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Abstract

TO WHAT EXTENT DO EXCHANGE RATES AND THEIR VOLATILITY AFFECT TRADE?

by

Marilyne Huchet-Bourdon and Jane Korinek

Trade deficits and surpluses are sometimes attributed to intentionally low or high exchange rate levels. The impact of exchange rate levels on trade has been much debated but the large body of existing empirical literature does not suggest an unequivocally clear picture of the trade impacts of changes in exchange rates. The impact of exchange rate volatility on trade also does not benefit from a clear theoretical cause-effect relationship. This study examines the impact of exchange rates and their volatility on trade flows in China, the Euro area and the United States in two broadly defined sectors, agriculture on the one hand and manufacturing and mining on the other. It finds that exchange volatility impacts trade flows only slightly. Exchange rate levels, on the other hand, affect trade in both agriculture and manufacturing and mining sectors but do not explain in their entirety the trade imbalances in the three countries examined.

Keywords: Exchange rate, US dollar, euro, yuan, volatility, trade, trade in agriculture, short-run effects, long-run effects, GARCH volatility, trade deficit, depreciation, currency movements, real exchange rate, exchange rate appreciation, exchange hedging.

JEL classification: F1, F31, O24, Q17

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Table of contents

Tables

Figures

Executive Summary

This study examines the impact of exchange rates and their volatility on trade flows in China, the Euro area and the United States in two broadly defined sectors, agriculture on the one hand and manufacturing and mining on the other. The question of exchange rate levels has been very much discussed recently and the large body of existing empirical literature does not suggest an unequivocally clear picture of the trade impacts of changes in exchange rates. The methodology used here in the econometric estimation takes into account recent advances in this area.

We find that the value of trade between the United States and China is more affected by currency changes than that of the US-Euro area or the Euro area-China. According to the implications of the model, a hypothetical 10% depreciation of the US dollar (or an equivalent 10% appreciation of the yuan) would have implied an improvement in the 2008 US agricultural trade surplus of USD 4.7 billion and a decrease in the US manufacturing deficit of USD 30.8 billion. This implies that a 10% depreciation of the US dollar (or 10% appreciation in the yuan) in 2008 would have brought the bilateral US trade deficit with China to USD -235 billion as compared to the actual deficit which was USD -270 billion, a decrease of the bilateral deficit by 13%. This confirms some of the findings in the literature (e.g. Evenett, 2010) which suggest that the trade imbalance between the United States and China is due to a number of factors of which the exchange rate is only one.

Euro area trade with China is less impacted by changes in exchange rates. Model elasticities imply that a 10% depreciation of the euro (or a 10% appreciation of the yuan) would have been associated with a hypothetical EUR -109 billion euro bilateral trade deficit as compared with the actual bilateral trade deficit of EUR –118 billion in 2008, or in other words a decrease in the Euro area trade deficit with China of 7.6%. This may be due in part to the types of goods that are traded with China for which demand may be less price elastic. International price movements in the agriculture sector are also somewhat mitigated by tariff structures which include a large share of specific (as opposed to ad valorem) tariffs.

Econometric model results reveal a higher long-term impact of the real exchange rate on exports than on imports in all sectors and all models, a finding which is echoed in much of the literature, but which lacks an intuitive interpretation.[1]

We find a more pronounced impact of exchange rates on exports of agriculture than that of manufacturing. One reason for this may be the relatively greater ease to change suppliers of agricultural goods than manufacturing owing to the fact that the former are

1. This finding, although robust among this group of countries, has not been confirmed in a separate analysis on two small, open economies.

more homogeneous than the latter. Additionally, price transmission mechanisms may be different in agriculture as compared with manufacturing or mining products.

We also find that short run exchange rate movements impact trade but their effect is difficult to interpret; in some cases, the impact is positive, and in others the impact is negative. These results are in line with other studies which conclude that short-run effects do not seem to follow a specific pattern.

At the sectoral level, the impact of exchange rate volatility on trade appears to be minimal. Exchange rate volatility does not seem to be a particularly powerful determinant in driving trade flows between large economies such as the United States, the Euro area and China.

Our study also confirms another finding in the literature: income is a strong driver of trade. A rise in national income leads to an increase in the value of domestic imports through the increased purchasing power of domestic consumers. Similarly, foreign income plays a significant role in determining domestic exports. Changes in Chinese income have a particularly strong effect on US agricultural exports to China: Chinese economic growth appears to be a key source of the United States-China bilateral agriculture trade surplus. One of the reasons could be the increased Chinese demand for meat and meat products: as households incomes increase in China, a rise in demand for meat follows which translates into an increase in demand for US agriculture exports, particularly of soybeans – the United State's third largest agricultural export product, which are used primarily for animal feed.

Exchange rates play an important role in linking a country to the global supply chains. Exports generally include a high import content and the impact of exchange rate depreciation or appreciation on any finished product is therefore complex. If an exchange rate depreciation makes exports of final products "cheaper," it makes imported components "more expensive" for domestic producers. Although exchange rate hedging mechanisms are available, they are probably somewhat prohibitive for some particularly small and medium-sized enterprises, who may have less long-term visibility of their foreign exchange needs.

I. Introduction

The economic crisis has had a differentiated impact on the world economies and on their trade, thereby changing trade patterns significantly in some cases. In the context of low employment related to recession, some policymakers are wanting to stimulate their exports, thereby hoping to improve their trade and current account balances[2]. Policymakers interested in implementing such policies have taken a closer look at exchange rate movements. Simply stated, depreciation of a country's currency makes its exports cheaper and its imports more costly. In the reality of a globalised economy, however, industries are vertically integrated, and exported products contain a large proportion of imported components. Imported components therefore become more costly for any given exporter and are not necessarily substitutable with domestically-produced products.

In addition, exchange rate levels have important implications for debt servicing and foreign investment flows.[3] A depreciation in a country's currency implies that the nominal value of debt denominated in foreign currencies increases relative to the country's resources in local currency whereas its local-currency denominated debt decreases in value for foreign creditors. Capital investments become cheaper to foreign investors when the currency is depreciated, which is particularly important for large economies that attract capital investments like the United States and, to a lesser extent, the European Union. If depreciation is the result of a loss of confidence in the economy, however, foreign investors may be more hesitant to invest.

Exchange rate changes affect firms within a given country differently. Firms face a number of risks when engaging in international trade, in particular economic and commercial risks that are determined by macroeconomic conditions over which they have little control, such as exchange rates and their volatility. Risk management tools are available to help firms mitigate the impact of such risks, especially in the short term. These techniques for securing exchange rate risk are sometimes complex, however, and do not cover all commercial and financial operations. Besides, such tools may not be available to all firms, and the cost of using them may be significant, especially for small firms and in situations of high volatility.[4]

Since the beginning of floating exchange rate regimes in 1973, many papers, both theoretical and empirical, have analysed the effects of exchange rates and exchange rate volatility on trade. No consensus has been reached regarding the effect of exchange rate volatility on trade in the large body of literature. As regards the level of the exchange rate, empirical studies find somewhat differing results as to their impacts on trade although there is a common understanding as to the direction of the impact of the exchange rate on exports and imports. To date, therefore, relevant research does not suggest a clear-cut relationship. This may be due, for example, to the lack of product or

2. See Trade Policy Working Paper No. 120 on global imbalances for an overview of their trade effects.

3. There are many other policy incentives for competitive depreciation. See Weber and Wyplosz (2009).

4. One way to avoid a mismatch between the currency in which goods are sold and the currency of the country in which the production facilities are located would be to relocate one part of production activities. This long-term strategy is very difficult in practise for small enterprises.

sector disaggregation in some studies, to the time period studied, or to the fact that some studies examine only short-run effects.

Despite this lack of consensus, the present economic situation seems to justify revisiting the question of the impacts of exchange rates and their volatility on trade flows. This exercise aims to help clarify the role of exchange rates in international trade, i.e. to what extent do exchange rates and their volatility impact trade flows.

This contribution proposes to fill a number of gaps in the empirical literature. Its aim is to study the effects of exchange rate levels, and exchange rate volatility on bilateral sectoral imports and exports over the last decade. Bilateral flows (imports and exports) will be examined between the Euro area (EA), the United States (US) and China. This differs from research done thus far which has focused more on the US dollar exchange rate and its effect on US trade flows with partners. This study will examine the effects of exchange rates in two distinct, broadly defined sectors: agriculture and non-agriculture.

The aim of this study therefore is to clarify the importance of the exchange rate in the evolution of the trade between three important economies. A keener knowledge of the impact of the exchange rate and its volatility on trade between the United States, the Euro area and China is of particular interest in the context of global imbalances. The analysis aims to determine whether the level of exchange rate or its volatility or both are key factors in bilateral trade flows. The estimated effects of a currency depreciation/appreciation on the 2008 trade balance of the three geographical areas will be used to illustrate econometric results.

The remainder of this paper is organized as follows. Section II presents the existing theory of exchange rate volatility and exchange rates and their impacts on trade. Section III describes some of the insights from the empirical literature on the relationship between the exchange rate and trade flows. Section IV outlines some of the developments in the three exchange rates under examination here. Section V presents the econometric analysis and the main findings. Finally the concluding section places the results reported here in the context of previous work and the policy debate.

II. Exchange rates and trade: what does the theory tell us?

The theoretical foundations for analysing the impact of currency depreciation on trade centres around the J-curve effect and the Marshall-Lerner condition.

The J-curve phenomenon states that following a depreciation of the national currency, a deterioration of the trade balance is then followed by an improvement. At the moment of depreciation, there is a price effect due to higher prices of imported goods. Since there are some delays in transactions which have been ordered several months before, the value of imports increases in the short term. Later, when traders have had some time to change their input strategy, they integrate their loss in competitiveness vis-à-vis goods produced abroad. This provokes a quantity effect: the volume of imports is adjusted downward while local production is probably increased to satisfy demand. In this way, adjustment of quantities traded are slower to adjust than are changes in relative prices. It is expected that the final effect in the longer term is a net improvement in the trade balance. This phenomenon is named the J-curve effect because when a country’s net trade balance is plotted on the vertical axis and time is plotted on the horizontal axis, the response of the trade balance to a devaluation or depreciation looks like the curve of the letter J.

The Marshall–Lerner condition has been cited as a technical reason explaining why a reduction in value of a nation's currency need not immediately improve its balance of payments. The condition states that, for a currency depreciation to have a positive impact in trade balance, the sum of price elasticity of exports and imports in absolute value must be greater than one. Since a devaluation or depreciation of the exchange rate implies a reduction in the price of exports, the quantity exported will increase. At the same time, the price of imports will rise and their quantity demanded will diminish.

The net effect of these two phenomena – greater quantities of exports at lower prices and diminished quantities of more expensive imports – depends on import and export price elasticities. If exported goods are price elastic, their quantity demanded will increase proportionately more than the decrease in price, and total export revenue will increase. Similarly, if goods imported are elastic, total import expenditure will decrease.

Regarding exchange rate volatility, a number of theoretical models have emerged in the literature. These models show how exchange rate volatility may impact trade flows positively or negatively depending on various factors among which assumptions about attitudes toward risk (see McKenzie, 1999 for more details).

One of the most common explanations of the negative relationship between exchange rate volatility and trade comes from transactions costs. It is suggested that the cost of conversion from one currency to another and the risk associated with potential changes in exchange rates have a dampening effect on trade flows. Most theoretical studies have indeed analysed the response of trading firms to exchange rate uncertainty by focusing on their degree of risk aversion. Hooper and Kohlhagen (1978) further outline the theory behind risk aversion. They have constructed a theoretical model for analysing the impact of exchange rate risk on traded prices and volumes, simultaneously considering both importers' and exporters' attitudes toward exchange rate risk. They find that an increase in exchange rate risk will reduce the volume of trade if traders are risk averse.

Theoretical studies question the negative impact of exchange rate volatility on trade. According to De Grauwe (1988), exchange rate variability may have either a positive or a negative impact on trade according to the degree of firms' risk aversion. If producers exhibit only a slight aversion to risk, they produce less for export as the higher exchange rate risk reduces the expected marginal utility of export revenues. If they are extremely risk averse, however, they will consider the worst possible outcome. This implies that an increase in exchange rate risk will raise the expected marginal utility of export revenue as producers will want to export more to avoid a drastic decline in their revenue stream. In other words, De Grauwe (1988), Dellas and Zilberfarb (1993) and Broll and Eckwert (1999) indicate that there are two opposing effects that determine the impact of exchange rate volatility on trade: a substitution effect, whereby greater uncertainty reduces trade flows, and an income effect, whereby firms increase international trade to offset a decline in total expected utility. In the case of extreme risk aversion, the income effect dominates the substitution effect and increased exchange rate risk leads to increased rather than reduced international trade.

Obstfeld and Rogoff (1998) also examine the behaviour of firms facing exchange rate risk. They suggest that risk-averse firms will attempt to hedge against future exchange rate movements. They thus apply a risk premium in terms of a mark-up to cover the costs of exchange rate movements. Such higher prices exert a negative effect on demand, production and consumption. Caporale and Doroodian (1994) suggest that the use of hedging exists, but that it entails some costs and limitations such as the difficulty for firms to foresee the volume and timing of their international transactions.

Some other studies focus on the reach of the trader, i.e. national vs. multinational firms. For instance, Broll (1994) recognises the increasing importance of multinational firms in the global trading environment and focuses on the economic behaviour of a risk-averse, multinational firm which produces in a foreign country and sells its output abroad. They assume that the multinational firm has monopoly power in the foreign market and faces exchange rate uncertainty. Exchange rate risk in this model is specified as the difference between the spot exchange rate and the expected one. If exchange risk is not reduced through hedging, production is shown to decline in the foreign country as a result of exchange rate uncertainty.

To summarise findings at the theoretical level, the effect of the exchange rate and exchange rate volatility on trade is ambiguous: the impact may be positive or negative depending on model assumptions, particularly on the behaviour of traders facing increased risk and on the transaction delay.

Specificities in agriculture

Many theoretical studies have attributed the impact of exchange rate volatility on trade to the degree of firms' risk aversion. It is probable therefore that some of the main characteristics of different sectors – price volatility, trade barriers, homogeneity of goods, and the size and reach of firms, for instance – will imply differentiated effects on trade of the exchange rate and its volatility.[5]

Price volatility is probably one of the main sources of risk in agricultural trade.[6] Many production decisions are taken well in advance of product sales, and there generally exists a certain amount of uncertainty about the price that will be received for final products (OECD, 2009a). Exchange rate variability can further affect the transmission of world prices to domestic prices. Some authors (Carter and Pick (1989), for instance) indicate that most of the world's grain trade is denominated in US dollars, which may introduce an additional transaction cost if both exporter and importer are located outside the United States but the goods are denominated in US dollars.

Carter and Pick (1989) underline the importance of transaction lags in the relationship between exchange rates and the trade balance. This is a particularly important issue in agriculture because delivery lags tend to be long.

5. The policy relevance of linkages among macroeconomic policy, the exchange rate and US agriculture was first described by Schuh (1974, 1976).

6. This is perhaps best illustrated by a small country which exports a large proportion of its agricultural production like New Zealand. "In New Zealand, with agriculture being one of the most export-oriented in the world, price risks largely originate in world markets, and include fluctuations of international commodity prices, exchange rates, international transportation costs, or changes in border measures imposed by importers"(Melyukhina, 2011).

III. Insights from the empirical literature

Despite the very large volume of empirical studies in this area over the last four decades, there is no clear consensus concerning the impact of exchange rates and exchange rate volatility on the volume trade (see McKenzie, 1999 or Bahmani-Oskooee and Hegerty, 2007 for interesting surveys). In fact, research results which find positive, negative or no effect of exchange rate volatility on the volume of international trade are based on varied underlying assumptions and only hold in certain cases.

Coric and Pugh (2008) apply a meta-analysis of the results found in the literature that range from strong negative to strong positive effects. They find 33 studies that conclude that exchange rate variability exerts an adverse effect on trade volumes. The other 25 studies examined conclude that this is not the case. Six of those studies conclude that exchange rate variability is trade-enhancing (Coric and Pugh, 2008).

The net impact of the exchange rate level on trade flows is also not clear in the literature. Some studies examine this question in the context of currency unions (Rose and Stanley, 2005) for an extensive meta-analysis). Many studies examine the impact of both the exchange rate level and volatility on trade in a single equation or set of equations. Results are highly contingent on the measure of volatility used, on the time period under question, whether short-term or long-term effects are examined, the econometric method used to estimate, the periodicity of the data, and whether or not effects are examined at the aggregate, sectoral, or product level. Some studies that examine the impacts in different sectors find that trade in some products responds positively to exchange rate variation and others negatively, so the net effect is highly determined by the composition of exported and imported products (e.g. Doroodian et al., 1999, Byrne et al., 2008). The heterogeneity found in model results extends to country coverage. To cite only one recent study, Chiu et al. (2010) apply the heterogeneous panel cointegration method to examine the long-run relationship between the real exchange rate and bilateral trade balance of the United States and its 97 trading partners for the period 1973–2006 using annual data. The empirical results indicate that a devaluation of the US dollar deteriorates its bilateral trade balance with 13 trading partners, but improves it with 37 trading partners, notably China.

Some studies have examined the effects of exchange rate changes on trade at the sectoral level. Mindful of the Marshall-Lerner condition, Houthakker and Magee (1969) estimate price elasticities for different commodities in the United States. They find that price elasticities are low for raw materials but high for finished manufactures. Carter and Pick (1989) examine the J-curve effect for US trade in agricultural goods. They pioneered research on the pass-through effect of exchange rate changes on agricultural exports and imports, and the net impact on the agricultural trade balance. They find evidence of the price effect of the J-curve: a depreciation leads to a decline in the agricultural trade balance. The quantity effect however is only partly explained by the J-curve effect.

Doroodian et al. (1999) find a J-curve effect only for agricultural goods, but not for manufacturing, using US data for 1977 to 1991. This could explain why some studies using aggregate data fail to support the J-curve hypothesis – perhaps the J-curve effect does not apply overall. Indeed, Hsing (2008) examined US trade with seven South American trading partners over the last 20 or 30 years according to the studied countries and showed that a J-curve exists for Chili, Ecuador and Uruguay while a lack of support is found for Argentina, Brazil, Colombia and Peru. These findings therefore suggest that the conventional wisdom of pursuing real exchange depreciation in order to improve the trade balance may not apply in some countries.

According to the literature on this topic, some of the studies find a negative effect of exchange rate volatility on agriculture trade (Perée and Steinherr, 1989; Cho et al., 2002; Kandilov, 2008; Doyle, 2001) while some others conclude a non significant effect (Caglayan and Di, 2008); Byrne et al. (2008)). Baek and Koo (2009) find that in the long run, while US agriculture exports are highly negatively impacted by the exchange rate, US agriculture imports are generally not affected. In the short run, on the other hand, the exchange rate is found to have significant effects on both imports and exports. Carter and Pick (1989) suggest that market factors other than exchange rate fluctuations are the primary determinants of US agriculture trade while Doroodian et al. (1999) show that an exchange rate depreciation has a prolonged and significant effect on the US agriculture trade balance.

As noted by Maskus (1986), the impact of exchange rate volatility may vary across sectors because these can have differing degrees of openness to international trade, different industry concentration levels and make different use of long-term contracts. According to his estimations run over the 1974-1984 period, real exchange rate risk reduces US agricultural trade more than other sectors which he attributes to a greater openness of the agriculture sector, to a low level of industry concentration, and lengthy trade contracts.

IV. Developments in exchange rates and trade between China, the Euro area and the United States

Exchange rate regimes

Since its inception in 1999, the euro is a floating currency.[7] Bénassy-Quéré (2009) and others suggest that the US dollar has enjoyed a status of a reserve currency since the end of World War II. The Chinese yuan renminbi, hereafter referred to as the yuan, has been described as a managed float since a system of dual exchange rates was abolished in 1994 (OECD, 2009b). During the first half of the 2000s, however, the yuan was effectively pegged to the US dollar.[8] In July 2005, the yuan was revalued by 2.1% against the US dollar and the bands of permissible daily movements increased to +/- 0.3%. The Chinese authorities announced that the value of the yuan would be set relative to a currency basket composed of the dollar, euro, won, and yen without, however, providing clear information regarding the weight of each currency in the basket.

Since 2005, large current account surpluses and rising capital inflows, particularly of foreign direct investment, have resulted in appreciation pressure on the yuan. To prevent this, the People’s Bank of China has sold yuan leading to large increases in foreign-exchange reserves, most of which are denominated in US dollars. The policy that began in 2005 of gradually appreciating the yuan against the dollar was abandoned in July 2008.

7. The euro was introduced to world financial markets as an accounting currency on 1 January 1999, replacing the former European Currency Unit (ECU) at a ratio of 1:1. Euro coins and banknotes entered circulation on 1 January 2002.

8. It is the nominal exchange rate here, that Chinese authorities keep under control.

Since August 2008, therefore, appreciation of the yuan has been stalled and its value has been broadly stable against the US dollar, returning to an effective peg.[9]

Bilateral exchange rate movements

The first years after the euro was established in January 1999 were characterised by a depreciation of the currency relative to the US dollar (Figure 1). Since then, it has tended to appreciate against the US dollar: by 35% since 2002, from EUR 1.127 per dollar in February 2002 to EUR 0.732 in June 2009.[10]

Figure 1. Real exchange rate of the euro relative to the US dollar

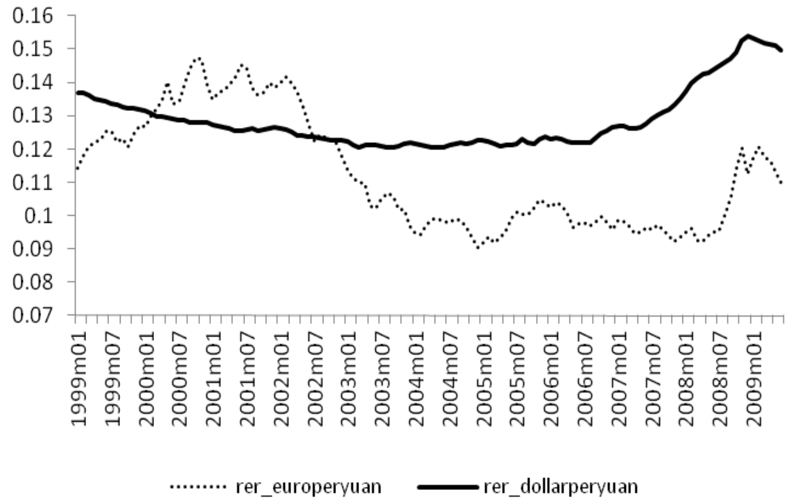
Source: IMF.

The real euro-yuan exchange rate follows a similar pattern, due to the strong correlation between the US dollar and the yuan (Figure 2). The dollar appreciated against the Chinese yuan by 11% from USD 0.136 per yuan in January 1999 to USD 0.121 in June 2005. Since July 2005, the dollar depreciated by 26% to USD 0.153 per yuan in December 2008. The first six months of 2009 saw a new depreciation in the real exchange rate of the yuan (by 2%) which has motivated authorities in some countries as well as international bodies to pressure the Chinese authorities to allow their currency to appreciate in order to help resolve world trade imbalances. The yuan depreciated by about 6 % relative to the euro in real terms over the first six-month period of 2009.

9. Estimates derived from an econometric model suggest that the weight of the US dollar in the “currency basket” has averaged over 0.9 since the 2005 announcement (OECD (2009b).

10. As shown in Annex A, the exchange rate is defined such that an increase in exchange rate reflects a depreciation of the national currency. We focus on the real exchange rate thereafter which is an indicator of price competitiveness. The real exchange rates are derived by multiplying the nominal exchange rate by the ratio of the foreign to local currency consumer price index.

Figure 2. Real exchange rate of the Euro and US dollar relative to the yuan



Source: IMF.

Bilateral trade flows

In 2008, imports from China and from the United States represented 11% and 8.5%, respectively, of total imports into the Euro area. The United States is the most important market outside Europe for Euro area exports: it absorbs 12% of extra-EU exports. The corresponding figure for China is 4.5%. China represented the third largest export market for US goods in 2008, absorbing 5.5 % of US exports and was the United States' second most important trading partner in terms of imports, providing 16% of total US imports.

In the bilateral trade flows of the three regions,[11] trade in manufactured goods largely outweighs trade in the agriculture sector. Trade in agriculture represents between one and five percent of total trade between the three areas with the exception of US exports to China where agriculture accounted for 17% of total trade in 2008.

The Euro area keeps a trade surplus vis-à-vis the United States whereas it faces a trade deficit with China (in both sectors). In addition, the trade deficit with China is increasing: from EUR 0.8 billion in 1999 to EUR 2 billion in 2008 for the agriculture sector, and from EUR 20 to 120 billion for manufacturing over the same period.

The United States faces a strong manufacturing trade deficit with China which was steadily increasing from 2002 when it was EUR 107 billion (USD 104 billion) until 2006 when it totalled EUR 191 billion (USD 275 billion). Since 2006, the US trade deficit with China has been relatively stable (Figure 3). In the agriculture sector, the United States is in trade surplus with respect to China, with an albeit small but increasing agriculture trade surplus of EUR 2.6 billion (USD 3.3 billion) in 2005 to EUR 6 billion (USD 8.7 billion) in 2008.

11. All details concerning data can be found in Annex A.

Figure 3. Trade balance between pair countries
(in billion euros)

Figure 3.a. Trade balance in agriculture

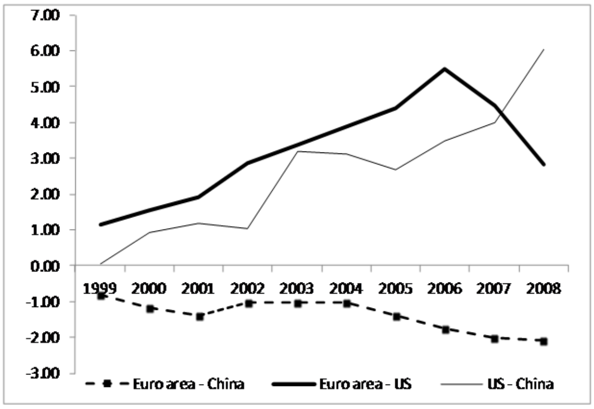
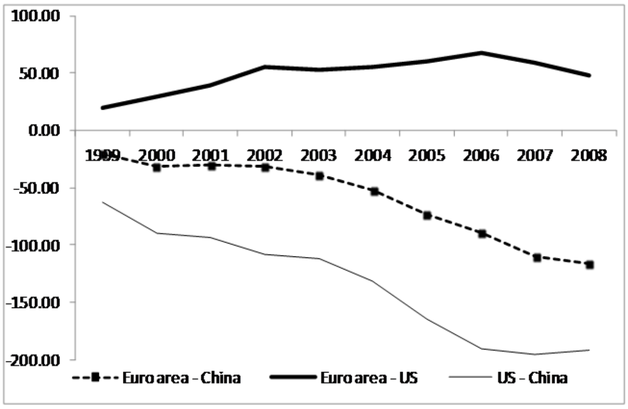


Figure 3.b. Trade balance in manufacturing



Source: Comext, OECD, USDA.

Although China shows a strong trade surplus with both the United States and the Euro area, particularly in the manufacturing sector, it should be kept in mind that some Chinese exports comprise little Chinese value added. China imports many intermediate products, in particular from South-East Asian neighbours and re-exports finished products towards the rest of the world. In addition, China opened its market considerably during its accession process to the WTO (China became a member of the WTO in 2001). The simple average Chinese tariff rate was reduced from 42.9% in 1992 to 16.6% in 2001 and to 9.8% after accession (OECD, 2006). This reduction in tariffs has undoubtedly contributed to the increase in China's integration in the world economy and its strong growth in trade.

China's strong trade surplus with some of its partners has enabled it to accumulate exchange reserves; half of its reserves are held in US Treasury bills and therefore finances US debt. China is thus holding many of its assets in dollars which would decline in value if the dollar depreciates. There is therefore a strong interdependency between the three large economies in terms of levels of trade in goods and cross-border capital flows.

V. Impact of exchange rates and their volatility on trade flows

Econometric model specification

In order to model the impact of exchange rates and their volatility on imports and exports in the three geographical areas, an autoregressive distributed lag (ARDL) model has been constructed with cointegration in the vein of Bahmani-Oskooee and Ardalani (2006) and Baek and Koo (2009). Import and export values are estimated in two separate equations including as determinants a proxy for income, the exchange rate and exchange rate volatility. This methodology was chosen for a number of reasons, both econometric and economic. In particular, it takes into account the mathematical properties of the series, i.e. the stationarity[12] or non stationarity of the variables. In order to do this, variables were checked for cointegration[13] properties in the model. This enables measurement of both short-run and long-run effects, which is important here due to delay in trade transaction and associated risks.

Import and export functions are formulated as follows with exchange rates included both in terms of levels and volatility.

$$\ln M_{i,t} = a + b \ln Y_{country,t} + c \ln ER_t + d \ln vol_t + \mu_t \quad (1)$$

$$\ln X_{i,t} = e + f \ln Y_{partner,t} + g \ln ER_t + h \ln vol_t + \varepsilon_t \quad (2)$$

Where $X_{i,t}$ is the value of the country (Euro area or the US)'exports in product i to the partner (the US and/or China), $M_{i,t}$ is the value of the country's imports in product i from the partner country,[14] Y is the real income (represented by industrial production index), ER stands for the real bilateral exchange rate, i.e. the nominal exchange rate deflated by the consumer price index, and vol is a measure of its volatility. All variables are taken in logarithm form which allows estimation of elasticities.

As Bahmani-Oskooee and Ardalani (2006) underline, Equation (2) is a reduced-form equation that is derived from a supply-and-demand model in which the export supply of good i by the country is perfectly elastic, whereas the partner demand for good i depends on the partner's income and the exchange rate (in level and its volatility). In the same way, Equation (1) is derived from a supply and demand model in which the supply of good i from the partner is assumed perfectly elastic whereas the demand by the country for this good depends on its income and the exchange rate. Thus, supply factors other than the exchange rate are excluded. Equations (1) and (2) refer to long-run relationships between the variables of interest. Following Bahmani-Oskooee and Ardalani (2006), we incorporate the short-run dynamics into the estimation procedure by specifying these equations in an error-correction model.

This method, known as an ARDL bounds-testing approach, was introduced by Pesaran et al. (2001)[15] and has several advantages. First, it enables estimation of short- and long-run parameters of the model simultaneously. Second, it is a more suitable method than the Johansen cointegration technique since variables included in the cointegration space can be stationary (such as a measure of exchange rate volatility) or non-stationary (such as imports or exports).[16] In other words, the bounds testing

12. Stationarity means that the variable fluctuates around a mean such that there is always a return toward an equilibrium level at short run. In other words, it means that no role of the variable is considered in the long run.

13. Cointegration means a stationary long term relationship: variables are cointegrated if there is a linear combination between the variables which is stationary. In other words, joint deviations of the variables from the steady-state position due to a certain shock on the sector will disappear. The theoretical long-run equilibrium is often considered to be reached after two years.

14. The value of exports also refers to what is often referred to in the literature as "inpayments". In the same way, the value of imports may also refer to "outpayments".

15. This approach has also been applied recently by Balg and Metcalf (2010).

16. Pesaran and Pesaran (1997).

procedure does not require pre-testing for unit roots of the variables included in the model.

The equations of imports and exports of product i (I being agriculture or manufactured goods) are estimated as a conditional ARDL-error correction model in two separate equations for each pair countries (Euro area with the United States and then China; the United States with China). Model equations and full details about the econometric method and data can be found in Annexes A and B.

Note that this methodology does not explicitly consider other possible factors that influence trade flows apart from income and bilateral exchange rates. This methodology does not consider, for example, the possible substitution and other effects of exchange rates other than the bilateral one of the country pair under consideration. Trade imbalances may be driven by factors other than the exchange rate as suggested by Evenett (2010). The exchange rate impacts the current account through its impact on price competitiveness, which can be approximated by the real exchange rate. Differentials in international market prices indeed affect trade balance. This is also the case of energy prices which impact trade costs. Other factors that will determine the relationship between the exchange rate and trade flows are characteristics of countries' integration in world trade such as their degree of openness, degree of diversification of exports, the value added of its exports and importance of trade margins.

Measures of exchange rate volatility

There is no consensus among researchers as to how to measure exchange rate volatility. One element in determining which measure of volatility is appropriate is whether the nominal or real exchange rate should be used.[17] In earlier studies, the nominal exchange rate was used most often (e.g. Hooper and Kohlagen, 1978, Thursby and Thursby, 1987). However, some researchers provided evidence that using nominal or real measures make little difference to the results (e.g. Qian and Varangis, 1994; McKensie and Brooks, 1997). Whilst it can be argued that the nominal series better captures the volatility driving the uncertainty faced by exporters (Bini-Smaghi, 1991), some researchers (e.g. Gotur, 1985; Tenreyro, 2004) make the case that the real exchange rate is the most appropriate measure. In particular, it affects trade through price competitiveness. Real exchange rates were used in this study.

Another determining element in the study of exchange rate volatility is the choice of appropriate measure of volatility. A number of measures of exchange rate volatility have been used as a proxy for risk or uncertainty in past studies[18] and there is no consensus about the appropriateness of one measure relative to another. The most common is some measure of variance. The volatility variable may be constructed as the standard deviation of the exchange rate variable or as a moving standard deviation (e.g. Cho et al., 2002; Bahmani-Oskooee and Mitra, 2008; Bahmani-Oskooee and Kovyryalova, 2008). Other contributions estimate exchange rate volatility with a Generalised Autoregressive Conditional Heteroskedasticity (GARCH) model (e.g. Doyle, 2001 and Del Bo, 2009).

17. Both for the exchange rate variable itself and for the computation of its volatility.

18. Discussions about different potential measures of exchange rate volatility can be found in Dell'Ariccia (1999), McKenzie (1999), IMF (2004) and Bahmani-Oskooee and Hegerty (2007).

The present empirical analysis has considered three different measures of exchange rate volatility:[19]

- a short run measure of volatility defined as a 12-month rolling window of the standard deviation in the past monthly real exchange rate[20]
- a similarly defined measure over five years to obtain a long-run measure of volatility, and
- a conditional volatility measure estimated from a GARCH model.

A moving standard deviation over 12 months has commonly been used in previous studies. It should be noted however that this exchange risk proxy focuses on short-term volatility rather than long term swings in exchange rates. Perée and Steinherr (1989) point out that exporters can easily, albeit not costlessly, insure against short term risk through forward market transactions. On the contrary, it is much more difficult and expensive to hedge against long-term risk. De Grauwe and de Bellefroid (1986) and De Grauwe (1988) argue also that short-run variability is irrelevant to trade. De Vita and Abbott (2004) find stronger impacts of exchange rate volatility on exports using a long-term volatility based on the past five years.

GARCH models are Generalized ARCH models, and were introduced by Bollerslev (1986). Autoregressive Conditional Heteroskedasticity (ARCH) models were introduced by Engle (1982), and are designed to model and forecast conditional variances. This procedure models the variance of each period's disturbance term as a function of the errors in the previous period. The variance of the dependent variable is modelled as a function of past values of the dependent variable and exogenous variables. In doing so, it allows volatility clustering, so that for example large variances in the past generate large variances in the future.

The three measures of volatility are shown in Figure 4 for each of the three country pairs. The short-term measure of volatility, the 12-month moving standard deviation measure (represented by the solid line in Figure 4) is less volatile than the others. This seems to confirm the key role of information, and the possibility of hedging, as explained above. For this reason, only results based on the two other measures of volatility – moving standard deviation over the five past years and GARCH model – are reported hereafter.[21]

19. Details about the definitions of volatility are presented in Annex C.

20. We also tested a volatility measured as a 12-month rolling window of standard deviation in the 12 centered monthly real exchange rate but results are quite similar.

21. Results using the 12–month moving standard deviation volatility measure are available upon request. Overall, estimated coefficients are found to be less significant.

Figure 4. Evolution of the exchange rate volatility measures by country pair

Figure 4a. Euro area-United States

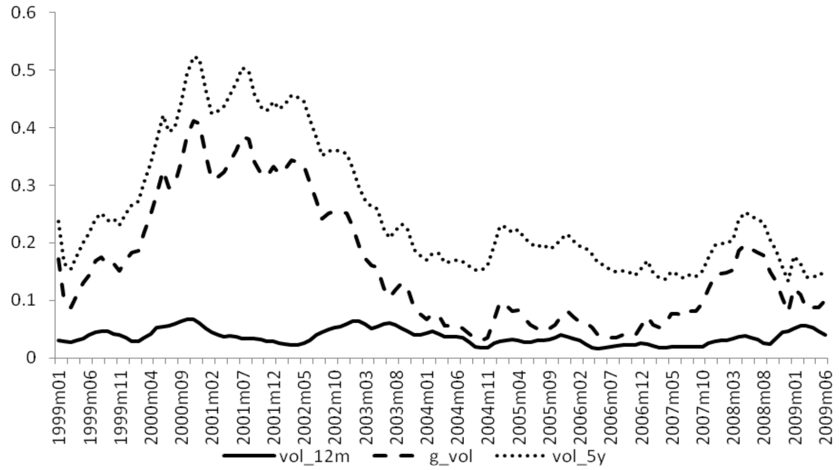


Figure 4b. Euro area-China

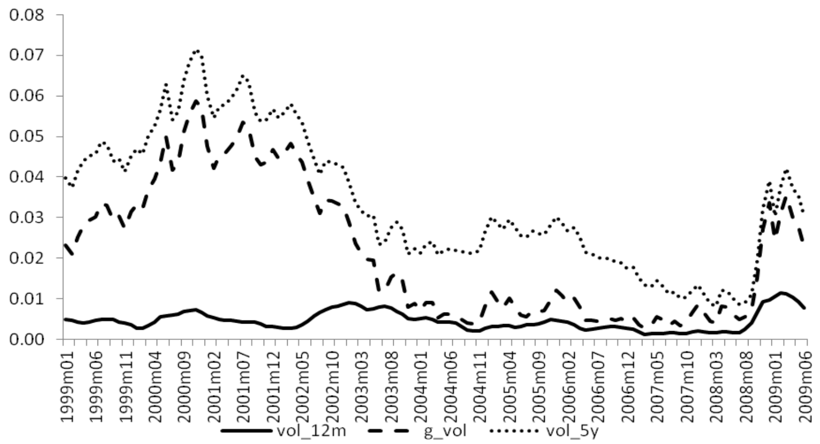
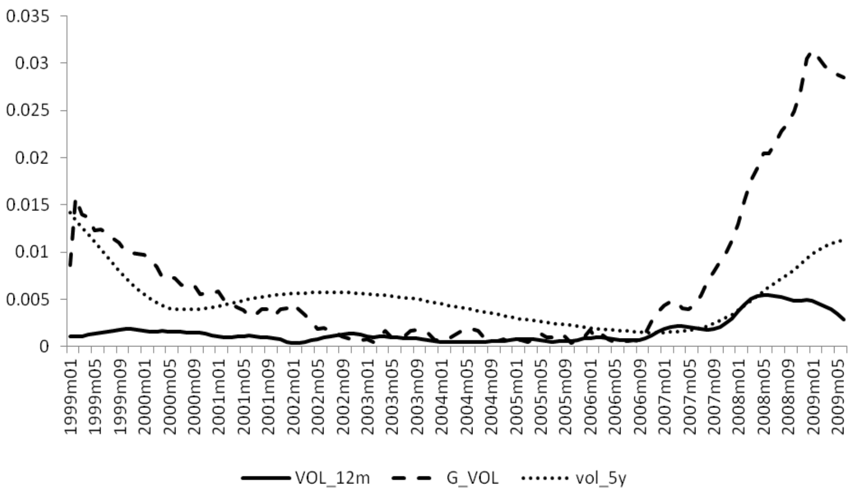


Figure 4c. United States-China



Empirical results

Econometric model results reveal a higher long-term impact of the real exchange rate, both in terms of significance and magnitude, on exports than on imports in all sectors and all models. [22] The stronger impact of exchange rate changes on exports as opposed to imports found here is echoed in much of the literature (Haynes et al., 1986; Baek and Koo, 2009; Bahmani-Oskooe and Ardalani, 2006).

The long-run value of exports of agricultural products is more sensitive to changes in exchange rate levels than manufacturing in two cases – Euro area agricultural exports to the United States and US agricultural exports to China. This may be linked to the changes in world agriculture commodity prices which are particularly relevant in determining agricultural trade flows in the last decade. However, results are somewhat difficult to interpret since some agricultural prices are negotiated in US dollars and the dollar has fallen in value with respect to the euro since 2002.

According to model estimates, a 10% depreciation in the euro leads to a 21.8% increase in European agricultural exports to the United States and a 9.4% increase in their manufacturing exports to the United States (Table 1).[23] Similarly, a 10% depreciation in the euro implies, other things being equal, no change in either European agricultural exports to China or European manufacturing imports from China. However, in the same case of a 10% depreciation in the euro, European exports of manufactures to China are set to increase by 15% and their agricultural imports from China increase by 9.5% according to model results, other things being equal.

In the United States-China case, a 10% depreciation in the US dollar (or 10% appreciation of the yuan) implies a 38.1% increase in US agricultural exports to China and a 13.1% decline in US manufacturing imports from China, other things being equal. Chiu et al. (2010) support the results found here that the depreciation of the US dollar improves its trade balance with China.

As is often the case in studies with multiple econometric models and a wide variety of results, some of the coefficients found are somewhat unexpected. In one model, a change in the level of the exchange rate is shown to play no role in the long term in determining trade flows – this is the case of US agriculture imports from China (Table 1). This result may possibly be explained as follows. Following a depreciation of the dollar, foreign exporters may squeeze their profit margins to offset the increase in their export prices in order to maintain their share of the US market (Baek and Koo, 2009; Haynes et al., 1986).

In another model, long-term manufacturing exports of the United States to China show an unexpected negative coefficient using the GARCH measure of volatility (Table 1). This may be the consequence of estimating a very large manufacturing sub-group: it is possible that positive and negative effects of real exchange rate in different products are offset, and that the net negative effect is higher. Bahmani-Oskooee and

22. Note that our results support cointegration among the variables (Annexes D and F). Some diagnostic tests are reported in Annex G.

23. Table 1 reports long-run elasticities of exchange rates on trade. Note that the results, including those for the exchange rate level, differ according to the measure of volatility used (GARCH or five-year. MSD). Results reported here are for models using GARCH measures of volatility but are relatively robust across models regardless of the measure of volatility used.

Wang (2007), studying manufacturing trade flows between the United States and China at the product level over the period 1978-2002, demonstrate that the estimated effect of the real exchange rate depends on the product. This unexpected negative effect may also be due to low price elasticities of Chinese demand for US non agricultural products.[24] This surprising result is also echoed in recent trade flows: despite the dollar real depreciation against the yuan over the period 2005-2008, US bilateral import and export values with China increased in both sectors.

Table 1. Estimated long-run effects on trade of a 10% depreciation in the national currency

	Garch		Five-year MSD	
	Agriculture	Manufacturing	Agriculture	Manufacturing
	Euro Area / United States			
Exports	21.8%	9.4%	13.1%	9.0%
Imports	0.0%	-0.8%	10.3%	4.8%
	Euro Area / China			
Exports	0.0%	15.0%	0.0%	7.9%
Imports	9.5%	0.0%	11.3%	3.1%
	United States/China			
Exports	38.1%	-22.1%	27.8%	9.5%
Imports	0.0%	-13.0%	0.0%	-11.0%

Model results reveal that short run exchange rate movements impact trade but their effect is difficult to interpret. In some cases, coefficients are non-significant (Annex E). In the cases where coefficients are significant, their impact can move in either direction, positive or negative. These results are in line with other studies which conclude that short-run effects do not seem to follow a specific pattern (e.g. Baek and Koo, 2009; Bahmani-Oskooee and Ratha, 2004). Estimated short-run coefficients of the exchange rate can be used to test the existence of the J-curve phenomenon, stating that following a depreciation of a national currency, a deterioration of the trade balance occurs, followed by an improvement. In this study, only non-agriculture trade between the Euro area and China confirm the existence of this phenomenon.

As for real exchange rate volatility, this variable is found not to be an important determining factor of bilateral trade transactions. Comparing the two measures of exchange rate volatility reported here, the five-year moving standard deviation is more often significant and of greater magnitude (Table 2). This would suggest that past information is particularly relevant in order to assess the impact of exchange rate volatility on trade. This finding confirms results found by others. Bahmani-Oskooee and Wang (2007) using a 12-month standard deviation find in studying the United States-China trade transactions that less than half of the export and import industries are sensitive to exchange rate volatility. When it is significant, the estimated impact can be either positive or negative. De Vita and Abbott (2004), estimating the impact of exchange rate volatility on UK exports to the European Union countries, also find stronger impacts of exchange rate volatility on exports using a long-run measure based on changes over five years.

24. The ten top US exports are products like electrical machinery and equipment, power generation equipment, air and spacecraft, plastics, optics and medical equipment.

Table 2. Estimated long-run elasticities of exchange rate volatility with respect to trade

	Garch		Five-year MSD	
	Agriculture	Manufacturing	Agriculture	Manufacturing
		Euro Area / United States		
Exports	-0.07	ns	0.19	0.06
Imports	0.13	ns	-0.22	-0.19
		Euro Area / China		
Exports	ns	-0.06	ns	-0.05
Imports	ns	-0.08	0.15	0.13
		United States/China		
Exports	ns	0.09	ns	-0.17
Imports	ns	ns	ns	0.09

ns: non significant.

As is found in many other econometric studies, the income variable is highly significant (Annex F includes a table of coefficients found for each variable in each of the three country-pair models). A rise in national income leads to an increase in the value of domestic imports through the increased purchasing power of national consumers. In a same way, foreign income plays a significant role in determining domestic exports. Changes in Chinese income have a particularly strong effect on US agricultural exports to China. Indeed, Chinese economic growth appears to be a key source of the agriculture trade surplus of the United States with China. One of the reasons could be the increased Chinese demand for meat and meat products: as household income increases in China, a strong rise in demand for meat follows which translates into an increase in US agriculture exports, particularly of soybeans, which are used primarily as animal feed.[25]

Impact of hypothetical currency depreciations on 2008 trade balances

In order to illustrate the impacts on trade and on current account balances of changes in the level of exchange rates, according to model results, a hypothetical experiment was undertaken which consists of estimating the impact on 2008 trade balances of a 10% depreciation in exchange rates.[26] This hypothetical experiment implies a sudden and constant change in exchange rates prior to the entire period, holding all other things in the economy constant, which is of course unlikely. This analysis is therefore included as an illustration in order to better understand the implications of long-run effects estimated by the econometric models.

In the case of Euro area trade with the United States, a 10% depreciation of the euro in real terms would have improved the Euro area's 2008 agricultural trade balance with the United States by EUR 2 billion according to models using GARCH volatility

25. The value of US soybean exports to China accounts for 60% of the agriculture exports of the United States in 2008.

26. Note that results cannot be extrapolated for greater changes in the currency depreciation due to the magnitude of the observed variability in the exchange rates (Figures 1 and 2). Results were similar when the effects of a 10% depreciation were calculated based on the average trade over the period 1999-2008.

(EUR 554 million in those with five-year moving standard deviation (MSD) measure of volatility) and its manufacturing trade balance would have improved by EUR 17 billion (EUR 10 billion in the case of the five-year MSD model).[27] A 10% depreciation of the euro (or an equivalent 10% appreciation of the US dollar) would therefore have implied a total Euro area trade surplus of EUR 70 billion with the United States (using GARCH, or 61 billion using the five-year MSD) as opposed to the total surplus of EUR 50 billion that actually existed.

The same experiment – a 10% real depreciation of the euro – would have implied a deterioration of Europe's agricultural trade balance with China: from EUR -2.08 billion to EUR -2.4 billion regardless of the measure of volatility. The trade balance in manufacturing between the Euro area and China, on the other hand, would have improved by EUR 9.5 billion in 2008 using GARCH model estimates. The total trade balance of the Euro area with China therefore would have remained relatively unchanged despite the 10% depreciation of its currency, at EUR -109 billion (using GARCH, or -119 using the five-year MSD) as compared to the 2008 actual trade balance of EUR -118 billion.

Trade between the United States and China is the most affected by currency changes in nominal terms. According to implications of the model, a depreciation of 10% of the US dollar (or an equivalent 10% appreciation of the yuan) would have implied an improvement in the 2008 US agricultural trade surplus of EUR 3.2 billion[28] using GARCH model coefficients (EUR 2.3[29] billion in the case of the five-year MSD) and a decrease in the US manufacturing deficit of EUR 21 billions[30] (EUR 29.5 billion in the five-year MSD models[31]). This implies that a 10% depreciation of the US dollar (or 10% appreciation in the yuan) in 2008 would have brought the US trade deficit with China to EUR -161 billion (USD -235 billion) using GARCH, as opposed to the actual deficit which was EUR -185 billion (USD -270 billion).[32] This confirms some of the findings in Evenett (2010) which generally suggest that the trade imbalance between the United States and China is due largely to factors other than the exchange rate. Evenett "contest the importance ascribed to the exchange rate regime (in contributions by Yu, Huang, and Wyplosz amongst others) and argue that the steps necessary to cut China's current account surplus lie elsewhere" (Evenett, 2010, p.11). Huang, in his contribution to Evenett (2010), suggests that one reason for the imbalances lies with asymmetric market liberalization and ensuing factor-cost distortion. Goods markets, Huang argues, have been almost completely liberalized. Factor costs, however, e.g. the price of labour and capital, have not which introduces macro-level distortions. Huang sights lack of labour mobility in China and stricter controls over capital outflows than inflows, as well as distortions in

27. Note that impacts of the exchange rate on trade differ somewhat depending on model specifications, i.e. which measure of volatility is used.

28. Or USD 4.7 billion.

29. USD 3.4 billion.

30. USD 30.8 billion.

31. USD 43.2 billion.

32. These findings hold in the case of relatively modest exchange rate variations of, for example, 10%. Since the data do not exhibit large variations in the exchange rate, especially in the US-China case, results should not be extrapolated to explain the effects of large exchange rate changes on trade flows.

prices of Chinese inputs such as energy and other resources, as more prominent causes for the current trade imbalances and current account surpluses.

Some recent firm-level research suggests that the impact of exchange rates on trade flows may be less than expected due to the types of firms that export. According to Berman, Martin and Mayer (2009), firms that export are generally more productive than those that do not. When in a situation of exchange rate depreciation, they tend to increase their margins rather than increasing the volume of goods exported. Higher pricing by exporters is also more pervasive in sectors and destination countries with higher distribution costs. An exchange rate depreciation also creates the incentive for some firms that previously did not export to do so, but since they are generally smaller their impact on trade flows is less evident at the macro level.

VI. Conclusions

This analysis has examined the impact of exchange rates on bilateral trade in three large economies – China, the Euro Area and the United States. The analysis was done in the context of a very large body of existing literature which motivated many of the choices concerning its methodology; it confirms many of the results found in the literature.

This study found the impact of exchange rate volatility on trade to be minimal at the sectoral level. Exchange rate volatility between large economies such as the United States, the Euro area and China does not seem to be driving trade flows. This result could change, however, for smaller economies or for developing countries that do not, contrary to China, effectively peg their currency.

This analysis confirms much of the existing literature in that short-run effects of the exchange rate on trade are limited. This analysis does not confirm the existence of the J-curve in the short-run although it may point to a longer-term interpretation of the J-curve as suggested by Rose and Yellen (1989) who find a short-run deterioration of trade balance followed by a long-run improvement. It is therefore advisable to concentrate future analysis on longer term effects of exchange rate levels on trade.

The long-run effect of exchange rates on trade is found to be stronger as regards the United States than the Euro area. In the case of US-China trade, where the largest effect was found, a 10% depreciation of the US dollar (or 10% appreciation in the yuan) would have implied a reduction in the US bilateral trade deficit with China in 2008 of 13%. The bilateral country model, Euro area – China, found less significant results. It is somewhat surprising that the United States-China exchange rate changes would have a higher impact on trade flows than those of the Euro area since the yuan has been effectively pegged to the dollar over a number of years covered in the study. One explanation for the larger effect on trade between the United States and China may be found in the composition of goods traded by each geographical area. If the Euro area countries trade in products that are less price elastic than those traded by the United States with China, trade impacts of exchange rate changes in the euro will be less. One example of this is the Euro area's main export product, encompassing 30% of its export value to China in 2008 – nuclear reactors. The exports of nuclear reactors are generally governed by long-term contracts which benefit from large project financing which undoubtedly includes exchange hedging mechanisms. Changes in the exchange rate in this particular product will therefore be reflected less strongly in their trade.

This study finds that exports are more sensitive than imports to changes in exchange rate levels[33]. Besides, the impact of exchange rates on exports in agriculture to be more pronounced than that for manufacturing. One reason for this may be the greater homogeneity of agricultural products as compared with manufactured goods, more easily allowing the possibility of changing suppliers. Additionally, price transmission mechanisms may be different in agriculture as compared with manufacturing.

In many of the relationships measured here, underlying factors often have differing, and sometimes opposing, effects. In the case of the agriculture sector, one particularity is that tariffs are often expressed as specific, as opposed to ad valorem, rates. The European Union and, to a lesser extent the United States, have an import tariff structure for agricultural products that is made up of many more specific tariffs (i.e. tariffs expressed in value per tonne of merchandise) than in the mining or manufacturing sectors where tariffs are generally expressed ad valorem (i.e. as a percentage of the value of the imported good). Ad valorem tariffs magnify the effect of international price changes since they are based on the imported price of the good, whereas specific tariffs have a dampening effect. In this way, the tariff structure in agriculture in the European Union and United States somewhat mitigates international price changes, including exchange rate changes, and would in principle reduce the effect of volatility in this sector.

The findings in this study confirm some of the analysis in Evenett (2010) that suggest that trade imbalances are more complex than the sole question of exchange rate levels. Wyplosz, in Evenett (2010), suggests that exchange rates are in disequilibria due in part to low (close to zero) US savings rates combined with continuing budget deficits. A change in the nominal exchange rate with trading partners would not correct for these disequilibria, he argues.

The impacts of exchange rates on trade should be regarded in the context of continuing integration of supply chains. Exports generally include a high import content and the impact of exchange rate depreciation or appreciation on any finished product is therefore complex. If an exchange rate depreciation makes its exports of final products "cheaper", it makes imported components "more expensive" for domestic producers. Although exchange rate hedging mechanisms are available, they are probably less accessible for some particularly small and medium-sized enterprises, who may have less long-term visibility of their foreign exchange needs.

As in many other studies, the main driver of trade flows is found to be income – which is specified as domestic income in the case of imports and foreign income in the case of bilateral exports. This finding is robust across the board in different country and sector models. Increases in income in China, in particular, have implied large changes in trade with its partners. Increased Chinese imports in agricultural products from the United States are particularly striking as Chinese consumers with increasing incomes consume more meat necessitating soybean imports from the United States used as animal feed. Soybeans are now the United States's third largest export product to China.

Finally, this study confirms the general picture of four decades of analytical work in this area. No particularly strong, clear picture emerges to explain trade patterns by changes in the exchange rate across all countries and all sectors. Many factors determine to what extent exchange rates impact trade: price elasticities at the product level, income

33. A further study on small open economies – Chile and New Zealand – does not permit confirmation of this result. This may be explained by a smaller degree of export diversification of the small open economies examined (OECD, 2011).

elasticities, product homogeneity and ease of changing suppliers, price transmission mechanisms, etc. This multitude of factors suggests that exchange rates are part of a bigger picture of determinants of trade flows.

This study also points to a lack in the large body of existing literature – the vast majority of studies on exchange rates and volatility examine the United States with its trading partners. Further research could be useful examining other countries with different characteristics – small economies, for example, including small, developing economies.

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Annex A.

Data definitions and sources

This study examines the effects of the exchange rate on bilateral trade flows on three pair countries: the Euro area with China and the Euro area with the United States, and the United States with China.

This study uses monthly data and the period under consideration ranges from 1999:1 to 2009:6, according to the availability of data. This period is chosen for consistency with the frequency of data and with the geographical area[1]. All the Euro area data correspond to the European Monetary Union of 12 EU countries (the eleven founders in 1999[2] and Greece which joined the Union in 2001): this enables having more available data, and maintaining a uniform dataset over the entire time period.

Monthly trade flows in value for the Euro area with its partners are available from the Comext database which provides detailed information on external trade by product for European countries. Concerning trade between the US and China, monthly trade data collected by OECD will be used for total trade and that available through the Foreign Agriculture Trade of the United States (FATUS) in the United States Department of Agriculture (USDA) for the agriculture sector. The WTO classification is used to distinguish between agriculture and non agriculture products following the definition in the GATT Uruguay Agreement on Agriculture. The agriculture sector includes, according to the HS2, HS4 and HS6 classification: chapters 01, 02, 03, 04, 05, 06, 07, 08, 09, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, commodities at HS4 digit 3301, 3501, 3502, 3503, 3504, 3505, 4101, 4102, 4103, 4301, 5001, 5002, 5003, 5201, 5202, 5203, 5301, 5302 and commodities at HS6 290543, 290544, 380910, 382360 plus fish and fish products. Imports are valued CIF and exports FOB.

Monthly exchange rate data are collected from the International Financial Statistics (IFS) of the International Monetary Fund (IMF). Real exchange rates are defined in the number of local currency units per foreign currency. Thus, an increase in exchange rate reflects a real depreciation of the national currency. Real exchange rates are derived by multiplying the nominal exchange rate by the ratio of the foreign to local currency consumer price index.

Real industrial production index is used as a proxy of income and is collected from Eurostat, IMF and OECD.

1. The Euro area exists since 1999.

2. The 11 European founders are Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxemburg, Netherlands, Portugal, Spain.

Annex B.

Econometric Methodology

Pesaran et al. (2001) suggest an alternative technique[1], the Auto-Regressive Distributed Lag (ARDL) or the bounds test approach to cointegration[2] to investigate the relationship between variables. The tests for long run relationship between variables are based on standard F-tests. There is no need for pre-unit-root testing. This is one of the main advantages of the bounds testing approach which makes it relatively more relevant for our topic because the volatility measure could be stationary whereas other variables could be non-stationary (Bahmani-Oskooee and Mitra (2008)). Besides, this technique generally provides unbiased estimates of the long run model and valid t-statistics even when some of the regressors are endogenous (Harris and Sollis (2003)). Inder (1993) and Pesaran and Pesaran (1997) have shown that the inclusion of the dynamics may help correct the endogeneity bias. Finally, the advantage of this approach is that it allows the distinction between short and long run effects.

The equations of imports and exports of product i (i stands agriculture or manufactured) are modelled as a conditional ARDL-error correction model for each pair countries (Euro area with the US and then China; the US with China).

$$\begin{aligned}\Delta \ln M_{it} &= c_0 + \sum_{k=1}^{n1} c_{1k}\Delta \ln M_{i,t-k} + \sum_{k=0}^{n2} c_{2k}\Delta \ln Y_{country,t-k} + \sum_{k=0}^{n3} c_{3k}\Delta \ln ER_{t-k} + \sum_{k=0}^{n4} c_{4k}\Delta \ln Vol_{t-k} \\ &\quad + \delta_0 \ln M_{i,t-1} + \delta_1 \ln Y_{country,t-1} + \delta_2 \ln ER_{t-1} + \delta_3 \ln Vol_{t-1} + \mu_t\end{aligned}$$

$$\begin{aligned}\Delta \ln X_{it} &= d_0 + \sum_{k=1}^{n1} d_{1k}\Delta \ln X_{i,t-k} + \sum_{k=0}^{n2} d_{2k}\Delta \ln Y_{partner,t-k} + \sum_{k=0}^{n3} d_{3k}\Delta \ln ER_{t-k} + \sum_{k=0}^{n4} d_{4k}\Delta \ln Vol_{t-k} \\ &\quad + \lambda_0 \ln X_{i,t-1} + \lambda_1 \ln Y_{partner,t-1} + \lambda_2 \ln ER_{t-1} + \lambda_3 \ln Vol_{t-1} + \zeta_t\end{aligned}$$

These equations include a linear combination of the lagged level of all variables (second line of each equation), commonly referred to as an error-correction term. These specifications provide estimates of both short-run and long-run effects. The short-run

1. Two main approaches were adopted in the past: the two-step residuals based procedure for testing the null of no-cointegration (Engle and Granger, 1987) and the system-based reduced rank regression approach due to Johansen (1991, 1995). These methods assume that the variables are integrated of order one (I(1)) or more. Pesaran et al. (2001) develop a new approach for testing the existence of a relationship between variables (they can be stationary I(0), integrated of order one I(1) or mutually cointegrated).

2. Cointegration means a stationary long term relationship: variables are cointegrated if there is a linear combination between the variables which is stationary.

effects are inferred from the estimates of $c_{1k},\ldots,c_{4k}$ or $d_{1k},\ldots,d_{4k}$ and the long-run effects by δ_0, δ_3 (or λ_0, λ_3 respectively) normalised by δ_0 (λ_0).

The first step in estimating error-correction models is to carry out the F-test for joint significance of the lagged level variables or for their cointegration. A problem arises in this step that is related to the choice of lag length. Although Pesaran et al. (2001) suggest imposing a fixed number of lags on each differenced variable; Bahmani-Oskooee and Ardalani (2006) have demonstrated that the F-test result is sensitive to the lag length. Following Bahmani-Oskooee and Wang (2007), we first estimate by the OLS method different ARDL models for all lags with a maximum of 12 lags. We use both Akaike's information criterion (AIC) and Schwartz Bayesian Criterion (SBC) [3] to select the optimum lags on each variable.

With the optimal lags, the presence of cointegration is then tested through an OLS estimation by restricting all estimated coefficients of lagged level variables equal to zero ($\delta_0 = \delta_1 = \delta_2 = \delta_3 = 0$ or $\lambda_0 = \lambda_1 = \lambda_2 = \lambda_3 = 0$). The null hypothesis of non cointegration is tested against the alternative by the mean of an F-test with an asymptotic non-standard distribution. If the computed F-statistic lies above the upper level of the band, the null is rejected, indicating cointegration. If the computed F-statistic lies below the lower level ban, the null cannot be rejected, supporting the absence of cointegration. If the statistics fall within the band, inference would be inconclusive. This is called a bounds testing procedure since the two sets of critical values provide critical value bounds for all possibilities of the regressors into purely I(0), I(1) or mutually cointegrated.

In a second step, after confirmation of the existence of a long run relationship between the variables in the model, the long run and short run models can be derived. Estimates of δ_0 - δ_3 (λ_0 - λ_3 respectively) are then used to form an error-correction term ECM_{t-1}.[4]

We replace the linear combination of lagged level variables (second line of each equation) by ECM_{t-1}. The error correction model is re-estimated by using the same lag structure as before. When all variables are adjusting toward their long-run equilibrium, the gap between the dependent and the independent variables measured by the coefficient associated to ECM_{t-1} must decrease. In other words, a negative and significant coefficient obtained for ECM_{t-1} not only will be an indication of adjustment toward equilibrium but also an alternative way of supporting cointegration among variables (Bahmani and Ardalani (2006)). The larger the error correction coefficient (in absolute value) the faster is the economy's return to its equilibrium, once shocked.

Finally, we run diagnostic tests. We test for stability of short-run and long-run coefficient estimates by applying the CUSUM and CUSUMQ tests proposed by Brown et al. (1975) to the residuals of the error-correction models. We present the conclusion in

3. The AIC and SBC are the two most popular model selection criteria. The strategy consists on choosing the number of lags for which the criteria are the smallest. These model selection criteria measure the "fit" of a given model by its maximized value of the log-likelihood function.

4. ECM(-1) represents the lagged linear combination of the variables: it represents the gap towards the equilibrium in period t-1. Its estimated associated coefficient corresponds to the reaction degree of the dependent variable regards to the previous gap towards the equilibrium.

tables G.1 and G.2 in Annex G[5]. We also produce a Ramsey Reset specification test, and a LM-test of non autocorrelation of residuals.

Cusum (cumulative sum) and Cusumq (cusum of squares test) are based on recursive residuals. Cusum is defined as $W_r = \frac{1}{\hat{\sigma}_{ols}} \sum_{j=k+1}^{r} v_j$ r=k+1, k+2, n

Where v_t is the recursive residual based on the first j observations.

The test employs a graphic technique and involves plotting W and a pair of straight lines for values of r = k+1, k+2, n. The straight lines are drawn assuming a 5% significance level.

In the same idea, Cusumq is based on the quantities: $WW_r = \frac{\sum_{j=k+1}^{r} \nu_j^2}{\sum_{j=k+1}^{n} \nu_j^2}$ r = k+1, k+2, n

5. Graphs are available upon request from the authors.

Annex C.

Alternative measures of volatility

The volatility of real bilateral exchange rate (ER) is reported in this paper by variable vol. As mentioned in the text, three measures of volatility were tested in empirical analysis. One is a GARCH-based measure. The two others are based on moving standard deviation of ER. For each month this measure is the standard deviation of previous 12 observations ending at current month in the first case. For the alternative case, it is the standard deviation of previous 60 observations (5 years). Only empirical results based on the 5-year moving standard deviation are reported in the document.

In a simple GARCH model it is assumed that ER itself follows a first order auto-regressive process:

$$ER_t = a_0 + a_1 ER_{t-1} + \varepsilon_t, \qquad (1)$$

where ε_t is white noise with E $(\varepsilon) = 0$ and V $(\varepsilon) = h^2$.

The conditional mean of ER_t is $a_0 + a_1 ER_{t-1}$. In order to forecast the variance of ER, the conditional variance of ε_t which is a time varying variable needs to be estimated. GARCH allows thus the variance of a variable like ER to change over time. The theoretical specification of a GARCH(p,q) model which is being used is as follows:

$$h_t^2 = \beta_0 + \beta_1 \varepsilon_{t-1}^2 + \ldots + \beta_q \varepsilon_{t-q}^2 + \varphi_1 h_{t-1}^2 + \ldots + h_{t-p}^2 \qquad (2)$$

Where p is the number of GARCH (lagged variance) and q the number of ARCH (lagged residual squared terms)

The GARCH model represented by Equation (2) includes a ARCH term (β's) which states that the variance of the current error term is a function of the variance of error term in the previous periods and a GARCH term (φ's) which summarizes last period's forecast variance. The GARCH (p,q) model is used to generate predicted value of h_t^2 as a measure of volatility of exchange rate.

Before estimating the GARCH model, we carry out an ARCH test. We use the Lagrange multiplier procedure proposed by Engle (1982). The first step is to regress the OLS squared residuals $\hat{\varepsilon}_t^2$ from the regression (1) on a constant and its own lagged values:

$$\hat{\varepsilon}_t^2 = \alpha_0 + \alpha_1 \hat{\varepsilon}_{t-1}^2 + \alpha_2 \hat{\varepsilon}_{t-2}^2 + \ldots + \alpha_q \hat{\varepsilon}_{t-q}^2 + e_t \qquad (3)$$

The ARCH(q) effect is carried out by testing the statistical significance coefficients $\alpha_0 = \ldots = \alpha_q = 0$.

Under the null hypothesis, the conditional homoskedasticity is tested. The LM statistic is asymptotically distributed as a chi-squared χ^2.

In a second step, once conditional heteroskedasticity in the residuals is established, the GARCH model is estimated. The order of GARCH is determined by significance of β's and φ's in (2). Our results suggest that a GARCH (1,1) specification is sufficient[1] for the following pair-countries: The Euro Area–United States and United States -China. A GARCH (2,2) is better for Euro Area-China.[2]

Next, the moving standard deviation measure of volatility is as follows:

$$Vol_t = \left[(1/m).\sum_{i=1}^{m} (ER_{t+i-1} - ER_{t+i-2})^2 \right]^{1/2}$$

ER: exchange rate; m: 12 or 60 observations according to the measure.

1. Other studies found a GARCH (1,1) specification like (Doyle, 2001).

2. Detailed results are available upon request from the authors.

Annex D.

Results of F-Test for Co-Integration Among Variables

We gather from Tables D.1. and D.2 below that calculated F-statistics are higher than the upper-bound critical values in the majority of cases, supporting cointegration among the variables in both models. This justifies keeping the lagged-level variables in the models. Note that the lagged-level variables will be retained even in the models that yielded insignificant F statistics. This is due to the significant and negative estimated associated coefficient of the ECM variable (Annex F).

Table D.1. Results with GARCH volatility

	Import-value model		Export-value model	
	Optimum lags	**F-statistic**	**Optimum lags**	**F-statistic**
Euro Area / United States				
Agriculture Sector	12,0,2,0	7.28	12,5,0,1	17.42
Non-agriculture sector	4,0,2,0	(2.94)	12,6,9,1	*3.83*
Euro Area /China				
Agriculture sector	3,0,0,0	*3.75*	3,0,0,0	5.59
Non-agriculture sector	8,0,1,0	*3.78*	12,8,12,1	8.97
United States /China				
Agriculture sector	1,3,7,1	15.33	6,8,0,0	20.68
Non-agriculture Sector	12,12,3,0	*4.61*	1,0,0,0	15.92

Table D.2. Results with five-year standard deviation volatility measure

	Import-value model		Export-value model	
	Optimum lags	**F-statistic**	**Optimum lags**	**F-statistic**
Euro Area / United States				
Agriculture sector	12,11,8,12	8.10	12,3,0,0	11.96
Non-agriculture sector	12,12,10,11	5.65	12,1,8,1	18.72
Euro Area /China				
Agriculture sector	3,0,0,0	4.65	3,0,0,0	5.65
Non-agriculture sector	8,0,1,0	7.58	12,11,12,12	7.43
United States /China				
Agriculture sector	7,3,7,2	10.27	6,8,0,3	22.45
Non-agriculture sector	12,2,0,6	13.54	1,1,0,0	19.59

Note: A trend is added in all specifications with the exception of agriculture imports of EA from the United States.
Critical values at 5% and 10 % if the model includes a constant and a trend are [4.066; 5.119] and [3.484; 4.458]
Critical values at 5% and 10 % if the model includes a constant only are [3.219; 4.378] and [2.711; 3.800].
Results that are reported in italic mean that we cannot conclude. Those in brackets correspond to a rejection of the test.

Annex E.

Estimated Short-Run Effects

Table E.1. Estimated short-run effects of import function (vol= GARCH

Pair country and variables	Lag order											
	0	1	2	3	4	5	6	7	8	9	10	11
Euro Area – United States												
Agriculture sector												
ΔLnY	1.18***											
	(4.31)											
ΔlnER	-0.76	1.36***										
	(1.63)	(2.96)										
ΔlnVol	0.07***											
	(2.80)											
Non-agriculture sector												
ΔLnY	0.11											
	(0.73)											
ΔlnER	-0.08	0.92***										
	(0.28)	(3.15)										
ΔlnVol	-0.00											
	(0.14)											
Euro Area – China												
Agriculture sector												
ΔLnY	0.64***											
	(2.87)											
ΔlnER	0.28*											
	(1.80)											
ΔlnVol	-0.00											
	(0.57)											
Non-agriculture sector												
ΔLnY	0.63***											
	(2.78)											
ΔlnER	0.82***											
	(3.21)											
ΔlnVol	-0.03**											
	(2.14)											
United States - China												
Agriculture sector												
ΔLnY	1.40	0.39	3.88**									
	(0.98)	(0.26)	(2.63)									
ΔlnER	3.68*	-0.16	-0.71	-0.97	-0.28	5.72**	6.31**					
	(1.73)	(0.06)	(0.27)	(0.38)	(0.11)	(2.33)	(2.56)					
ΔlnVol	0.07**											
	(2.16)											
Non-agriculture sector												
ΔLnY	-0.25	-0.10	1.89	2.14*	1.27	2.64**	2.06*	2.57**	1.40	1.32	3.45**	3.52**
	(0.24)	(0.09)	(1.61)	(1.89)	(1.07)	(2.23)	(1.74)	(2.16)	(1.16)	(1.08)	(2.58)	(2.59)
ΔlnER	-2.76*	-0.60	2.90*									
	(1.67)	(0.34)	(1.79)									
ΔlnVol	0.02											
	(1.05)											

Note: t-ratios in absolute value are reported in brackets.

Table E.2. Estimated short-run effects of export function (vol= GARCH

Pair country and variables	Lag order											
	0	1	2	3	4	5	6	7	8	9	10	11
Euro Area – United States												
Agriculture sector												
ΔLnY	-0.42	2.56***	3.72***	1.98**	3.35***							
	(0.46	(2.88)	(4.07)	(2.13)	(3.53)							
ΔlnER	0.87***											
	(8.29)											
ΔlnVol	0.03											
	(1.49)											
Non-agriculture sector												
ΔLnY	-0.47	0.66	-0.43	-0.39	2.70**	3.64***						
	(0.49)	(0.66)	(0.42)	(0.38)	(2.42)	(3.43)						
ΔlnER	-0.03	0.75***	0.27	0.39	-0.27	0.03	-0.18	-0.57**	1.30***			
	(0.12)	(2.73)	(0.99)	(1.44)	(1.02)	(0.10)	(0.64)	(2.02)	(4.65)			
ΔlnVol	0.04*											
	(1.84)											
Euro Area - China												
Agriculture sector												
ΔLnY	0.56											
	(1.15)											
ΔlnER	-0.03											
	(0.10)											
ΔlnVol	0.02											
	(0.48)											
Non-agriculture sector												
ΔLnY	0.66***	-3.52***	-2.93***	-2.54***	-2.23***	-1.94***	-1.60***	-0.78***				
	(2.97)	(4.27)	(3.98)	(3.87)	(3.88)	(4.03)	(4.36)	(3.31)				
ΔlnER	-0.52*	0.13	-1.03***	-0.68*	-1.32***	-0.33	-0.69*	-0.54	0.85**	-0.17	-0.24	0.76**
	(1.68)	(0.34)	(2.80)	(1.83)	(3.63)	(0.89)	(1.91)	(1.40)	(2.26)	(0.42)	(0.62)	(2.00)
ΔlnVol	-0.00											
	(0.41)											
United States - China												
Agriculture sector												
ΔLnY	1.66*	-10.39***	-10.58***	-9.44***	-8.90***	-7.49***	-5.70***	-2.20**				
	(5.25)	(5.25)	(5.93)	(5.44)	(5.36)	(4.77)	(4.30)	(2.35)				
ΔlnER	4.61***											
	(2.94)											
ΔlnVol	-0.08											
	(1.23)											
Non-agriculture sector												
ΔLnY	1.18***											
	(3.79)											
ΔlnER	-1.31**											
	(2.32)											
ΔlnVol	0.05**											
	(1.91)											

Note: t-ratios in absolute value are reported in brackets.

Table E.3. Estimated short-run effects of import function (vol= five-year MSD

Pair country and variables	Lag order											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Euro Area – United States												
Agriculture sector												
ΔLnY	1.76	-3.34**	-1.06	-3.17**	-0.12	-1.96*	-1.86	-5.95***	-3.74*	-4.43**	-2.75*	
	(1.63)	(2.61)	(0.86)	(2.65)	(0.10)	(1.68)	(1.13)	(-3.26)	(1.91)	(2.40)	(1.80)	
ΔlnER	0.13	0.05	0.12	-0.68	-0.41	-0.74	-1.08**	0.61				
	(0.27)	(0.09)	(0.22)	(1.33)	(0.77)	(1.44)	(2.11)	(1.14)				
ΔlnVol	3.55***	-0.71	0.35	3.73*	-1.54	0.11	4.71**	-7.08***	3.07	-2.38	3.30	-3.31*
	(2.68)	(0.34)	(0.16)	(1.79)	(0.74)	(0.05)	(2.29)	(3.33)	(1.34)	(1.00)	(1.42)	(1.99)
Non-agriculture sector												
ΔLnY	0.81	-2.17**	-1.27	-0.35	-1.18	-1.05	-0.33	-1.15	2.79**	0.69	0.98	2.45***
	(1.25)	(2.19)	(1.25)	(0.34)	(1.08)	(1.02)	(0.30)	(1.01)	(2.45)	(0.65)	(1.00)	(2.91)
ΔlnER	-0.14	0.43	0.25	-0.12	-0.11	0.35	0.09	0.12	0.75**	0.82***	0.71**	
	(0.47)	(1.18)	(0.76)	(0.35)	(0.33)	(1.07)	(0.27)	(0.36)	(2.52)	(2.82)	(2.28)	
ΔlnVol	0.17	0.21	0.26	-0.59	0.55	1.41	-0.14	-2.49**	1.34	0.92	0.26	1.18
	(0.23)	(0.17)	(0.21)	(0.47)	(0.43)	(1.07)	(0.11)	(2.00)	(0.99)	(0.65)	(0.19)	(1.15)
Euro Area - China												
Agriculture sector												
ΔLnY	0.82***											
	(3.61)											
ΔlnER	0.36***											
	(2.72)											
ΔlnVol	0.05**											
	(1.99)											
Non-agriculture sector												
ΔLnY	1.36***											
	(4.67)											
ΔlnER	0.90***											
	(3.75)											
ΔlnVol	0.09***											
	(3.83)											
United States-China												
Agriculture sector												
ΔLnY	1.06	0.22	3.84***									
	(0.78)	(0.16)	(2.72)									
ΔlnER	4.64**	-0.37	1.47	2.17	2.08	4.44*	6.61***					
	(2.24)	(0.16)	(0.63)	(093)	(0.90)	(1.96)	(2.78)					
ΔlnVol	1.74	-2.37*										
	(1.49)	(1.97)										
Non-agriculture sector												
ΔLnY	-0.32	-2.57**										
	(0.32)	(2.41)										
ΔlnER	-1.21***											
	(5.42)											
ΔlnVol	0.94	-1.31	0.18	-0.51	1.35	-1.93**						
	(1.13)	(1.00)	(0.13)	(0.39)	(1.03)	(2.35)						

Note: t-ratios in absolute value are reported in brackets.

Table E.4. Estimated short-run effects of export function (vol = five-year MSD

+	Lag order											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Euro Area – United States												
Agriculture sector												
ΔLnY	1.17	2.29**	3.16***									
	(1.26)	(2.37)	(3.18)									
ΔlnER	0.59***											
	(5.82)											
ΔlnVol	0.09***											
	(3.49)											
Non-agriculture sector												
ΔLnY	0.12											
	(0.14)											
ΔlnER	0.05	-0.36	-0.05*	-0.40	-0.91***	-0.66**	-0.91***	-1.27**				
	(0.21)	(1.23)	(1.84)	(1.47)	(3.38)	(2.42)	(3.53)	(4.29)				
ΔlnVol	0.72***											
	(2.37)											
Euro Area - China												
Agriculture sector												
ΔLnY	0.54											
	(1.11)											
ΔlnER	0.11											
	(0.50)											
ΔlnVol	0.01											
	(0.22)											
Non-agriculture sector												
ΔLnY	0.14	-4.46***	-4.11***	-3.76***	-3.34***	-2.85***	-2.39***	-1.72***	-0.98**	-0.76**	-0.30	
	(0.51)	(3.56)	(3.58)	(3.59)	(3.58)	(3.46)	(3.44)	(2.92)	(2.06)	(2.14)	(1.30)	
ΔlnER	-0.26	-0.57	-0.71*	-1.10**	-1.98***	-0.39	-1.64***	-0.81*	0.38	-0.51	-0.75*	0.51
	(0.77)	(1.34)	(1.76)	(2.51)	(4.65)	(0.81)	(3.73)	(1.93)	(0.90)	(1.24)	(1.82)	(1.26)
ΔlnVol	0.07	0.54	-1.00	-0.50	0.79	-1.00	0.83	-0.82	-0.63	2.28	-1.74	3.10**
	(0.54)	(0.78)	(1.29)	(0.62)	(1.04)	(1.22)	(0.82)	(0.67)	(0.47)	(1.47)	(1.08)	(2.47)
United States - China												
Agriculture sector												
ΔLnY	1.54*	-10.79***	-10.67***	-9.94***	-9.41***	-8.03***	-5.98***	-2.04**				
	(1.68)	(5.49)	(6.05)	(5.81)	(5.73)	(5.20)	(4.63)	(2.25)				
ΔlnER	3.51***											
	(2.96)											
ΔlnVol	-2.33	12.60*	-12.15**									
	(0.49)	(1.69)	(4.66)									
Non-agriculture sector												
ΔLnY	1.23***											
	(4.13)											
ΔlnER	0.67**											
	(2.03)											
ΔlnVol	-0.12***											
	(3.58)											

Note: t-ratios in absolute value are reported in brackets.

ANNEX F.

ESTIMATED LONG-RUN EFFECTS

Results of this study show that estimated coefficient of the lagged error correction model ECM is negative and highly significant in all cases. This confirms the long term relationships between variables in levels. It is thus relevant to use such an error correction model.

Table F.1. Estimated long-run effects –Import model (vol=GARCH)

	Constant	lnY	lnER	LnVol	ECMt-1
Euro Area – United Sates					
Agr Sector	9.69*	2.29**	0.10	0.13***	-0.51***
	(1.90)	(2.07)	(0.48)	(4.41)	(2.68)
Man Sector	-0.18	0.05	-0.08*	-0.00	-0.32***
	(0.62)	(0.73	(1.67)	(0.14)	(8.58)
Euro Area - China					
Agr Sector	10.06***	2.15***	0.95**	-0.03	-0.30***
	(3.60)	(3.59)	(2.11)	(0.56)	(3.62)
Man Sector	15.27***	1.47***	0.42	-0.08*	-0.42***
	(8.91)	(3.91)	(1.42)	(1.99)	(3.02)
United States –C hina					
Agr Sector	9.84***	1.35**	-0.58	0.00	-0.61***
	(3.91)	(2.37)	(0.75)	(0.19)	(7.48)
Man Sector	19.40***	-0.10	-1.30*	0.03	-0.54**
	(3.38)	(0.07)	(1.83)	(0.90)	(2.15)

Table F.2. Estimated long-run effects –Export model (vol=GARCH)

	Constant	lnY	lnER	LnVol	ECMt-1
Euro Area – United States					
Agr Sector	13.55***	1.36**	2.18***	-0.07**	-0.40***
	(4.99)	(2.29)	(3.89)	(2.60)	(3.73)
Man Sector	8.86**	3.19***	0.94***	-0.03	-0.35**
	(2.65)	(4.33)	(3.12)	(1.31)	(2.49)
Euro Area - China					
Agr Sector	11.99***	1.04	-0.06	0.03	-0.53***
	(2.78)	(1.09)	(0.10)	(0.49)	(4.38)
Man Sector	-3.19	5.63***	1.50***	-0.06***	-0.90***
	(0.57)	(4.35)	(4.64)	(2.96)	(4.19)
United States - China					
Agr Sector	-29.37***	11.57***	3.81****	-0.06	-1.21***
	(4.08)	(6.50)	(2.92)	(1.21)	(9.24)
Man Sector	6.08**	2.00***	-2.21**	0.09**	-0.59***
	(2.22)	(3.32)	(2.58)	(2.26)	(7.20)

Note: t-ratio in absolute value are reported in brackets.

Table F.3. Estimated long-run effects – import model (vol = 5-year MSD)

	Constant	lnY	lnER	LnVol	ECM_{t-1}
Euro Area – United States					
Agr Sector	7.50***	2.61***	1.03***	-0.22***	-1.96***
	(5.12)	(8.40)	(18.60)	(5.01)	(4.91)
Man Sector	9.81***	2.77***	0.48***	-0.19***	-0.85**
	(5.44)	(7.27)	(3.88)	(2.91)	(2.42)
Euro Area-China					
Agr Sector	9.16***	2.56***	1.13***	0.15*	-0.32***
	(3.93)	(4.45)	(3.76)	(1.90)	(3.95)
Man Sector	14.15***	1.80***	0.31***	0.13***	-0.75***
	(16.02)	(8.43)	(2.75)	(4.85)	(4.50)
United States - China					
Agr Sector	11.21***	1.34**	-0.07	0.02	-0.93***
	(3.77)	(2.13)	(0.22)	(0.32)	(5.80)
Man Sector	7.62***	2.76***	-1.10***	0.09*	-1.10***
	(3.04)	(5.77)	(3.33)	(1.82)	(4.38)

Table F.4. Estimated long-run effects –export model (vol = five-year MSD)

	Constant	lnY	lnER	LnVol	ECM_{t-1}
Euro Area – United States					
Agr Sector	11.85***	1.89***	1.31***	0.19***	-0.45***
	(4.71)	(3.35)	(3.70)	(2.89)	(3.85)
Man Sector	14.68***	1.87***	0.90***	0.06***	-1.47**
	(15.29)	(8.73)	(11.84)	(3.93)	(7.05)
Euro Area -China					
Agr Sector	12.61***	1.02	0.20	0.02	-0.53***
	(2.99)	(1.05)	(0.50)	(0.22)	(4.34)
Man Sector	5.73	3.41***	0.79***	-0.05*	-1.56***
	(1.52)	(3.96)	(5.29)	(1.71)	(5.19)
United States-China					
Agr Sector	-31.57***	11.78***	2.78***	0.08	-1.26***
	(4.68)	(7.04)	(3.04)	(0.98)	(9.77)
Man Sector	7.93***	2.82***	0.95**	-0.17***	-0.70***
	(3.21)	(4.57)	(2.03)	(3.95)	(8.20)

Note: t-ratio in absolute value are reported in brackets.

Annex G.

Diagnostic Tests

Some of the diagnostic tests undertaken are reported below. According to the adjusted R^2, the explanatory power of our estimated models is satisfactory. Additionally, CUSUM and CUSUMSQ tests mostly support stability of the short-run and the long-run coefficient estimates. (Graphical presentations of these test results have been not reported for reasons of space but they are available upon request.) Third, the LM test for serial correlation is significant only in four cases out of the 24 models. Finally, Ramsey's Reset test clearly indicates that all 24 models are well specified.

Table G.1. Diagnostic tests with GARCH volatility measure

	Import-value model				
	$\bar{R}^2$	**CUSUM**	**CUSUMQ**	**LM**[a]	**RESET**[b]
Euro Area / United States					
Agriculture sector	0.77	Stable	Unstable	*30.80*	0.22
Non-agriculture sector	0.65	Stable	Stable	*28.96*	0.00
Euro Area /China					
Agriculture sector	0.44	Stable	Stable	19.07	0.14
Non-agriculture sector	0.53	Stable	Stable	21.58	0.47
United States /China					
Agriculture sector	0.42	Stable	Stable	19.30	0.09
Non-agriculture sector	0.64	Stable	Stable	20.73	0.73
	Export-value model				
	$\bar{R}^2$	**CUSUM**	**CUSUMQ**	**LM**	**RESET**
Euro Area / United States					
Agriculture sector	0.76	Stable	Stable	21.76	0.62
Non-agriculture sector	0.75	Stable	Stable	20.86	0.76
Euro Area /China					
Agriculture sector	0.47	Stable	Unstable	20.68	0.68
Non-agriculture sector	0.69	Stable	Stable	*34.02*	2.37
United States /China					
Agriculture sector	0.48	Stable	Stable	15.13	1.53
Non-agriculture sector	0.36	Stable	Stable	21.67	1.32

Table G.2. Diagnostic tests with five-year moving standard deviation volatility measure

	Import-value model				
	$\overline{R}^2$	**CUSUM**	**CUSUMQ**	**LM**[a]	**RESET**[b]
Euro Area / United States					
Agriculture sector	0.76	Stable	Stable	22.88	0.00
Non-agriculture sector	0.69	Stable	Unstable	25.57	0.81
Euro Area / China					
Agriculture sector	0.46	Stable	Stable	16.43	0.17
Non-agriculture sector	0.61	Stable	Stable	19.05	1.74
United States / China					
Agriculture sector	0.53	Stable	Stable	8.54	0.52
Non- agriculture sector	0.65	Stable	Stable	21.63	1.15
	Export-value model				
	$\overline{R}^2$	**CUSUM**	**CUSUMQ**	**LM**	**RESET**
Euro Area / United States					
Agriculture sector	0.71	Stable	Stable	27.54	0.02
Non- agriculture sector	0.75	Stable	Stable	18.61	0.04
Euro Area / China					
Agriculture sector	0.47	Stable	Unstable	17.91	0.64
Non-agriculture sector	0.72	Stable	Unstable	13.07	0.00
United States / China					
Agriculture sector	0.51	Stable	Unstable	20.16	0.95
Non- agriculture sector	0.41	Stable	Stable	20.45	1.15

a. The Lagrange Multiplier Test (LM) of residual correlation is distributed as χ^2 with 12 degrees of freedom. At the 5% (1%) level of significance, its critical value is 21.03 (26.22)

b. Ramsey's Reset test for functional misspecification is distributed as χ^2 with one degree of freedom. Its critical at 5% significance level is 3.84.