harberger (1950, 1953), Alexander (1959), Armington (1969), Houthakker and Magee (1969), and Hooper (1976, 1978). For a more recent survey see in particular Sawyer and Spinkle (1996).

[6] USIT stands for "U.S. International Transactions".

[7] Country-specific foreign variables are computed as cross section averages of the variables of interest (exports, imports, output and real effective exchange rate, respectively).

all the models mentioned above use single equations and rely on the assumption that the right-hand side variables are exogenous, whereas we estimate the model in a vector error correction form. Regarding the empirical papers reviewed above, three specific aspects of the empirical approach call for particular attention: the best measure of relative prices, the effects of foreign and domestic demand on trade flows (the "elasticity puzzle") and the strong comovements between exports and imports.

2.1.1 Relative prices

The first empirical issue relates to the choice of our relative price measure. Many papers use relative export prices in the export volume equation and relative import prices in the import volume equation (this is the case in Pain et al., 2005, and in Fagan, Henry and Mestre, 2001). As we do not model trade prices separately, we use the real effective exchange rate instead and consider the impact of real exchange rate changes on real trade flows directly. This parsimonious specification considerably simplifies the model. Nonetheless, a number of alternative competitiveness indicators have been developed recently, which appear to have a better fit in trade equations (see e.g. Thomas, Marquez and Fahle, 2008, for the United States). However, such measures are typically not available for a broad number of countries. We therefore decided to use the real effective exchange rates, in view of the wider data coverage, of their extensive use in the empirical literature and of their prominence in the policy debate.[8]

2.1.2 Domestic and foreign demand

The second modelling choice that is worth highlighting relates to the demand terms. On the export side, foreign demand is often defined as a weighted average of output in foreign countries (Hooper, Johnson and Marquez, 2000), while several papers use a weighted average of foreign imports (e.g. Anderton, di Mauro and Moneta, 2004), in which case the ratio of exports to foreign demand can be interpreted as market share. In principle, we could do

[8] Exchange rate developments receive overwhelmingly more attention in the policy debate than other competitiveness measures. A potential extension would consist in adding export and import prices into the model. However, it is at this stage unclear whether this is feasible given the sharp increase in the number of parameters to be estimated that this would imply.

both as our dataset includes foreign GDP and foreign imports. We opted for the weighted average of foreign output, which is broader: a rise in demand in a foreign country could be addressed to goods that are locally produced or to imported goods, using a weighted average of foreign imports would only consider the latter. On the import side, several papers have used somewhat more sophisticated measures, e.g. by breaking down domestic demand by category (investment, private consumption and government spending), given that these categories have different import contents. This is for example the approach of Pain et al. (2005) in their study of trade flows in OECD economies. An extension of the model, where we would consider the components of domestic demand separately, does not seem feasible at this stage given the loss in degrees of freedom that this would imply.

The effect of demand on real trade quantities is characterized by a well-known empirical regularity for the United States (but also for other countries), which is referred to as the Houthakker-Magee (1969) puzzle. Indeed, empirical works show that the demand elasticity is significantly higher on the import side (where it is commonly estimated to be above one) than on the export side (where it is generally equal to one). This represents a puzzle because it implies that, to prevent the trade balance from permanently moving towards a deficit, the exchange rate should permanently depreciate (this is also under the condition that foreign and domestic output grow at similar rates). Another puzzling implication of having a demand elasticity above one is that output should be completely imported in the long-run, barring a permanent depreciating trend. In fact, many papers have addressed this point by *imposing* a long-run demand elasticity of one. This is for instance the case of Pain et al. (2005) in one of their specifications. In this work, no restrictions are imposed on parameters and demand elasticities are freely estimated for each county.

2.1.3 The relation between exports and imports

One noticeable empirical regularity is the strong comovement between exports and imports across countries (Figure 1 reports real exports and imports for selected economies). This comovement is somewhat puzzling because one could think of several shocks that should have the opposite effect on real exports and imports. For instance, a ceteris paribus appreciation of the real effective exchange rate can be expected to decrease exports - because it reduces price competitiveness - but increase imports - by lowering relative import prices. Three main factors may explain the strong comovements observed on Figure 1. First, demand shocks are transmitted across countries and can ultimately affect both exports and imports. For example, a rise in domestic demand will increase imports, which should raise foreign exports and foreign income, which in turn should raise domestic exports. This type of transmission mechanism is accounted for in our GVAR framework through the foreign demand terms. Second, taking an open macroeconomic perspective, the intertemporal budget constraint imposes stationarity of the current account balance.[9] To the extent that the trade balance is the most important component of the current account, this would imply stationarity of the trade balance and, in turn, that exports and imports cointegrate with each other.[10] Third, the fragmentation of production across countries implies some comovement between exports and imports. Thus, several studies show from input-output tables that the import content of exports is high: whenever exports increase by one unit, imports also increase substantially (e.g. because exporting firms must import some of the components or raw materials).

2.1.4 Global imbalances

Indirectly, this paper contributes to the literature on global trade imbalances. This contribution is only indirect because we do not address the root causes of global imbalances such as Bernanke's "Global Saving Glut" and other structural factors that are reviewed in Bracke et al. (2008). This literature obviously overlaps with the empirical trade literature reviewed above, as empirical trade models are often used to quantify the effect of exchange rate changes and output shocks on trade flows.[11] Obstfeld and Rogoff (2005, 2006) argue that a very sizeable depreciation of the dollar is necessary to reduce the US trade balance: this could reach over 30% in their preferred specification, but they also present simulations

[9] Empirical evidence on the subject is mixed, see in particular Wu (2000), for a recent application and discussion. The author finds support for the mean-reverting property of the current account.

[10] Another complication is that stationarity of the trade balance implies that export and import *values* cointegrate with each other, whereas we consider here export and import *volumes* (i.e., in real terms). Accordingly, while we considered the possibility that real exports and imports cointegrate with each other with coefficients [1,-1], our empirical results suggest that this is not the case for most countries.

[11] Bertaut, Kamin and Thomas (2008) present simulations from the Fed's USIT model to analyse the sustainability of the US trade deficit. Ferguson (2005) addresses the global imbalances issue by reviewing simulation results from the Fed's FRB global model.

where the depreciation could even be higher, at 64%. Blanchard, Giavazzi and Sa (2006) also conclude, based on a portfolio model of exchange rate and current account determination, that a substantial dollar depreciation will accompany the adjustment in the U.S. current account deficit. This result did not go unchallenged; in particular, Engler, Fidora and Thimann (2007) argue that supply side effects could actually reduce the magnitude of the dollar depreciation by a significant proportion. Against this background, the present paper re-assesses the impact of exchange rate and demand shocks on real trade flows within a GVAR framework.

2.2 Global VAR Modelling

The present paper would not have been possible without previous developments of the GVAR framework. The GVAR model was first introduced by Pesaran, Schuermann and Weiner (2004) and subsequently developed through several contributions. In particular, Pesaran and Smith (2006) show that the VARX* models can be derived as the solution to a DSGE model, where over-identifying long-run theoretical relations can be tested and imposed if acceptable. Dées et al. (2007b) present the first attempt to implement and test for the long-run restrictions within a GVAR approach. Dées et al. (2007a) derive the GVAR approach as an approximation to a global factor model. Finally, Chudik and Pesaran (2009) formally establish the conditions under which the GVAR approach is applicable in a large systems of endogenously determined variables. They also discuss the relationship between globally dominant economies and factor models.[12]

The GVAR framework was applied in the past to a variety of questions. This includes an analysis of the international linkages of the euro area (Dées et al., 2007a), a credit risk analysis (Pesaran et al., 2006, and Pesaran, Schuermann and Treutler, 2006), an assessment of the role of the US as dominant economy (Chudik, 2007), the construction of a theoretically coherent measure of steady-state of the global economy (Dées et al., 2008) and a counterfactual experiment of the UK's and Sweden's decision not to join EMU (Pesaran, Smith and Smith, 2007). Our paper presents the first application of the GVAR methodology to the issue of international trade and global imbalances.

[12] A textbook treatment of GVAR approach can be found in Garratt et al. (2006).

Before concluding this section and turning to the outline of the model, one final point on the methodology is in order. This point does not specifically relates to the GVAR literature, but more broadly to studies aiming to estimate elasticities within a VECM framework in general. Indeed, standard practice consists in interpreting the coefficients of the cointegrating relations as long-run elasticities. This interpretation turns out to be wrong, however, because it disregards the full dynamics of the system (see Johansen, 2005, and Lütkepohl, 1994, for a discussion of the interpretation of cointegrating coefficients in the cointegrated vector autoregressive model). In the present paper, we consistently base our results instead on generalised impulse-response functions, focusing on the shocks we are interested in. As many of the authors who estimated trade elasticities only report the cointegrating vectors and not the impulse-responses, this makes the comparison of our results with previous studies difficult (however, we do report our cointegrating vectors for comparison purposes). One drawback of this approach is that the shocks that we consider are not identified and do not correspond to a thought experiment in which some of the variables (e.g., the exchange rate) would move independently from the others. At this stage of the development of the literature, there is no possibility to identify shocks in a GVAR context. We therefore need to keep this caveat in mind when interpreting the results.

3 The GVAR Approach to Global Macroeconomic Modelling

One recurrent problem in the global macroeconometric literature is the heavy parameterization of the empirical models. This issue, which is sometimes referred to as the "curse of dimensionality"[13], arises when the number of countries is relatively large compared to the available time dimensions, making it impossible to estimate an unrestricted global VAR even when as few as two or three macroeconomic variables per economy are included. The restrictions which have been imposed in the literature to overcome this problem can be broadly divided into two categories: (*i*) data shrinkage (as, for instance, in factor models) and (*ii*) shrinkage of parameter space (e.g. spatial models or Bayesian shrinkage). An alternative way to overcome the dimensionality problem is the GVAR modelling approach

[13] This expression was coined by Richard Bellman.

originally proposed by Pesaran, Schuermann and Weiner (2004).

The GVAR approach can be briefly described in two steps. In the first step, country-specific small-dimensional models are estimated, which include domestic variables and cross section averages of foreign variables. In the second step, the estimated coefficients from the country-specific models are stacked and solved in one big system (global VAR), which can be used for different purposes, such as the analysis of impulse-responses, the forecast of variables, etc.

The use of a GVAR framework can be motivated in several different ways: Dées et al. (2007a), for instance, derive the GVAR approach as an approximation to a global common factor model, while Chudik and Pesaran (2009) obtain the GVAR approach as an approximation to a large system, where *all* variables are *endogenously* determined. We follow the latter approach in motivating our analysis below.

Let $\mathbf{x}_{it}$ denote a $k_i \times 1$ vector of macroeconomic variables belonging to country $i \in \{1, .., N\}$ where N denotes the number of countries. Collect all variables in the $k \times 1$ vector $\mathbf{x}_t = (\mathbf{x}'_{1t}, \mathbf{x}'_{2t}, ..., \mathbf{x}'_{Nt})'$ with $k = \sum_{i=1}^{N} k_i$ denoting the total number of variables. Our starting point is to assume that all macroeconomic variables in the global economy are endogenously determined. Few would dispute this rather general assumption: there are complex trade and financial linkages among economies and agents are forward looking. In the case of trade flow variables, such as aggregate exports and imports in country $i \in \{1, .., N\}$, endogeneity is implicit in their construction since the exports from country i_1 to country i_2 are the imports from country i_2 to country i_1 and vice versa. Suppose that the vector of all collected macroeconomic variables in the world economy is generated from the following factor augmented VAR model,

$$\mathbf{\Phi}(L, p)(\mathbf{x}_t - \boldsymbol{\delta}_0 - \boldsymbol{\delta}_1 t - \mathbf{\Gamma}\mathbf{f}_t) = \mathbf{u}_t, \tag{1}$$

where $\mathbf{\Phi}(L, p) = \mathbf{I}_k - \sum_{\ell=1}^{p} \mathbf{\Phi}_\ell L^\ell$, $\mathbf{\Phi}_\ell$ for $\ell = 1, .., p$ are $k \times k$ matrices of unknown coefficients, $\boldsymbol{\delta}_j$ for $j = 0, 1$ are $k \times 1$ vectors capturing the deterministic trends, $\mathbf{f}_t$ is an $m \times 1$ vector of unobserved common factors, $\mathbf{\Gamma}$ is a $k \times m$ matrix of factor loadings and $\mathbf{u}_t$ is a $k \times 1$ vector of cross sectionally weakly dependent error terms.[14] The number of parameters

[14] See Pesaran and Tosetti (2007) for a definition of strong and weak cross section dependence.

to be estimated grows at quadratic rate with the number of variables and it is therefore not feasible to consistently estimate the unrestricted VAR model (1) if k and T are of the same order of magnitude.

To cope with the "curse of dimensionality" problem of such a big model, Chudik and Pesaran (2009) proposed a shrinkage of parameter space approach, which shrinks the parameter space only in the limit as $N \to \infty$. Assuming that the coefficients corresponding to the foreign variables in the matrix polynomial $\mathbf{\Phi}(L,p)$ are small (of order N^{-1}), it can be shown that, under few additional assumptions as stated in Chudik (2007),

$$\mathbf{\Phi}_{ii}(L)\left(\mathbf{x}_{it} - \boldsymbol{\delta}_{0,i} - \boldsymbol{\delta}_{1,i}t - \mathbf{\Gamma}_i\mathbf{f}_t\right) - \mathbf{u}_{it} \overset{q.m.}{\to} \mathbf{0}_{k_i}, \tag{2}$$

as well as

$$\mathbf{f}_t - \left(\mathbf{\Gamma}_i^{*\prime}\mathbf{\Gamma}_i^*\right)^{-1}\mathbf{\Gamma}_i^{*\prime}\left(\mathbf{x}_{it}^* - \boldsymbol{\delta}_{0i}^* - \boldsymbol{\delta}_{1i}^*t\right) \overset{q.m.}{\to} \mathbf{0}, \tag{3}$$

uniformly in $t \in \{1, 2, ..., T\}$ as $N, T \overset{j}{\to} \infty$, such that $T/N \to 0$[15]; where the 'star' variables are the following cross section averages

$$\mathbf{x}_{it}^* = \mathbf{W}_i'\mathbf{x}_t,\ \mathbf{\Gamma}_i^* = \mathbf{W}_i'\mathbf{\Gamma},\ \boldsymbol{\delta}_{\ell i} = \mathbf{W}_i'\boldsymbol{\delta}_\ell \text{ for } \ell = 0, 1,$$

$\mathbf{\Phi}_{ii}(L) = \mathbf{I}_{k_i} - \sum_{\ell=1}^{p}\mathbf{\Phi}_{\ell,ii}L^\ell$, $[\mathbf{\Phi}_{\ell,ij}]$ constitutes a conformable partitioning of the $k \times k$ matrix $\mathbf{\Phi}$ into $k_i \times k_j$ submatrices and matrix $\mathbf{W}_i$ is a $k \times k_i^*$ dimensional matrix of weights that defines k_i^* country-specific cross section averages of foreign variables.[16] Matrix $\mathbf{W}_i$ can be any arbitrary non-random (or pre-determined) matrix of weights as long as it is granular, namely the following conditions are satisfied.

$$\|\mathbf{W}_i\| = O\left(N^{-\frac{1}{2}}\right), \tag{4}$$

and

$$\frac{\|\mathbf{W}_{ij}\|}{\|\mathbf{W}_i\|} = O\left(N^{-\frac{1}{2}}\right), \tag{5}$$

[15] $T/N \to 0$ is required in the case of variables integrated of order one, while $T/N \to \kappa$, where $0 \leq \kappa < \infty$, is sufficient in the case of stationary variables.

[16] See Chudik and Pesaran (2009) for further details on the analysis of infinite-dimensional VARs. Chudik (2007) provides detailed derivation of equations (2) and (3).

where $[\mathbf{W}_{ij}]$ represents a conformable partitioning of $k \times k_i^*$ matrix $\mathbf{W}_i$ into $k_j \times k_i^*$ dimensional submatrices $\mathbf{W}_{ij}$.

Equation (3) implies that the unobserved common factors can be approximated by cross section averages of endogenous variables, an idea originally proposed by Pesaran (2006).[17] Together with equation (2), we obtain the following country-specific VARX* (p_i, q_i) models

$$\mathbf{\Phi}_{ii}(L, p_i)\,\mathbf{x}_{it} \approx \mathbf{a}_{i0} + \mathbf{a}_{i1}t + \mathbf{\Lambda}_i(L, q_i)\,\mathbf{x}_{it}^* + \mathbf{u}_{it}, \tag{6}$$

where the cross section averages $\mathbf{x}_{it}^*$ are asymptotically uncorrelated with the errors $\mathbf{u}_{it}$, and $p_i = q_i = p$. Lags for domestic and foreign variables would no longer be the same if the unobserved common factors were introduced directly in the residuals in the infinite dimensional VAR model (1).[18] We introduce the notation p_i and q_i because we allow for different lags across countries as well as different lags for domestic and foreign variables in the empirical application below.

Once estimated on a country by country basis, individual VARX* models (6) for $i = 1, .., N$, can be stacked together and solved as one system by explicitly taking into account that $\mathbf{x}_{it}^* = \mathbf{W}_i'\mathbf{x}_t$. In particular, we can write models (6) as

$$\mathbf{B}_i(L, p_i, q_i)\,\mathbf{x}_t = \mathbf{a}_{i0} + \mathbf{a}_{i1}t + \mathbf{u}_{it}, \tag{7}$$

where

$$\mathbf{B}_i(L, p_i, q_i) = \left[\mathbf{\Phi}_i(L, p_i)\,\mathbf{E}_i', \mathbf{\Lambda}_i(L, q_i)\,\mathbf{W}_i'\right],$$

and $\mathbf{E}_i$ is $k \times k_i$ is a selection matrix that selects vector $\mathbf{x}_{it}$, namely $\mathbf{x}_{it} = \mathbf{E}_i'\mathbf{x}_t$. Let $p = \max_i\{p_i, q_i\}$ and construct $\mathbf{B}_i(L, p)$ from $\mathbf{B}_i(L, p_i, q_i)$ by augmenting $p - p_i$ or $p - q_i$ additional terms in powers of L by zeros. Stacking equations (7) for $i = 1, .., N$ yields the following GVAR model

$$\mathbf{G}(L, p)\,\mathbf{x}_t = \mathbf{a}_0 + \mathbf{a}_1 t + \mathbf{u}_t, \tag{8}$$

[17] The minimum number of country-specific cross section averages, $\min_{i\in\{1,..,N\}} k_i^*$, has to be at least as large as the number of unobserved common factors for the consistent inference of the country-specific models (2).

[18] See Pesaran and Chudik (2009).

where $\mathbf{u}_t = (\mathbf{u}'_{1t}, ..., \mathbf{u}'_{Nt})'$, $\mathbf{a}_\ell = (\mathbf{a}'_{\ell 1}, ..., \mathbf{a}'_{\ell N})'$ for $\ell = 0, 1$, and

$$\mathbf{G}(L,p) = \begin{pmatrix} \mathbf{B}_1(L,p) \\ \vdots \\ \mathbf{B}_N(L,p) \end{pmatrix}.$$

GVAR model (8) can be used for impulse response or persistence profile analysis in the usual manner.

4 The GVAR Trade Model (1980Q1-2007Q4)

There are many modelling choices involved in the construction of a GVAR model. The first one relates to the selection of the variables to include in the model. This choice, of course, depends on the empirical application under study. First, since we want to model global trade, we include real exports and imports, which are our main variables of interest. Next, following the models reviewed in Section 2, we also include real output and the real effective exchange rate, which play the role of demand and relative price terms. Finally, to account for possible common factors influencing global imbalances, we include the price of oil and cross section averages of endogenous variables, which capture possible *unobserved* common factors. A second important modelling choice involves the appropriate time and country coverage. In our case, we want to maximize data availability, in order to cope with the "curse of dimensionality" problem, conditional, however, on the reliability of the available time series. These considerations lead us to exclude countries for which the time series are too short or too volatile. The following subsections present the dataset, the model and the long-run identification procedure.

4.1 Data

Our country sample comprises 21 countries, including 14 advanced countries and 7 emerging market economies.[19] Unlike Dées et al. (2007a), we do not consider the euro area as a whole, including, instead, the five largest euro area countries: Germany, France, Italy, Spain and

[19] Due to the difficulty of finding reliable time series on real exports and imports for some countries for the whole period 1980Q1-2007Q4, our country coverage is slightly smaller than that of Dées et al. (2007a). The full list of countries is presented in Appendix A.

the Netherlands. There are several reasons behind this choice. First, available time series are much longer for the individual countries than for the aggregate (as the euro was introduced in 1999). Second, although some trade series are computed backwards (for example, the IMF WEO provides current account data for the euro area starting in 1997), it is questionable to treat the euro area as a single entity before the euro was actually created, especially when it comes to assessing the impact of exchange rate changes on trade.[20] The different choice made by Dées et al. (2007a) can be easily understood given that the focus of their paper is specifically on the euro area. Finally, by adding five countries (at the cost of removing the aggregate euro area), we simply increase the N dimension of the panel, which enables us to reach a better understanding of the determinants of trade across countries.

Our country-specific VARX* models include 9 variables.[21] In addition to the 5 key series (exports, imports, GDP, real exchange rate and oil prices, all in real terms and in logs)[22], we construct four country-specific foreign series corresponding to cross section averages of exports, imports, output and real exchange rate in foreign countries. Thus, the country specific vector of domestic variables is

$$\mathbf{x}_{it} = (ex_{it}, im_{it}, y_{it}, rer_{it})' \text{ for } i \in \{1, .., N-1\},$$

while for the US model (country $i = N$) we follow Dées et al. (2007a) and include the (logarithm of) real price of oil as endogenous variable,

$$\mathbf{x}_{Nt} = \left(ex_{Nt}, im_{Nt}, y_{Nt}, rer_{Nt}, p_t^{oil}\right)'.$$

The corresponding vector of country-specific foreign variables is

$$\mathbf{x}_{it}^* = \left(ex_{it}^*, im_{it}^*, y_{it}^*, rer_{it}^*, p_t^{oil}\right)' \text{ for } i \in \{1, .., N-1\},$$

[20] Nominal exchange rate fluctuations of the legacy currencies vis-à-vis each other were substantial in the years preceding 1999, especially if one goes back to 1980.

[21] Table A1 reviews the data sources in details.

[22] We used seasonally adjusted data. When the original series downloaded from the IMF and the other sources were not seasonally adjusted, we seasonally adjusted them ourselves using the Census X12 program in Eviews.

and for the US,

$$\mathbf{x}^*_{Nt} = \left(ex^*_{Nt}, im^*_{Nt}, y^*_{Nt}, rer^*_{Nt}\right)'.$$

To construct the foreign variables we use trade weights (see Table A2) which correspond, for each country in the sample, to the trade shares of foreign countries in total exports and imports over the period 2000-2002. The choice of the weights one should employ in constructing relative variables is still an open question in the empirical literature. The preferred option in open economy macroeconomic modelling typically consists in using trade weights. Another option is to use GDP weights (i.e. shares of individual countries on the world output). It has been shown however that weights are likely to be of secondary importance if certain conditions are satisfied, namely when the so-called small open economy or 'granularity' conditions apply (see Chudik 2007 and Chudik and Pesaran 2009).

In the estimation of the VARX* models, we also include dummy variables to take into account various episodes of currency and balance of payments crises.[23]

4.2 Individual Country Models

Following the GVAR literature, we estimate country-specific VARX* models (6) , which can be written in the following error-correction representation:

$$\Delta\mathbf{x}_{it} = \mathbf{c}_{i0} - \boldsymbol{\alpha}_i\boldsymbol{\beta}_i'\left[\mathbf{z}_{i,t-1} - \boldsymbol{\gamma}_i\left(t-1\right)\right] + \boldsymbol{\Lambda}_{i0}\Delta\mathbf{x}^*_{it} + \boldsymbol{\Psi}_i\left(L\right)\Delta\mathbf{z}_{i,t-1} + \mathbf{u}_{it}, \tag{9}$$

where $\mathbf{z}_{it} = \left(\mathbf{x}'_{it}, \mathbf{x}^{*\prime}_{it}\right)'$, $\boldsymbol{\alpha}_i$ is a $k \times r_i$ matrix of rank r_i and $\boldsymbol{\beta}_i$ is a $(k_i + k^*_i) \times r_i$ matrix of rank r_i. It is clear from (9) that this formulation allows for possible cointegration within domestic variables as well as between domestic and foreign variables.

To estimate (9), several choices must be made about the unit root properties of the data, the number of cointegrating vectors and the way foreign variables should be treated. We address these different issues in details in the following subsections.

[23] The dummy list is not provided in the data appendix but it is available upon request.

4.3 Unit Root Tests

Whether or not macroeconomic variables are integrated processes has long been the subject of debate in the literature. Output, imports, exports and oil prices (all variables being expressed in real terms) are commonly assumed to be integrated of order 1, $I(1)$ for short. This assumption has been confirmed in the present application by running a series of unit root tests on these variables.[24] More controversial perhaps is the case for the real exchange rate variable. There is a long standing debate in the empirical literature in international finance about the validity of the relative Purchasing Power Parity condition (PPP), which implies the stationarity of the real exchange rate.[25] Not surprisingly, unit root tests performed on the real exchange rate variables in our panel were not able to reject the null of a unit root in level, while the majority of tests rejected the presence of a unit root in first differences (see Table B4). These results may possibly be due to a lack of power of these tests, given the relatively short time span of data considered (about a quarter of a century). In our analysis, we treat the real exchange rates as $I(1)$ processes since there is little difference in small samples between a unit root series and a series that is mean-reverting with a very long half-life statistic.

4.4 Long-run Relations

In the economic literature, there is a reasonable degree of consensus about the long-run properties of a macroeconomic model, no matter the chosen econometric framework (VAR, DSGE, etc.). On the contrary, the identification of the short-run dynamics of such models is still controversial, as identification schemes often lack support from economic theory or are rejected by the data.[26] While theories of the short-run relations generally focus on the optimization behavior of agents in a particular moment of time, theories of the long-run relations look at equilibrium conditions between the observed variables which hold over a

[24] For reasons of space, we do not report the results in the appendix but they are available upon request.

[25] The general failure to reject the unit roots in real exchange rates may be explained by a lack of power of the tests, given the relative short sample available in the post-Bretton Woods period. Some evidence of mean reversion has been found in studies which have tried to increase the power of these tests by means of long-span or panel-data (e.g. Lothian and Taylor, 1996, and Frankel and Rose, 1996). Other papers, instead, have found positive results by using non-linear models (e.g. Taylor, Peel and Sarno, 2001).

[26] See Garratt et al. (2006) for a comprehensive review of long and short-run identification methods in the marcroeconometric literature.

certain (longer) period of time. In the data, we generally observe deviations from such equilibria, in the form of linear combinations of the variables under consideration (the term $\boldsymbol{\beta}_i' [\mathbf{z}_{i,t-1} - \boldsymbol{\gamma}_i (t-1)]$ in (9) represents these deviations, while $\boldsymbol{\beta}_i$ is the matrix containing the parameters that describe such equilibrating relations).

Given the arguments above, particular importance is given in our modelling strategy to the identification of the long-run (cointegrating) relations among the variables. The identification of such relations, however, is not straightforward since there are many candidate long-run relations borrowed from economic theory, which might hold in our framework and need to be tested.

Among our variables, namely $\{y_{it}, ex_{it}, im_{it}, rer_{it}\}$ (plus the oil price and the corresponding foreign variables), we consider the following long-run relationships (Table 1):

Table 1: Theoretical Long-run Relations

Purchasing Power Parity	$rer_{it} \sim I(0)$
Output Convergence	$y_{it} - y_{it}^* \sim I(0)$
Balassa-Samuelson effect	$rer_{it} - \omega_i (y_{it} - y_{it}^*) \sim I(0)$
Stationarity of Real Trade Balance	$ex_{it} - im_{it} \sim I(0)$
Traditional trade equations:	
Export	$ex_{it} - \delta_{i1} rer_{it} - \delta_{i2} y_{it}^* \sim I(0)$
Import	$m_{it} - \gamma_{i1} rer_{it} - \gamma_{i2} y_{it} \sim I(0)$
Enhanced trade equations:	
Export	$ex_{it} - \delta_{i1} rer_{it} - \delta_{i2} y_{it}^* - \delta_{i3} im_{it} \sim I(0)$
Import	$im_{it} - \gamma_{i1} rer_{it} - \gamma_{i2} y_{it} - \gamma_{i2} ex_{it} \sim I(0)$

It is important to stress that a possible misspecification of the cointegrating relationships can have a severe impact on the constructed GVAR model, with implications for the stability of the GVAR, the behavior of the impulse-response functions and the shape of the persistence profiles. For all these reasons, in the following analysis particular attention is given to testing for the number of cointegrating vectors and to their identification.

4.4.1 System approach

We start with the system approach, where all 9 country-specific variables are treated in one system and the foreign variables enter as weakly exogenous for the inference about the cointegrating vectors in (9). The econometrics of VARX* models have been developed by Harbo et al. (1998) and Pesaran, Shin and Smith (2000). Assuming that the foreign variables are weakly exogenous, we estimate country-specific VARX* models and then we test for the number of cointegrating vectors and for the weak exogeneity of foreign variables.

Results for the number of cointegrating vectors chosen by the trace statistics at the 5% nominal level[27] are reported in Table B1, which also shows the sensitivity of the test to different choices of the lags. The Bayesian information criterion (BIC) tends to select $p_i = 2$, and $q_i = 1$ for almost all countries, which is our preferred choice for the estimation. With the exception of 7 countries[28], the cointegration test is found to be sensitive to the choice of lags. Furthermore, results are quite heterogenous across countries suggesting that there is no or only one cointegrating relationship in several economies. The weak exogeneity assumption is broadly confirmed across countries at the 1% nominal size of the tests, where only in three cases (representing 3% rejection rate) the null hypothesis of weakly exogenous foreign variables was rejected. However, for different nominal size of the tests, we obtain higher rejection rates, which are reported in Figure 2. Ideally, we would expect the rejection rate broadly following the nominal size of the tests if the null hypothesis was valid, which does not seem to be entirely the case.

Since there is some, although rather weak, evidence against the weak exogeneity assumption, we complement the cointegration tests based on VARX* models with traditional Johansen cointegration tests based on VAR models, where all country-specific variables are treated as endogenous. Since including all nine variables in a VAR would substantially reduce the degrees of freedom, motivated by the theoretical relationships in Table 1, we estimate country-specific VAR models in five variables $(ex_{it}, im_{it}, y_{it}, y^*_{it}, rer_{it})'$. The results of these tests, reported in Table B2, show that there is again a lot of heterogeneity across countries, and the number of cointegrating vectors is at most 2 when the lags are chosen by

[27] Critical values are taken from MacKinnon, Haug and Michelis (1999) .

[28] Argentina, Australia, China, Germany, Italy, Norway, and Spain.

the BIC.

There could be at least two reasons for the difference between Table B1 and B2: an inferior small sample performance of the cointegration tests or the omission of foreign variables other than y^*_{it}, which might be part of the cointegration space. Before testing for the latter possibility, we focus on the small sample performance of the cointegration tests.

4.4.2 Small sample performance of the cointegration tests

To shed some light on the small sample properties of the cointegration tests in our panel of countries, we conduct series of simple Monte Carlo (MC) experiments. For each country we estimate a VARX* model with the number of cointegrating vectors imposed according to the results of the trace statistics in Table B1 (with the lags selected by the BIC), and we take these models as the data generating processes (DGPs) for our set of countries. To generate country-specific star variables, separate VAR(2) models in $\Delta\mathbf{x}^*_{it}$ are estimated. Assuming that the residuals are randomly distributed with variance-covariance matrix equal to that estimated from the data, we generate $R = 10000$ replications and we test for the number of cointegrating relations in each replication. The resulting rejection rates of the trace statistics are reported in Table B3[29]. As an alternative experiment, we take as DGPs the estimated individual VARX* models with two cointegrating vectors imposed for each country; results for this alternative specification are also reported in Table B3.

The findings of the MC experiments suggest that the size of the tests is very poor - in most cases above 20% - while the power is good - in most cases above 95%. These experiments, however, do not take into account the fact that, in reality, we do not know the true DGPs and the number of lags to include. Thus, the true performance of the tests is likely to be worse than the results presented in Table B3.

In another series of experiments we use again the estimated VARX* models as DGP, this time imposing some of the overidentifying theoretical restrictions which have not been statistically rejected. Overidentifying long-run restrictions in general lengthen the persistence profiles of a shock to the estimated cointegrating relation, resulting in many cases in

[29] Note that in each replication we impose the correct number of lags, which, however, is not known in practice.

poor power of the cointegration tests.[30]

Since the performance of the cointegration tests for the dimensions of our data set is not likely to be very good (partially due to the large number of coefficients which need to be estimated), we explore an alternative, parsimonious approach.

4.4.3 Parsimonious approach

Due to the small sample properties of the cointegration tests, we do not take the results in Tables B1 and B2 as granted, investigating instead the cointegration properties further by series of smaller-scale models. There is a trade-off between the system approach, where all country-specific variables are estimated in one system (and thereby reducing the degrees of freedom), and a more parsimonious approach, where various subsets of country-specific variables are considered. The advantage of the system approach is that it treats all variables jointly in a system, but this is also its main disadvantage as many coefficients need to be estimated (recall we have 9 variable in each VARX* model). Many of the estimated parameters do not need to be statistically significant and the resulting performance of system approach might end up to be not particularly good. On the other hand, we can estimate subsystems of variables. These subsystems would generally deliver more reliable estimates with the drawback, however, that a large number of lags might be necessary to approximate the true DGP. Therefore, truncating the lags can have substantially negative impact on the performance of the test statistics.

As a trivial example of a subsystem we can consider the real exchange rate variable only and conduct unit root tests to check the validity of PPP. As previously stressed, the results in Table B4 show a failure of the tests to reject the null of non-stationarity of the real exchange rates. Inspired by the theoretical long-run relationships listed in Table 1, we conduct unit root tests also for the stationarity of the real trade balance ($ex_{it} - im_{it}$) and for the output convergence relation ($y_{it} - y^*_{it}$). The results, reported in Table B4, show that the output convergence does not hold (perhaps with the exception of Brazil) and the stationarity of real trade balance is accepted only in the case of the Netherlands. The former finding is broadly in line with empirical literature, see for example pair-wise

[30] To save space, we do not present these results in the appendix, but make them available upon request.

approach to output convergence and PPP by Pesaran (2007) and Pesaran et al. (2008), respectively.

In order to test for the Balassa-Samuelson relation, we estimate bivariate VAR models in two variables $(rer_{it}, y_{it} - y^*_{it})'$. The results of the Johansen trace statistics are reported in Table B5: cointegration is confirmed only in the case of Sweden, with the estimated Balassa-Samuelson coefficient $\omega_i = 0.24$.[31] As for the PPP, the output convergence and the stationarity of trade balance, we do not find support for the validity of a 'pure' Balassa-Samuelson relationship in our dataset.

Finally, we examine the trade equations which are of particular interest given the topic of our paper (Table B6). In particular, the following three and four variable VARs are estimated: the traditional trade equations for exports $(ex_{it}, y^*_{it}, rer_{it})'$ and for imports $(im_{it}, y_{it}, rer_{it})'$; and two enhanced trade equations for exports $(ex_{it}, y^*_{it}, rer_{it}, im_{it})'$ and for imports $(im_{it}, y_{it}, rer_{it}, ex_{it})'$. Overall, in many countries we find evidence for either simple or enhanced import equations, while on the export side the cointegration is found only in a small subset of countries.

4.4.4 The chosen long-run cointegrating relationships

How to put various pieces of evidence together is not straightforward since the evidence from the cointegration tests often depend on the number of lags, leading to contradictory results. Following the results from our parsimonious approach, we chose not to impose PPP, output convergence or Balassa-Samuelson relationship for any country.[32]

Regarding the trade equations, we follow a simple rule. A cointegrating vector is imposed only if we have evidence from smaller-scale (3- or 4-variable) models and only in the case in which the elements of the cointegrating vector satisfy the signs suggested by the economic theory. The final choice for the number of cointegrating vectors and their estimates are reported in Table B7. These cointegrating vectors were then imposed in the

[31] Note that the absence of cointegration between the real exchange rate and the relative real per capita income does not imply that the Balassa-Samuelson effect is not there. It is often the case in the empirical literature on the equilibrium real exchange rate that once a larger set of variables is considered (such as terms of trade, government consumption etc), the cointegration is confirmed between the exchange rates and the fundamentals.

[32] Note that the chosen nominal size of the unit root and cointegration tests was 5%, hence one rejection in 21 cases should be expected on average, even if the null did not hold.

country-specific VARX* models, where we also test for the validity of the chosen overidentifying restrictions. These restrictions are tested using the log-likelihood ratio statistic at the 1% confidence level. The last column of Table B7 shows the critical values of this test which have been computed by bootstrapping from the solution of the GVAR model[33]; none of the imposed overidentifying restrictions has been rejected, which is reassuring.

Two countries were treated differently: the Netherlands and China. The Netherlands is the only country for which unit root tests reject the null of non-stationarity for both the export and import series, which is in line with later finding of stationarity of the real trade balance. Since the Netherlands is a small open economy where a large share of imports is re-exported, we do impose a cointegrating relationship featuring imports and exports for this country. In the case of China, any attempt to identify the long-run relationships ended up to be unsuccessful, resulting in instability of the GVAR model and/or unreasonable persistence profiles. For this reason, China is the only country for which we impose 3 exactly identified cointegrating vectors, as suggested by the cointegration test conducted on the VARX* model.

The bootstrap means of the persistence profiles showing the effect of system wide shocks to the cointegrating relationships are reported in Figure 2.[34] Persistence profiles make it possible to examine the speed at which the long-run relations converge to their equilibrium states. All persistence profiles in Figure 3 are well behaved which is again reassuring for our choice of the long-run overidentifying relations.

4.5 Robustness Tests and Further Results

One important issue that may arise in the present estimation framework is the potential instability of the parameters over time. For example, Hooper, Johnson and Marquez (2000) report extensive stability tests for trade equations among the G7 countries (based on Chow tests, they conclude that the equations are stable overall, but they also find some instability

[33] See the appendix of Dées et al. (2007b) for a detailed description of the GVAR bootstrapping procedure and of the log-likelihood ratio statistic for testing over-identifying restrictions on the cointegrating relations.

[34] Persistence profiles were introduced by Pesaran and Shin (1996) to examine the effect of system-wide shocks on the dynamics of the long-run relations. See also Dées et al. (2007b) for a theoretical exposition of persistence profiles in the context of GVAR. Persistence profiles have a value of unity at the time of impact and should converge to zero as the time horizon reaches infinity.

for the European countries, especially Germany in the wake of the reunification). Partly, we have preempted the problem by using time dummies for specific events such as the German reunification and currency crises. Nevertheless, to check whether or not our parameters are stable over time, we performed a battery of structural break tests: PK_{sup} and PK_{msq} are based on the cumulative sums of OLS residuals, R is the Nyblom test for time-varying parameters and QLR, MW and APW are the sequential Wald statistics for a single break at an unknown change point.

The results, reported in Table B8, show that there is broad evidence in favour of the stability of the parameters, with numbers in line with other GVAR models in the literature. The main reason for the rejections seems to be breaks in the error variances as opposed to breaks in the parameter coefficients. Once breaks in error variances are allowed for by performing the heteroskedasticity-robust version of the tests, parameters seem to be reasonably stable. In the simulation exercises, the possibility of breaks in variance is dealt with by using bootstrap means and bootstrap confidence intervals in the persistence profiles and in the generalized impulse responses analysis.

5 Simulation Results

Our GVAR model contains 85 variables (4 variables per country plus the price of oil). Hence, this is also the total number of possible simulations we can run to assess the effects of a shock to one of the variable in our system on all the others. However, given the strong interest that academics and policy-makers have shown on the possible factors which may reduce the US current account deficit, we present the results for 3 different simulations: a shock to US domestic output, a shock to the US dollar, and a shock to output in foreign (from a US perspective) countries.

In the absence of strong a priori information to identify the short-run dynamics of our system (remember that we have 85 variables, so exact identification would require 3570 restrictions!), we use the generalized impulse response function (GIRF) approach[35] which consider the response associated with unit (one standard error) shifts in the observed

[35] This approach has been proposed by Koop, Pesaran and Potter (1996) and further developed in Pesaran and Shin (1998).

variables. Clearly, when we shock US output we will not be able to distinguish between the possible causes of the shift, e.g. between a demand or a supply shock, but the response of the other variables in the system would still be informative about the implications of this shock for the evolution of the US current account. The GIRF have also the nice property of being invariant to the ordering of the variables, which is of particular importance in big macroeconomic systems.

5.1 Shock to US Output

The first shock that we consider is a positive shock to domestic output in the US. One-standard-deviation shock corresponds in this case to an increase of US GDP of 0.6%. One noticeable result is the large effect on US imports which increase by around 2% after one year and by around 1.3% in the long-run (after 3 years). In addition, we find that this shock would have a significant and large effect on foreign countries. Figure 4 shows the effect of this shock on the GDP of the rest of the world after one year: the bars represent the bootstrapped mean values of the GIRF across the sample, while the 90% bootstrapped confidence intervals are represented by the thinner lines. Unsurprisingly, a positive shock to US output would stimulate output in almost all foreign countries. The effect is especially large in the US neighboring countries, such as Canada and Mexico. It also has a strong effect on some European countries, particularly on the smaller ones (Switzerland and the Netherlands). Surprisingly perhaps, many Asian countries are not significantly affected by the shock (a noticeable exception being Singapore, for which the effect is large). Large Asian countries appear to be relatively insulated from the shock (esp. China and Japan). This may seem somewhat counter-intuitive given the common perception that Asian countries are very dependent on US growth, but it is also in line with evidence of a decoupling of the Asian business cycle[36]. The same figure also shows the effect of the same shock on geographical regions, which are constructed by grouping together the countries in these regions using GDP weights.[37]

[36] See Pula and Peltonen (2009) for a recent discussion of the question of emerging Asia's decoupling.

[37] The region Europe includes the 5 largest euro area countries, i.e. Germany, France, Italy, Spain and the Netherlands; Asia includes China, Thailand, Korea and Singapore while Latin America includes Mexico, Brazil and Argentina.

Figure 5 presents the response of exports to the US output shock: exports increase significantly in almost all countries in the world, consistently with the rise in US imports. The effects of higher growth abroad will also reflect in an increase of US exports, which is found to be statistically and economically significant in the first couple of years after the shock. The ranking of countries in Figure 4 and 5 appears to match broadly, suggesting that the geographical proximity and the trade linkages are important channels in the transmission of a US output shock to the rest of the world. For instance, it is very intuitive to find that Canada and Mexico are among the countries whose exports and output increase by the largest amounts. In the case of the reaction of exports to a rise in US output, one can note that the effect is very substantial in many countries: as our model is symmetric, this also implies that a US slow-down generally is associated with a fall in world trade.

5.2 Shock to the US Dollar

The next shock that we consider is a positive shock to the US real effective exchange rate, which corresponds to an appreciation of the US dollar of roughly 2.5% on impact. The shock has an unambiguous effect on US real exports, which fall by 1.3% in the first year. This result can be reconciled with recent evidence showing a substantial acceleration in US exports towards the end of 2007 and the start of 2008, in the wake of the marked dollar depreciation that took place previously. However, the magnitude of the effect seems quite large, compared to other results in the literature.[38] On the import side, by contrast, the dollar appreciation fails to significantly lift up US imports, which increase by 0.7% after one year and by roughly 1% in the long-run (notice, however, that the effect on US imports becomes statistically significant only after year 2). This is in line with a growing body of the literature showing that pass-through is very limited in the US, at least once one excludes commodity prices (see, e.g., Marazzi et al., 2005). As a result of the low pass-through to US import prices, relative prices (the ratio of US import prices to US domestic prices) do not react significantly when the dollar fluctuates, which considerably limits the expenditure

[38] Our preliminary results imply that a 10% appreciation of the dollar would trigger a fall by more than 5% in US real exports, which appears to be very large. Having said that, Pain et al. (2005) also find a high effect (5.2%), and Hooper, Johnson and Marquez (2000) an even higher effect (their elasticity is above one). However, these comparisons are not without caveats because they refer to a different definition of relative prices.

switching effect. Finally, in spite of the effect on net exports, there is no marked effect on US real output: this is not surprising given that the United States is a relatively closed economy.

Figure 6 suggests that foreign economies are heterogeneously affected by an appreciation of the US dollar, which triggers very different shifts in the real effective exchange rates of foreign countries. Emerging Asian countries, whose currencies tend to follow the dollar (sometimes through hard pegs), also tend to experience an appreciation in effective terms. The same effect is found for Latin American countries, especially for Brazil. Among European countries, instead, the dollar appreciation tends to be associated with a *depreciation* of the currency in effective terms. However, for many European countries (the UK, Sweden, Norway, Italy, Spain) the effect is not statistically significant. One potential explanation is that for these countries the weight of other European countries in their effective exchange rate is larger. For France and Germany, by contrast, the dollar appreciation is associated with a marked depreciation. This is also the case for Japan.

The reaction of real exports in foreign countries (Figure 7) basically mirrors the effect of the dollar appreciation on foreign countries' exchange rates. Japanese exports are those that are most strongly affected by the dollar appreciation, which is in line with the result of Japan being the country that depreciates most. The effect on imports (not reported here) does not appear to be significantly different from zero in any of the foreign economies.

5.3 Shock to German Output

As a last exercise we look at the effect of a shock to output in foreign countries. Given the large number of countries in our sample, many possible simulations could be performed; however, to keep this paper within reasonable space limits, we choose to show only one example to illustrate the way the model can be used. Germany being the third largest economy in the world and the first economy in the Eurozone, the effect of a shock to German output is more likely to be relevant for the configuration of global trade imbalances (compared to smaller countries). A positive one s.d. shock to German GDP, which corresponds to an increase by 0.8% in the short-run and by around 0.7% in the longer run, is found to have economically and statistically significant effects on other European countries (see Figure 8).

This is not surprising given the strength of the European business cycle. Interestingly, we find that the effect of a positive shock to German output on US output is not negligible, at above 0.1%. Higher output growth in Germany would also have a positive effect on foreign exports (see Figure 9). In particular, the effect on US exports is found to be significant and roughly stable at 0.4% for the first 2 years.

6 Conclusion

This paper has presented results from a GVAR model applied for the first time to the issue of global trade imbalances. The approach proposed in the present paper distinguishes itself from previous contributions on the subject in two main ways. First, the use of a GVAR framework allows to better model international trade linkages, which play a crucial role in the context of global imbalances. Indeed, what characterized the present constellation of global current account positions was the dispersion among many different countries and regions: the use of a GVAR model is therefore particularly well suited to tackle the issue of global imbalances. Second, while most empirical trade papers model real exports and imports separately, we show that there is value added in jointly modelling them, because cross-country evidence shows significant comovements between exports and imports. We explore different explanations for such comovements: cross-border spillovers of output shocks, the stationarity of the trade balance in the long-run, and the fragmentation of production across national borders, which implies a strong import content of exports. We find compelling evidence in favour of our "enhanced" trade equations, in which exports and imports are part of the same cointegrating vector. In addition to these two main contributions, we also discuss the interpretation of trade elasticities in a VECM context: whereas most papers using this technique interpret the coefficients of their cointegrating relation as trade elasticities, we argue that it is preferable to rely on the impulse-response functions.

We present the results for three possible shocks which may influence the current configuration of global trade imbalances: a shock to US output, a shock to the US real exchange rate and a shock to German output. The main result of these simulations is that a deceleration in US output would have a larger effect on the trade balance than a depreciation of the US dollar. We find that a depreciation of the dollar would efficiently stimulate US exports (in fact, our elasticity is on the high side, compared to other studies); meanwhile, such depreciation would be hardly able to significantly reduce US imports in the long-run. Concerning this latter result, our estimate is consistent with recent papers that found that exchange rate pass-through to the US (excluding oil) is very low (see e.g. Marazzi et al., 2005, or Bussière and Peltonen, 2008, and the literature reviewed therein). By contrast, a slow down in domestic demand in the US would efficiently reduce the US trade deficit through the downward effect on imports, which we find to be large (although not as large as often reported in the literature). However, one important side effect of a reduction in US demand is that output in other countries would also fall significantly, with negative repercussions on these economies, and on world trade. We find however that this negative feedback effect is not large enough to offset the overall impact on the US trade balance.

If positive shocks to foreign output were to take place simultaneously, this would significantly contribute to the reduction in the US deficit through the stimulating effect on US exports. The ideal scenario, therefore, would feature a negative shock to US demand and a positive shock in foreign countries. This in fact could result from some of the policy prescriptions that G7 final communiqués[39] repeatedly called for, urging the US to encourage domestic savings and European countries and Japan to implement structural reforms aiming at higher productivity growth.

These policy implications should however be interpreted with caution, given the preliminary nature of the results presented in this paper. One caveat with the results that we have presented is in particular the non-structural nature of the exercise that we have conducted. In particular, the impulse-response functions that we present do not build on identified shocks. It is very likely, in practice, that elasticities differ depending on the nature of the shock. Current estimation techniques unfortunately do not allow for such identification schemes. Accordingly, we believe that further exploring the identification of shocks in a GVAR context is a promising avenue for future research.

[39] See e.g. the Annex on Global Imbalances from the meeting on April 21, 2006.

References

Alexander, S. S. (1952), "Effects of Devaluation on a Trade Balance", *IMF Staff Papers*, vol. 2, pp. 263-278.

Anderton, R., F. di Mauro and F. Moneta (2004), "Understanding the Impact of the External Dimension on the Euro Area: Trade, Capital Flows and other International Linkages", ECB Occasional Paper No. 12.

Armington, P. S. (1969), "A Theory of Demand for Products Distinguished by Place of Production", *IMF Staff Papers*, vol. 26, pp. 158-178.

Blanchard, O., F. Giavazzi and F. Sa (2005), "The U.S. Current Account and the Dollar", NBER Working Paper No. 11137.

Bertaut, C., S. Kamin and C. Thomas (2008), "How Long Can the Unsustainable U.S. Current Account Deficit Be Sustained?", International Finance Discussion Paper No. 935.

Bussière, M. and T. Peltonen (2008), "Exchange Rate Pass-Through in the Global Economy: The Role of Emerging Market Economies", ECB Working Paper No. 1059.

Chudik, A. (2007), "GVAR Approach and the Dominance of the US Economy ", Mimeo, University of Cambridge.

Chudik, A. and M. H. Pesaran (2009), "Infinite Dimensional VARs and Factor Models", ECB Working Paper No. 998.

Dées, S., F. di Mauro, M. H. Pesaran, L. V. Smith (2007a), "Exploring the International Linkages of the Euro Area: a Global VAR Analysis", *Journal of Applied Econometrics*, vol. 22, pp. 1-38.

Dées, S., S. Holly, M. H. Pesaran, L. V. Smith (2007b), "Long-run Macroeconomic Relations in the Global Economy", *Economics, the Open Access, Open Assessment E-Journal*, Kiel Institute for the World Economy, vol. 1(3).

Dées, S., M. H. Pesaran, L. V. Smith and R. P. Smith (2008), "Identification of New Keynesian Phillips Curves from a Global Perspective", IZA Discussion Paper No. 3298.

Engler, P., M. Fidora and C. Thimann (2007), "External Imbalances and the US Current Account: How Supply-Side Changes Affect an Exchange Rate Adjustment", ECB Working Paper No. 995 and *Review of International Economics* (forthcoming).

Fagan, G., J. Henry and R. Mestre (2001), "An Area-Wide Model (AWM) for the Euro Area", ECB Working Paper No. 42.

Ferguson, R. W. (2005), "U.S. Current Account Deficit: Causes and Consequences", Remarks by Vice Chairman Roger W. Ferguson, Jr. to the Economics Club of the University of North Carolina at Chapel Hill, Chapel Hill, North Carolina April 20, 2005.

Frankel, J. A. and A. K. Rose (1996), "A Panel Project on Purchasing Power Parity: Mean Reversion within and between Countries", *Journal of International Economics*, 40, pp. 209-224.

Garratt, A., K. Lee, M. H. Pesaran and Y. Shin (2006), "Global and National Macroeconometric Modelling: A long-run Structural Approach", Oxford University Press.

Goldstein, M. and M. S. Kahn (1985), "Income and Price Effects in Foreign Trade", R. W. Jones and P. B. Kenen Eds, Handbook of International Economics, Vol. 2, North Holland, Amsterdam.

Harbo, I., S. Johansen, B. Nielsen, and A. Rahbek (1998), "Asymptotic Inference on Cointegrating Rank in Partial Systems", *Journal of Business and Economic Statistics*, Vol. 16, pp. 388-399

Harberger, A. (1950), "Currency Depreciation, Income and the Balance of Trade", *Journal of Political Economy*, Vol. 58, No. 1 (Feb., 1950), pp. 47-60.

Harberger, A. (1953), "A Structural Approach to the Problem of Import Demand", *American Economic Review*, Vol. 43, No. 2, Papers and Proceedings of the Sixtyfifth Annual Meeting of the American Economic Association (May, 1953), pp. 148-159.

Hooper, P. (1976), "Forecasting U.S. Export and Import Prices and Volumes in a changing World Economy", International Finance Discussion Paper No. 99, Board of Governors of the Federal Reserve.

Hooper, P. (1978), "The Stability of Income and Price Elasticities in U.S. Trade, 1957-1977", International Finance Discussion Paper No. 119, Board of Governors of the Federal Reserve.

Hooper, P., K. Johnson and J. Marquez (1998), "Trade Elasticities for the G-7 Countries", International Finance Discussion Paper No. 119, Board of Governors of the Federal Reserve. Updated version published as Princeton Studies in International Economics No. 87, August 2000.

Houthakker, H. S. and S. P. Magee (1969), "Income and Price Elasticities in World Trade", *Review of Economics and Statistics*, vol. 51, pp. 111-125.

Johansen, J. (2005), "Interpretation of Cointegrating Coefficients in the Cointegrated Vector Autoregressive Model", *Oxford Bulletin of Economics and Statistics*, vol. 67(1), pp. 93-104.

Koop, G., M. H. Pesaran and S. M. Potter (1996), "Impulse Response Analysis in Nonlinear Multivariate Models", *Journal of Econometrics*, No. 74, pp. 119-147.

Laxton, D, P. Isard, H. Faruqee, E. Prasad and B. Turtelboom (1998), "MULTIMOD Mark III, The Core Dynamic and Steady-State Models", IMF Occasional Paper No. 164.

Levin, A., J. Rogers and R. Tryon (1997), "Evaluating International Economic Policy with the Federal Reserve's Global Model", *Federal Reserve Bulletin*, October 1997, pp. 797-817.

Lothian, J. R. and M. P. Taylor (1996), "Real Exchange Rate Behavior: The Recent Float from the Perspective of the Past Two Centuries", *Journal of Political Economy*, 104, pp. 488-510.

Lütkepohl, H. (1994), "Interpretation of Cointegrating Relations", *Econometric Reviews*, Vol. 13, pp. 391–394.

MacKinnon, J. G., A. A. Haug and L. Michelis (1999), "Numerical Distribution Functions of Likelihood Ratio Tests for Cointegration", *Journal of Applied Econometrics*, vol. 14(5), pp. 563-77.

Marazzi, M., N. Sheets, R. Vigfusson, J. Faust, J. Gagnon, J. Marquez, R. Martin, T. Reeve and J. Rogers (2005), "Exchange Rate Pass-Through to U.S. Import Prices: some New Evidence", International Finance Discussion Paper No. 832, Board of Governors of the Federal Reserve System.

Obstfeld, M. and K. Rogoff (2005), "Global Current Account Imbalances and Exchange Rate Adjustments", *Brookings Papers on Economic Activity*, vol. 1, pp. 124-140.

Obstfeld, M. and K. Rogoff (2006), "The Unsustainable US Current Account Position Revisited", in: Clarida, R., ed. "G7 Current Account Imbalances: Sustainability and Adjustment", The University of Chicago Press.

Pain, N., A. Mourougane, F. Sédillot and L. Le Fouler (2005), "The New OECD International Trade Model", OECD Economics Department Working Papers No. 440.

Pesaran, M. H. (2006), "Estimation And Inference In Large Heterogeneous Panels With A Multi-factor Error Structure", *Econometrica,* 74 (4), pp. 967-1012.

Pesaran, M. H. (2007), "A Pair-Wise Approach To Testing For Output And Growth Convergence", *Journal of Econometrics*, 138, pp. 312-355.

Pesaran, M. H. and A. Chudik (2009), "Estimation of Infinite Dimensional VARs with Dominant Units", mimeo, University of Cambridge.

Pesaran, M. H., T. Schuermann and B. J. Treutler (2006), "Global Business Cycles And Credit Risk", in ' The Risks of Financial Institutions ', Mark Carey and Rene M. Stultz (eds.), pp. 419-473.

Pesaran, M. H., T. Schuermann, B. J. Treutler and S. M. Weiner (2006), "Macroeconomic Dynamics and Credit Risk: A Global Perspective", *Journal of Money, Credit and Banking*, vol. 38, pp. 1211-1262.

Pesaran, M. H., T. Schuermann. and S. M. Weiner (2004), "Modelling Regional Interdependencies Using A Global Error-Correcting Macroeconometric Model", *Journal of Business and Economics Statistics*, vol. 22, pp. 129-162.

Pesaran, M. H. and Y. Shin (1996), "Cointegration and Speed of Convergence to Equilibrium", *Journal of Econometrics*, Vol.71(2), pp.117-143.

Pesaran, M. H., Y. Shin, and R. P. Smith (2000), "Structural Analysis of Vector Error Correction Models with Exogenous I(1) Variables," *Journal of Econometrics*, Vol.: 97, pp. 293-343

Pesaran, M. H. and R. P. Smith (2006), "Macroeconomic Modelling with a Global Perspective", *Manchester School*, University of Manchester, vol. 74(1), pp. 24-49.

Pesaran, M. H, V. L. Smith, and R. P. Smith (2007), "What if the UK or Sweden Has Joined the Euro in 1999? An Empirical Evaluation Using a Global VAR", *International Journal of Finance and Economics*, vol. 12, pp. 55-87.

Pesaran, M. H., R.P. Smith, T. Yamagata and L. Hvozdyk (2008), "Pairwise Tests of Purchasing Power Parity", forthcoming in *Econometric Reviews.*

Pesaran, M. H. and E. Tosetti (2007), "Large Panels with Common Factors and Spatial Correlations", IZA Discussion Paper No. 3032.

Pula, G. and T. Peltonen (2009), "Has Emerging Asia Decoupled? An Analysis of Production and Trade Linkages using the Asian International Input-Output Table", ECB Working Paper No. 993, January 2009.

Sawyer, W. S. and R. L. Sprinkle (1996), "The Demand for Imports and Exports in the US: A Survey", *Journal of Economics and Finance*, 20(1), pp. 147-178.

Taylor, M. P., D. A. Peel and L. Sarno (2001), "Nonlinear Mean-Reversion in Real Exchange Rates: Toward A Solution to the Purchasing Power Parity Puzzles", *International Economic Review*, 42, pp. 1015-1042.

Thomas, C. P., J. Marquez and S. Fahle (2008), "Measuring U.S. International Relative Prices: A WARP View of the World", International Finance Discussion Paper No. 917, Board of Governors of the Federal Reserve System.

Wu, Jyh-Lin (2000), "Mean Reversion of the Current Account: Evidence from the Panel Data Unit-Root Test", *Economic Letters*, Volume 66, Issue 2, pp. 215-222.

A Data Appendix

Table A1: Data sources

Country	rer_{it}	y_{it}	x_{it}	m_{it}	max time span
Argentina	BCS	GI	GI	GI	1980Q1-2007Q4
Australia	BIS	OECD	OECD	OECD	1979Q1-2007Q4
Brazil	BCS	Pes+BIS	IFS	IFS	1979Q4-2007Q4
Canada	IFS	OECD	OECD	OECD	1979Q1-2007Q4
China	IFS	IFS+WEO1	GI$^{(1)}$	GI$^{(1)}$	1980Q1-2007Q4
France	BIS	OECD	OECD	OECD	1979Q1-2007Q4
Germany	IMF	OECD	OECD	OECD	1979Q1-2007Q4
Italy	BIS	OECD	OECD	OECD	1979Q1-2007Q4
Japan	BIS	OECD	OECD	OECD	1979Q1-2007Q4
Korea	BIS	OECD	OECD	OECD	1979Q1-2007Q4
Mexico	BIS	OECD	OECD	OECD	1979Q1-2007Q4
Netherlands	IMF	OECD	OECD	OECD	1979Q1-2007Q4
New Zealand	IMF	OECD	OECD	OECD	1979Q1-2007Q4
Norway	IMF	OECD	OECD	OECD	1979Q1-2007Q4
Singapore	IMF	GI	IMF	IMF	1980Q1-2007Q4
Spain	IMF	OECD	OECD	OECD	1979Q1-2007Q4
Sweden	IMF	OECD	OECD	OECD	1979Q1-2007Q4
Switzerland	IMF	OECD	OECD	OECD	1979Q1-2007Q4
Thailand	BCS	GI+Pes	IMF	IMF	1979Q1-2007Q4
UK	IMF	OECD	OECD	OECD	1979Q1-2007Q4
US	BIS	OECD	OECD	OECD	1979Q1-2007Q4

Notes: (^{1}) Interpolated from annual data. We have used data from the following sources:

(I) The OECD: we used real exports, imports and output from the OECD Economic Outlook quarterly database, with codes XGSV, MGSV and GDPV, respectively.

(II) The IMF: for real exports, imports and GDP we used IFS lines 72, 73 and 99.v; for the real nominal effective exchange rate we used IFS line REC.

(III) The BIS: for real GDP we used the code 9.9B.BVP; for the real nominal effective exchange rate we used BIS code QTGA. National sources through Global Insight/World Market Monitor (GI).

(IV) Some of the variables compiled by Prof. Pesaran and available on-line on his website, Pes):

http://www.econ.cam.ac.uk/faculty/pesaran/.

(V) For the exchange rate we also completed missing observations from raw data, i.e. from bilateral exchange rates and price indices provided by the IMF/IFS (BCS).

(VI) For a few series/countries we were missing some of the data at a quarterly frequency; in this case we interpolated the annual data from the IMF World Economic Outlook (WEO)

(VII) For oil prices in dollar, we used the OECD series OEO.Q.WLD.WPBRENT.

Table A2: Trade Weight Matrix

	Arg.	Aust.	Brazil	Can.	China	France	Germ.	Italy	Japan	Korea	Mex.	Neth.	N.Zeal.	Norw.	Sing.	Spain	Swed.	Switz.	Thail.	U.K.	U.S.	Sums
Arg.	0.000	0.005	0.359	0.010	0.115	0.026	0.050	0.040	0.024	0.017	0.044	0.033	0.001	0.001	0.002	0.048	0.007	0.007	0.012	0.018	0.182	1.000
Aust.	0.001	0.000	0.007	0.017	0.188	0.026	0.047	0.028	0.197	0.073	0.007	0.016	0.063	0.002	0.057	0.010	0.012	0.009	0.040	0.054	0.148	1.000
Brazil	0.122	0.008	0.000	0.023	0.115	0.041	0.086	0.044	0.051	0.032	0.038	0.046	0.001	0.006	0.012	0.026	0.011	0.013	0.010	0.031	0.285	1.000
Can.	0.001	0.005	0.006	0.000	0.054	0.011	0.019	0.009	0.032	0.012	0.025	0.005	0.001	0.009	0.002	0.003	0.004	0.004	0.004	0.025	0.771	1.000
China	0.005	0.030	0.017	0.022	0.000	0.026	0.075	0.025	0.220	0.124	0.010	0.033	0.003	0.003	0.054	0.013	0.007	0.010	0.029	0.036	0.260	1.000
France	0.002	0.007	0.009	0.009	0.046	0.000	0.260	0.131	0.023	0.010	0.004	0.081	0.001	0.015	0.011	0.126	0.019	0.041	0.004	0.114	0.088	1.000
Germ.	0.002	0.007	0.012	0.009	0.077	0.156	0.000	0.105	0.038	0.018	0.009	0.127	0.001	0.024	0.010	0.066	0.033	0.063	0.005	0.115	0.125	1.000
Italy	0.004	0.010	0.013	0.010	0.061	0.178	0.248	0.000	0.026	0.015	0.007	0.066	0.002	0.009	0.005	0.094	0.018	0.057	0.005	0.084	0.089	1.000
Japan	0.001	0.047	0.009	0.023	0.297	0.022	0.048	0.017	0.000	0.093	0.013	0.020	0.006	0.003	0.034	0.009	0.005	0.010	0.049	0.029	0.265	1.000
Korea	0.002	0.035	0.013	0.017	0.326	0.017	0.051	0.018	0.193	0.000	0.011	0.016	0.004	0.003	0.037	0.010	0.005	0.005	0.017	0.023	0.196	1.000
Mex.	0.005	0.003	0.016	0.031	0.043	0.008	0.027	0.009	0.035	0.018	0.000	0.004	0.001	0.001	0.006	0.016	0.003	0.003	0.003	0.007	0.762	1.000
Neth.	0.003	0.005	0.012	0.007	0.078	0.110	0.331	0.062	0.030	0.013	0.004	0.000	0.001	0.023	0.012	0.045	0.028	0.016	0.008	0.120	0.092	1.000
N.Zeal.	0.001	0.269	0.004	0.021	0.121	0.025	0.048	0.024	0.135	0.042	0.010	0.013	0.000	0.001	0.032	0.008	0.008	0.006	0.023	0.050	0.160	1.000
Norw.	0.001	0.002	0.007	0.041	0.038	0.091	0.164	0.039	0.022	0.011	0.001	0.101	0.000	0.000	0.007	0.030	0.121	0.007	0.003	0.236	0.079	1.000
Sing.	0.001	0.046	0.006	0.006	0.275	0.031	0.051	0.012	0.131	0.068	0.006	0.029	0.006	0.003	0.000	0.004	0.004	0.012	0.069	0.042	0.201	1.000
Spain	0.008	0.006	0.012	0.006	0.047	0.249	0.210	0.131	0.023	0.013	0.020	0.065	0.001	0.011	0.002	0.000	0.018	0.022	0.004	0.103	0.051	1.000
Swed.	0.002	0.013	0.009	0.012	0.049	0.079	0.219	0.054	0.031	0.012	0.005	0.087	0.001	0.136	0.005	0.037	0.000	0.016	0.005	0.114	0.115	1.000
Switz.	0.001	0.007	0.007	0.012	0.050	0.118	0.334	0.127	0.035	0.008	0.005	0.047	0.001	0.004	0.009	0.038	0.013	0.000	0.008	0.064	0.113	1.000
Thail.	0.004	0.043	0.010	0.011	0.190	0.019	0.035	0.018	0.271	0.044	0.005	0.024	0.005	0.002	0.087	0.009	0.005	0.013	0.000	0.030	0.175	1.000
U.K.	0.002	0.014	0.008	0.025	0.081	0.123	0.180	0.060	0.038	0.015	0.004	0.095	0.003	0.044	0.018	0.056	0.029	0.026	0.008	0.000	0.172	1.000
U.S.	0.004	0.012	0.021	0.252	0.167	0.029	0.062	0.022	0.101	0.039	0.152	0.022	0.003	0.005	0.019	0.008	0.009	0.013	0.014	0.046	0.000	1.000
Sums:	0.172	0.573	0.556	0.565	2.418	1.383	2.542	0.974	1.655	0.674	0.378	0.928	0.107	0.303	0.422	0.656	0.357	0.351	0.320	1.340	4.327	

B Table Appendix

Table B1: Sensitivity of Johansen's trace test statistics to lag choice

This table shows the sensitivity of the Johansen's trace test statistics to the choice of lags in VARX* models containing 9 variables (domestic exports, imports, real exchange rate and output, country-specific foreign variables and the price of oil). For each choice of the lags of domestic (p) and foreign variables (q), the table reports the number of cointegrating relationships according to the trace statistics at the 5% nominal level.

Country	**VARX*(p,q)**			
	(1,1)	**(2,1)**	**(2,2)**	**(3,2)**
Argentina	0	0	0	0
Australia	1	1	1	1
Brazil	2	1	1	1
Canada	3	3	1	2
China	3	3	3	3
France	1	1	0	1
Germany	2	2	2	2
Italy	2	2	2	2
Japan	3	2	2	2
Korea	1	0	0	1
Mexico	2	1	1	1
Netherlands	1	1	1	2
NewZealand	2	1	1	1
Norway	2	2	2	2
Singapore	4	3	4	3
Spain	1	1	1	1
Sweden	2	4	2	2
Switzerland	2	1	2	2
Thailand	2	3	2	3
U.K.	2	1	1	0
U.S.	3	2	2	3

Table B2: Number of cointegrating relationships selected by Johansen's trace test statistics in country-specific VARs

The table reports the number of cointegrating vectors selected according to the Johansen's trace test statistics at the 5% nominal level in VAR models containing 5 variables $(rer_{it}, y_{it}, y^*_{it}, x_{it}, m_{it})'$. The number of lags is chosen by the Akaike and the Bayesian information criteria.

	Number of coint. vectors		Number of lags	
Country	(AIC lags)	(BIC lags)	**AIC**	**BIC**
Argentina	**1**	**0**	3	1
Australia	**0**	**1**	3	1
Brazil	**0**	**2**	2	1
Canada	**2**	**2**	2	2
China	**1**	**1**	2	2
France	**0**	**1**	2	1
Germany	**1**	**2**	2	1
Italy	**0**	**0**	2	1
Japan	**2**	**2**	4	1
Korea	**3**	**1**	4	1
Mexico	**1**	**2**	4	1
Netherlands	**1**	**2**	2	1
NewZealand	**0**	**1**	2	1
Norway	**0**	**1**	3	1
Singapore	**1**	**2**	2	1
Spain	**0**	**1**	3	1
Sweden	**1**	**1**	3	2
Switzerland	**1**	**1**	2	1
Thailand	**1**	**1**	3	1
U.K.	**1**	**1**	2	1
U.S.	**1**	**1**	2	1

Table B3: Small sample performance of the Johansen's trace test statistics

The table reports the small sample performance of the Johansen's rank reduction trace test statistics for the two different DGPs. The left columns report rejection rates obtained from DGPs given by the estimated individual VARX* models with 2 cointegrating vectors imposed. The right columns report rejection rates obtained from DGPs given by the estimated individual VARX* models with the number of cointegrating vectors selected by the Johansen's trace statistics. Rejection rates in bold font correspond to size of the tests.

	DGP is given by estimated individual VARX* models with 2 cointegrating vectors imposed.						DGP is given by estimated country models with number of CVs selected by test.					
Country	$r = 0$	$r = 1$	$r = 2$	$r = 3$	$r = 4$	$r = 5$	$r = 0$	$r = 1$	$r = 2$	$r = 3$	$r = 4$	$r = 5$
Argentina	0.99	0.62	**0.50**	0.90	0.99		**0.22**	0.80	0.98	1.00	1.00	
Australia	1.00	0.94	**0.23**	0.85	0.99		1.00	**0.23**	0.80	0.98	1.00	
Brazil	1.00	0.83	**0.30**	0.89	0.99		1.00	1.00	**0.13**	0.88	0.99	
Canada	1.00	0.77	**0.36**	0.88	0.99		1.00	0.74	**0.39**	0.88	0.99	
China	1.00	0.91	**0.35**	0.77	0.97		1.00	1.00	0.95	**0.26**	0.79	
France	1.00	0.99	**0.28**	0.76	0.97		0.90	**0.31**	0.82	0.97	1.00	
Germany	1.00	0.90	**0.26**	0.85	0.99		1.00	0.93	**0.24**	0.85	0.99	
Italy	1.00	0.98	**0.20**	0.84	0.98		1.00	0.98	**0.20**	0.84	0.98	
Japan	1.00	0.99	**0.28**	0.77	0.97		1.00	0.98	**0.27**	0.77	0.97	
Korea	1.00	0.89	**0.35**	0.79	0.97		**0.36**	0.70	0.94	0.99	1.00	
Mexico	1.00	0.93	**0.23**	0.86	0.99		0.97	**0.24**	0.82	0.98	1.00	
Netherlands	1.00	1.00	**0.21**	0.81	0.98		1.00	**0.19**	0.83	0.98	1.00	
NewZealand	1.00	0.87	**0.27**	0.87	0.99		0.98	**0.24**	0.81	0.98	1.00	
Norway	1.00	0.96	**0.21**	0.85	0.99		1.00	0.96	**0.21**	0.85	0.99	
Singapore	1.00	0.99	**0.24**	0.80	0.98		1.00	1.00	0.98	**0.17**	0.86	
Spain	1.00	1.00	**0.23**	0.79	0.98		1.00	**0.24**	0.80	0.97	1.00	
Sweden	1.00	1.00	**0.18**	0.84	0.99		1.00	1.00	1.00	1.00	**0.01**	
Switzerland	1.00	1.00	**0.20**	0.82	0.98		1.00	**0.24**	0.79	0.97	1.00	
Thailand	1.00	0.92	**0.23**	0.85	0.99		1.00	0.99	0.67	**0.43**	0.90	
UK	1.00	1.00	**0.23**	0.79	0.98		0.99	**0.23**	0.80	0.98	1.00	
US	1.00	1.00	**0.27**	0.77	0.97	1.00	1.00	1.00	**0.27**	0.77	0.96	1.00

Table B4: Selected ADF unit root tests

The table reports the ADF unit root tests. The number of lags is chosen by the modified AIC criterion to avoid the size distortion which result from a shorter lag truncation when using standard information criteria. Deterministic terms included in the regressions are intercept and linear trend. Values significant at 5% level are highlighted by bold font. Similar results are obtained when the intercept is the only deterministic term included.

	$y_{it} - y^*_{it}$			$ex_{it} - im_{it}$			rer_{it}		
Country:	level	Δ	Δ^2	level	Δ	Δ^2	level	Δ	Δ^2
Argentina	-1.9	**-4.3**	**-16.4**	-2.7	**-3.9**	**-16.0**	-2.3	**-10.8**	**-18.5**
Australia	-2.1	**-5.9**	**-15.8**	0.0	**-6.2**	**-18.9**	-0.9	**-3.7**	**-16.3**
Brazil	**-4.3**	**-10.7**	**-17.4**	-2.4	**-12.8**	**-18.3**	-2.1	**-8.7**	**-14.8**
Canada	-1.0	-3.5	**-18.5**	-0.8	**-5.3**	**-16.9**	-0.8	-2.5	**-13.9**
China	-2.4	-3.2	**-6.8**	-2.9	**-4.2**	**-5.3**	-1.4	-2.7	**-15.0**
France	-1.5	**-3.8**	**-18.6**	-1.4	**-5.0**	**-18.1**	-2.3	**-5.1**	**-15.2**
Germany	-1.8	-2.7	**-18.8**	-1.7	**-12.3**	**-20.0**	-3.0	**-5.0**	**-15.3**
Italy	-1.0	**-11.7**	**-17.8**	-2.1	**-5.7**	**-20.5**	-2.2	-2.3	**-13.8**
Japan	-1.9	-2.8	**-19.1**	-1.2	-2.4	**-21.8**	-1.2	**-4.5**	**-14.5**
Korea	-1.6	**-5.5**	**-17.4**	-1.7	**-5.2**	**-17.1**	-1.9	**-5.2**	**-14.0**
Mexico	-1.9	**-5.5**	**-17.7**	-2.7	**-5.9**	**-17.7**	-2.4	**-4.4**	**-16.5**
Netherlands	-2.3	-2.6	**-21.5**	**-3.5**	**-13.9**	**-20.6**	-2.0	**-9.6**	**-18.1**
NewZealand	-1.3	-2.9	**-17.8**	-2.1	**-12.4**	**-19.2**	-1.9	-2.7	**-16.0**
Norway	-1.5	-2.4	**-26.2**	0.0	**-14.8**	**-22.0**	-2.7	**-9.1**	**-16.0**
Singapore	-2.1	-3.0	**-16.1**	-3.2	**-14.0**	**-21.2**	-2.0	-3.4	**-14.5**
Spain	-1.6	-2.8	**-24.5**	-2.4	-2.6	**-20.3**	-1.8	**-5.4**	**-17.7**
Sweden	-0.7	-2.9	**-29.4**	-2.6	**-13.1**	**-19.7**	-2.6	**-4.5**	**-14.4**
Swizterland	-1.1	-2.8	**-18.2**	-2.1	**-5.0**	**-22.0**	-1.7	**-5.4**	**-14.1**
Thailand	-1.2	-2.6	**-16.0**	-1.9	**-10.7**	**-14.5**	-1.5	**-8.2**	**-13.6**
UK	-1.9	-3.2	**-17.2**	-2.2	-3.3	**-20.2**	-2.0	**-8.1**	**-13.6**
USA	-2.2	**-6.6**	**-20.4**	-2.2	-2.2	**-16.1**	-1.7	**-3.5**	**-15.3**

Table B5: Tests for Balassa-Samuelson relation

This table reports the number of cointegrating vectors selected according to Johansen's trace test statistics (at 5% nominal size of the test) based on bivariate VAR models in $(rer_{it}, y_{it} - y_{it}^*)'$ with the number of lags selected by BIC criterion (reported in the the right column). $\widehat{\omega}_i$ is the estimate of the level relationship $rer_{it} - \omega_i\,(y_{it} - y_{it}^*)$ in a VAR with one cointegrating relationship imposed.

country	Number of cointegrating vectors selected by trace statistics	Estimate $\widehat{\omega}_i$	Number of lags BIC
Argentina	0	-1.18	1
Australia	0	-0.34	1
Brazil	0	-2.99	1
Canada	0	0.36	2
China	0	0.57	2
France	0	-0.02	1
Germany	0	0.18	2
Italy	0	0.73	2
Japan	0	1.13	1
Korea	0	-1.39	2
Mexico	0	-0.22	2
Netherlands	0	3.79	1
NewZealand	0	-0.70	1
Norway	0	-0.38	2
Singapore	0	-0.11	2
Spain	0	1.73	2
Sweden	**1**	**0.24**	**3**
Switzerland	1	-0.52	2
Thailand	0	-0.77	2
UK	0	-1.76	2
USA	0	0.95	1

Table B6: Number of cointegrating relationships selected by Johansen's trace test statistics

This table reports the number of cointegrating vectors selected according to the Johansen's trace test statistics (at 5% nominal size of the test) based on three and four variable VAR models. The number of lags reported in parentheses are chosen by BIC and AIC information criteria.

	Exports				Imports			
Variables included in VAR:	$(x_{it}, y^*_{it}, rer_{it})$		$(x_{it}, y^*_{it}, rer_{it}, m_{it})$		$(m_{it}, y_{it}, rer_{it})$		$(m_{it}, y_{it}, rer_{it}, x_{it})$	
Lag selection criterion:	AIC	BIC	AIC	BIC	AIC	BIC	AIC	BIC
Country								
Argentina	0 (1)	0 (1)	0 (2)	0 (1)	1 (2)	1 (2)	1 (2)	1 (2)
Australia	0 (2)	0 (1)	0 (3)	0 (1)	0 (3)	1 (1)	0 (3)	1 (1)
Brazil	0 (2)	0 (2)	0 (2)	1 (1)	0 (4)	1 (1)	0 (4)	1 (1)
Canada	0 (2)	0 (2)	0 (2)	0 (2)	0 (2)	0 (2)	1 (2)	1 (2)
China	0 (2)	0 (2)	1 (2)	1 (2)	0 (4)	1 (2)	1 (2)	1 (2)
France	0 (2)	0 (2)	0 (2)	0 (2)	0 (2)	0 (2)	0 (2)	0 (1)
Germany	0 (2)	0 (2)	0 (2)	1 (1)	0 (3)	0 (1)	1 (1)	1 (1)
Italy	0 (2)	0 (2)	0 (2)	0 (1)	0 (2)	0 (2)	0 (2)	1 (1)
Japan	1 (3)	0 (2)	1 (3)	1 (2)	1 (4)	3 (1)	1 (4)	2 (1)
Korea	0 (2)	0 (2)	1 (3)	0 (1)	2 (4)	1 (1)	1 (4)	1 (1)
Mexico	0 (2)	0 (2)	2 (4)	1 (1)	1 (4)	0 (2)	0 (2)	1 (1)
Netherlands	0 (4)	0 (2)	1 (2)	1 (1)	0 (4)	1 (1)	1 (4)	1 (1)
New Zealand	0 (2)	0 (2)	0 (2)	1 (1)	0 (3)	0 (1)	0 (4)	0 (1)
Norway	0 (3)	0 (2)	0 (3)	0 (2)	0 (2)	0 (1)	0 (3)	1 (1)
Singapore	1 (2)	1 (2)	1 (2)	1 (2)	0 (4)	1 (1)	0 (4)	2 (1)
Spain	0 (3)	1 (1)	0 (3)	1 (1)	0 (3)	0 (1)	0 (3)	0 (1)
Sweden	0 (3)	0 (2)	0 (3)	0 (2)	0 (4)	1 (2)	1 (3)	1 (2)
Switzerland	0 (2)	0 (1)	1 (4)	1 (1)	0 (2)	1 (1)	0 (2)	1 (1)
Thailand	0 (3)	1 (2)	0 (3)	1 (2)	2 (3)	1 (2)	1 (3)	0 (1)
UK	0 (2)	0 (2)	0 (2)	0 (1)	1 (4)	1 (2)	1 (2)	1 (1)
US	1 (2)	1 (2)	1 (3)	1 (1)	0 (4)	0 (2)	1 (2)	1 (2)

Table B7: Over-identified long-run relationships

The table reports the estimates of the cointegrating vectors in the country-specific VECMs, where theory-based over-identifying restrictions have been imposed to all countries (but China). The table also reports, for each VARX* country-specific model, the number of cointegrating relations imposed and the log-likelihood ratio statistic for testing these long-run relations (number of over-identifying restrictions in brackets). The bootstrapped upper one percent critical value of the LR statistics is provided in the last columns. Sample 1980Q1-2007Q4.

Country	**Exports**	**Imports**	**#CV**	**LLR(df)**	**99%CV**
Argentina		$im_t - 2.90y_t - 0.72rer_t$	1	10.61(7)	36.49
Australia		$im_t - 2.15y_t - 0.47rer_t$	1	31.43(7)	39.12
Brazil		$im_t - 1.09y_t - 0.00rer_t$	1	43.08(7)	45.20
Canada	$ex_t - 1.58y_t^* + 0.64rer_t$	$im_t - 0.61ex_t - 1.00y_t - 0.42rer_t$	2	48.52(12)	84.93
China			3	-	-
France			0	-	-
Germany	$ex_t - 1.58y_t^* + 3.69rer_t$	$im_t - 0.62ex_t - 1.02y_t - 0.14rer_t$	2	53.92(11)	64.95
Italy	$ex_t - 1.17y_t^* + 1.29rer_t$	$im_t - 0.14ex_t - 2.00y_t - 0.10rer_t$	2	67.90(11)	75.88
Japan	$ex_t - 0.86y_t^* + 0.55rer_t$	$im_t - 0.62ex_t - 0.75y_t - 0.54rer_t$	2	60.56(12)	68.08
Korea		$im_t - 1.53y_t - 0.97rer_t$	1	25.74(7)	50.99
Mexico		$im_t - 0.16ex_t - 2.86y_t - 0.67rer_t$	1	20.30(6)	43.18
Netherlands	$ex_t - im_t$	$im_t - 2.21y_t - 0.28rer_t$	2	54.15(14)	63.47
New Zealand	$ex_t - 0.30im_t - 0.79y_t^* + 0.30rer_t$		1	36.03(6)	53.21
Norway			0	-	-
Singapore		$im_t - 1.22y_t - 0.37rer_t$	1	33.06(7)	49.55
Spain	$ex_t - 2.78y_t^* + 1.74rer_t$		1	53.93(7)	58.74
Sweden		$im_t - 2.86y_t - 2.54rer_t$	1	23.66(7)	41.10
Switzerland		$im_t - 2.32y_t - 0.56rer_t$	1	29.71(7)	50.00
Thailand		$im_t - 1.65y_t - 0.97rer_t$	1	34.98(7)	47.78
U.K.		$im_t - 2.12y_t - 0.39rer_t$	1	11.25(7)	38.06
U.S.	$x_t - 1.52y_t^* + 1.10rer_t$	$im_t - 0.58ex_t - 1.24y_t - 1.04rer_t$	2	52.98(11)	73.65

Table B8: Stability tests

The table shows the number (percentage) of rejections of the null of parameter stability per variable across the country-specific models at 5% level. Different tests for structural breaks are considered: PK_{sup} and PK_{msq} are based on the cumulative sums of OLS residuals, R is the Nyblom test for time-varying parameters and QLR, MW and APW are the sequential Wald statistics for a single break at an unknown change point. Statistics with the prefix 'r' denote the heteroskedasticity-robust version of the tests. The critical values of the tests, computed under the null of parameter stability, are calculated by bootstrap.

Tests	**Domestic variables**					**Numbers(%)**
	ex_{it}	im_{it}	y_{it}	rer_{it}	p_t^{oil}	
PK_{sup}	0(0)	1(4.8)	3(14.3)	1(4.8)	0(0)	5(5.9)
PK_{msq}	0(0)	0(0)	3(14.3)	1(4.8)	0(0)	4(4.7)
R	2(9.5)	3(14.3)	6(28.6)	5(23.8)	0(0)	16(18.8)
r-R	2(9.5)	1(4.8)	2(9.5)	4(19)	0(0)	9(10.6)
QLR	5(23.8)	6(28.6)	9(42.9)	8(38.1)	0(0)	28(32.9)
r-QLR	2(9.5)	1(4.8)	6(28.6)	1(4.8)	0(0)	10(11.8)
MW	3(14.3)	4(19)	7(33.3)	7(33.3)	0(0)	21(24.7)
r-MW	1(4.8)	1(4.8)	4(19)	1(4.8)	0(0)	7(8.2)
APW	5(23.8)	6(28.6)	9(42.9)	8(38.1)	0(0)	28(32.9)
r-APW	2(9.5)	1(4.8)	6(28.6)	1(4.8)	0(0)	10(11.8)

C Figure Appendix

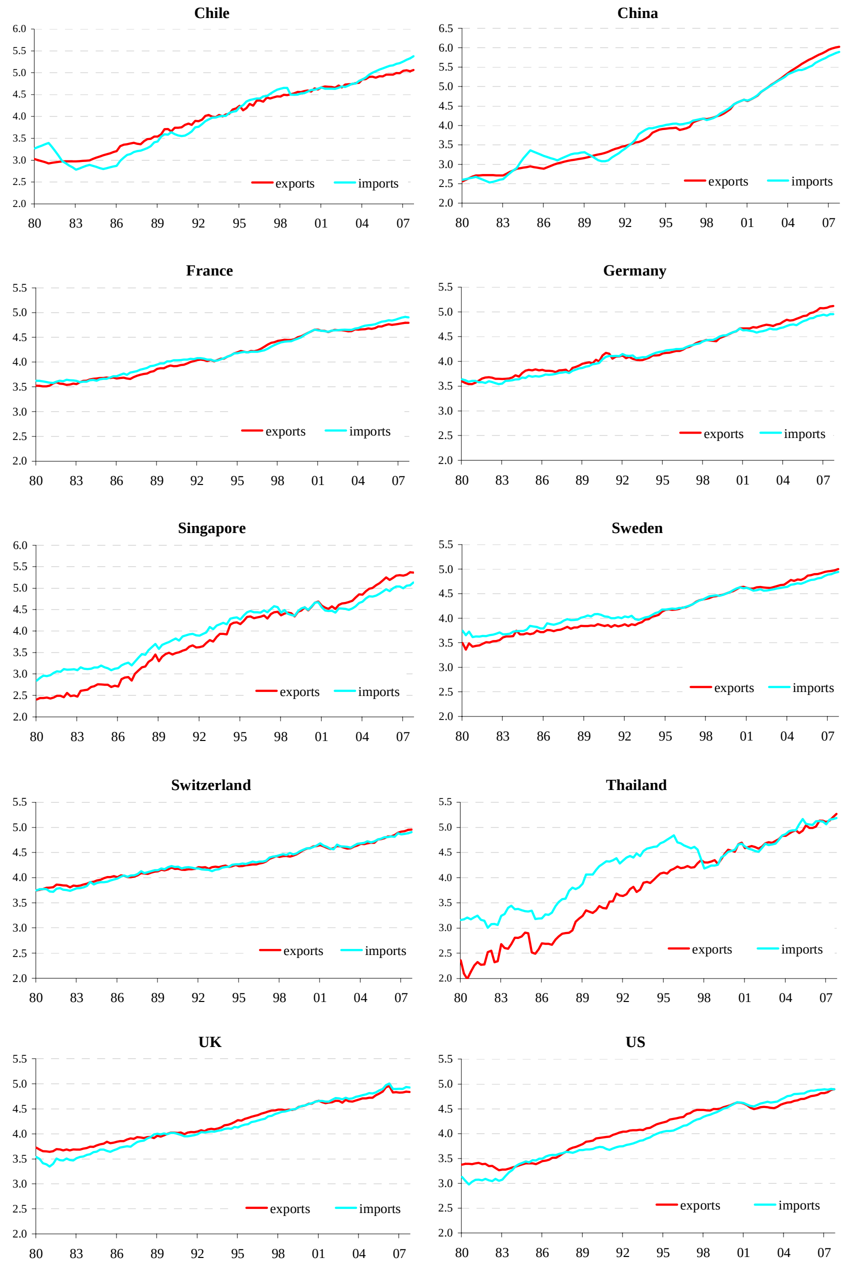

Figure 1: Real Exports and Imports, Selected Economies. *(Note: data in logarithms, source: See data Appendix)*

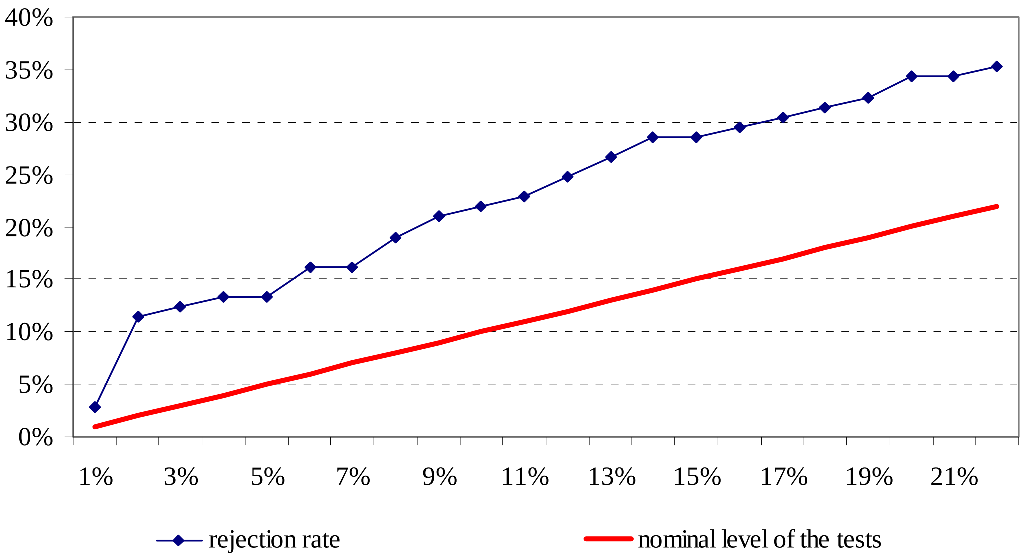

Figure 2: Rejection rate of the weak exogeneity tests as a function of the nominal level of the tests.

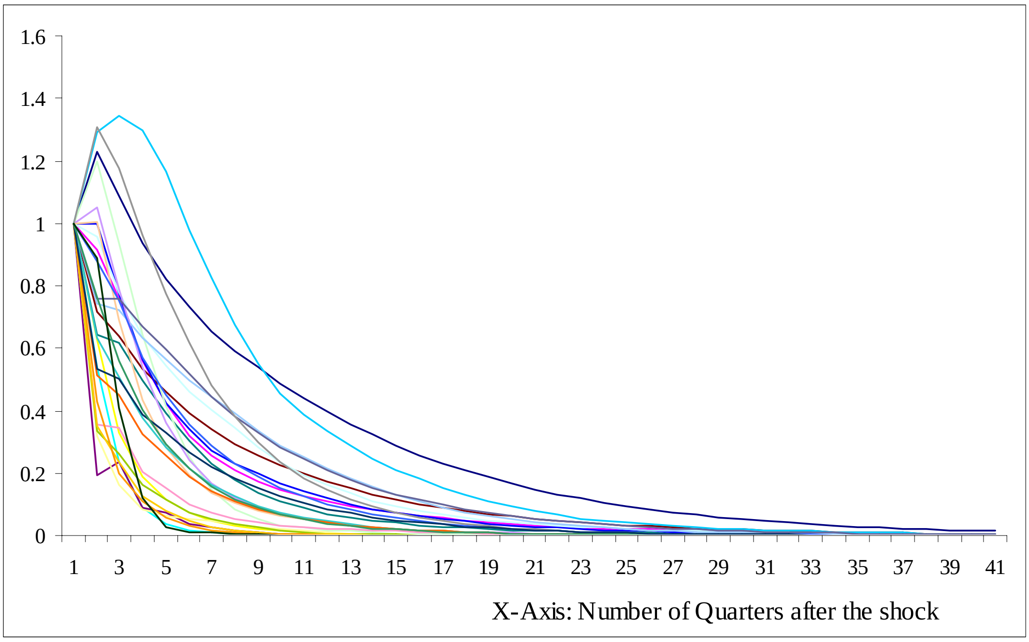

Figure 3: Bootstrap means of persistence profiles of the effect of system wide shocks to the cointegrating relations.

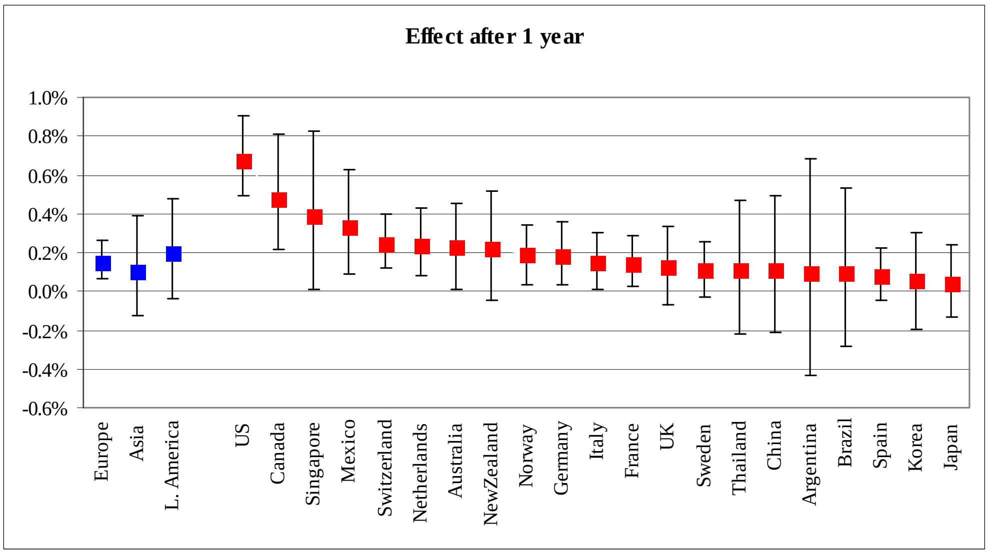

Figure 4: Shock to US output (+ 0.6%), effect on output in the rest of the world.

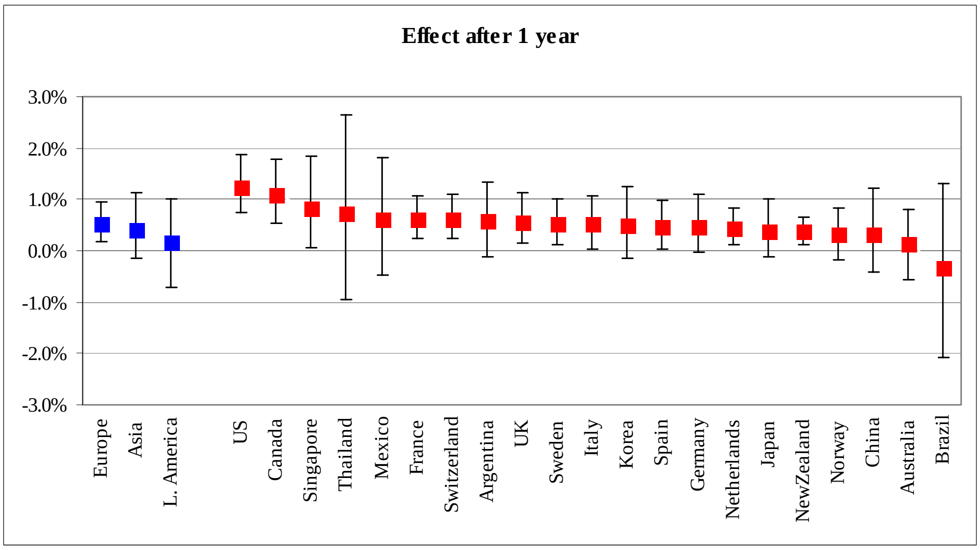

Figure 5: Shock to US output (+ 0.6%), effect on exports in the rest of the world.

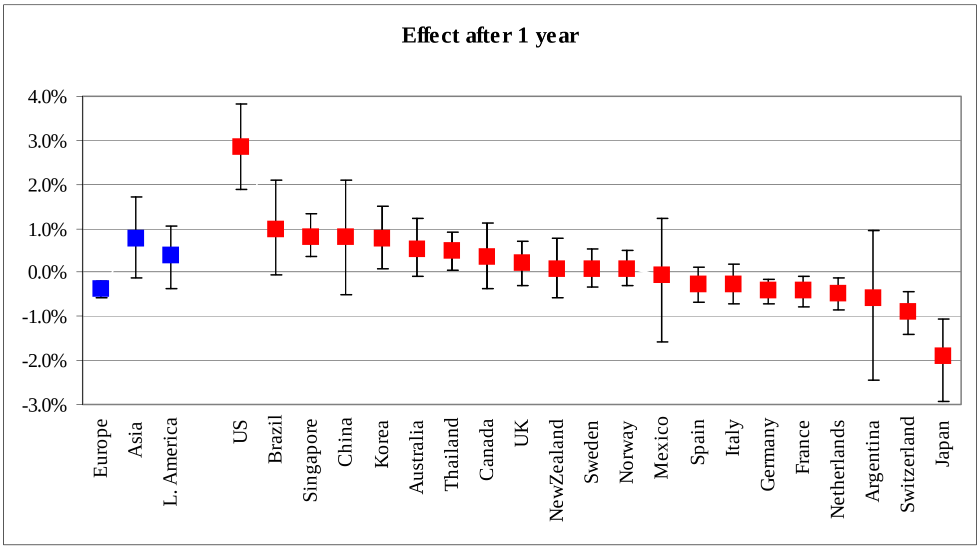

Figure 6: Effect of a US dollar appreciation (2.6%) on REER in the rest of the world.

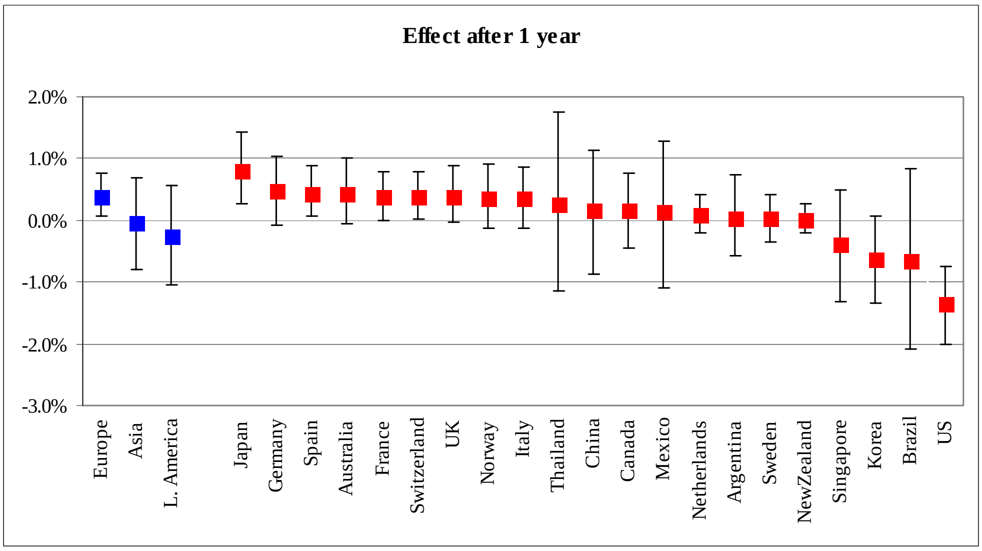

Figure 7: Effect of a US dollar appreciation (2.6%) on exports in the rest of the world.

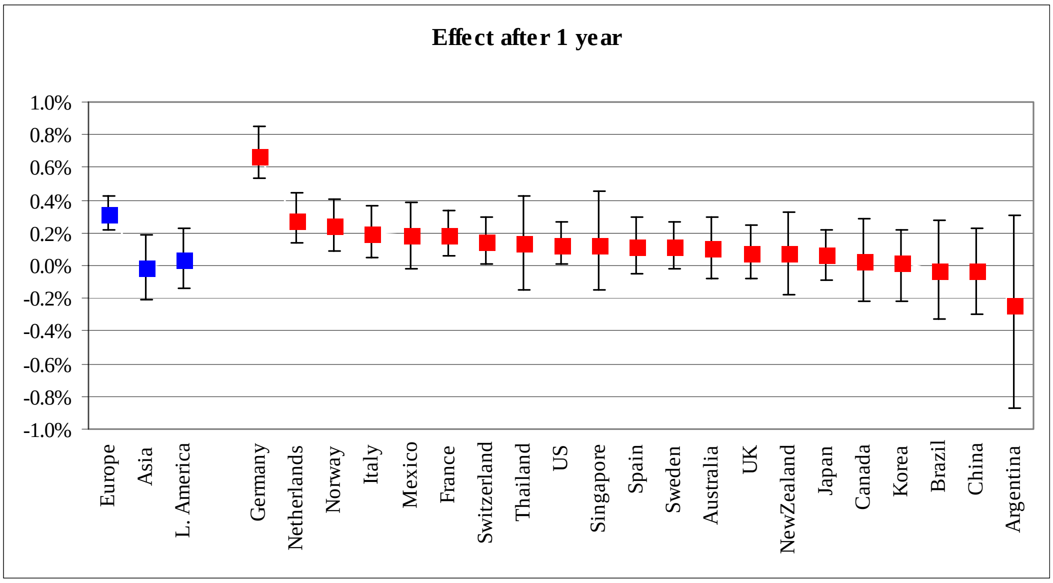

Figure 8: Shock to German output (+ 0.8%), effect on output in the rest of the world.

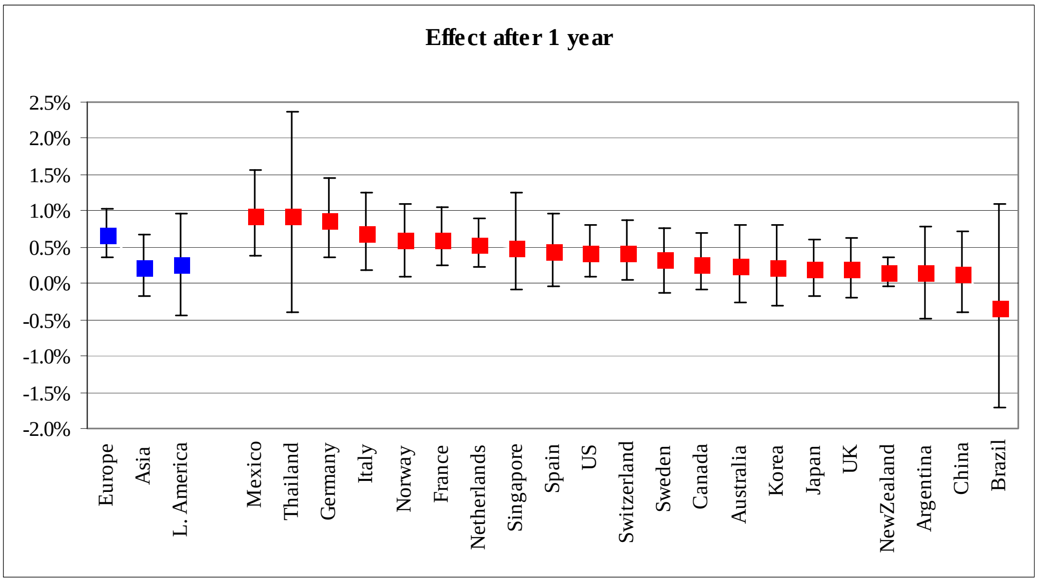

Figure 9: Shock to German output (+ 0.8%), effect on exports in the rest of the world.