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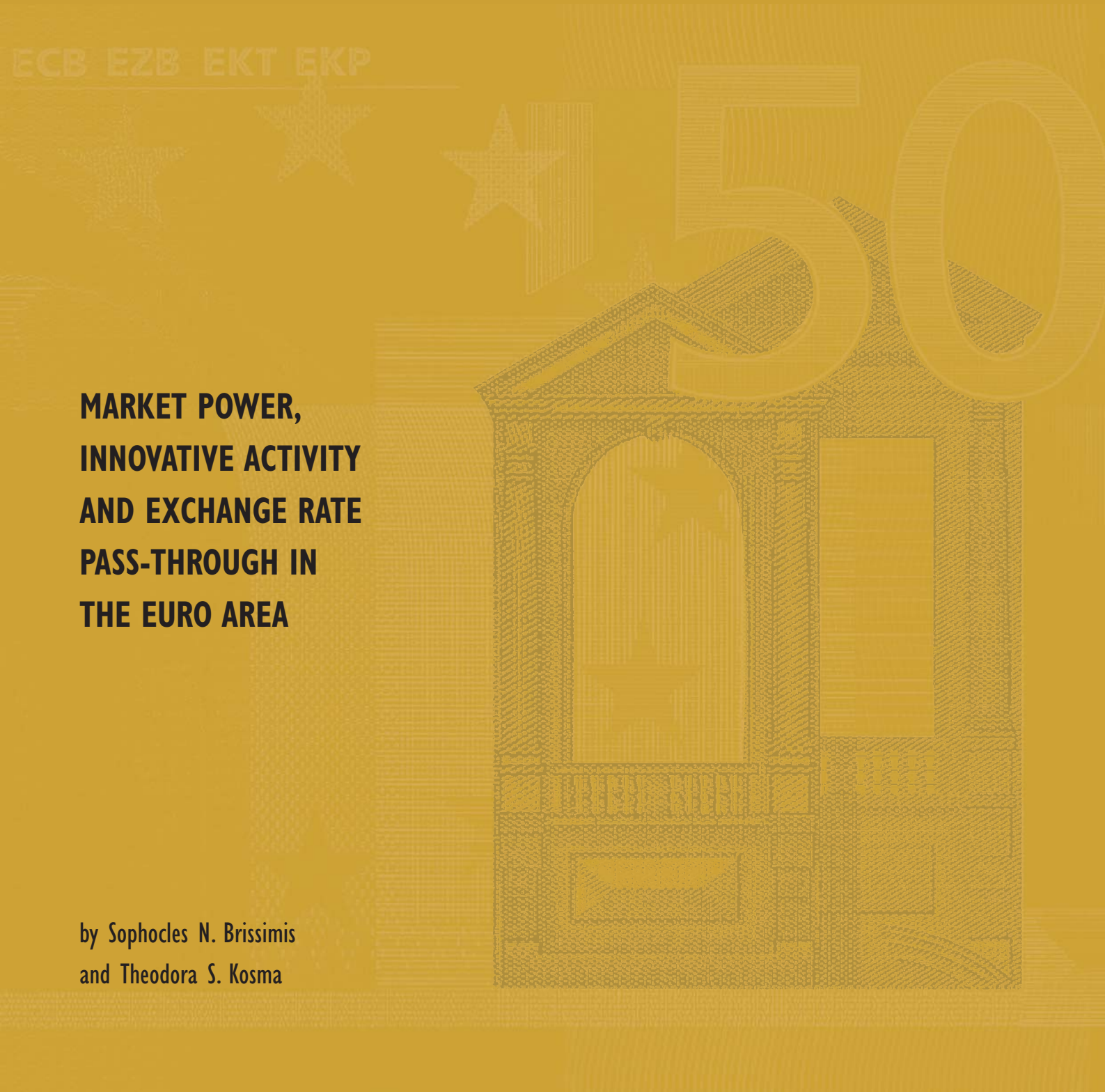

MARKET POWER, INNOVATIVE ACTIVITY AND EXCHANGE RATE PASS-THROUGH IN THE EURO AREA

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In 2005 all ECB publications will feature a motif taken from the €50 banknote.

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CONTENTS

Abstract

This paper examines exchange rate pass-through in the euro area by accounting for the impact of exchange rate changes on exporting firms' market power, cost structure and competitiveness. An international oligopoly model where exporting firms simultaneously decide on their pricing and innovation strategies is used as the basis for the econometric analysis. The estimations are carried out on data for manufacturing imports of three large euro area countries (Germany, France, Netherlands) from three major non-euro area import suppliers (US, Japan, UK). The results show that exporting firms' price and innovation decisions in each source country are jointly determined and that total pass-through to euro area import prices is low. There are also indications that other factors, such as interactions with domestic producers, may be important for the determination of pass-through. Finally, euro area import prices are found to be sticky in local currency in the short run.

JEL Classification: C32, F39, L13, O31

Keywords: Exchange rate pass-through, market power, innovative activity, multivariate cointegration, euro exchange rate

Non-technical summary

Exchange rate pass-through has been extensively analysed in the international economics literature. The incomplete exchange rate pass-through that is documented in the majority of the empirical studies is attributed to deviations from perfectly competitive markets. While the evidence for the US is extensive, only a few studies examine the exchange rate pass-through for the euro area.

An issue that is rather under-investigated relates to the impact of exchange rate changes on firms' market power, cost structure and competitiveness, and the implications for exchange rate pass-through. Empirical studies ignoring these relationships are likely to underestimate the degree of pass-through, since they do not account for all the channels through which exchange rate changes affect firms' quantity and price-setting decisions.

This paper examines exchange rate pass-through in the euro area using the model developed by Brissimis and Kosma (2005) as the basis for the econometric estimations. The model considers an international oligopoly where exporting firms simultaneously decide on their pricing strategy and cost-reducing investment in process innovation. The main empirical implication of the model is that exchange rate variations affect firms' innovation strategy through their impact on market share. This channel should be taken into account for the determination of total pass-through, i.e. the total effect of exchange rate changes working through all interactions in the system. The model produces two equilibrium relationships, one corresponding to the firms' price-setting strategy and one to their innovation decisions. These two equations are estimated using data on manufacturing imports of three large euro area countries (Germany, France, the Netherlands) from three major non-euro area import suppliers (US, Japan, the UK). The empirical methodology employed is the Johansen multivariate cointegration technique that accounts for both short-run and long-run links among the variables. The dynamics of the models are explored using impulse response analysis. The results indicate that firms' price-setting and innovation decisions are jointly determined in equilibrium, although other factors, such as interactions with domestic producers, may also be important for the determination of equilibrium exchange rate pass-through. The pass-through to these three euro area countries' import prices is empirically found to be rather low. Finally, euro area import prices are found to be predetermined in the short run, i.e. they are sticky in

local currency. The creation of the monetary union and the consequent structural shift in euro area product market conditions, namely the reduction in the share of imports of euro area countries that are subject to exchange rate changes, may be partly responsible for the instability that is evident in the majority of the models estimated.

1. Introduction

An issue that has been extensively analysed in the international economics literature relates to the responsiveness of traded goods prices to exchange rate changes, the exchange rate pass-through. Most of the theoretical studies adopt imperfect competition as the framework of analysis and regard incomplete exchange rate pass-through as the endogenous outcome of the profit maximising strategy of firms that sell their products in international markets. As to the empirical literature, there is sufficient evidence that market power plays a significant role in the determination of the optimal degree of pass-through. The majority of the studies, however, are based on data for the US. The empirical evidence on the euro area exchange rate pass-through on the other hand is limited (Campa and Minguez, 2004; Anderton, 2003; Warmedinger, 2004 and Faruquee, 2004).

An issue that is rather under-investigated in the literature relates to the impact of exchange rate changes on exporting firms' market power, cost structure and competitiveness, and the implications for exchange rate pass-through. An important relationship that holds in a Cournot oligopolistic model is that between the market share of the exporters in their destination market, and the exchange rate. Specifically, an appreciation of the exporters' currency, by increasing their cost, reduces their market share (see Shy, 1996); the converse holds for exporters' currency depreciations[1]. If this relationship is not taken into account in empirical work, the estimates of the exchange rate pass-through are likely to suffer from a significant downward bias. However, Bernhofen and Xu (2000) and Brissimis and Kosma (2004), even after controlling for this endogeneity in their estimations, cannot conclude that market power and its dependence on the exchange rate are the only factors on which to base the analysis of exchange rate pass-though[2].

Consequently, other determinants of pass-through are to be looked for. Recent advances in the industrial organisation literature point to the importance of innovative activity, and in particular process innovation, for the determination of firms' optimal quantity and pricing decisions. Process innovation, by reducing the cost of producing

[1] Given that market share is a determinant of the mark-up, this relationship should be taken into account when estimating total exchange rate pass-through.

[2] These studies estimate long-run pricing equations. In these equations, the exchange rate coefficient captures the direct effect of exchange rate changes, i.e. the one working only through the price equation. This coefficient must be one in the long run when all adjustments

existing products, influences price. This literature relates market structure to firms' incentive to adopt process innovation, in the sense that market structures that guarantee a larger market share to firms lead to greater incentive to invest in process-improving R&D. In an international setting, these links become more complicated since there is now a role for the exchange rate. Exchange rate changes, as already indicated, are negatively related to exporting firms' market share in the destination market. Therefore, exchange rate changes, by influencing market share, influence innovative activity and thus cost and price. If these links between exchange rate, market share, innovative activity and price are taken into account in empirical work, the biases in the estimates of the exchange rate pass-through are likely to be eliminated. This framework may be relevant for the analysis of euro area exchange rate pass-through since the main exporters to the euro area are characterised by a high degree of technological sophistication. Furthermore, the euro area constitutes a significant export destination for many exporters; thus, euro fluctuations, by influencing the market share of these exporters, may influence their innovative activity and thus their cost structure and price.

This paper investigates the determinants of exchange rate pass-through in the euro area by focusing on the empirical implications of the model developed by Brissimis and Kosma (2005). The model considers an international oligopoly where exporting firms simultaneously formulate their pricing and innovation strategies. The model predicts that exchange rate variations affect firms' competitiveness, and thus exchange rate pass-through, through the impact of market share on innovative activity. The two optimal relationships corresponding to the pricing and innovation decisions of firms that are derived, are estimated using data for manufacturing imports of three large euro area countries (Germany, France, the Netherlands) from three major non-euro area import suppliers (US, Japan, the UK). Given the nonstationarity of the data used in estimation, the appropriate methodology to identify long-run relationships in systems is the Johansen multivariate cointegration technique. In the presence of indirect effects of exchange rate changes both in the short run and the long run, the exchange rate pass-through cannot be obtained from a single equation framework, thus the adoption of this estimation technique is further warranted. The

related to pricing decisions have taken place. An exchange rate coefficient different from one provides indication of omitted variables or omitted interactions among variables.

dynamics of the pass-through are investigated using impulse responses derived from VEC models.

To preview the results, there is evidence that the pricing and innovation decisions of exporting firms in each source country are jointly determined. However, there are indications of instability in the relevant relationships, possibly linked to the creation of the monetary union. The estimation results further indicate that there may be other channels through which exchange rate changes affect firms' optimal pricing decisions, e.g. interactions with domestic producers. As to the estimates of pass-through, they are found to be rather low and different among countries. Finally, the dynamic analysis indicated that import prices in the euro area are predetermined in the short run, i.e. they are sticky in local currency.

The model's implications may be of particular interest for policy makers in the euro area. They suggest that the indirect effects euro fluctuations may have on the cost structure and competitiveness of euro area countries' trading partners should be taken seriously into account. The impact of these fluctuations on euro area inflation may be more multidimensional than what it seems at first sight.

The remaining of the paper is structured as follows. Section 2 presents a literature review. Section 3 provides a brief description of the model used as the basis for our econometric estimations. Section 4 presents the econometric method and discusses the estimation results. Finally, Section 5 provides concluding remarks.

2. Literature review

The extent to which exchange rate changes are reflected in traded good prices, commonly referred to as the degree of exchange rate pass-through, has for a long time been the focus of interest in the international economics literature. In this literature two issues are of particular importance; one relates to whether traded goods prices respond proportionately or less than proportionately to exchange rate changes, i.e. whether the pass-through is complete or incomplete, and the other to whether incomplete pass-through is likely to be more than just a short-run phenomenon. The available evidence indicates that the unresponsiveness of import prices to exchange rate changes is not just a short-run phenomenon but persists for a long time. This finding motivated a lot of research that focuses on uncovering the determinants of long-run incomplete exchange rate pass-through.

Most of the theoretical studies on exchange rate pass-through focus on the microfoundations of firms' pricing and adopt imperfect competition as the framework of analysis. One strand focuses on the interaction between firms exporting to a foreign market and their domestic competitors and obtains pass-through from the industry equilibrium defined by the intersection of the supply relationships of foreign and domestic firms, both derived from profit maximisation. Dornbusch (1987), in one of the most representative studies of this category, concludes that the degree of exchange rate pass-through to the industry equilibrium price depends on the market share of foreign firms, measured by the relative number of foreign firms that compete in the importer's market. He also finds that the industry equilibrium price pass-through is dependent on the degree to which foreign exporters exercise their market power in the importer's market, measured by the ratio of marginal cost (in the importer's currency) to the price the foreign supplier faces in the importer's market. Thus, the industry equilibrium price pass-through will always be less than one, since it depends on the relative number of firms that experience cost changes related to exchange rate changes.

The other strand of this theoretical literature recognises the existence of domestic firms but concentrates on the analysis of the supply relationship of foreign firms only, also derived from profit maximisation; in this context, the determinants of import price pass-through are examined (e.g. Bernhofen and Xu, 2000; Feenstra, 1989 and Feenstra *et al.,* 1996). The main finding of these studies is that the import price pass-through can be complete. This is likely to be the case when the mark-up and marginal cost of firms are constant and thus unaffected by the exchange rate. However, if either of those varies with the exchange rate, the pass-through will be incomplete. The mark-up varies when the price elasticity of demand, a component of the mark-up, is not constant along the demand curve[3] (Feenstra *et al.,* 1996). Furthermore, market share, another component of the mark-up, may depend on the exchange rate (see, Bernhofen and Xu, 2000)[4]. As for marginal cost, this will be related to the exchange rate to the extent that firms rely on imported inputs (see, Menon, 1996); the marginal cost will also depend on the exchange rate when it is not constant with respect to output and output varies with the exchange rate (see, Yang, 1997 and Adolfson, 1999).

[3] This result is derived from studies that adopt a Bertrand framework.

While there is a large literature on the determinants of long-run exchange rate pass-through, considerably less effort has been devoted to examining the determinants of short-run pass-through. There are two categories of studies in this direction. The studies of the first category focus on the microfoundations of short-run pass-through by adopting two-period oligopolistic games with dynamic demand side effects[5]; the other studies relate short-run pass-through to the optimal invoicing strategy of firms. The paper by Froot and Klemperer (1989) is the first and most representative study of the former category. These authors relate short-run pass-through[6] to the persistence of exchange rate shocks and conclude that firms are more likely to respond to shocks that are large and permanent than to those that are small and temporary. Foreign firms facing a permanent depreciation of their currency will price more aggressively in the first period – the short-run pass-through will be greater – since they regard this pricing strategy as an investment in market share (the market share built in the current period is likely to determine tomorrow's profits, due to consumer switching costs). In a similar vein, Gross and Schmitt (2000) also conclude that the short-run pass-through is incomplete, but the interdependence of firms' prices both within and across periods leads to the conclusion that short-run pass-through can be greater than long-run pass-through. Thus, if the firm, whose currency has appreciated, chooses a price that leads to losses in terms of market share, the firm has to correct its price in order to avoid further losses. These studies provide a richer pattern for pass-through than that assumed in empirical work. Most empirical studies accept as a reasonable outcome of the econometric estimation a short-run pass-through coefficient that is lower than the corresponding long-run one.

As for the studies of the latter category, they relate incomplete short-run pass-through to nominal rigidities. In an open economy, there is another important dimension of nominal rigidities: it does not only matter whether prices are infrequently adjusted but also in which currency these prices are set. If firms set prices in the importer's currency, the short-run pass-through will be zero; on the contrary, if prices are set in the producer's currency, the short-run pass-through will be complete. Bacchetta and van Wincoop (2002) adopt a partial equilibrium model to

[4] As already mentioned, this is a property of Cournot competition.
[5] Dynamic demand-side effects refer mainly to consumer switching costs.

examine the optimal invoicing strategy of firms. The choice of the currency of price setting is made before the exchange rate is known. Therefore, the optimal invoicing strategy of firms depends on the uncertainty of their profits under the two invoicing options. When the price is set in the importer's currency there is uncertainty about the price denominated in the exporter's currency. When prices are set in the exporter's currency there is demand uncertainty, since the price in the importer's currency fluctuates with the exchange; demand uncertainty leads further to cost uncertainty to the extent that cost is dependent on output. If the demand elasticity is large and the cost curve is convex[7], then local currency pricing (pricing in the currency of the importer) is the optimal strategy for firms and, thus, the short-run exchange rate pass-through is zero. This finding is based on the assumption of a single firm exporting to a foreign market. When many firms from a country export to a foreign market, strategic complementarities among firms' decisions play a role in the determination of the optimal invoicing strategy. Thus, when the exporting country has a large market share in the sense that it can influence the industry price, demand uncertainty is reduced (and so is cost uncertainty) when all firms price in the same currency, since relative prices are constant. Therefore it is profitable for firms to follow a producer currency pricing strategy[8]; the short-run pass-through is therefore complete. On the other hand, when firms from many countries export to a foreign market, firms from countries with small market shares are also likely to follow a producer currency pricing strategy if firms from other countries do so. This has useful implications for the strategy of euro area exporters. With the adoption of the single currency, what matters for firms' invoicing decisions is the market share of the union as a whole and not that of individual countries; therefore producer currency pricing is likely to emerge as the dominant invoicing strategy by euro area exporters. In a similar vein, Devereux *et al.* (2004) adopt a general equilibrium model in which both pass-through and the exchange rate are treated as endogenous. They conclude that firms will tend to invoice in the currency of the country that is characterised by a lower volatility of money growth. Firms from countries with higher money growth volatility will experience

[6] These models give useful insights on the determinants of the first- and second-period price responses. The first-period response corresponds to short-run pass-through, while the second-period response to long-run pass-through.
[7] These characteristics tend to increase demand and cost uncertainty respectively.

more unstable marginal costs[9]; thus, they will price in the importer's currency and the short-run pass-through will be zero[10]. This is likely to be the case for the euro area imports, given that the European Central Bank pursues a stability-oriented monetary policy. Thus, the euro area short-run pass-through to import prices is linked to the emergence of the euro as a major currency of invoicing. Apart from the arguments mentioned so far, monetary network effects[11] tend to favour the emergence of the euro as a major invoicing currency (Hartmann, 1998).

As for the empirical evidence on the exchange rate pass-through, the countries that have mainly attracted the attention of researchers are the larger economies and especially those of the US, Japan and Germany. The majority of these studies analyse pass-through under the assumption of imperfectly competitive markets and attribute the finding of incomplete long-run pass-through to imperfectly competitive markets and to the existence of market power by firms.

The evidence for the euro area, though, is rather limited. The majority of the existing empirical studies adopt imperfect competition as the framework of analysis. It is generally found that both short-run and long-run pass-through is incomplete (e.g. Anderton, 2003 and Warmedinger, 2004). An exception is the study by Campa and Minguez (2004), which concludes that the long-run pass-through is complete for most of the industries and countries examined[12]. The few studies on the euro area also consider three other issues. One relates to the possibility of a different response of import prices of euro area member countries to the euro fluctuations[13]. The second relates to the possibility of differences in the pricing behaviour of the exporters to the euro area depending on their country of origin. Finally, some studies examine, among other things, whether a structural break in the pricing behaviour of exporters to the euro area has occurred and whether this is associated with the adoption of the euro.

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[8] In this model the firms prefer the invoicing strategy that reduces demand uncertainty and thus cost uncertainty. So when demand uncertainty is reduced the producer pricing strategy becomes attractive.

[9] The fraction of wages that are set after the exchange rate change is realised, is smaller than when more conservative monetary policies are followed.

[10] As mentioned above, cost uncertainty makes the local currency pricing strategy more attractive.

[11] The more a currency is used, the more transaction costs associated with its use are reduced.

[12] Only for France and Germany was long-run pass-through found to be incomplete.

[13] This is an important issue that is related to the source of inflation differentials among euro area member countries

With regard to the first issue, Campa and Minguez (2004), using data for the EMU member countries and 13 different one- and two-digit industries, find that the short-run pass-through differs across industries and countries. This result is considered to be an indication of the importance of industry characteristics in the determination of the exchange rate pass-through. The country's general macroeconomic conditions, i.e. inflation, seem to matter less. On the other hand, Warmedinger (2004), using aggregate import price data, finds that pass-through (which in his study is related to pricing-to-market effects) is different across euro area countries[14] both in the short run and the long run.

As to the second issue, Anderton (2003), using import prices for goods imported in the euro area from seven different non-euro area exporters and applying panel estimation techniques, finds that non-EU exporters pass through a larger amount of euro fluctuations to import prices compared with their EU competitors. This result is attributed to the establishment of the Single European Market and the consequent harmonisation of product standards that may have increased the price elasticity of demand and thus decreased market power of the EU exporters to euro area countries. Furthermore, he finds that US exporters to the euro area pass through nearly the full amount of the euro fluctuations to its import prices. The fact that large countries have greater monopoly power is put forward as a possible explanation for this empirical finding. Finally, there is no evidence in favour of the assumption that the adoption of the euro has caused a structural break in the pricing behaviour of the exporters to the euro area (e.g. Campa and Minguez, 2004 and Warmedinger, 2004).

Even though most of the empirical studies find that the short-run pass-through is incomplete, they do not try to relate it to the invoicing strategy of firms. Faruquee (2004) estimates a VAR model from which the impulse response functions for the euro area manufacturing import prices are derived. He concludes that the short-run pass-through is incomplete and thus manufacturing import prices of the euro area are predetermined in the short run. By performing calibrations which are based on a model that adopts the new open economy macroeconomics framework, he concludes that the pattern of import price pass-through in the euro area is consistent with a high degree of local currency pricing by exporters to the euro area.

[14] The countries used in the analysis are: France, Germany, Netherlands, Italy and Spain.

Another strand of the empirical literature on the euro area exchange rate pass-through focuses on consumer price pass-through, which is evidently of great importance for the European Central Bank that has a clear commitment to price stability. A change in import prices is likely to lead to a change in producer prices as euro area producers set their prices in line with their foreign competitors. Moreover, import prices are a part of consumer prices. In this context, the interest focuses not only on the impact of euro fluctuations on the euro area aggregate consumer prices, but also the impact of such fluctuations on the individual countries' consumer prices. Thus, exchange rate pass-through is also relevant for the analysis of inflation differentials in the euro area member countries. The studies of this category estimate Vector Error Correction Models (VECM) using aggregate import, producer and consumer prices[15]. They find that euro area consumer prices are not very responsive to euro fluctuations. This result holds for the individual countries' consumer prices (Hufner and Schroder, 2002). It should be kept in mind, however, that national consumer prices' responses to euro exchange rate changes are different even in the long run. Furthermore, the time profile of the responses obtained from impulse response functions appears to be different as well. Campa and Minguez (2004) conclude that the differential response of consumer prices across member states is related to the degree of openness of individual countries.

3. The model

In this section we provide a brief description of the model, developed in Brissimis and Kosma (2005), which will be used as the basis for our econometric estimations. The model considers the pricing and innovation decisions of oligopolistic foreign firms that compete with domestic firms in the importer's market. The firms produce a homogeneous product[16,17] and simultaneously choose both the amount of

[15] Some studies also include oil prices and a variable measuring the output gap to account for supply and demand shocks, respectively, which are likely to influence consumer prices. A short-run interest rate is also included to capture the impact of central bank's policy. The inclusion of a variable capturing the central banks' reactions is appropriate when central banks target consumer price inflation and thus try to insulate prices from exchange rate changes (Hufner and Schroder, 2002).

[16] Oligopolistic firms are considered to be homogeneous with respect to their main characteristics, i.e. cost structure, conjectural variations (capturing the firm's beliefs concerning the reaction of other firms to its decisions), proportion of investment in process innovation to output and effectiveness of this investment.

[17] As this model represents a first attempt to analyse the implications of investment in process innovation for pass-through, the simplest possible framework is adopted.

output produced and the amount of real resources directed towards process innovation[18]. We concentrate only on foreign firms' pricing and innovation decisions since the model structure implicitly assumes that domestic firms' decisions are unaffected by the exchange rate.

It is assumed that the unit cost of production[19] of the foreign firm is:

$c_j^* = c_j^*(x_j^*)$, where $x_j^* = a_j^* q_j^*$, or $c_j^* = c_j^*(a_j^* q_j^*)$ $(j = 1,....,n^*)$

x_j^* corresponds to total resources committed to innovative activity and α_j^* to their proportion to the foreign firm's output q_j^*[20]. The unit cost of production is, therefore, assumed to be dependent on the amount of cost-reducing investment; a higher commitment of resources to process innovation leads to greater cost reductions for the firm.

The profit function of the firm – expressed in the currency of the importer – is defined as follows:

$$\Pi_j^* = p(X)(1-\alpha_j^*)q_j^* - ec_j^*(a_j^* q_j^*)q_j^*, \qquad (j = 1,....,n^*) \qquad (1)$$

where p is the industry price, e is the exchange rate defined as the home currency price of the foreign currency, $X = Q + \sum_{j=1}^{n^*} q_j^*$ is the total supply in the importer's market and Q and $\sum_{j=1}^{n^*} q_j^* = Q^*$ the domestic and foreign firms' supply, respectively. According to this specification, only a part of the firm's total output is sold in the market, i.e. $(1-\alpha_j^*)q_j^*$[21]. The firm simultaneously chooses the quantity of

[18] Firms may also invest in product innovation. The incentive to adopt this investment is influenced by firms' strategic considerations related mainly to potential gains in terms of consumer loyalty. It is not influenced by firms' market share and the exchange rate, as does the incentive to adopt process innovation. Given that product innovation does not depend on the exchange rate, it is not expected to introduce any bias in the estimation of the pass-through elasticity in our model.

[19] The unit cost of production is assumed to be constant for every output level and equal to the marginal cost.

[20] We assume that the firm finances investment in process innovation from its own resources, i.e. using a proportion of its output, in order to abstract from the analysis of the impact of alternative ways of investment financing on the firm's innovation decisions.

[21] The term $\alpha_j^* p q_j^*$ captures the total cost of innovative activity, i.e. the revenue foregone, and as such it is subtracted from the firm's total revenue.

output q_j^* and the fraction of output α_j^* directed towards innovative activity, therefore, the two first-order conditions for profit maximisation are[22]:

$$\partial \Pi_j^* / \partial q_j^* = 0 \text{ and } \partial \Pi_j^* / \partial \alpha_j^* = 0$$

By summing up over n^*[23] each of the two optimality conditions, we obtain the profit-maximising conditions for the industry as a whole. The industry supply relationship is given by:

$$p = \frac{ec^*(1-\mu^*)}{(1-\alpha^*)(1-\beta^* s^*)}$$ [24] (2)

The proportion of investment in process innovation to output for the industry is given by:

$$\alpha_j^* = e\mu_j^* c_j^* / p \quad (3)$$

The price and the proportion of investment in process innovation to output are seen to be jointly determined. Solving the two equations (2) and (3), yields the reduced-form:

$$p = ec^* \frac{(1-\mu^*\beta^* s^*)}{(1-\beta^* s^*)} \quad (4)$$

$$\alpha^* = \mu^* \frac{(1-\beta^* s^*)}{(1-\mu^*\beta^* s^*)} \quad (5)$$

Taking logarithms of both sides of (4) and (5) and using linear approximations to the Taylor series expansion of the logarithms, the following estimable equations for the industry price (p) and process-innovation intensity (α^*) are obtained:

$$\ln p = \ln e + \ln c^* + (1-\mu^*)\beta^* s^* \quad (6)$$

$$\ln \alpha^* = \ln \mu^* - (1-\mu^*)\beta^* s^* \quad (7)$$

Equations (6) and (7) show that both the industry price (expressed in the currency of

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[22]The analysis here focuses on the supply decisions of foreign firms only. The profit maximisation problem of domestic firms can be formulated in a similar way, except for the presence of the exchange rate variable.

[23] n^* is the number of foreign firms.

[24] $\mu_j^* = -[\partial c_j^*(\alpha_j^* q_j^*)/\partial(\alpha_j^* q_j^*)][(\alpha_j^* q_j^*)/c_j^*(\alpha_j^* q_j^*)]$ is the (positive) cost elasticity with respect to the amount of output going to process innovation (it is a measure of the effectiveness of investment in process innovation). Finally, $\beta^* = \eta\theta^*/n^*$, where η the (positive) elasticity of market demand, i.e. $\eta = -(\partial X/\partial p)(p/X)$, $\theta_j^* = (\partial X/\partial q_j^*)$ is a parameter showing how the market supply reacts to the firm's own supply decisions, and s^* the foreign firms' market share, i.e. $s^* = Q^*/X$.

the importer) and process-innovation intensity depend on the effectiveness of investment in process innovation (i.e. the parameter μ^*). Also, the coefficients of market share in the two equations are equal in magnitude but of opposite sign.

Differentiation of (6) with respect to the exchange rate yields the following expression for the total exchange rate pass-through:

$$\varphi = \frac{\partial \ln p}{\partial \ln e} = 1 + \left(1 - \mu^*\right)\beta^* \frac{\partial s^*}{\partial \ln e} \tag{8}$$

The pass-through elasticity depends on the effectiveness of investment in process innovation, in the sense that, the higher this effectiveness is, the more pass-through will occur. For $\mu^* < 1$ and given that $\beta^* > 0$, if market share decreases following a depreciation of the exchange rate[25], the pass-through will be incomplete. It will, however, be larger than that obtained from models not assuming process innovation. Bernhofen and Xu (2000), for example, derive the following elasticity:

$$\varphi = \frac{\partial \ln p}{\partial \ln e} = 1 + \beta^* \frac{\partial s^*}{\partial \ln e} \tag{9}$$

This is based on the following industry supply relationship, obtained from a homogeneous-product oligopoly model:

$$\ln p = \ln e + \ln c^* + \beta^* s^* \tag{10}$$

Equations (9) and (8) differ in the factor $(1-\mu^*)$. Intuitively, a depreciation of the importer's currency by increasing exporters' cost (expressed in the currency of the importer) decreases their market share (this critically depends on the assumption that domestic competitors are unaffected by exchange rate changes); but process innovation reduces cost. The latter weakens the exchange rate-induced impact of market share on the pass-through elasticity. If $\mu^* = 1$, there will be complete pass-through. Finally, if $\mu^* > 1$, the price will rise proportionately more than the exchange rate change. The greater effectiveness of investment in process innovation leads to greater cost reductions. This effect tends to outweigh the exchange rate-induced impact of market share on the pass-through elasticity and thus reinforces the direct

[25] In an oligopolistic market structure framework a depreciation of the importer's currency increases the marginal cost of foreign firms and shifts their reaction functions inwards; their supply in the importer's market and their market share are thus reduced, i.e. $\partial s^* / \partial \ln e < 0$ (cf. Shy, 1996). However, when domestic firms' behaviour is also influenced by exchange rate changes, this argument may not hold.

cost effect of exchange rate changes. In conclusion, the pass-through elasticity can be not only less than or equal to one but also greater than one. However, exchange rate pass-through cannot be calculated by estimating equilibrium relationship (6) since an estimate of the exchange rate impact on market share is also required. Thus, a full system dynamic analysis must be adopted.

4. Empirical investigation

This section provides empirical evidence on the importance of interactions between the exchange rate, market share, innovative activity and price, as derived from the model of the previous section, for the determination of the exchange rate pass-through. The empirical investigation concentrates on the pricing and innovation decisions of US, Japanese and UK manufacturing firms exporting to three euro area countries: Germany, France and the Netherlands. The analysis is based on monthly observations for the period from 1988:1 to 2004:6.

How relevant is the above theoretical model for the analysis of the exchange rate pass-through? A few stylised facts can help illustrate this. First, the source countries under consideration have a significant market share in the euro area destination countries: over the sample period, US exports accounted, on average, for about 10 percent of each of these countries' imports, Japanese exports for 6 percent and UK exports for 9 percent[26]. Second, the three source countries are characterised by a high degree of technological sophistication: for the period 1988 to 2001, their R&D expenditure as a percentage of GDP was 2.6 percent for the US, 3 percent for Japan and 2 percent for the UK. Third, R&D effectiveness as proxied by the number of patents granted is also very high: for the period 1988 to 2000, the annual average number of patents was about 12 thousand in the US, 10 thousand in Japan and 2 thousand in the UK[27]. These features appear to be consistent with the hypotheses of the theoretical model which offers a more promising way of analysing exchange rate pass-through than do models of imperfect competition that rely solely on market power.

The main empirical implication of the theoretical model is that process-innovation intensity and price-setting decisions of exporting firms are simultaneously

[26] Market shares are calculated on the basis of data from Eurostat's Comext database.
[27] R&D expenditure and patent data, at annual frequencies, are from the Main Science and Technology Indicators of the OECD.

determined. The two reduced-form equations (6) and (7) are equilibrium relationships and as such can be estimated with the Johansen multivariate cointegration technique. Extensions of this methodology allow us to test restrictions on the equilibrium relationships, implied by theory (cf. Johansen and Juselius, 1992) and also obtain estimates of the short-run parameters of the model (Johansen and Juselius, 1995) and cumulative impulse responses; the latter give us an estimate of the long-run exchange rate pass-through, i.e. the total effect of changes in the exchange rate working through all interactions in the system.

4.1 Cointegration analysis

The Johansen technique involves the estimation of a vector error correction model (VECM) of the following form:

$$\Delta z_t = \Gamma_1 \Delta z_{t-1} + ... + \Gamma_{k-1} \Delta z_{t-k+1} + \Pi z_{t-k} + \Psi D_t + u_t \qquad (11)$$

This may be considered as a reparameterisation of an initial VAR model. Δ is the first-difference operator, z_t the vector of endogenous variables and D_t the vector of deterministic and/or exogenous variables, such as seasonal dummies. This specification contains information for both the short-run and the long-run relationships via the estimates of Γ_i and Π respectively. The matrix Π can be expressed as $\Pi = \alpha\beta'$, where α represents the matrix of the speed of adjustment parameters and β the matrix of long-run coefficients. The rank of the Π matrix – the number of cointegrating vectors – is determined by the trace and the maximum eigenvalue statistics proposed by Johansen (1988).

An important issue when testing for cointegration using the Johansen technique concerns the correct specification of the model's deterministic components and of the changes in the trend behaviour of the data, related to regime shifts. Zhou (2003) argues that failure to correctly specify the model's deterministic trends and capture changes in the trend components may bias the results towards rejecting cointegration[28]. This is of particular importance when euro area data are considered. The economic integration effects related to the Single Market Program are likely to have influenced the model's deterministic components. Zhou (2003) suggests that the

[28] The inability of Campa and Minguez (2004) to find cointegration among the variables used in their estimations may reflect the fact that they did not account for structural breaks in the trend behaviour of the data.

best modelling strategy is to split the sample into different sub-samples[29], specify for each sub-sample the model's deterministic components using the relevant tests and then test for cointegration. Given the nature of the economic integration process, the exact timing of the impact of the Single Market Program implementation cannot be known *a priori.* We therefore do not split the sample into different sub-samples but sequentially exclude observations from the end of the sample when cointegration (or reasonable relationships) among the variables used in estimation cannot be found for the entire sample and only stop when the number of cointegrating vectors implied by theory is established[30].

The econometric analysis involves the estimation of VAR models such as (11), for every exporting/importing country combination. This approach is preferred to the estimation of euro area wide import price equations since it avoids the heterogeneity biases that are likely to affect estimations when the individual countries' equations are characterised by parameter and/or dynamic heterogeneity (cf. Imbs *et al*., 2002). The vector of endogenous variables is: $z = \left[p \quad e \quad c^* \quad s^* \quad \alpha^* \right]$, where p corresponds to the bilateral manufacturing import prices (expressed in euros) of the euro area countries , e to the euro nominal exchange rate (defined as euros per foreign currency), c^* to the exporters' producer price indices used as a measure of foreign marginal cost, s^* to the ratio of the euro area country's manufacturing imports from each exporter to its total manufacturing imports, measuring market share and α^* to productivity used as an indicator of firms' process-innovation intensity[31,32,33].

[29] In his study of the interest rate linkages within the European Monetary System (EMS), Zhou splits his sample into three sub-samples corresponding to different degrees of EMS integration.

[30] For each sub-sample we specify the model's trend components on the basis of the so-called Pantula principle proposed by Johansen (1992), which constitutes a joint test of deterministic components and rank order (see Harris and Sollis, 2003).

[31] Alternatively, R&D expenditure could be used, but this may not be a good choice. First, it includes expenditure on both process and product innovation and this could be a source of size bias. Second, small firms and firms operating in traditional sectors of the economy do not have separate R&D departments or R&D budgets. However, they can still achieve cost reductions by acquiring knowledge from external sources (see Wakelin, 1998 and Basile, 2001). Third, data on R&D expenditure are available only infrequently. In view of these difficulties, it would be reasonable to capture firms' process-innovation intensity by using an indicator of the output of innovative activity, i.e. productivity. As noted by Calabuig and Gonzalez-Maestre (2002), productivity can be regarded as the output of process innovation.

[32] All variables are expressed in logs except for the market share variable.

Starting from the cointegration tests, the hypothesis that there are two cointegrating vectors cannot be rejected for any of the models estimated[34,35,36] (Table 1)[37]. The two vectors estimated correspond to the equilibrium relationships describing exporting firms' price-setting and process-innovation intensity decisions, which appear to be simultaneously determined. However, further testing is required in order to assess whether these two relationships are subject to the restrictions implied by the theoretical model.

We thus proceed with the identification of these two relationships by imposing and testing over-identifying restrictions[38]. These restrictions are the unit restriction on the exchange rate coefficient in the price vector and the exclusion restrictions on the coefficients of the exchange rate and the foreign marginal cost in the innovation-intensity vector. Acceptance of the unit restriction on the exchange rate coefficient in the first vector would imply that this coefficient may be considered as bias-free. The exclusion restriction on the exchange rate coefficient in the second vector implies that the impact of the exchange rate on innovation intensity is not direct but is transmitted through its impact on market share. The restricted long-run structure, thus, reads as follows:

$$\beta' = \begin{bmatrix} \beta_1' \\ \beta_2' \end{bmatrix} = \begin{bmatrix} 1 & -1 & \beta_{13} & \beta_{14} & 0 \\ 0 & 0 & 0 & \beta_{24} & 1 \end{bmatrix} \tag{12}$$

A further prediction of the theoretical model is that the market share coefficients in the two vectors should be equal in magnitude but of opposite sign. Therefore an

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[33] Before proceeding to the estimation of the models, we investigate the stationarity properties of the data by using ADF tests; these tests confirm that all of the variables used in estimation are $I(1)$ .The results are not reported but are available upon request.

[34] Pretesting indicated that the appropriate model specifications are those summarised in Table 2.

[35] Misspecification tests indicate the presence of non-normal error. However, this may not be a serious problem, as Cheung and Lai (1993) have shown that the trace test statistic is robust in the presence of non- normal errors.

[36] Autocorrelation tests also indicate that all models perform well. Even in the very few cases where the null of no autocorrelation is rejected at the 5 percent level of significance, it cannot be rejected at the 1 percent level of significance. Jacobson *et al*. (2002) argue that these specification tests are asymptotic and may thus suffer from size distortions in small samples. Inference at the 1 percent level of significance is therefore justified.

[37] It should be noted though, that in most models two vectors could not be found for the full sample (Table 2).

[38] Identification of the long-run structure can be attempted without imposing any restrictions on the matrices of the short-run parameters – Γ_i – or the speed of adjustment parameters – α – (see Pesaran and Shin, 2002).

additional cross-equation restriction is also imposed and tested on these coefficients and the new restricted structure becomes:

$$\beta' = \begin{bmatrix} \beta_1' \\ \beta_2' \end{bmatrix} = \begin{bmatrix} 1 & -1 & \beta_{13} & \beta_{14} & 0 \\ 0 & 0 & 0 & -\beta_{14} & 1 \end{bmatrix} \tag{13}$$

It should be noted though that the additional cross-equation restriction on the market share coefficients is not essential for the empirical validation of the model.

The results of the LR tests for the over-identifying restrictions, reported in Table 3, indicate that the theoretical model provides a good description of price-setting and innovation-intensity relationships in the case of Japanese and UK exporters to France and of Japanese and US exporters to the Netherlands, since the structure implied by (12) cannot be rejected; furthermore, the additional cross-equation restriction on the market share coefficients, implied by (13), cannot be rejected for the Japan-France and Japan-Netherlands models (Table 3). In the other models, although the price and innovation intensity of exporting firms appear to be simultaneously determined, the restrictions are not accepted[39,40].

Given that our sample covers the period of significant developments towards increased monetary integration, including the introduction of the single currency in 1999, which are likely to have influenced the stability properties of the long-run structure, we perform robustness tests on the estimated models. Two types of tests are applied. One looks at the stability of the estimated cointegrating vectors. In this test, plotted values of the recursively estimated eigenvalues are examined[41]. The other test investigates the stability of the over-identifying restrictions over time. It involves the recursive estimation of the LR-test statistic for the over-identifying restrictions, which is plotted at each point in time against the respective critical value. Since the stability of the restricted long-run structure does not exclude shifts in the freely varying

[39] The coefficients of the over-identified vectors (or just identified vectors for those models for which the over-identifying restrictions are rejected) are reported in Table 4.

[40] The market share coefficients in the price and the innovation-intensity vectors, reported in Table 4, correspond to the semi-elasticities of import prices and innovation intensity, respectively with respect to market share (as already mentioned, market share variables are not expressed in logs). The corresponding long-run elasticities are obtained by multiplying the market share coefficients in each vector by the respective average market share.

[41] Since a relationship exists between the eigenvalues and α and β, i.e. the matrices of the speed of adjustment parameters and of the cointegrating vectors respectively, any shifts or trends in the time path of the eigenvalues can be regarded as an indication of instability of α and/or β (see Hansen and Johansen, 1999).

parameters, the constancy of the individual unrestricted coefficients will also be tested by plotting the recursively estimated coefficients against their +/- 2SE bands[42].

Unsurprisingly, the recursively estimated models provide evidence of instability. As indicated by the recursively estimated eigenvalues[43] (Figures 1 to 9) the shift is found to have occurred at some point of time between 1997 and 2000 in most of the models. Specifically, the long-run price and innovation-intensity equations take the form predicted by the theoretical model prior to 1997 (this also holds for some of the models for which the restrictions are initially rejected for the full sample, i.e. the UK-Netherlands and US-Germany models); but after 1997, a shift in the estimated relationships seems to have occurred (Figures 10 to 25). Finally, the graphs of the recursively estimated individual unrestricted coefficients plotted against their +/- 2SE bands, also provide evidence of instability of the coefficients of the market share variables in both vectors; the instability appears at some point of time between 1997 and 2001[44]. The latter could be interpreted as providing evidence of changes in the relationship between market structure and firms' pricing and innovation-intensity decisions, an issue that must be investigated further.

Thus, the prices and innovation intensity of each of the three exporters to the euro area considered in this paper appear to be interdependent. Also, the results of testing over-identifying restrictions combined with the stability analysis indicate that, for most of the models the equilibrium price and innovation-intensity equations satisfy the restrictions implied by the theoretical model for the period up to 1997. Thereafter, the instability of the cointegrating equations reported here may reflect a structural shift in the euro area product market conditions related to the introduction of the single currency. Specifically, with the establishment of the monetary union, the number of import suppliers to individual euro area countries that are subject to exchange rate-induced changes in competitiveness has decreased substantially (cf. Campa and Minguez, 2004). Given that price-setting and innovation decisions of exporting firms depend to a significant extent on the nature of product market competition, non-euro area import suppliers are likely to have revised their strategies

[42] The recursive estimations are performed by conditioning on the full-sample estimates of the short-run parameters, which gives us sufficient degrees of freedom (cf. Hansen and Johansen, 1999).

[43] Considering that the process of monetary integration may have been effectively completed some time before the adoption of the euro, we choose 1995 or 1997 as the starting point of our recursive estimations.

towards becoming more competitive and less vulnerable to exchange rate-induced cost changes. Also, the euro depreciation in the first years after its adoption may also have induced non-euro area exporters to reconsider their competition strategies in order to avoid market share losses.

4.2 Short-run analysis

This section investigates the dynamics of exchange rate pass-through focusing on long-run pass-through (after all adjustments have taken place). The coefficient of the exchange rate in the price vector (Table 5) measures only the partial pass-through, derived from the price relation only, which excludes the effects working through other variables of the system and equilibrium relationships (cf. Adolfson, 2001). Thus, the models are now estimated as VECMs in which the restrictions imposed on equilibrium relationships are explicitly taken into account[45]. The long-run pass-through is then obtained from the cumulative impulse response to one percent change in the exchange rate. This analysis also enables us to draw a better picture of the time profile of the import price response (and of potential differences among exporters).

Before proceeding to the analysis of the results, an issue regarding the models' specification needs to be discussed. The general to specific procedure is followed by constraining to zero the coefficients of variables with very low levels of significance (see Gross and Schmitt, 2000 and Harris and Sollis, 2003). The LR-test statistics for the exclusion of the insignificant terms from the models, reported in Table 6, show that the estimated models[46] are correctly specified.

The results of the impulse response analysis indicate that the import price pass-through in the euro area countries examined ranges between 31 and 53 percent for most of the models estimated (Table 7), except for the US-France, Japan-Germany and UK-Germany models, where the pass-through is found to be rather low, between

[44] These graphs are not reported but are available upon request.
[45] When the sets of restrictions implied by (12) and (13) cannot be rejected for the larger part of the sample or the full sample (on the basis of the LR tests and the recursively estimated LR-test statistics) we use these over-identified vectors as error correction terms. For the cases where these restrictions are rejected for the full sample (US-France, Japan-Germany and UK-Germany models) we use the just-identified vectors as error correction terms.
[46] The models in differences are estimated with Full Information Maximum Likelihood. The Japan-France, Japan-Germany and Japan-Netherlands models are estimated with 1 lag. The UK-France, UK-Germany and UK-Netherlands models are estimated with 4 lags. The US-France, US-Germany and US-Netherlands models are estimated with 5, 3 and 3 lags, respectively.

12 and 16 percent (Table 7). Our pass-through estimates are comparable to those obtained by Anderton (2003) and Warmedinger (2004), but are lower than those of Faruquee (2004). The empirical analysis in these studies differs from ours in two respects. First, these authors use data at different levels of aggregation – euro area import price data (Anderton, 2003; Faruquee, 2004) or import price data at the country level but not disaggregated according to import suppliers (Warmedinger, 2004). Further, they do not account for the indirect effects exchange rates may have on exporting firms' cost structure and competitiveness. However, they include variables that account for competition from domestic firms (Anderton, 2003; Warmedinger, 2004) and for the feedback of import prices to domestic competitors' prices (Faruquee, 2004).

Another interesting result of the impulse response analysis relates to the positive relationship found between the import suppliers' market share and the exchange rate; this result holds for all models estimated except for the US-Netherlands model (Table 7). Interestingly, the larger the effect of the exchange rate on market share, the lower the degree of exchange rate pass-through (Table 7). As already indicated, we would expect a negative relationship between market share and the exchange rate if domestic producers are unaffected by the exchange rate. However, domestic producers may in fact be influenced by exchange rate changes directly due to their reliance on imported inputs, and/or indirectly due to their interaction with import suppliers (for a discussion see Marston, 2001). When domestic producers' competitiveness is also influenced by exchange rate changes, the relationship between exporters' market share and the exchange rate is not necessarily negative. The dependence of domestic producers' competitiveness on exchange rate changes and its implications for exchange rate pass-through is an issue that must be investigated further. Moreover, given that exporters' market share is a positive function of innovative activity (see Yamawaki and Audretsch, 1988), improved competitiveness may completely outweigh the impact of exchange rate changes on market share.

Also, impulse response functions provide a picture of the time profile of import price responses. A noticeably different behaviour among export suppliers emerges from these impulse responses. As to Japanese producers' pass-through, there is evidence of pass-through undershooting in the short run and, in particular, evidence of perverse pass-through. This may be due to either supply adjustment costs (Kasa,

1992) and capacity constraints[47] or to inelastic import demand and consumer switching costs (Tivig, 1996; Gross and Schmitt, 2002)[48]. However, most of these producers' pass-through occurs within the first year (Figures 26, 29 and 32). This also holds for UK exports to France (Figure 27). On the other hand, there is evidence of pass-through overshooting[49] in the short run in the case of UK exports to Netherlands and Germany (Figures 30 and 33) and US exports to all three destination markets (Figures 28, 31 and 34). This is an interesting result which may be related to Gross and Schmitt-type of explanations (Gross and Schmitt, 2000): exporters overreact in the short run but in the long run have to adjust their behaviour to the prevailing market conditions. Also, despite the initial overshooting, adjustment to the long-run value is rather immediate.

Finally, an issue of particular importance relates to whether euro area import prices are predetermined in the short run, i.e. whether they are sticky in local currency. This can be tested by imposing a zero restriction on the coefficient of the first lag of the exchange rate in the import price equations estimated in differences, i.e. by testing whether short-run pass-through is zero. For all the models estimated, the restriction that this coefficient is zero is accepted except for the US-France and Japan-Netherlands models (Table 8). Thus, there is evidence of a significant degree of local currency pricing at least among the major exporters to the euro area[50]. These results are in accordance with the results of Faruquee (2004) who also finds that euro area import prices are sticky in local currency. Indeed, Hartman (1998) reports that before 1998 a significant proportion of the individual euro area countries' trade was denominated in their currencies. This seems to hold and after the adoption of the euro probably due to the monetary network effects associated with the adoption of the

[47] Specifically, an appreciation of the currency of the importer is expected to lead to a reduction in the price of the imported good. But the appreciation increases the demand for the imported good and, if the supply does not increase due to the above-mentioned constraints, the price of the imported good may not decrease but will remain constant and even increase.
[48] Usually, when there are consumer switching costs and today's market share determines tomorrows' profits, foreign firms have an incentive to lower their prices, after an appreciation of the currency of the importer, since this will also increase their future profits. But when demand is inelastic, in the sense that market share is not very responsive to price changes, firms are likely to increase their prices as they value current profits more.
[49] Warmedinger (2004) also reports some kind of overshooting.
[50] The results for the US exporters should be interpreted with caution since these producers are normally expected to follow a producer currency pricing strategy. As to Japanese and UK exporters, it appears that they tend to follow a destination currency pricing strategy (Faruque, 2004).

single currency (Hartmann, 1998) and the stability-oriented monetary policy pursued by the European Central Bank (Devereux *et al*., 2004).

5. Conclusions

This paper examined the importance of interactions between the exchange rate, market share, innovative activity and price for the determination of the euro area exchange rate pass-through, focusing on the empirical implications of the model developed by Brissimis and Kosma (2005). The model considers an international oligopoly where exporting firms simultaneously decide on their pricing and investment in process innovation. The two equilibrium relationships, as derived from this model, that correspond to such decisions were estimated using the Johansen cointegration technique and data on manufacturing imports of three large euro area countries (Germany, France and the Netherlands) from three major non-euro area import suppliers (US, Japan and the UK).

The estimation results indicate that the pricing and innovation decisions are jointly determined, as predicted by the theoretical model. However, there are indications that there may still be other factors at work that influence the euro area import price pass-through. Moreover, robustness analysis of the equilibrium relationships shows that there are signs of instability since 1997. The adoption of the euro appears to have caused a structural shift in the market conditions non-euro area import suppliers face, in the sense that the number of their competitors that are exposed to exchange rate changes has been reduced significantly. In anticipation of this change and in order to safeguard their presence in euro area markets and be less vulnerable to exchange rate changes, non-euro area exporters are likely to have been reconsidering their pricing and innovation strategies.

The analysis of the impulse response functions further indicates that the degree of exchange rate pass-through to euro area import prices is rather low. Also, the negative relationship between import suppliers' market share and the exchange rate is not confirmed by the empirical analysis but instead a positive relationship is found. This result may have contributed to the lower than expected estimates of exchange rate pass-though. A negative relationship between market share and the exchange rate would be based on the assumption that domestic producers are unaffected by exchange rate changes. Our empirical findings appear to question the validity of this

hypothesis. Domestic firms in the euro area may also be exposed to exchange rate changes through their reliance on imported inputs and their interaction with the exporters. If this is the case, the model could be extended to account for the dependence of domestic producers on the exchange rate in order to correctly determine the degree of exchange rate pass-through. Finally, our estimation results show that euro area import prices are predetermined in the short run, i.e. they are sticky in local currency.

Appendix. Data definitions and sources

Bilateral manufacturing import prices, which are unit values expressed in euros (1995=100), are constructed from data obtained from the Comext database of the Eurostat. The euro bilateral nominal exchange rates are period averages and are taken from the International Financial Statistics (IFS) of the IMF. The Japanese, UK and US manufacturing producer price indices (1995=100) are obtained from the Main Economic Indicators of the OECD. Market share is the ratio of the manufacturing imports of France, Germany and Netherlands, from each of the three exporters, to their total manufacturing imports from the world. These data are also taken from Eurostat's Comext database. Manufacturing productivity is the ratio of each exporter's manufacturing production index to the corresponding employment index (1995=100); Source: Main Economic Indicators of the OECD.

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Table 1. Cointegration tests

Countries[1]	Trace test statistic[2] r=0	r=1	r=2
Japan-France	104.9 (87.3)	67.06 (63)	40.53 (42.4)
UK-France	111.9 (87.3)	67.93 (63)	35.57 (42.4)
US-France	97.06 (68.5)	50.31 (47.2)	26.57 (29.7)
Japan-Netherlands	122.9 (87.3)	72.45 (63)	42.33 (42.4)
UK-Netherlands	97.33 (68.5)	50.79 (47.2)	19.4 (29.7)
US-Netherlands	90.32 (68.5)	54.07 (47.2)	28.08 (29.7)
Japan-Germany	101.8 (87.3)	66.92 (63)	41.6 (42.4)
UK-Germany	102.4 (68.5)	51.04 (47.2)	20.55 (29.7)
US-Germany	111.7 (87.3)	66.57 (63)	42.26 (42.4)

Notes: 1. The first country name refers to the exporter and the second to the importer.
2. Numbers in parentheses are critical values at the 5 percent significance level.

Table 2. Models' specification

Countries[1]	Sample	Number of lags	Deterministic components
Japan-France	1988-2002	4	Linear trend in cointegrating vectors and constant in the VAR
UK-France	1988-2004	6	Linear trend in cointegrating vectors and constant in the VAR
US-France	1988-2004	5	Constant in the VAR
Japan-Netherlands	1988-2002	4	Linear trend in cointegrating vectors and constant in the VAR
UK-Netherlands	1988-2004	6	Constant in the VAR
US-Netherlands	1988-2004	3	Constant in the VAR
Japan-Germany	1988-2001	7	Linear trend in cointegrating vectors and constant in the VAR
UK-Germany	1988-1998	6	Constant in the VAR
US-Germany	1988-2002	4	Linear trend in cointegrating vectors and constant in the VAR

Note: 1. The first country name refers to the exporter and the second to the importer.

Table 3. Test of restrictions

Countries[1]	LR tests for the over-identifying restrictions	
	No cross-equation restriction imposed on market share coefficients [2]	Cross-equation restriction imposed on market share coefficient[2]
Japan-France	2.2253 (0.5270)	2.6202 (0.6232)
UK-France	5.4259 (0.1431)	No convergence
US-France	12.304 (0.0064)**	17.403 (0.0016)**
Japan-Netherlands	9.1287 (0.0276)*	9.3681 (0.0525)
UK-Netherlands	16.269 (0.0010)**	19.847 (0.0005)**
US-Netherlands	2.9558 (0.3985)	22.972 (0.0001)**
Japan-Germany	15.644 (0.0013)**	15.851 (0.0032)**
UK-Germany	20.848 (0.0001)**	29.283 (0.0000)**
US-Germany	33.224 (0.0000)**	31.713 (0.0000)**

Notes: 1. The first country name refers to the exporter and the second to the importer.
2. Number in parentheses are probabilities to accept the over-identifying restrictions.
**denotes rejection at the 1 percent significance level.
* denotes rejection at the 5 percent significance level.

Table 4a. Coefficients on cointegrating vector variables

	Japan-France[1]		UK-France		US-France	
	Price vector[2]	Innovation-intensity vector	Price vector	Innovation-intensity vector	Price vector	Innovation-intensity vector
p	1	0	1	0	1	0
e	-1	0	-1	0	-0.587 (0.195)	-0.211 (0.206)
c*	-4.628 (1.326)	0	-0.263 (0.395)	0	-4.603 (0.304)	-3.249 (0.322)
s*	8.057	-8.057 (3.423)	9.667 (4.545)	-26.430 (7.044)	-10.680 (2.774)	-6.689 (2.933)
α^*	0	1	0	1	0	1
trend	-0.0023 (0.0010)	0.0024 (0.00042)	-0.0012 (0.0009)	-0.0064 (0.0008)		
	Japan-Netherlands[1]		UK-Netherlands		US-Netherlands	
	Price vector[2]	Innovation-intensity vector	Price vector	Innovation-intensity vector	Price vector	Innovation-intensity vector
p	1	0	1	0	1	0
e	-1	0	-0.275 (0.205)	2.231 (0.569)	-1	0
c*	-2.123 (0.937)	0	-0.731 (0.236)	2.783 (0.655)	-1.303 (0.375)	0
s*	4.672	-4.672 (1.409)	3.402 (2.137)	15.459 (5.932)	-15.706 (3.468)	-20.651 (3.478)
α^*	0	1	0	1	0	1
trend	-0.0024 (0.0007)	-0.0018 (0.0003)				

Table 4b. Coefficients on cointegrating vector variables

	Japan-Germany [1]		UK-Germany		US-Germany	
	Price vector[2]	Innovation-intensity vector	Price vector	Innovation-intensity vector	Price vector	Innovation-intensity vector
p	1	0	1	0	1	0
e	-0.272 (0.153)	0.024 (0.177)	-0.204 (0.124)	0.570 (0.146)	-0.927 (0.371)	-0.138 (0.044)
c*	-0.512 (1.003)	-2.422 (1.143)	-0.0489 (0.163)	0.335 (0.191)	-0.374 (1.557)	0.655 (0.184)
s*	1.075 (5.129)	-12.356 (5.844)	6.023 (3.876)	1.653 (4.541)	2.904 (5.779)	-0.203 (0.682)
α^*	0	1	0	1	0	1
trend	-0.0044 (0.0015)	-0.0058 (0.0017)			-0.005 (0.0023)	-0.0045 (0.0003)

Note: 1. The first country name refers to the exporter and the second to the importer.
2. Numbers in parentheses are asymptotic standard errors.

Table 5. Exchange rate coefficient in the price vector

Countries[1]	
Japan-France	1
UK-France	1
US-France	0.59
Japan-Netherlands	1
UK-Netherlands	0.27
US-Netherlands	1
Japan-Germany	0.27
UK-Germany	0.20
US-Germany	0.93

Note: 1. The first country name refers to the exporter and the second to the importer.

Table 6. LR-test statistic for the exclusion restrictions on insignificant coefficients

Countries[1]	
Japan-France	X^2 (15) = 6.63387 (0.9670) [2]
UK-France	X^2 (35) = 14.4175 (0.9992)
US-France	X^2 (41) = 23.9898 (0.9843)
Japan-Netherlands	X^2 (19) = 10.5355 (0.9385)
UK-Netherlands	X^2 (52) = 38.2897 (0.9219)
US-Netherlands	X^2 (38) = 15.3747 (0.9996)
Japan-Germany	X^2 (15) = 5.53868 (0.9865)
UK-Germany	X^2 (44) = 25.3987 (0.9889)
US-Germany	X^2 (36) = 15.8416 (0.9986)

Notes: 1. The first country name refers to the exporter and the second to the importer.
2. Numbers in parentheses are probabilities to accept the exclusion restrictions.

Table 7. Cumulative change after 48 months

Countries[1]	Import prices (percentage change)	Market share
Japan-France	0.51	0.002
UK-France	0.53	0.002
US-France	0.12	0.02
Japan-Netherlands	0.47	0.002
UK-Netherlands	0.35	0.007
US-Netherlands	0.31	-0.002
Japan-Germany	0.14	0.007
UK-Germany	0.16	0.03
US-Germany	0.34	0.01

Note: 1. The first country name refers to the exporter and the second to the importer.

Table 8. Restriction on the short-run exchange rate pass-through

Countries[1]	Wald test statistic for the restriction on the short-run exchange rate pass-through
Japan-France	1.4792 (0.2239)[2]
UK-France	0.26548 (0.6064)
US-France	7.9898 (0.0047) **
Japan-Netherlands	6.8322 (0.0090) **
UK-Netherlands	2.4671 (0.1162)
US-Netherlands	3.0914 (0.0787)
Japan-Germany	2.1638 (0.1413)
UK-Germany	0.15705 (0.6919)
US-Germany	3.6996 (0.0544)

Notes: 1. The first country name refers to the exporter and the second to the importer.
2. Numbers in parentheses are probabilities to accept the restriction.
**denotes rejection at the 1 percent significance level.
* denotes rejection at the 5 percent significance level.

Recursively estimated eigenvalues

Figure 1. Japan-France model

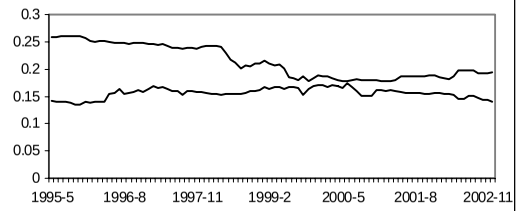


Figure 2. UK-France model

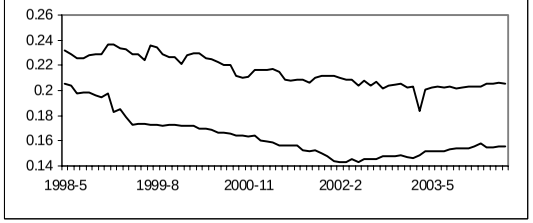


Figure 3. US-France model

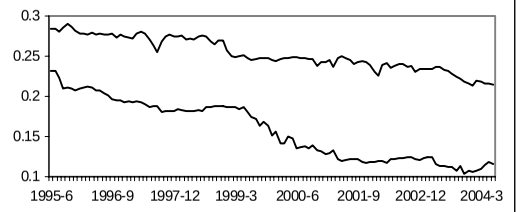


Figure 4. Japan-Netherlands model

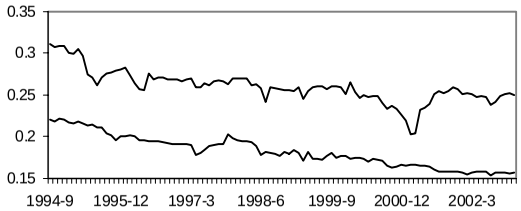


Figure 5. UK-Netherlands model

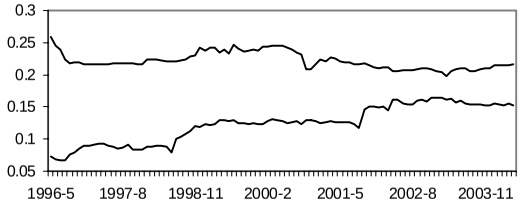


Figure 6. US-Netherlands model

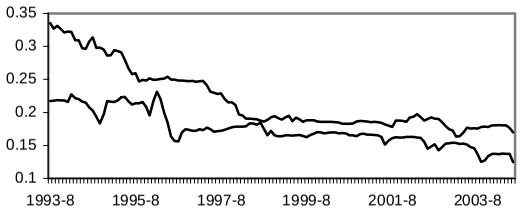


Figure 7. Japan-Germany model

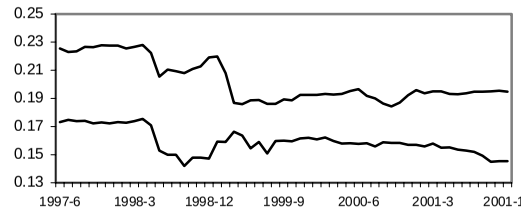


Figure 8. UK-Germany model

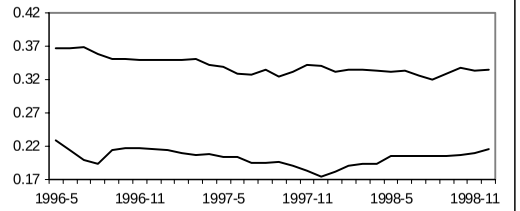
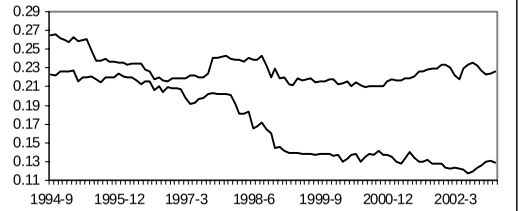


Figure 9. US-Germany model



Recursively estimated LR tests for the over-identifying restrictions

Figure 10. Japan-France model
No cross equation restriction imposed on market share coefficients

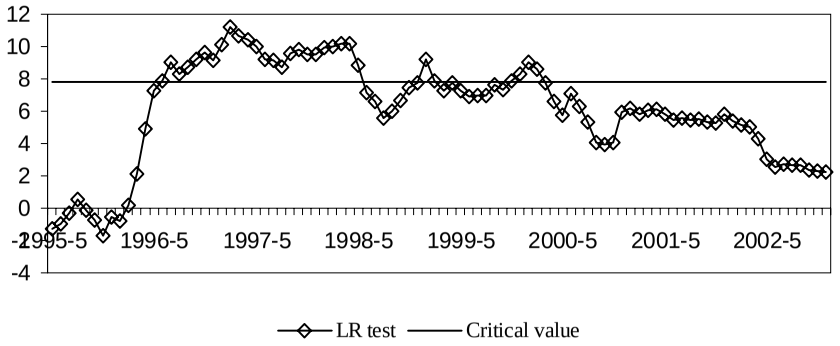


Figure 11. Japan-France model
Cross-equation restriction imposed on market share coefficients

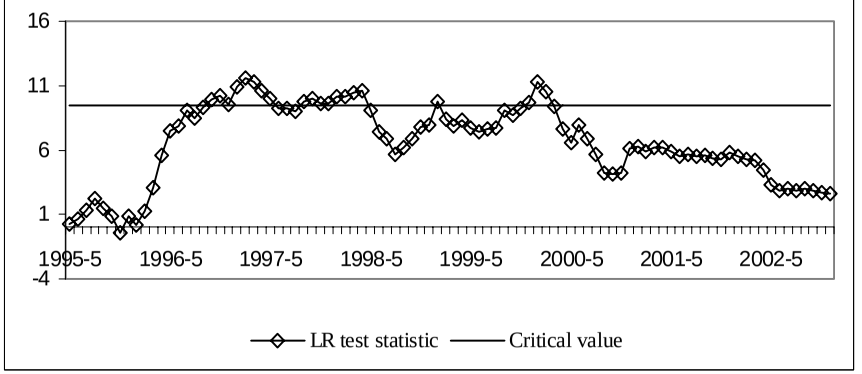


Figure 12. UK-France model
No cross-equation restriction imposed on market share coefficients

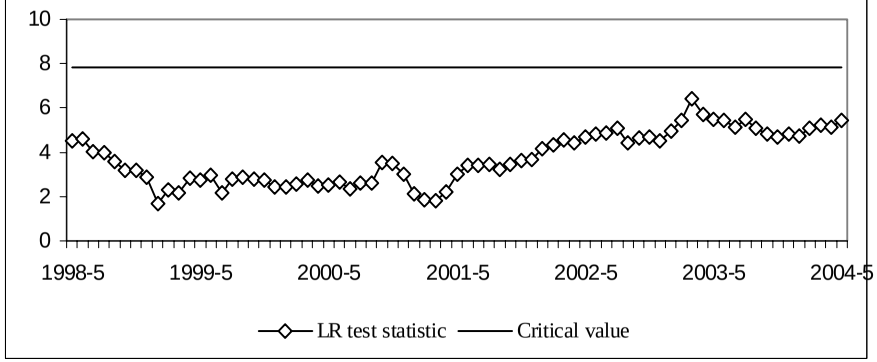


Figure 13. US-France model
No cross-equation restriction imposed on market share coefficients

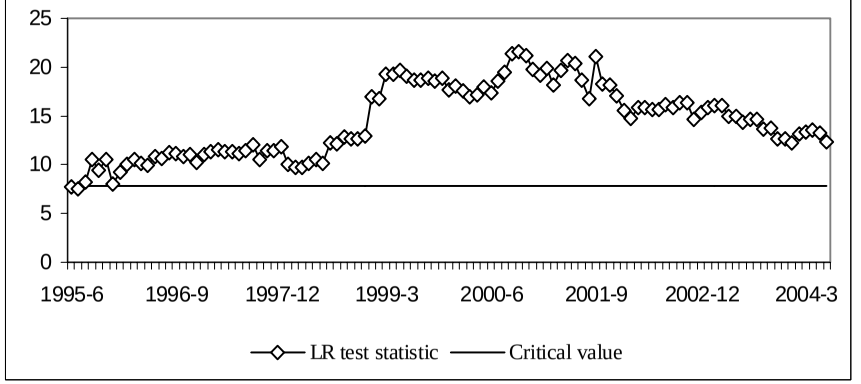


Figure 14. US-France model
Cross-equation restriction imposed on market share coefficients

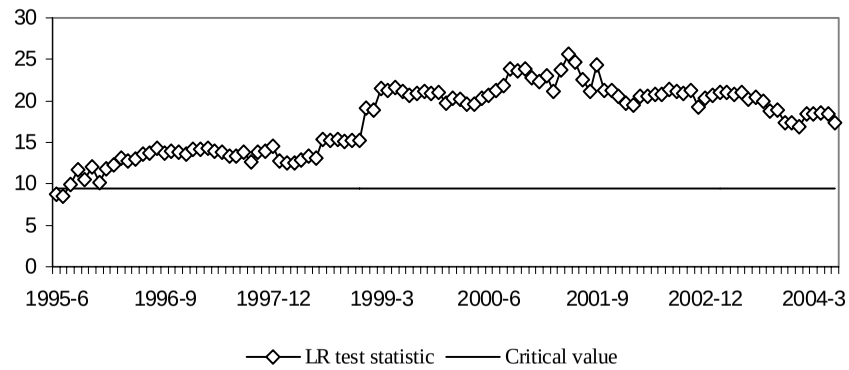


Figure 15. Japan-Netherlands model
No cross-equation restriction imposed on market share coefficients

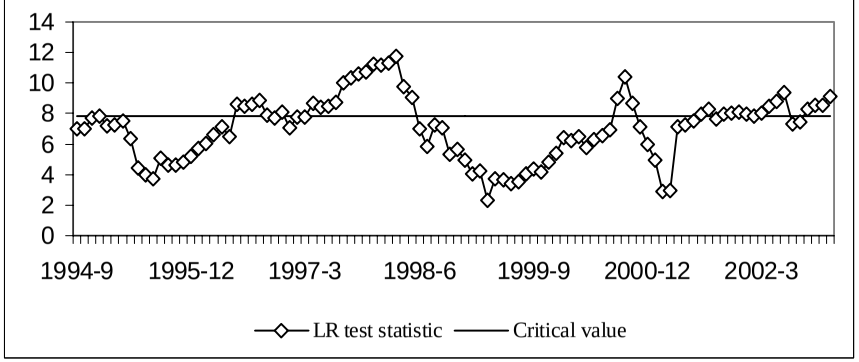


Figure 16. Japan-Netherlands model
Cross equation restriction imposed on market share coefficients

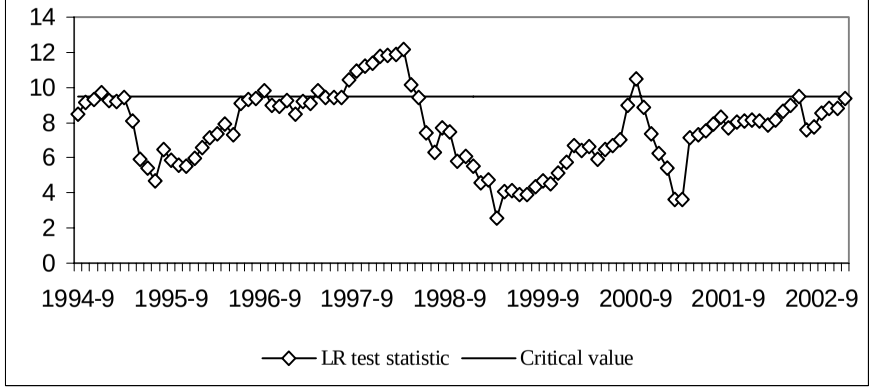


Figure 17. UK-Netherlands model
No cross-equation restriction imposed on market share coefficients

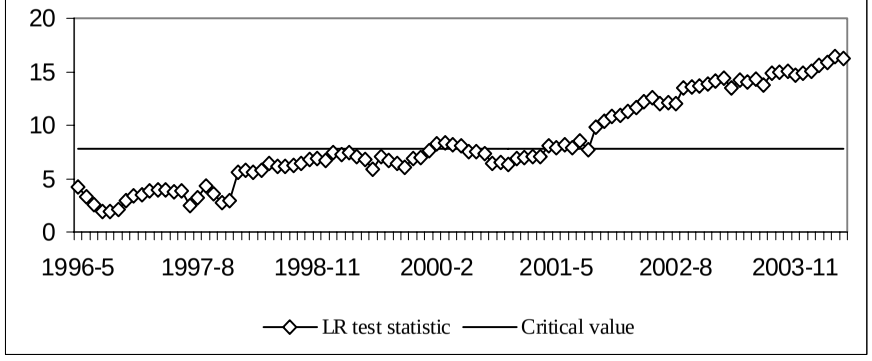


Figure 18. UK-Netherlands model
Cross-equation restriction imposed on market share coefficients

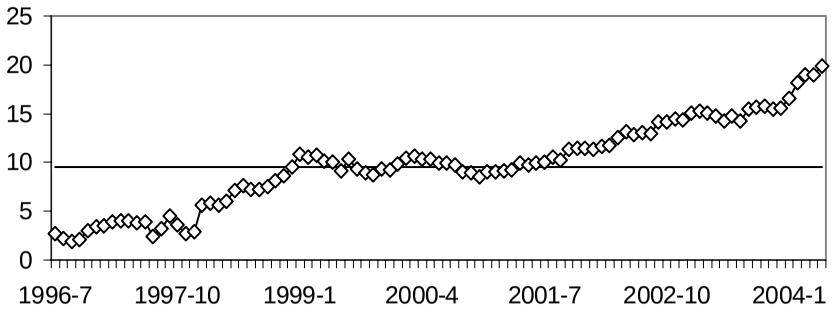


Figure 19. US-Netherlands model
No cross-equation restriction imposed on market share coefficients

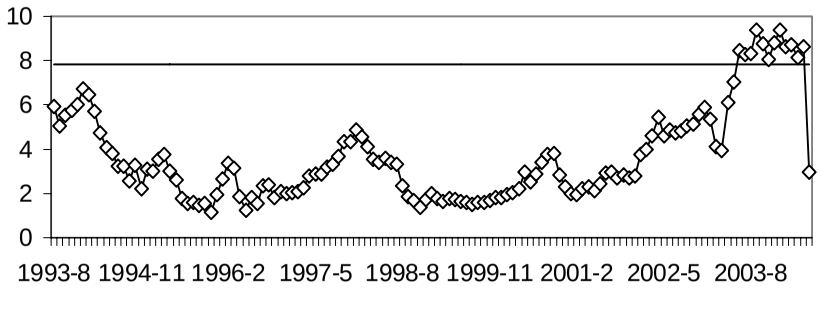


Figure 20. Japan-Germany model
No cross-equation restriction imposed on market share coefficients

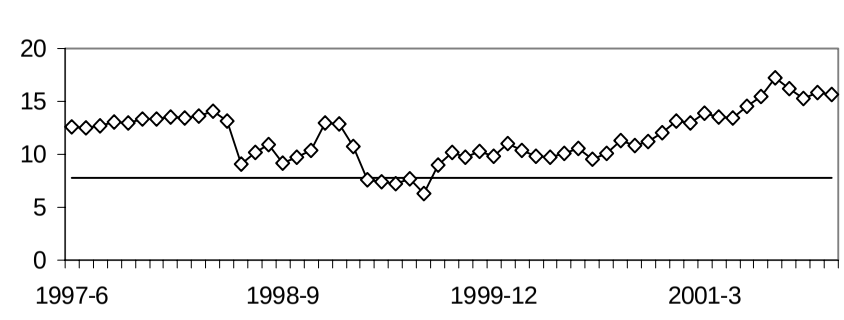


Figure 21. Japan-Germany model
Cross-equation restriction imposed on market share coefficients

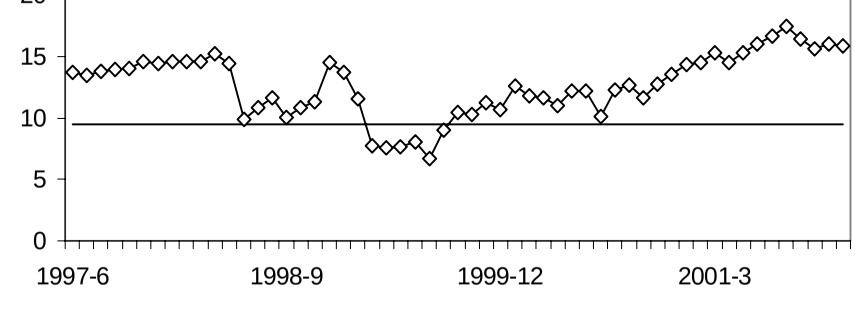


Figure 22. UK-Germany model
No cross-equation restriction imposed on market share coefficients

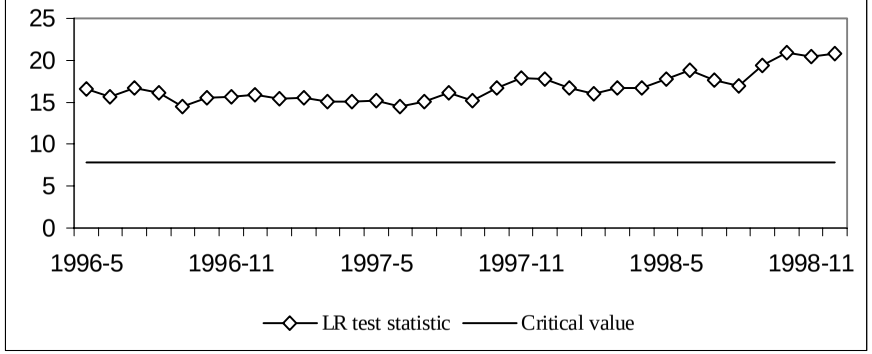


Figure 23. UK-Germany model
Cross-equation restriction imposed on market share coefficients

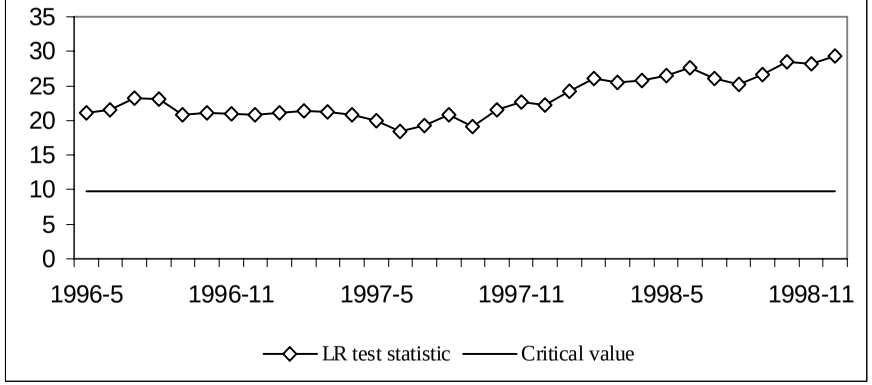


Figure 24. US-Germany model
No cross-equation restriction imposed on market share coefficients

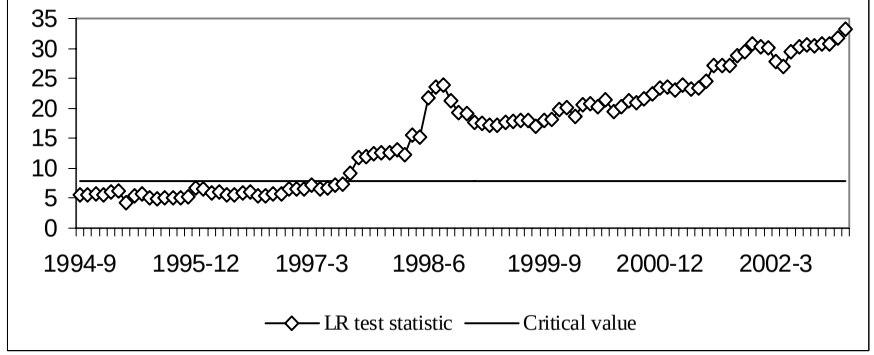
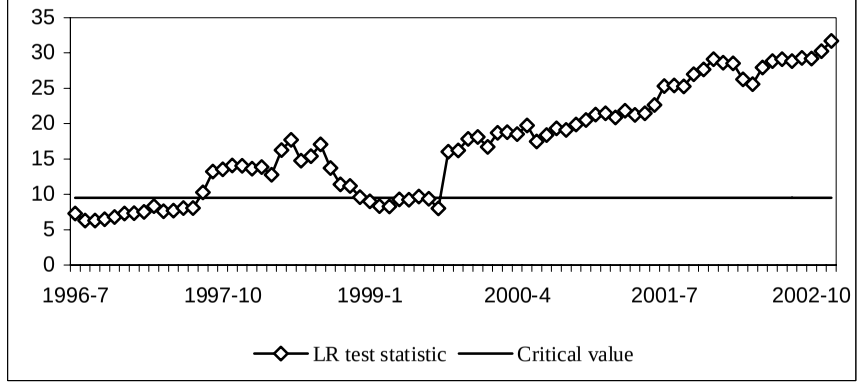


Figure 25. US-Germany
Cross-equation restriction imposed on market share coefficients



Impulse Response Functions

Figure 26. Japan-France model

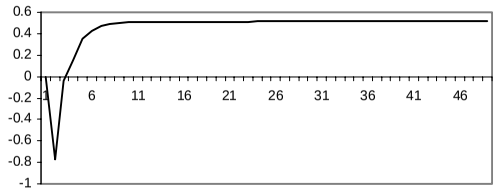


Figure 27. UK-France model

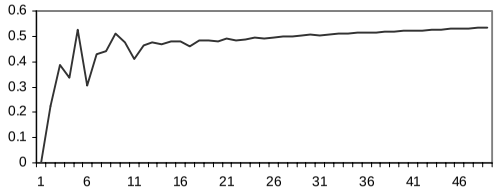


Figure 28. US-France model

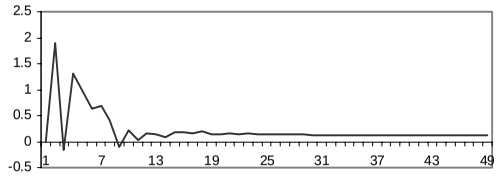


Figure 29. Japan-Netherlands model

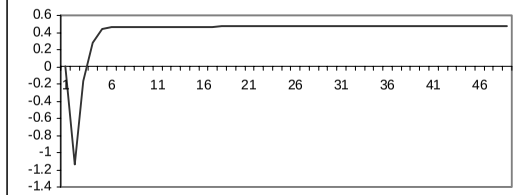


Figure 30. UK-Netherlands model

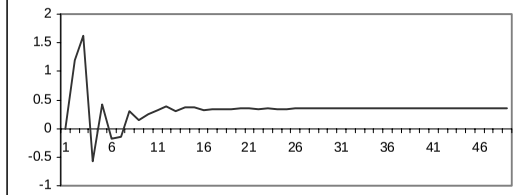


Figure 31. US-Netherlands model

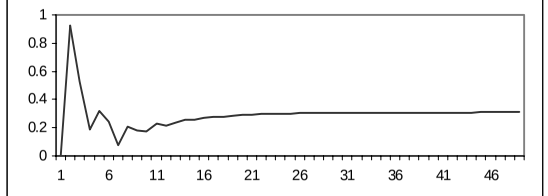


Figure 32. Japan-Germany model

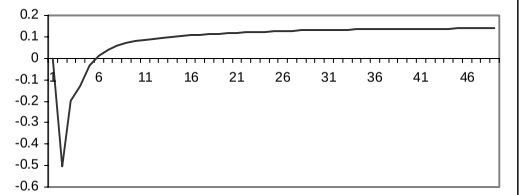


Figure 33. UK-Germany model

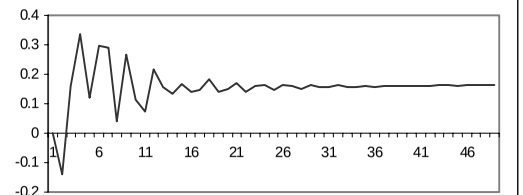
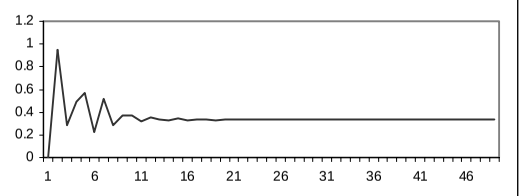


Figure 34. US-Germany model



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