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In 2009 all ECB publications feature a motif taken from the €200 banknote.

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Abstract

This paper uses a Global Vector Auto-Regression (GVAR) model in a panel of 21 emerging market and advanced economies to investigate the factors behind the dynamics of global trade flows, with a particular view on the issue of global trade imbalances and on the conditions of their unwinding. 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. The latter proves to be very important due to the internationalisation of production and the high import content of exports. The model can be used to gauge the effect on trade flows of various scenarios, such as an output shock in the United States, a shock to the US real effective exchange rate and shocks to foreign (German and Chinese) variables. Results indicate in particular that world exports respond much more to a (normalised) shock to US output than to a real effective depreciation of the dollar. In addition, the model can be used to monitor trade developments, such as the sharp contraction in world trade that took place in the wake of the financial crisis. While the fall in imports seems well accounted for by the model, the fall in exports of several countries remains partly unexplained, suggesting perhaps that specific factors might have been at play during the crisis.

Keywords: International trade, global imbalances, global VAR, exchange rates, trade elasticities

JEL Classification: F10, F17, F32, C33

Non-technical Summary

The issue of what drives exports and 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 questions have received a lot of attention. The first one is the effect of 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 one 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 on 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 (this issue was extensively addressed in recent editions of the International Monetary Fund's World Economic Outlook, see IMF 2005, 2006, 2007, 2008). 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 Sá, 2006), as well as the expected changes in output in the United States and in the rest of the world (IMF 2006, p. 24-27). 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. Indeed, global trade imbalances have started to adjust, while international trade flows have contracted sharply. The magnitude, the synchronicity and the suddenness of this adjustment are very noticeable, begging the question how one can rationalise such dramatic developments. What is also remarkable is that global imbalances have started to adjust without being associated with a depreciation of the dollar: in the initial phase of the crisis, the dollar actually appreciated against most currencies.

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 one country, or even to one country pair; rather, it involves a large number of countries, as documented in Bracke et al. (2008). 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 key feature of our model is that exports and imports are modelled jointly, in contrast to the existing literature, which typically considers them separately. We find that this innovation is important, given that exports and imports appear to comove substantially for a variety of countries. Such comovement can derive in particular from the strong import content of exports: with globalisa-

tion and the internationalisation of production, the production of exported goods and services tends to use a substantial amount of imported components (as documented in Hummels, Ishii and Yi, 2001). This stylised 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 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 large system (global VAR), which can be used for different purposes, such as the analysis of impulse response functions or monitoring exercises.

We present in this paper a selection of results, which correspond to different applications of our GVAR model for trade. In particular, we use the 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 variables. Results indicate in particular that world exports respond much more to a (normalised) shock to US output than to a real effective depreciation of the dollar (the average response of world exports to the US output shock is around 0.5%, against 0.17% for the shock to the US real effective exchange rate). This appears to be consistent with the fact that the adjustment of global imbalances that took place in the wake of the 2008 financial crisis was not accompanied by a sharp depreciation of the dollar, contrary to what many observers expected. The paper provides a ranking of the countries (from most to least affected) for each of these shocks. We also look at the ability of the model to explain the sharp and synchronised world trade contraction that took place in the last quarter of 2008, conditioning on the explanatory variables of our model. The model performance is especially good on the import side; however, the fall in exports is clearly under-predicted, which may suggest that specific factors - not accounted for by the model - played a role during the crisis.

1 Introduction

The question of what drives exports and 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 Sá, 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 documented in Bracke et al. (2008). 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, instead, 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 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 model presented in the IMF World Economic Outlook (IMF, 2007), the forecasting model developed at the World Trade Organization (Keck and Raubold, 2006), 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, Levin, Rogers and Tryon, 1997), 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 simulation 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. One feature of the model that is particularly appealing is that the restrictions under which the GVAR modelling strategy works are well known and easily interpretable as small open economy assumptions (see Chudik and Pesaran, 2009). Therefore, a fundamental difference with other existing global models of trade is that we are being explicit about the conditions under which our modelling framework is justified in a large system of endogenously determined variables. The second main contribution is that we estimate export and import equations jointly, in contrast to the existing literature, which typically estimates them separately. This proves to be very important given the substantial comovements between exports and imports observed in the data. Such comovements may come in particular from the vertical integration of production chains, also known as the fragmentation of production across borders (Hummels, Ishii and Yi, 2001), e.g., exporting firms typically import components, inducing comovements between exports and imports.

We use the results from our GVAR model to carry out two main exercises. In the first exercise, the model is used to simulate the effects 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 variables (for the latter, we chose Germany and China, two countries that are systemically important and belong to two separate regions, which provides a sense of regional and global dynamics). The main results are as follows. First, a shock to US output significantly affects exports from other countries, in particular from Canada and Mexico, small open Asian economies, but also several European countries. Second, a US real exchange rate appreciation would have smaller effects than a US output shock on exports from the other regions of the world (the average response of world exports to the US output shock is around 0.5%, against 0.17% for the shock to the US real effective exchange rate). Japan is an important exception, showing a strong and significant response of its exports to a US appreciation. Overall, the fact that world exports react substantially more to a (normalised) output shock in the United States than to a depreciation of the US dollar helps assess what variables are typically associated with trade adjustments. This result is in particular in line with the fact that the adjustment in global imbalances observed in the wake of the 2008 financial crisis was not associated with a sharp depreciation of the dollar (contrary to what many observers had expected). The large effect of a US output shocks on exports from other countries may also indirectly illustrate the importance of the trade channel in the transmission of shocks across countries. Third, shocks to foreign variables (focusing on Germany and China) also have the expected effects on the rest of the world (namely, shocks to Germany affect primarily European countries and shocks to China the Asian region). For each of these shocks, the paper provides a ranking of the countries, from most to least affected.

In addition, we also set out to use the model in a monitoring/forecasting exercise, focusing on trade developments in the last quarter of 2008. In this second application of the model, we aim to compare the growth rates of exports and imports among the 21 countries in the sample with the model's prediction, conditioning on the observed values of real output and real exchange rates for this particular quarter. The objective is to see whether the collapse in world trade that took place in the wake of the financial crisis can be rationalised by our model, i.e., whether the explanatory variables we use to model trade successfully account for this recent evolution. What makes this second exercise particularly interesting is that the collapse in world trade was particularly sharp, sudden (world exports contracted by more than 6% in the last quarter of 2008 only) and synchronised across regions. Results indicate that the model successfully accounts for the drop in imports among the 21 countries in our sample, on average, although there are significant cross-country differences in terms of how well the model performs. On the export side, the model clearly under-predicts the fall in real exports for the panel as a whole, although it does predict accurately the drop in exports in the United States and most European countries. This suggests that specific factors, not accounted for in the model, might have played a role during the crisis.

The rest of the paper is organised as follows. Section 2 reviews the related economic literature and compares our approach to previous papers on the topic; it also motivates the modelling strategy regarding the choice of relative prices and demand terms, as well as the relation between exports and imports. Section 3 outlines the main features of the GVAR model. Section 4 reports the estimation results, Section 5 presents the results of the different model's applications, focusing on specific adjustment scenarios and on trade developments as of the end of 2008, while Section 6 concludes. Finally, in the Appendix we provide a detailed explanation of the choice and estimation of the long-run macroeconomic restrictions for our panel of countries.

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 characterise 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).[1] 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

[1] 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). Work on the so-called "J-curve" effect of exchange rate depreciations was presented in Magee (1973, 1974), who focused on the role of currency contracts.

the US economy, the updated version of the USIT[2] 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, other models using a similar approach are the IMF MULTIMOD model (Laxton et al., 1998) and the model of Boyd et al. (2001), who empirically evaluate the effects of the real exchange rate on the balance of payments using structural cointegrating vector autoregressive distributed lag (VARDL) models, among 8 OECD countries. Our approach is also somewhat related to the literature focusing on the relation between international trade and the business cycle, such as Prasad (1999) or Burstein, Kurz and Tesar (2008) and the papers reviewed therein. However, the focus here is on the effects of various shocks on trade flows, rather than the role of international trade in the propagation of shocks.

Compared to these models, the main contribution of the present paper is therefore to link individual country models together through the foreign variables[3] and to model exports and imports jointly.[4] These country specific foreign variables capture unobserved common factors in the spirit of Pesaran's (2006) Common Correlated Effects estimators (see Dées et al. 2007a for a related discussion). Regarding the empirical papers reviewed above, three specific aspects of the empirical approach call for particular attention: (i) the best measure of relative prices, (ii) the effects of foreign and domestic demand on trade flows (the "elasticity puzzle") and (iii) 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

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

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

[4] The role of vertical integration to explain US imports was explored in one of the specifications presented in the IMF WEO article on "Exchange Rates and the Adjustment of External Imbalances " (IMF, 2007). The results of this analysis showed that, compared with the standard model, the price elasticity of imports was higher and the income elasticity was lower, which is in line with our findings.

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 approach follows Boyd et al., 2001, who discuss the issue in greater detail and review the use of relative price terms in the literature). This parsimonious specification considerably simplifies the model: a potential extension would consist in adding export and import prices into the model. However, it is at this stage unclear whether this would result in an improvement of the model given the sharp increase in the number of parameters to be estimated that this would imply. Meanwhile, 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.

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 both as our dataset includes foreign GDP and foreign imports. We opted for the weighted average of foreign output in the long run, 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.[5] 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 characterised 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

[5] However, in the short run, both measures are included. Our long-run restrictions are furthermore not rejected by the data.

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.[6] 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. 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). The importance of the import content of exports is documented for instance in Hummels, Ishii and Yi (2001).

[6]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.

2.1.4 Global imbalances

Indirectly, this paper contributes to the literature on global imbalances. This contribution is only indirect because we focus on global *trade* imbalances and 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.[7] 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 where the depreciation could even be higher, at 64%. Blanchard, Giavazzi and Sá (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; for instance, 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 effect of exchange rate changes and output fluctuations on real trade flows within a GVAR framework, but it does not investigate the factor behind saving/investment imbalances.

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.[8]

The GVAR framework was applied in the past to a variety of questions. This includes an analysis

[7] 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.

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

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.

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 simulation results on the generalised impulse response functions, focusing on the shocks we are interested in (this approach is also that of Boyd et al., 2001). 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).

3 The GVAR Approach to Global Macroeconomic Modelling

One recurrent problem in the global macroeconometric literature is the heavy parameterisation of the empirical models. This issue, which is sometimes referred to as the "curse of dimensionality"[9], 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 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

[9] This expression was coined by Richard Bellman.

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,

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

where $\boldsymbol{\Phi}(L,p) = \mathbf{I}_k - \sum_{\ell=1}^{p} \boldsymbol{\Phi}_\ell L^\ell$, $\boldsymbol{\Phi}_\ell$ 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, $\boldsymbol{\Gamma}$ 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.[10] The number of parameters 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 $\boldsymbol{\Phi}(L,p)$ are small (of order N^{-1}), it can be shown that, under few additional

[10] See Chudik, Pesaran and Tosetti (2009) and Pesaran and Tosetti (2009) for a definition and a discussion of strong and weak cross section dependence.

assumptions as stated in Chudik (2007),

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

as well as

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

uniformly in $t\in\{1,2,...,T\}$ as $N,T\overset{j}{\rightarrow}\infty$, such that $T/N\rightarrow 0$;[11] 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.[12] 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

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

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).[13] 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

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

[12] 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).

[13] 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).

(1).[14] 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

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

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

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 the endogenous variables, the latter capturing possible *unobserved* common factors. A second important modelling choice involves the appropriate time and country coverage. In our case, we want to maximise data availability, in

[14] See Pesaran and Chudik (2009).

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

We use quarterly data starting in 1980 and ending in 2007. Our country sample comprises 21 countries, including 14 advanced countries and 7 emerging market economies.[15] 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 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.[16] The different choice made by Dées et al. (2007a) can be easily reconciled with the specific focus of their paper 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.[17] In addition to the 5 key series (exports, imports, GDP, real exchange rate and the price of oil, all in real terms and in logs)[18], 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

[15] 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 Table 1.

[16] 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.

[17] Table 1 reviews the data sources in details.

[18] 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.

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

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

and for the US,

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

Our set of real exchange rates does not constitute a closed system and therefore we treat this variable as any other endogenous variable.[19]

To construct the foreign variables we use trade weights (see Table 2) 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 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.[20]

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:

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

where $\mathbf{z}_{it} = (\mathbf{x}_{it}', \mathbf{x}_{it}^{*\prime})'$, $\boldsymbol{\alpha}_i$ 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.

[19] In Dées et al. (2007a, 2007b, and 2008) real exchange rates are constructed as a closed system where the N-th effective real exchange rate can be derived as a function of the remaining $N-1$ exchange rates. Our real effective exchange rates come from IMF IFS and BIS databases and therefore they cannot be considered as a closed system.

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

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.

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.[21] 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.[22] 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 A4 in the Appendix). 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. 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.[23] While theories of the short-run relations generally focus on the optimisation 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 certain (longer) period of time. In the data, we generally observe deviations

[21] For reasons of space, we do not report the results but they remain available upon request.

[22] 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).

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

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

The identification of such relations, however, is not straightforward since there are many candidate long-run relations borrowed from economic theory, which might or might not 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 well-known long-run relationships: (*i*) relative Purchasing Power Parity (PPP), which states that the real exchange rate is stationary (at least when the same baskets of goods are used in the construction of price indices), (*ii*) output convergence, which implies that domestic and foreign output cointegrates, (*iii*) stationarity of trade balance[24], and (*iv*) relaxation of relative PPP hypothesis by taking into account possible Balassa-Samuelson effect. Assuming export and import prices (expressed in the same numeraire) cointegrates, stationarity of nominal trade balance would imply that the export volumes and import volumes cointegrates as well. We note that the rejection of the cointegration between export and import volumes does not necessary imply that the nominal trade balance is not stationary. Regarding the Balassa-Samuelson effect, the relaxation of PPP would be necessary only if output convergence did not hold.

In addition, we consider two possibilities for the trade equations. The traditional export and import volume long-run equations in the literature feature only demand and relative price terms. However, due to fragmentation of production, imports could be part of the export cointegrating relations (this is the case when some of the imports constitute inputs for the manufacturing process of exported goods) or, on the other hand, exports could be part of the import volume long-run relation (this would be the case when part of the manufacturing process is outsourced abroad). We therefore introduce "enhanced" trade equations, where the possibility of cointegration between exports and imports is also taken into account. All long run relations considered in this paper are summarised in the table below.

[24] 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.

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, we pay particular attention to testing for the number of cointegrating vectors and to their identification. General modelling strategy is described briefly below, while detailed description of our estimation and testing procedure is relegated to the Appendix. We start with the traditional system approach, treating all 9 country-specific variables in one system and then we conduct sensitivity tests to different choices of the lags for domestic and foreign variables. With the exception of few countries, we found that no conclusive inference about the number of long-run relations could be made. This seems to be related to the dimensionality problem, because treating all 9 variables in one system requires lots of coefficients to be estimated. We conduct Monte Carlo experiments to investigate this issue further, and found out that indeed the performance of cointegrating tests is not very good for the dimension of our systems. Motivated by these findings, we conduct also a parsimonious approach, where only selected subsets of country-specific variables are jointly estimated in one system at the same time. Estimating smaller dimensional VARs for subsets of country-specific variables gives us additional pieces of evidence to consider. Testing the stationarity of real exchange rate, which is a trivial example of system with one variable only, is a valid test for the relative PPP hypothesis. Similarly, treating the difference between domestic and country-specific foreign output and the real effective exchange rate in a bivariate VAR and testing for cointegration is a valid test for the Balassa-Samuelson relation.

4.4.1 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, stationarity of the trade balance or the Balassa-Samuelson relationship for any country.[25]

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 3. These cointegrating vectors were then imposed in the country-specific VARX* models, where we also test for the validity of the chosen overidentifying restrictions in a full system approach. These restrictions are tested using the log-likelihood ratio statistic at the 1% confidence level. The last column of Table 3 shows the critical values of this test which have been computed by bootstrapping from the solution of the GVAR model[26]; 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.[27] Persistence profiles make it possible to examine the speed at which the long-run relations converge to their equilibrium states. All persistence profiles

[25] 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.

[26] 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.

[27] 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.

in Figure 2 are well behaved which is again reassuring for our choice of the long-run overidentifying relations.[28]

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 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 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 4, show that there is broad evidence in favour of the stability of the parameters. 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 generalised impulse responses analysis.

5 Applications of the Model

In this section we present a selection of results, which correspond to different applications of our GVAR model for trade.[29]

In particular, we use the model to simulate the effects that shocks to selected variables of our system may have on the other variables over time. To this aim, given the difficulty in identifying the structural shocks in the GVAR framework, we make use of the generalised impulse response function

[28] Eigenvalues of the solved GVAR model provide another way of checking the dynamics of the system. The largest eigenvalue of the constructed GVAR model is equal to one in absolute value. There are exactly 58 eigenvalues that are equal to one (in absolute value), which is equal to the number of variables minus the number of cointegrating relations (85-27), and therefore it matches the number of overall stochastic trends.

[29] Given the space constraint, we present only selected results for each application.

(GIRF) approach[30], which consists in looking at the response associated with unit (in our case one-standard-error) shifts to the observed variables. We then present the results of the generalised forecast error variance decomposition (GFEVD). Finally, we present a forecasting exercise which aims at addressing the following topical policy question: is the sharp contraction in trade experienced by the world economy in the last quarter of 2008 consistent with the observed fall in real output and the observed real exchange rate configuration? To answer this question we use our GVAR model to compute the forecast of real exports and imports for the 21 countries in our model conditioning on the observed values of real outputs and real exchange rates for the year 2008.

5.1 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 variables in our system on all the others. Given the strong interest that academics and policy-makers have shown on the possible factors that may reduce the US current account deficit, we first present the results for two simulations which have been generally studied in the literature: a shock to US domestic output, and a shock to the US real exchange rate. The other two simulations for which we present the results are a shock to German real output (which proxies an expansionary shock in Europe) and a shock to Chinese real imports (which proxies an expansionary shock in Non-Japan Asia).

In the absence of strong a priori information to identify the short-run dynamics of our system (with 85 variables exact identification would require 3570 restrictions, a clear overstretch of the data), we use the generalised impulse response function (GIRF) approach. Clearly, when we shock US output we will not be able to distinguish between the possible causes of the shift, 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.[31] 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.

5.1.1 Shock to the US Real Output

The first shock that we consider is a positive shock to domestic output in the US. A one-standard-deviation shock corresponds in this case to an increase of US GDP of 0.6%. One noticeable result

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

[31] Note that, although we recognise that the term "shock" might not be entirely appropriate in this framework, given the lack of identification of the structural shocks in the system, in the rest of the paper we refer to one-standard-error shifts to the observable variables as shocks.

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 signignificant and large effect on foreign countries. Figure 3 shows the effect of this shock on the GDP of the rest of the world after one year: the red squares 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). 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.[32]

Figure 4 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 3 and 4 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.

5.1.2 Shock to the US Real Effective Exchange Rate

The next shock that we consider is a positive shock to the US real effective exchange rate, which corresponds to an appreciation 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

[32] 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. Note that the confidence intervals for these regions are also computed by bootstrap.

magnitude of the effect seems quite large, compared to other results in the literature.[33] On the import side, by contrast, the appreciation fails to significantly lift up US imports, which increase by 0.7% after one year and by roughly 1% in the long-run (however, the effect on US imports becomes statistically significant only after year 2).[34] This is in line with a growing body of the literature showing that pass-through is very limited in the US (see, e.g., Marazzi et al., 2005, or Bussière and Peltonen, 2008). 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 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 5 suggests that foreign economies are heterogeneously affected by an appreciation of the US real effective exchange rate, 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 some Latin American countries. 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.

The reaction of real exports in foreign countries (Figure 6) basically mirrors the effect of the real 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. Europe is also significantly affected by the appreciation and registers a sizeable increase in its exports, which is however somewhat smaller than the increase resulting from a US output shock. The effect on exports in Non-Japan Asian (NJA) countries is basically zero since the currencies of these countries tend to follow the appreciation of the US real exchange rate. The effect on imports (not reported here) does not appear to be significantly different from zero in any of the foreign economies.

[33] 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.

[34] This result is not shown in the paper but remains available upon request.

5.1.3 Shock to Foreign Variables

When moving to foreign - from a US perspective - economies, many possible simulations could be performed due to the large number of countries in our sample. However, to keep the paper within reasonable space limits, we choose to show only two simulation exercises to illustrate the way the model can be used. Our choice of the foreign variables coincides with the willingness to assess how expansionary shocks in Europe and Asia would influence global real trade flows.

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-standard-deviation shock to German GDP, which corresponds to an increase by 0.8% at the time of the impact, is found to have economically and statistically significant effects on other European countries (see Figure 7). 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 8). In particular, the effect on US exports is found to be significant and roughly stable at 0.4% for the first two years.

As far as Asia is concerned, to look at the effects of shocks to Chinese variables is certainly of great interest given the increasing importance of this country in global trade. Figures 9 and 10 show the results of a shock to Chinese real imports on output and exports in the rest of the world. Differently from the US and Germany cases, we chose here to look at a shock to Chinese imports since China is important in the world economy mainly because of its trade relationships with the rest of the world. Although for most of the countries the confidence intervals are quite large and some of the GIRF are therefore not statistically significant[35], the general picture from Figures 9 and 10 is still informative. A one-standard-error shock to Chinese imports, which corresponds to an increase of 1.9% at the time of the impact, has an economically significant effect on other Asian countries, with Korean, Singaporean and Thai real output increasing by 0.4% after one year, and a smaller but still considerable effect on the real output of Japan and New Zealand which increase by 0.2%. The effect on Eurozone countries and on the US are instead quite small and largely insignificant with the exception of a few countries.[36] The effect on exports in the rest of the world, shown in Figure

[35] We believe this result may be due to data issues. In particular, the series for China are interpolated from annual data for the first part of the sample. This can partly affect the inference of the model for China leading to less precise parameter estimates.

[36] It is somehow interesting that the European country which seems to benefit the most from an expansionary shock to Chinese imports is the Netherlands, i.e. one of the most open economies in the Eurozone characterised by a large

10, are basically consistent with those on output: real exports of Asian countries benefit the most from a positive shock to Chinese imports. These results clearly suggest the presence of a strong Asian business cycle and of an increased vertical specialisation in international trade among Asian economies. Many papers indeed have documented that vertical specialisation - alternatively known as international fragmentation of production - has been increasing over time (e.g., see Hummels, Ishii and Yi, 2001) and can be seen as one of the main driving force of the international transmission of business cycles (Burstein, Kurz and Tesar, 2008).

5.2 Generalised Forecast Error Variance Decomposition

In a structural VAR framework, the forecast error variance decomposition (FEVD) is performed on a set of orthogonalised shocks, or structural innovations, and can therefore be interpreted as the contribution of the i-th innovation to the variance of the h-step ahead forecast of the model. In this case, the sum of the single innovation contributions add up to one. In reduced-form VARs, the lack of identification of the reduced form errors, which implies that the correlation between shocks is in general different from zero, invalidates the traditional interpretation of the FEVD.

An alternative approach in the GVAR context, followed for instance in Dées et al. (2007b), is to compute the Generalised FEVD. This approach, like the GIRF, has the advantage of being invariant to the ordering of variables in the system, a nice feature in a high dimension system such as ours. The GFEVD computes the proportion of the variance of the h-step ahead forecast errors of each variable that is explained by conditioning on contemporaneous and future values of the non-orthogonalised (generalised) shocks of the system. It is important to notice that, given the general non-zero correlation between such errors, the individual shock contributions to the GFEVD need not sum to unity.[37]

We present the results for a selected sample of variables, which we believe of potential interest for their importance in global trade flows. Table 5 shows the GFEVD for US and German real imports while Table 6 the GFEVD for Japanese and Chinese real exports. Since our model contains 85 endogenous variables, and since presenting the contribution of each of them to the forecast variance of the selected variables would take too much space, we only show the contributions of the ten top determinants at the eight-quarter horizon. The last two rows in each decomposition show the sum of the contributions of the ten top determinants and the sum of all contributions (of the 85 variables in our model), respectively.

transit trade.

[37] For a derivation of the generalised forecast error variance decomposition in a GVAR framework, see Dées et al. (2007b).

Starting with real imports, results for the US show that domestic variables, i.e., real exchange rate, imports and GDP, contribute equally to the forecast variance after two years (explaining alone more than one-third of the total variance). The contribution of the same domestic variables at shorter horizon is however much more heterogeneous, with the real exchange rate almost unimportant before one year and the real GDP playing the role of the main determinant. This result can be easily reconciled with the general finding in the literature of very small exchange rate pass-through to US imports in the short-run and a high domestic demand elasticity. The results for Germany, instead, show that domestic variables are able to explain more than half of the forecast variance of real imports after two years. Domestic GDP, however, contributes much less than in the US while domestic exports play the biggest role, explaining alone one-forth of the forecast variance. This finding confirms the result of section 4.4, i.e., that exports and imports in Germany are both part of a cointegrating vector and are endogenously determined. Among the foreign variables, the price of oil is an important determinant of German imports, a finding that may again be explained by the strong export content of imports for this economy.

Table 6 shows the results for real exports of the two major Asian economies, Japan and China. For both countries the real exchange rate is one of the key determinants, explaining alone more than one-tenth of the export forecast variance decomposition. In the case of Japan, domestic imports are also a very important determinant, suggesting that for this country, as for Germany, exports and imports move together in the long run, a result which is confirmed by our identified long-run relations (see section 4.4). Among the foreign variables, the real price of oil and the US real exchange rate are contributing substantially to the Japanese exports variance decomposition as well as some Asian variables that capture foreign demand (such as Korean GDP and Singaporean exports).[38] In addition to the real price of oil, which is also an important determinant, the foreign variables which explain most of the variance decomposition of Chinese exports are Asian variables, such as Thai exports and Korean exports and GDP, confirming the previous finding of a strong Asian business cycle and vertical trade integration (see results of section 5.1.3).

[38] Notice that the contribution of foreign variables is much more dispersed than that of domestic ones. That is the reason why only a few foreign demand variables enter in the top ten ranking. For example, Chinese variables seem to be very important at horizons less than one year, explaining more than 6% of the total variance of Japanese imports. They loose, however, most of their importance at longer horizons, the reason why they do not enter in the ten top determinants at the eight-quarter horizon.

5.3 The Collapse of Global Trade in 2008Q4

One of the main features of the current financial crisis is the sharp contraction in global trade that took place at the end of 2008 and continued in the beginning of 2009. In this section we want to answer the following policy question which can be easily addressed by our model: can the sharp contraction in trade experienced by the world economy in the last quarter of 2008 be rationalised by the observed fall in demand and the change in relative prices? If this is the case, this suggests that the explanatory variables we are using to model trade successfully account for this dramatic evolution; otherwise, this may suggest that specific factors were at play during the crisis, which might call for different policy measures. To answer this question, we use our GVAR model to compute the forecasts of real exports and imports for the 21 countries conditioning on the actual values of real outputs and real effective exchange rates for the year 2008. In addition to computing the conditional forecasts of real exports and imports, we also disentangle the contributions to the predicted values of conditioning on domestic variables (y_{it} and rer_{it} of country i) and on foreign variables (y_{jt} and rer_{jt} for $j \neq i$).

Figures 11 to 14 present the results of the forecasting exercise. Figure 11 shows the actual vs. predicted values of the export quarterly growth in 2008Q4 for the 21 countries.[39] The first two bars in the figure show that the model forecasts a fall in the aggregate real exports of 3% against an actual fall in 2008Q4 of 7.1%.[40] Looking then at individual countries, the histogram shows that apart from a few countries, namely Canada, Australia and Singapore, the model is able to correctly predict the sign of export growths for that quarter but it generally gets the size wrong by under-estimating the fall. In particular, the model fails to forecast the unprecedented high fall in exports for most of the emerging economies, such as China, Mexico, Korea and Argentina, and for a few developed countries, such as Japan, Italy and Spain.

The results for the import growth are shown in Figure 13: the model predicts a fall in aggregate real imports of 4.1% in 2008Q4 against a realised fall of 5.5%. Again, the model correctly predicts the direction of import growth for most of the countries with a few relevant exceptions. In particular, the model forecasts an increase in imports for the US and Canada and a fall in imports for Japan (for the latter country, the model predicts a -8.8% import growth against a realised increase of 3%). It should be said, however, that the increase in imports in Japan in the last quarter of 2008 was quite surprising and definitively difficult to forecast given the economic situation in the country and

[39] Both the forecast values and the variable contributions are computed by bootstrapping from the solution of the GVAR and correspond to the median values.

[40] To construct the aggregate values for exports (imports), we use the average of the exports (imports) weights for the countries in the model between 2000 and 2006.

abroad (Japanese GDP, for instance, decreased by 3.2% on a quarterly basis in 2008Q4). Japanese imports may have been supported by the strong yen appreciation in the end of 2008.

Figure 12 and 14 present the contributions of foreign and domestic variables in explaining the forecasted values of export and import growths discussed above (and shown in Figure 11 and 13). Figure 12 shows that domestic variables seem to be the main factors responsible for the drop in real exports in most of the large developed economies, e.g., the US, Germany, France, Italy and (partly) Japan, while foreign variables play a dominant role in explaining the fall in exports from most of the emerging markets, such as Mexico, China, Korea, Brazil and Argentina, and from some developed small open economies, such as the Netherlands, the UK and Switzerland. Results from the import decomposition suggest that, for some countries, the fall in imports experienced in 2008Q4 was mainly caused by the external economic situation (captured by the foreign variables) and less from domestic developments (as we would expect to be given the typically large elasticity of imports to domestic demand). In particular, this is true for China, Mexico, Argentina and Thailand among the emerging economies and for Switzerland, the Netherlands, Norway, New Zealand and Spain among the developed ones.

Overall, this forecasting exercise suggests that, for the particular quarter under examination, our model seems to capture relatively well the fall in real imports whereas it under-predicts the fall in real exports. This may suggest that specific factors, not accounted for in the model, were at play during the crisis.

6 Conclusion

This paper has presented results from a GVAR model applied for the first time to the issue of global imbalances and global trade flows. 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 model, which is specifically designed to account for international linkages, is particularly well suited to tackle the issue of global imbalances given the dispersion among many different countries and regions of global trade imbalances. Second, while most empirical trade papers model real exports and imports separately, we show that there is value added in jointly modelling them, in particular because of the internationalisation of production chains across the world. The aim of the paper was not to carry out a structural exercise, but to assess what variables are typically associated with trade adjustments.

The model can be used to gauge the effect on trade flows of various scenarios, such as a shock to US output, a shock to the US real exchange rate and a shock to foreign (German and Chinese) variables. The main results show, first, that a shock to US output significantly affects exports from other countries, in particular Canada and Mexico, small open Asian economies, but also several European countries. Second, a US real exchange rate appreciation would significantly stimulate exports from foreign economies, but to a lower extent than the shock to US output. This result is in particular in line with the fact that the adjustment in global imbalances observed in the wake of the 2008 financial crisis was not associated with a sharp depreciation of the dollar (as many observers had expected). The large effect of a US output shocks on exports from other countries may also explain the importance of the trade channel in the transmission of shocks across countries. Third, shocks to foreign variables (focusing on Germany and China) also have the expected effects on the rest of the world. For each of these shocks, the paper has provided a ranking of the countries, from most to least affected.

In addition, we also explored the factors behind the noticeable contraction in world trade that took place in the wake of the financial crisis. In a different application of the model, for instance, we aimed to compare the growth rates of exports and imports among our 21 countries with the model's prediction for the last quarter of 2008 (conditioning on the observed real output and real exchange rate developments). The objective was to see whether the model we have estimated is able to account for the collapse in world trade over that period. What makes this second exercise particularly interesting is that the collapse in world trade was particularly large, sudden (world exports contracted by more than 6% in the last quarter of 2008 only), and synchronised across countries. Results indicate that the model successfully accounts for the drop in imports among the 21 countries in our sample, on average, in spite of some cross-country differences in terms of how well the model performs. On the export side, instead, the model under-predicts the fall in real exports for the panel as a whole, although it does predict accurately the fall in exports from the United States and most European countries. This suggests that specific factors, not accounted for in the model, might have played a role during the crisis.

Overall, the model we have outlined in this paper lends itself to a variety of simulation and forecasting/monitoring exercises, exploring different aspects of global trade flows. Looking forward, the model can be extended in various directions; one possibility would be to aim to identify shocks. This extension, however, seems at this stage very challenging, such that we leave it for future research.

Table 1: 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+WEO$^{(1)}$	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 effective exchange rate we used IFS line REC.

(III) The BIS: for real GDP we used the code 9.9B.BVP; for the real 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 his co-authors, 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 2: 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	0.066	0.044	0.051	0.032	0.038	0.046	0.001	0.006	0.012	0.028	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	0.020	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	0.128	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	0.086	0.033	0.063	0.005	0.115	0.125	1.000
Italy	0.004	0.010	0.013	0.010	0.061	0.176	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	0.287	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	0.180	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	0.016	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	0.080	0.038	0.015	0.004	0.095	0.003	0.044	0.018	0.058	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	

Table 3: 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 4: 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)

Table 5: GFEVD of US and German real imports

The table shows the Generalised Forecast Error Variance Decomposition of US and German real imports in terms of their ten top determinants at the eight-quarter horizon. The last two rows for each forecasted variable show the sum of contributions of the ten top variables and the sum across all possible determinants (the 85 variables in the model).

Contribution	**Quarters**						
	0	2	4	6	8	10	12
				US Real Imports (%)			
US RER	1.6	6.8	12.9	22.6	31.1	36.4	39.4
US IMP	76.8	53.7	41.8	35.0	31.1	28.9	27.8
US GDP	12.4	42.5	39.6	34.3	30.4	28.6	28.3
Korea GDP	1.2	2.9	5.3	8.3	10.3	10.6	9.9
Switz.RER	0.1	3.7	6.1	8.2	9.5	10.3	11.0
Spain IMP	1.1	5.7	7.2	7.4	6.9	6.2	5.8
Singap RER	0.0	0.3	1.7	4.3	6.4	7.3	7.4
France RER	6.7	5.6	5.2	5.2	5.4	5.8	6.2
Germany RER	0.6	2.3	3.5	4.5	4.9	5.1	5.2
Argentina GDP	0.0	2.5	3.6	4.3	4.8	5.3	5.6
*Sum of Top*10	100.7	126.0	126.9	134.1	140.6	144.5	146.6
Sum of Total	166.1	183.9	192.3	206.7	217.7	224.4	227.6
				German Real Imports (%)			
Germany EXP	25.0	43.2	51.9	55.4	55.8	55.2	54.6
Germany IMP	73.3	54.4	45.2	40.6	38.9	39.2	40.5
Germany GDP	11.4	12.3	16.2	19.9	22.8	24.7	25.7
Price of Oil	1.3	3.4	6.9	9.8	10.8	10.5	9.9
Korea GDP	4.4	5.0	7.1	9.2	10.3	10.4	9.8
China RER	0.4	2.9	6.5	8.6	9.1	8.6	7.9
Mexico IMP	12.1	10.6	9.2	8.3	8.1	8.5	9.4
NewZeal EXP	6.5	8.6	8.0	6.4	5.0	4.1	3.8
Switz.EXP	1.3	2.3	3.4	4.0	4.2	4.1	4.1
Italy IMP	5.5	6.0	5.5	4.5	3.6	2.9	2.4
*Sum of Top*10	141.4	148.9	159.9	166.6	168.6	168.2	168.0
Sum of Total	199.2	209.5	218.7	223.1	223.8	223.1	222.5

Table 6: GFEVD of Japanese and Chinese real exports

The table shows the Generalised Forecast Error Variance Decomposition of Japanese and Chinese real exports in terms of their ten top determinants at the eight-quarter horizon. The last two rows for each forecasted variable show the sum of contributions of the ten top variables and the sum across all possible determinants (the 85 variables in the model).

Contribution	**Quarters**						
	0	2	4	6	8	10	12
				Japanese Real Exports (%)			
Japan EXP	71.3	55.6	46.3	39.7	37.0	37.6	39.6
Japan IMP	10.1	19.3	24.9	28.5	30.1	31.6	33.5
Japan RER	3.4	13.2	24.6	29.1	26.9	23.5	21.4
Price of oil	0.8	3.1	9.8	16.8	19.1	18.3	17.2
US RER	8.3	12.1	14.5	15.2	14.3	12.8	11.3
Singap.RER	5.2	5.4	7.3	8.3	7.6	6.3	5.3
Korea GDP	0.0	0.0	1.3	3.8	5.2	5.2	4.5
Singap.EXP	2.1	3.8	4.4	4.6	4.6	4.8	5.3
Australia RER	0.4	2.1	3.7	4.4	4.5	4.3	4.3
Spain RER	1.2	4.6	6.5	6.0	4.4	3.3	3.1
*Sum of Top*10	102.8	119.3	143.4	156.5	153.5	147.8	145.5
Sum of Total	164.8	206.5	227.1	227.4	220.9	217.9	218.3
				Chinese Real Exports (%)			
China GDP	0.1	6.1	18.8	31.2	39.9	46.9	51.6
China RER	2.3	0.0	4.7	15.3	24.5	31.9	37.7
Price of Oil	0.1	1.8	10.6	15.6	12.3	7.4	3.8
Switz.IMP	2.0	4.7	8.4	8.9	7.8	6.7	6.0
UK RER	0.5	1.6	4.4	6.7	7.3	7.2	6.9
Thailand EXP	0.2	0.2	2.5	5.3	6.3	6.5	6.3
France RER	7.0	10.5	10.7	7.7	5.9	5.4	5.5
China EXP	91.1	85.3	52.7	17.5	5.6	2.9	2.5
Korea.EXP	1.4	4.0	6.3	5.5	4.2	3.6	3.5
Korea GDP	0.1	0.1	1.9	4.0	4.2	3.5	2.7
*Sum of Top*10	104.8	114.2	121.1	11.6	118.9	122.3	126.5
Sum of Total	183.5	193.5	192.6	178.8	176.7	182.7	189.9

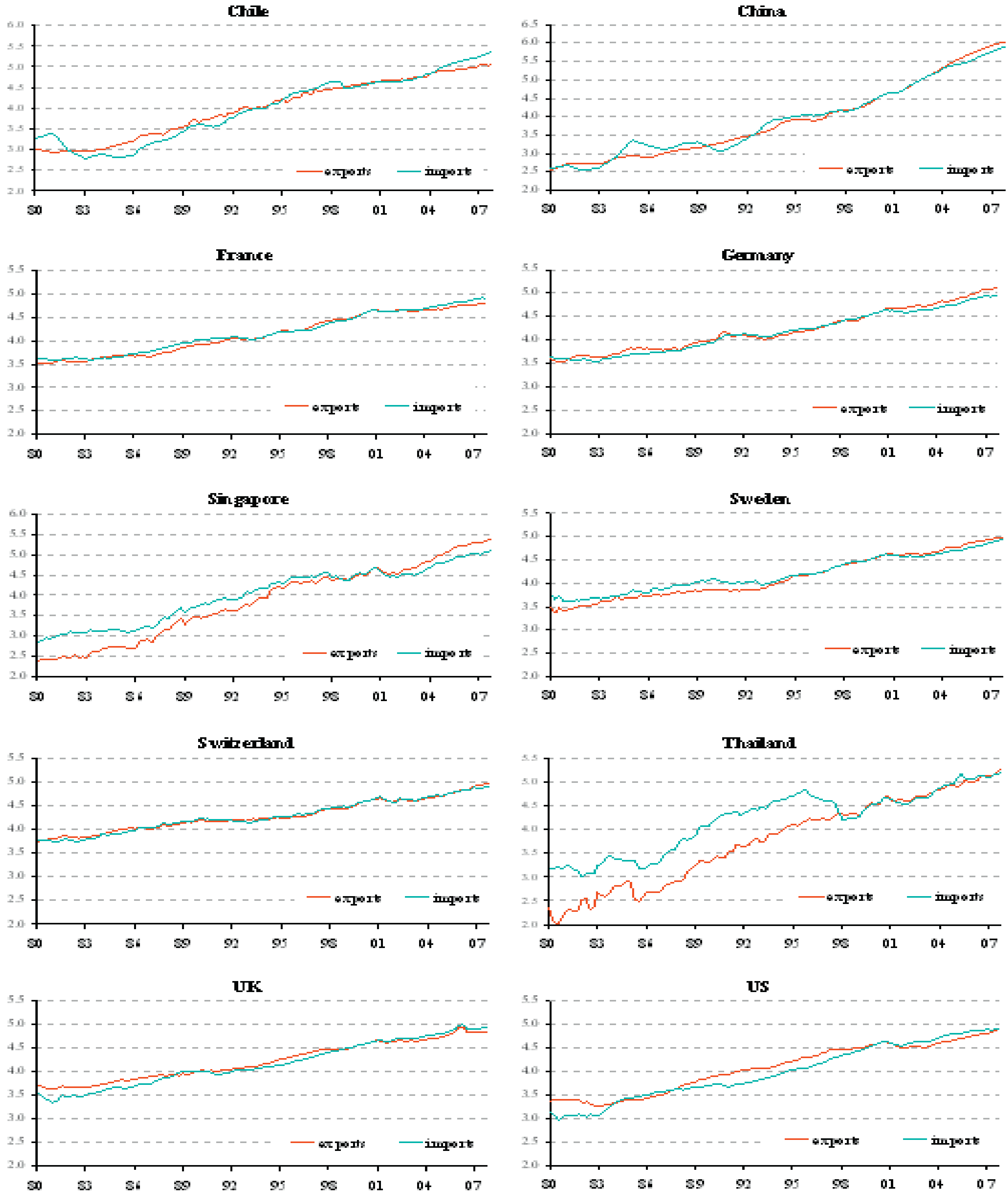

Figure 1: Real Exports and Imports, Selected Economies. *(Note: data in logarithms, source: See Table 1)*

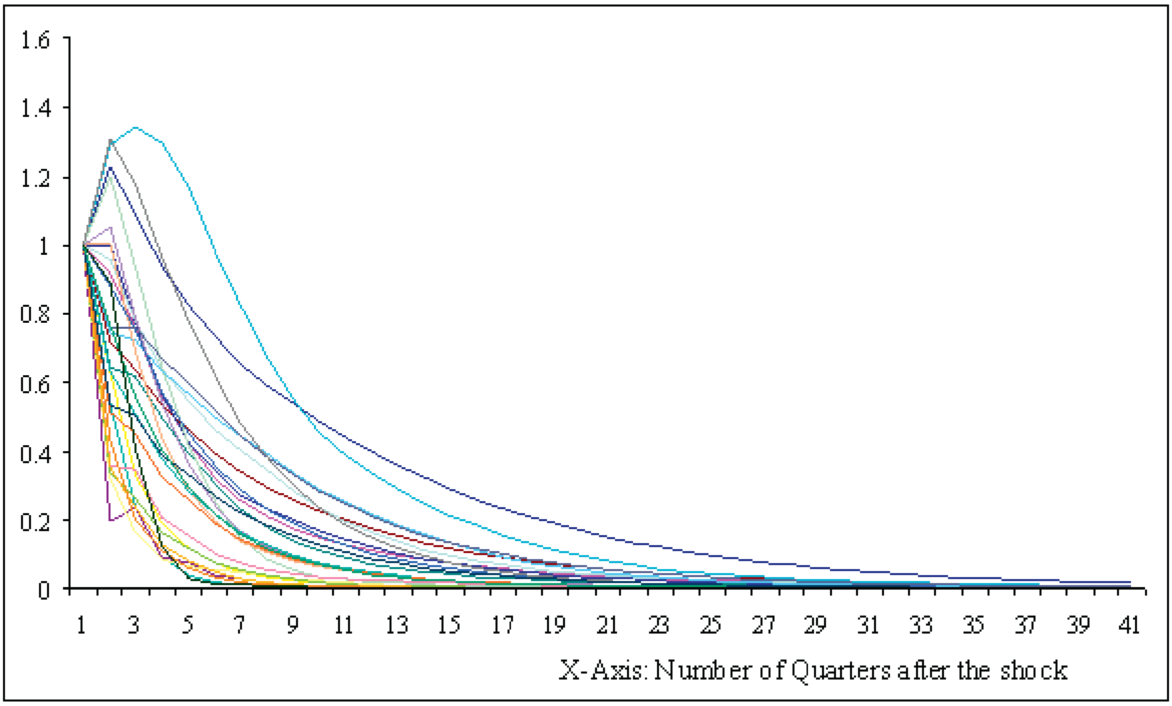

Figure 2: Bootstrap means of the persistence profiles of the effect of system wide shocks to the cointegrating relations

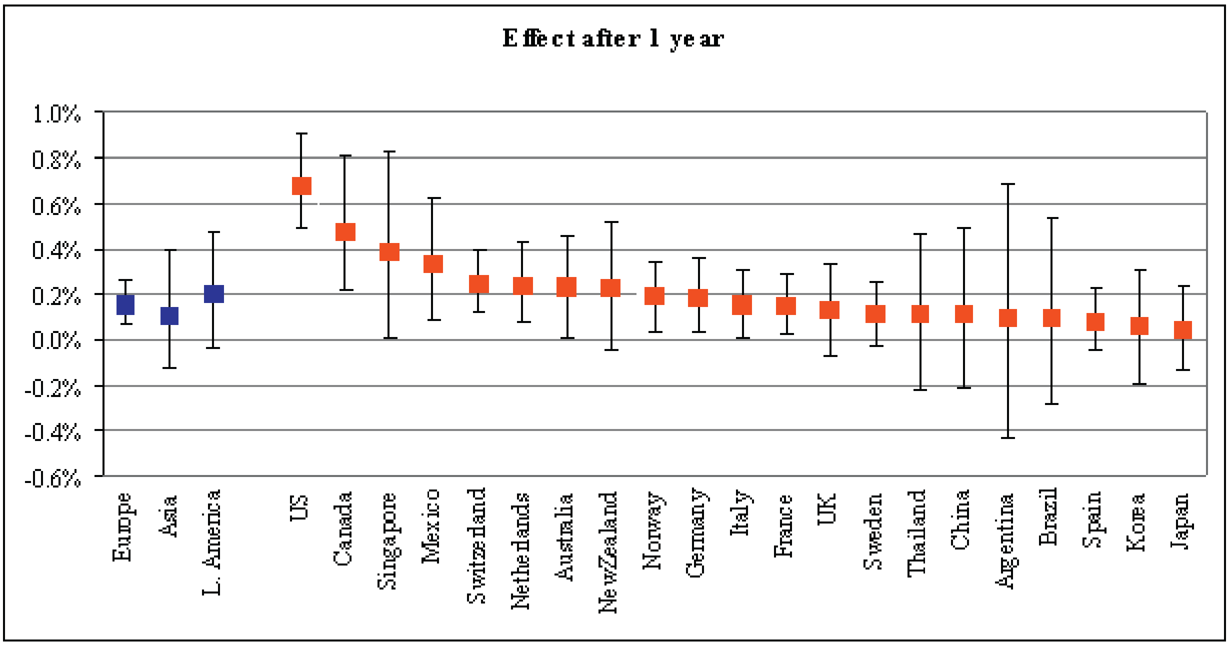

Figure 3: Shock to US output (+ 0.6%), effect on output in the rest of the world.

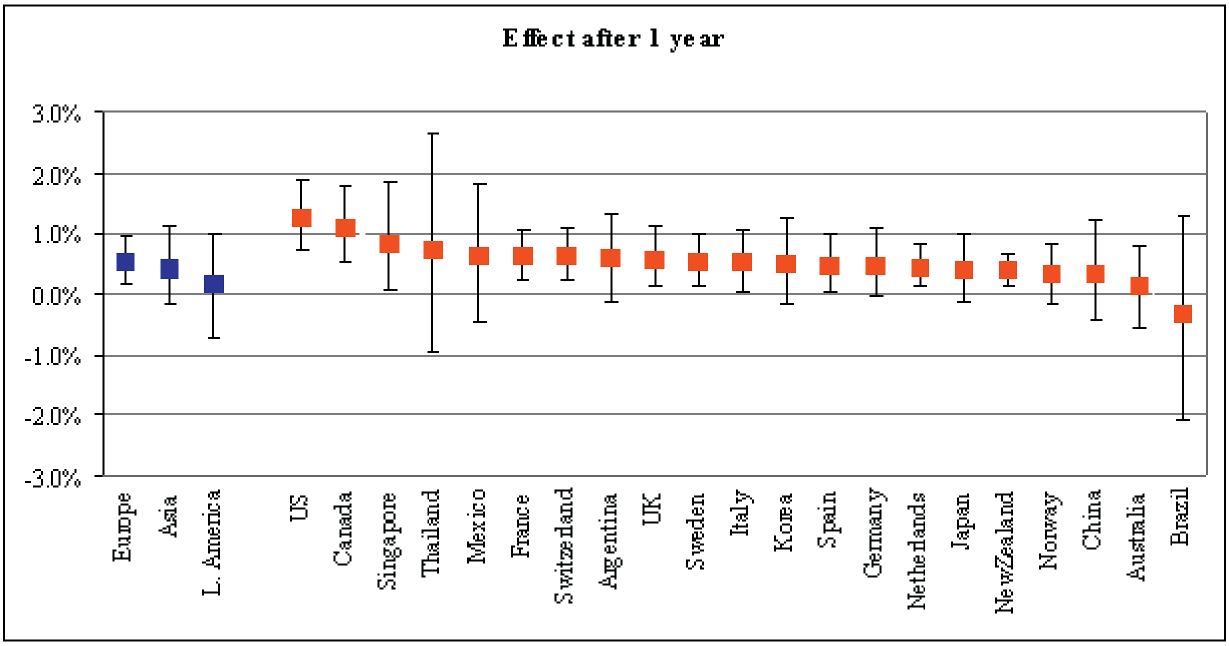

Figure 4: Shock to US output (+ 0.6%), effect on exports in the rest of the world.

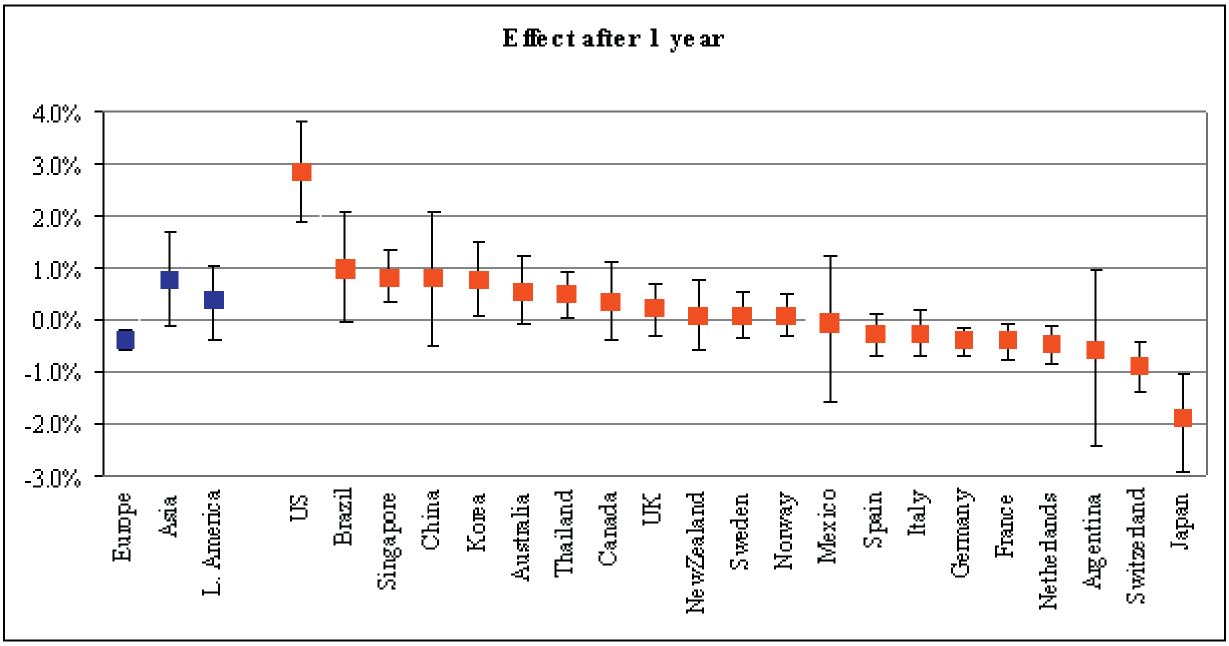

Figure 5: Effect of a US REER appreciation (2.6%) on REER in the rest of the world.

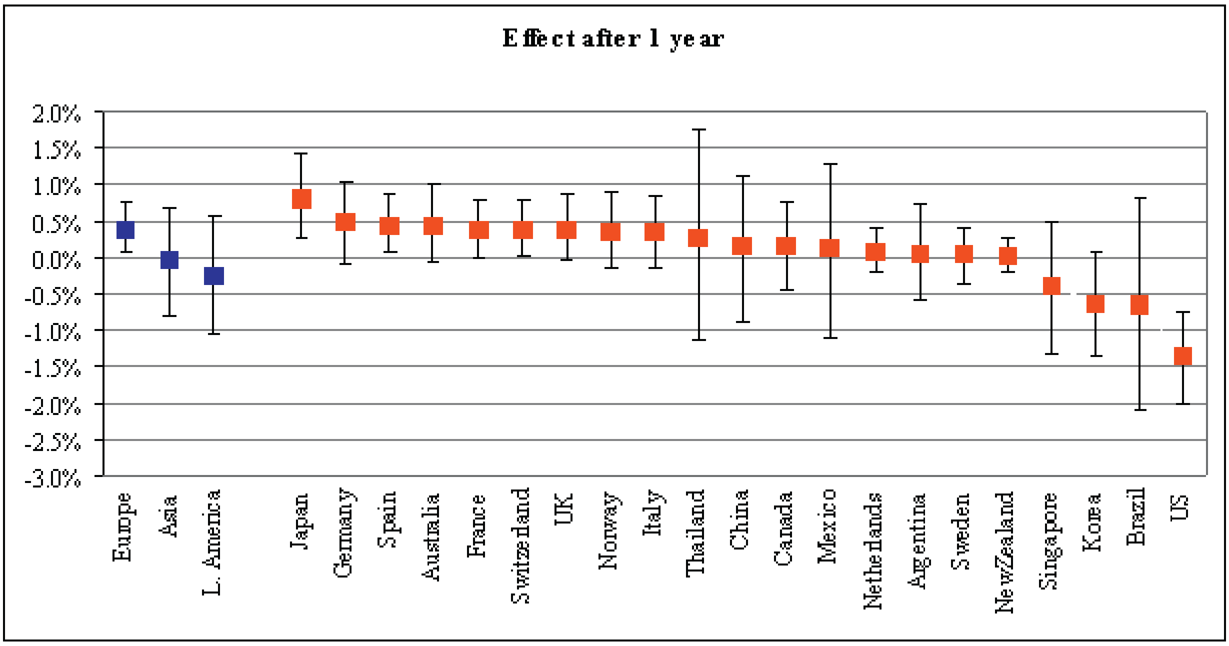

Figure 6: Effect of a US REER appreciation (2.6%) on exports in the rest of the world.

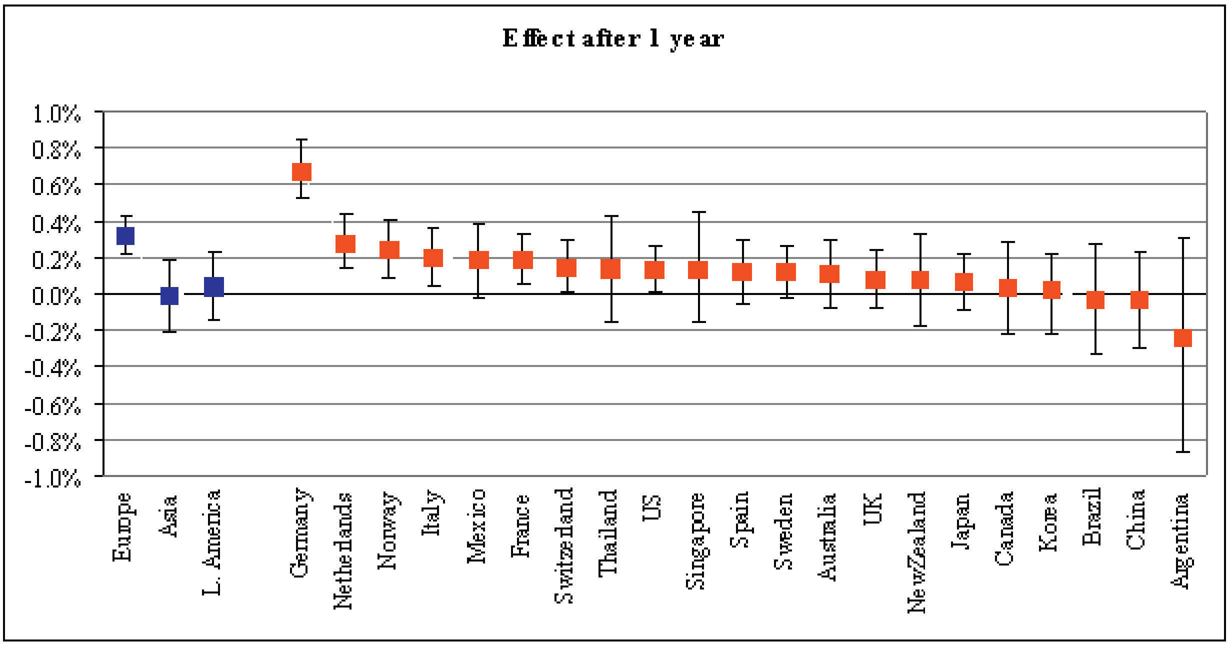

Figure 7: Shock to German output (+ 0.8%), effect on output in the rest of the world.

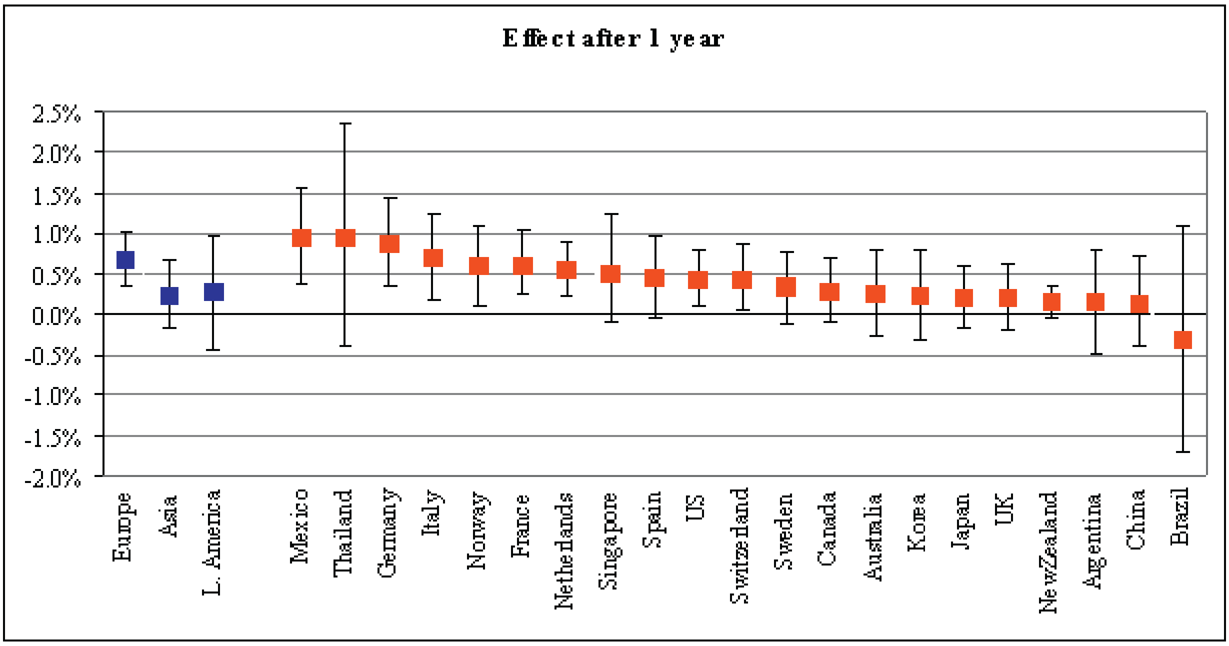

Figure 8: Shock to German output (+ 0.8%), effect on exports in the rest of the world.

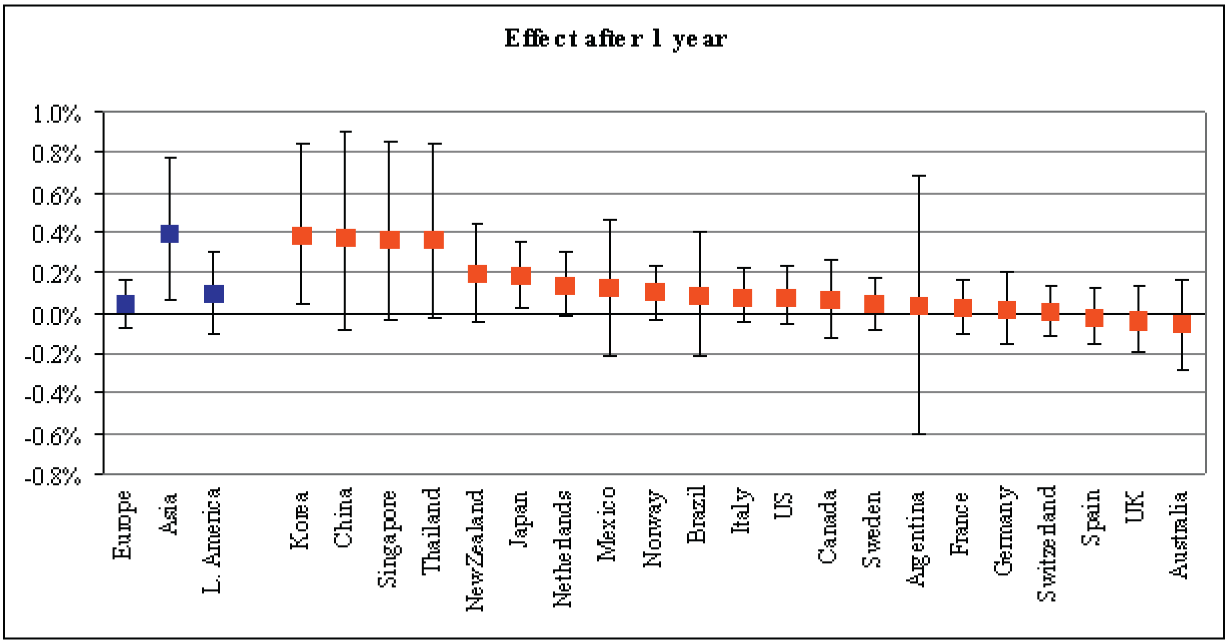

Figure 9: Shock to Chinese imports (+ 1.9%), effect on output in the rest of the world.

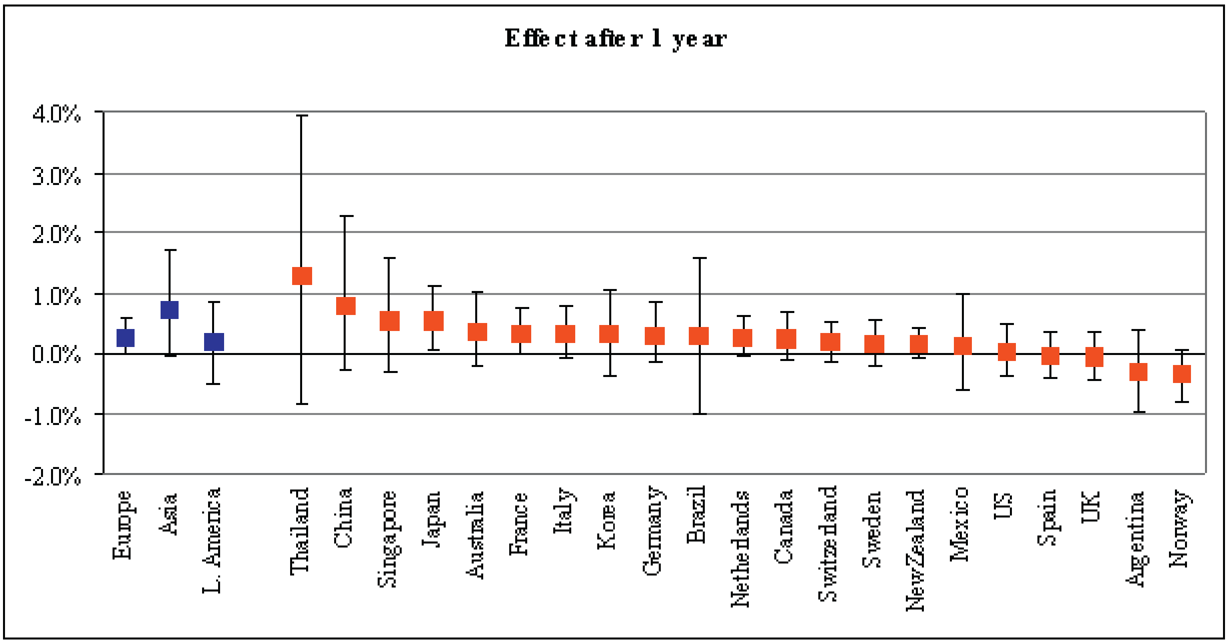

Figure 10: Shock to Chinese imports (+ 1.9%), effect on exports in the rest of the world.

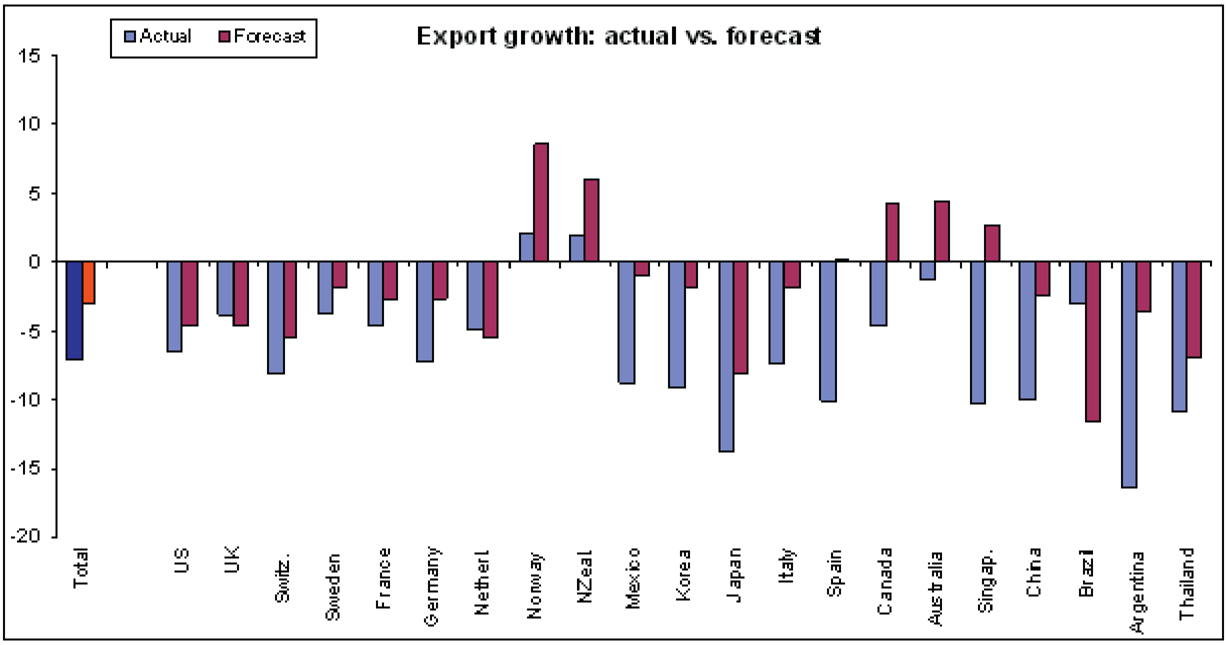

Figure 11: Actual vs. Forecasted real exports in 2008Q4.

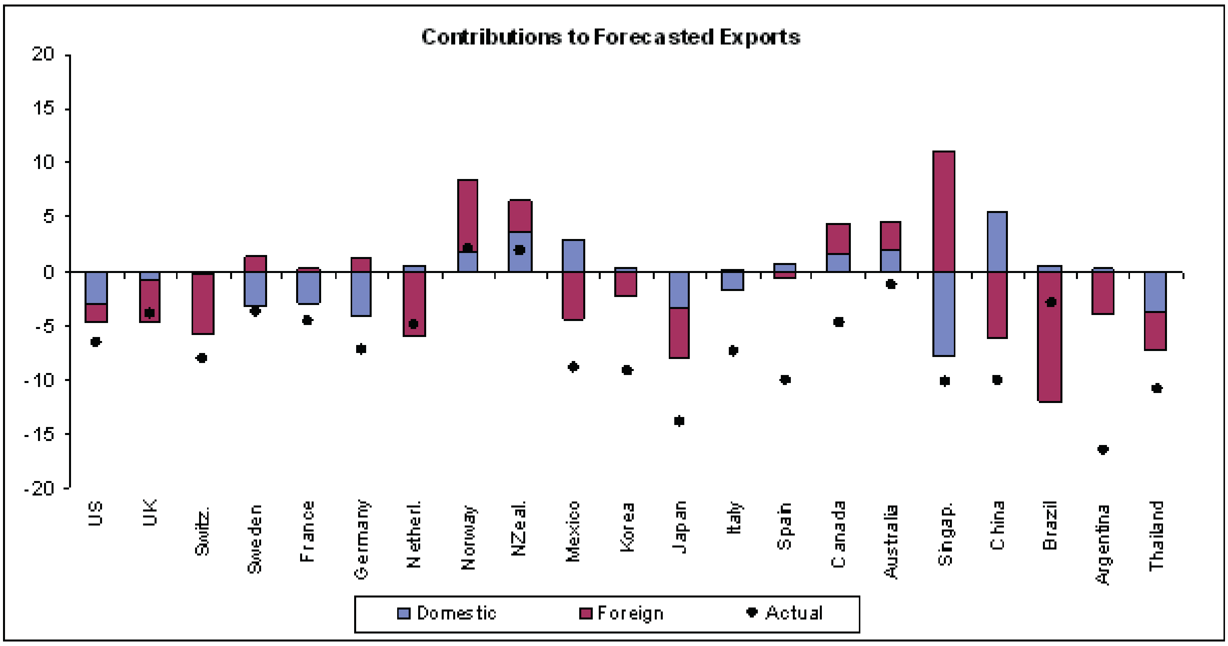

Figure 12: Contributions of domestic and foreign variables to forecasted real exports in 2008Q4.

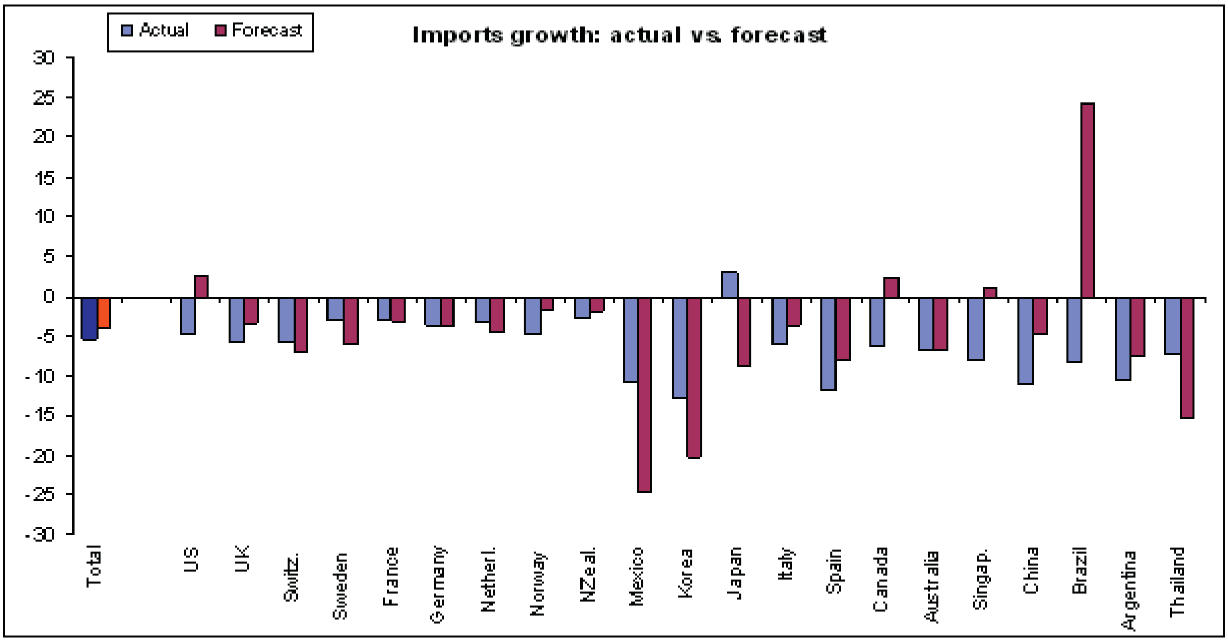

Figure 13: Actual vs. Forecasted real imports in 2008Q4.

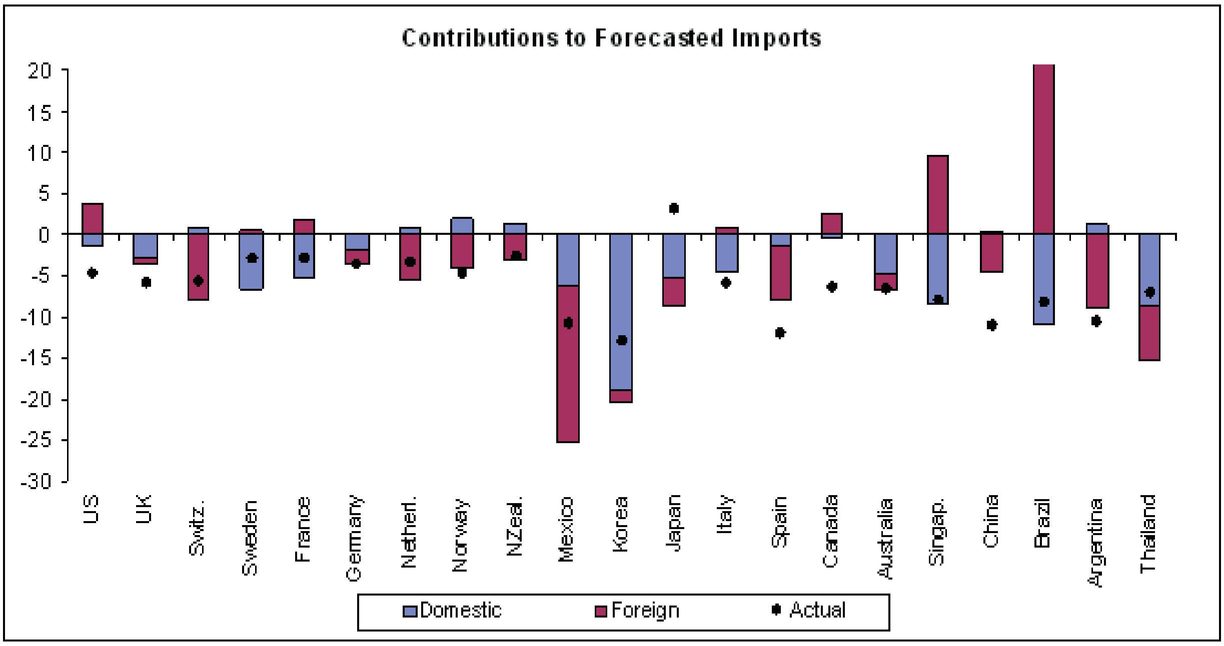

Figure 14: Contributions of domestic and foreign variables to forecasted real imports in 2008Q4.

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A Appendix: Estimation of Long-Run Relations

A.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[41] are reported in Table A1, 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[42], 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.

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 discussed in section 4.4, 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 A2, 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 the BIC.

There could be at least two reasons for the difference between Table A1 and A2: 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.

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

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

A.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 A1 (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(1) 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 A3.[43] 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 A3.

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 A3.

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 poor power of the cointegration tests.[44]

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.

A.3 Parsimonious approach

Due to the small sample properties of the cointegration tests, we do not take the results in Tables A1 and A2 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

[43] Note that in each replication we impose the correct number of lags, which, however, is not known in practice.
[44] To save space, we do not present these results in the Appendix but they remain available upon request.

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 A4 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 discussed in section 4.4, 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 A4, 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 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 A5: cointegration is confirmed only in the case of Sweden, with the estimated Balassa-Samuelson coefficient $\omega_i = 0.24$. 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.[45]

Finally, we examine the trade equations which are of particular interest given the topic of our paper (Table A6). 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.

[45] 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.

Table A1: 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 A2: 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 A4: 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**
Switzerland	-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 A5: Tests for the 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 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 A6: 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)

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