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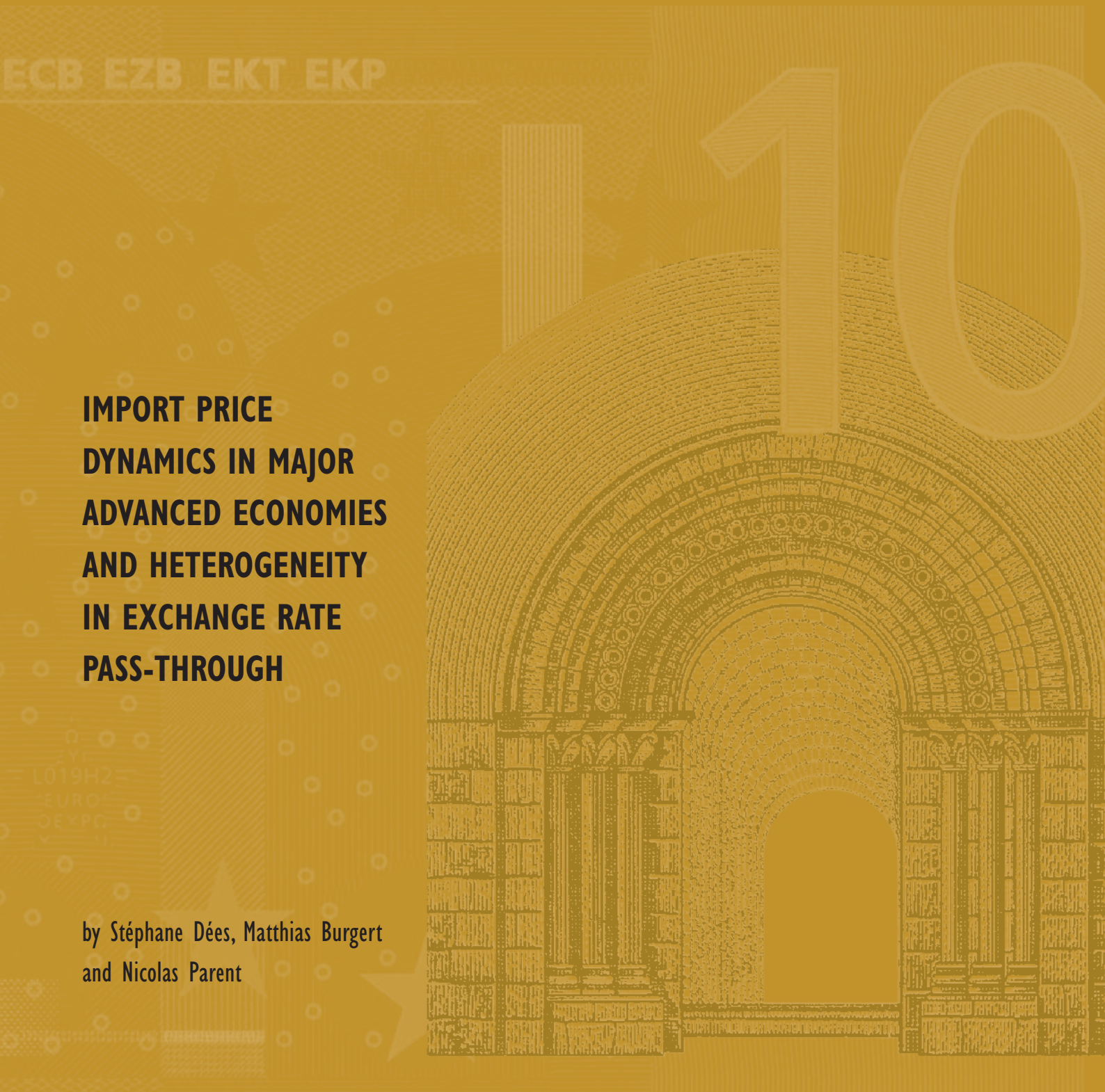

IMPORT PRICE DYNAMICS IN MAJOR ADVANCED ECONOMIES AND HETEROGENEITY IN EXCHANGE RATE PASS-THROUGH

by Stéphane Dées, Matthias Burgert and Nicolas Parent

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Abstract

This paper aims at showing heterogeneity in the degree of exchange rate pass-through to import prices in major advanced economies at three different levels: 1) across destination markets ; 2) across types of exporters (distinguishing developed economy from emerging economy exporters); and 3) over time. Based on monthly data over the period 1991-2007, the results show first that large destination markets exhibit the lowest degree of pass-through. The degree of pass-through for goods imported from emerging economies is also significantly lower than for those from developed economies. Regarding the evolution over time, no clear change in pricing behaviours can be identified and particular events, like large exchange rates depreciations during the Asian crisis, seem to influence the degree of pass-through related to imports from emerging economies.

Keywords: *Pricing to Market, Exchange rate pass-through, Import price modeling.*

JEL Classification: E31, F3, F41.

Non-technical summary

Several empirical studies show that exchange rate pass-through to import prices has declined in major advanced economies over the past decades. While the source of the decline in pass-through is difficult to identify, the period also corresponds to a rise in trade integration with emerging economies (EEs hereafter).

If the decline in exchange rate pass-through had been related to the increasing importance of EEs in major advanced economies' imports, this would suggest that EE exporters have a pricing behaviour that differs significantly from exporters from developed economies (DEs thereafter). Exporters from a given country may choose a different pricing strategy than exporters from another country as a result of differences in the composition of the goods that they export leading to different degrees of pass-through in the importer country. Also, because EE firms would like to gain market shares in the advanced economies, they would tend to follow a pricing-to-market behaviour when exporting to these markets. As a result, their exchange rate pass-through is lower as a way to remain competitive in these markets. Although one could argue the opposite by stressing that EEs export less sophisticated goods with lower profit margins and therefore have lower ability to buffer the impact of exchange rate changes. Competitive pressures can be so strong for some types of goods that firms are constrained by their competitors' pricing decisions.

Another important aspect concerns the different degree of pass-through across importing countries. The U.S. are shown to exhibit lower pass-through than other advanced economies. The relative importance of EEs in the composition of imports might partly explain these differences. The size of the market might also matter with exporters tending to follow higher pricing-to-market strategy to large and competitive markets (where a large number of exporters compete) relative to small and less competitive ones.

Based on monthly data over the period 1991-2007, this paper aims at showing heterogeneity in the degree of exchange rate pass-through to import prices

in major advanced economies at three different levels: 1) across destination markets ; 2) across types of exporters (distinguishing developed economy from emerging economy exporters); and 3) over time.

The results show first evidence of differences in exchange rate pass-though to import prices across major advanced economies. The U.S. has the lowest degree of pass-through, while Japan and Canada have the highest. Pass-through to European economies' import prices lies somewhere in between. This result has been explained by the tendency for exporters to adopt a pricing-to-market strategy for large, competitive markets like the U.S. These results also support the negative relationship between the share of imports invoiced in the local currency and the degree of exchange rate pass-through. Second the results show that the degree of pass-through for EE exporters is in general lower than for DE ones. Finally, no clear trend in the degree of pass-through (whether downwards or upwards) has been identified over the period considered (1991-2006). However, particular events, like large exchange rate depreciations during the Asian crisis, seem to have greatly influenced the degree of pass-through.

1 Introduction

Several empirical studies show that exchange rate pass-through to import prices has declined in major advanced economies over the past decades. For instance Ihrig et al. (2006) show that the G-7 economies experienced a numerical decline in the responsiveness of import prices to exchange rate movements between 1975-1989 and 1990-2004. This decline in the pass-through is for nearly half of them statistically significant. While the source of the decline in pass-through is difficult to identify, Marazzi et al. (2005) mention the increased presence of Chinese exporters in U.S. markets as a possible explanation[1]. Indeed, the 1990s also corresponds to a rise in trade integration with emerging economies (EEs hereafter). As shown in Figure 1, the share of U.S. imports coming from EEs has increased from 28% in 1990 to 47% in 2006. Similarly, in the same period, this share has increased from 21% to 38% in the euro area, from 39% to 60% in Japan, from 8% to 18% in the United Kingdom and from 7% to 19% in Canada.

[FIGURE 1 HERE]

If the decline in exchange rate pass-through had been related to the increasing importance of EEs in major advanced economies' imports, this would suggest that EE exporters have a pricing behaviour that differs significantly from exporters from developed economies (DEs thereafter)[2]. As underlined by Marazzi et al. (2005), exporters from a given country may choose a different pricing strategy than exporters from another country as a result of differences in the composition of the goods that they export leading to different degrees

[1] Marazzi et al. (2005) detect a particular step down in the pass-through coefficient around the time of the Asian financial crisis and document a shift in the export pricing behaviour of emerging Asian firms around that time.

[2] In this paper, the naming convention for the groups of economies is as follows: major advanced economies refer to the U.S., the euro area, Japan, the U.K. and Canada; developed economies (DEs) refer to the IMF classification of *World Economic Outlook* group named "Advanced Economies" (this group obviously includes the above major advanced economies) less the "Newly industrialised economies"; Emerging Economies (EEs) refer to the IMF classification of *World Economic Outlook* group named "Emerging and Developing Economies" plus the "Newly industrialised economies". An alternative grouping however envisages the case where the countries belonging to the group "Newly industrialised economies" are considered as DEs.

of pass-through in the importer country. In other words, because EE firms would like to gain market shares in the advanced economies, they would tend to follow a pricing-to-market behaviour when exporting to these markets. Also, their exchange rate pass-through is lower as a way to remain competitive in these markets. Although one could argue the opposite by stressing that EEs export less sophisticated goods with lower profit margins and therefore have lower ability to buffer the impact of exchange rate changes. Competitive pressures can be so strong for some types of goods that firms are constrained by their competitors' pricing decisions.

Another important aspect concerns the different degrees of pass-through across importing countries. The U.S. are shown to exhibit lower pass-through than other advanced economies. The relative importance of EEs in the composition of imports might partly explain these differences. The size of the market might also matter with exporters tending to follow higher pricing-to-market strategy to large and competitive markets (where a large number of exporters compete) relative to small and less competitive ones.

In the literature, most of the differences in pricing behaviours have been studied at the sectoral levels[3]. At the macro level, however, exchange rate pass-through coefficients are usually estimated with respect to an aggregate of a country's trade partners (e.g. Campa and Goldberg, 2005), without distinguishing across types of partners.

A few studies attempt however to estimate the role of EEs in the declining pass-through among major advanced economies. Using quarterly data on bilateral U.S. import prices, Marazzi et al. (2005) estimate country- or region-specific pass-through coefficients for the period 1991-2004 for different U.S. trade partners (EU, Japan, Canada and Asian NIEs). They do not find significant differences in exchange rate pass-through across U.S. trade partners and conclude that a shift in the geographical orientation of trade could be only a partial explanation for the decline in pass-through. To assess the potential differences in

[3] See for instance Gagnon and Knetter (1995), Yang (1997) Campa and Gonzalez Mingez (2006). For a more comprehensive survey, see Gaulier et al. (2006).

pricing behaviours between EEs and DEs, Vigfusson et al. (2007) and Bussière and Peltonen (2008) examine pass-through from the other side of the transaction by estimating the exchange rate sensitivity of export prices. Vigfusson et al. (2007) find that the prices charged on exports to the U.S. are more responsive to exchange rates than in the case of export prices to other destinations, which is consistent with results in the literature suggesting that import price pass-through in the U.S. market is relatively low. Bussière and Peltonen (2008) find that the degree of pricing-to-market in EEs is sizeable and increasing over time, consistent with the decline in pass-through in major advanced economies.

This paper aims at showing heterogeneity in the degree of exchange rate pass-through to import prices in major advanced economies at three different levels: 1) across destination markets ; 2) across types of exporters (distinguishing DE from EE exporters); and 3) over time. Based on monthly data over the period 1991-2007, the results show first that large destination markets exhibit the lowest degree of pass-through. Second, the degree of pass-through for goods imported from EEs is also significantly lower than for those from DEs. Finally, regarding the evolution over time, no clear change in pricing behaviours can be identified. However, particular events, like large exchange rate fluctuations during the Asian crisis, seem to influence the degree of pass-through related to imports from EEs.

The rest of this paper proceeds as follows: Section 2 provides a theoretical framework that serves as a basis for our empirical analysis. Section 3 presents the empirical evidence and discusses the results. Section 4 concludes.

2 Theoretical Framework

The observed low degree of pass-through of exchange rate changes to import prices is likely to be related to the fact that exporters may adjust their price to these changes in order to maintain their competitiveness in the destination market. Such a pricing-to-market behaviour (Krugman, 1987) is only possible in

imperfect competition as it requires that export prices are set above the marginal cost. Before reviewing the literature on heterogeneity in pricing behaviour, we present first the theoretical framework that we will use to model import price dynamics in the empirical part of our analysis.

2.1 Import price equation

Here we follow Betts and Devereux (1996, 2000) to derive import price determination. It is assumed that a share α of the exporters price their exports in their own currency (producer currency pricing - PCP) and the remaining exporters price their products in the currency of the importing country (local currency pricing - LCP). Moreover, frictions in the price setting process à la Calvo (1983) are introduced, i.e. only part of the exporters $(1-\zeta)$ are allowed to change their price in the current period. The aggregation of pricing behaviours over these two types of exporters gives the following import price Euler equation where import prices (p_t) depend on expected future import price inflation $(E_t\Delta p_{t+1})$ - discounted by a factor R -, current and expected future change in foreign exchange rates (Δs_t and $E_t\Delta s_{t+1}$) and on the real marginal costs of the exporters (mc_t)(see details of the derivation in Appendix 1):

$$\begin{aligned}\Delta p_t &= RE_t\Delta p_{t+1} + \left(\frac{(1-\zeta)(1-\zeta R)}{\zeta}\right)[s_t + mc_t - p_t] \\ &\quad +\alpha\left[\Delta s_t - RE_t\Delta s_{t+1}\right]\end{aligned} \tag{1}$$

The unknown parameters are the discount factor (R), the percentage of firms that can change their price $(1-\zeta)$, and the share of firms that price in producer currency (α).

We can use Eq. (1) to measure exchange rate pass-through by assuming that firms pricing in producer currency follow a full pass-through strategy while those that price in local currency do not pass through exchange rate changes in their export prices. The average degree of pass-through is therefore measured by α. This might contradict the assumptions of most models that currency choice is

exogenous, implying that exchange rate pass-through of PCP and LCP should equalise. However, such assumption is only justified in the very long-run, while α represents the short-term pass-through. Also, Gopinath et al. (2007) show empirically that exchange rate pass-through of PCP and LCP do not equalise even after most prices have had time to adjust.

2.2 Heterogeneity in pricing behaviour

Several New Open Economies models attempt to study the microeconomic foundations of trade price behaviours and explain the incomplete exchange-rate pass-through in terms of pricing-to-market. These models attempt to justify theoretically some heterogeneity in pricing behaviour. After a brief review of the literature, we provide some empirical evidence at the product level before concluding about what we could expect at the macro level in our empirical analysis.

2.2.1 Theoretical justification to incomplete pass-through

Heterogeneity might arise for three main reasons: conditions in the destination markets, the type of exporters (or exported goods) and the nature of the shocks underlying the exchange rate changes.

Heterogeneity across destination markets

Pricing-to-market is mainly explained as a pricing reaction to competitive pressures encountered by the exporting firm in the destination market. As argued by Taylor (2000), the strengthening of competition in the destination market forces firms to follow the market price, and therefore to absorb exchange-rate changes. Bachetta and Van Wincoop (2005) integrate the optimal invoicing choice at the level of the firm into a general equilibrium open economy model and find that the more competition firms face in foreign markets, as reflected in market share and product differentiation, the more likely they will price in the local currency.

Heterogeneity across types of exporters

The type of exporters (or the type of goods they export) can also explain partly heterogeneity in the degree of pass-through. In particular, the search for higher export market shares influences the firms' pricing behaviours. Feenstra et al. (1996) show that the pass-through elasticity "might initially decline as market share rises, but will increase towards unity as market share approaches 100 percent". Indeed, starting from a low enough market share, an increase in the exporter's market share gives the firm a wider room for manoeuvre to absorb exchange-rate changes through mark-up adjustments. If its initial market share is high however, a further expansion of it makes its market power so strong that its incentive to price-to-market decreases. Firms that are either small or new as exporters will therefore follow strategies to increase their market shares on mature markets and will tend to adopt pricing-to-market behaviours. Similarly, firms exporting goods that are supplied by many exporters, facing high competition on the destination markets, will follow pricing-to-market behaviours to maintain or gain market shares.

Importance of the nature of the shocks and time-varying dimension

Pricing strategies also depend on the nature of the shocks leading to changes in exchange rates. In a model with distribution costs, Corsetti and Dedola (2005) show that the degree of exchange rate pass-through depends on the type of shocks hitting the economy. Similarly, in a model in which firms' future demands depend on current market shares, Froot and Klemperer (1989) show that the pricing strategies (i.e. the magnitude and the sign of the pass-through) depend on whether exchange rate changes are thought to be temporary or permanent.

2.2.2 Empirical evidence at the product level

Heterogeneity in pricing behaviour has been shown empirically at a very disaggregated level. Gaulier et al. (2008) estimate pricing-to-market behaviours at the product level for a large number of countries. They show strong heterogeneity of pricing behaviours 1) across sectors, 2) across exporting countries

and 3) across destination markets. Their estimates suggest that destination-specific market structure affects the pricing strategy as exporters tend to follow pricing-to-market behaviour for large markets, while they tend to pass exchange rate changes into their prices when goods are exported to smaller markets or where their market share is large enough. This is consistent with Vigfusson et al. (2007), who find that the prices charged on exports to the U.S. are more responsive to the exchange rate than is the case for export prices to other destinations (which from the import side could explain why import price pass-through in the U.S. market is relatively low).

Gaulier et al. (2006) also find a strong heterogeneity of pricing-to-market coefficients across products and explain such heterogeneity either by the nature of the traded goods or by the markets' structures in which the goods are traded. More specifically, they find that pricing-to-market tends to be more pronounced for consumption goods than for capital goods. Consumption goods tend indeed to be more consistent with oligopolistic market structure, where firms try to remain in the market by adjusting their margins to exchange rate changes.

Although no empirical evidence in a time-varying dimension exists to our knowledge, many studies show that the degree of exchange rate pass-through changes over time. These changes might be related to the nature of the shock underlying the exchange rate changes. For instance, Vigfusson et al. (2007) find that moves in the exchange rate sensitivity of export prices over time have been significantly affected by country and region-specific factors, including the Asian financial crisis (for emerging Asia), deepening integration with the United States (for Canada), and the effects of the 1992 ERM crisis (for the U.K.).

2.2.3 What can we expect at the macro level?

First, in order to assess the importance of destination market size, Table 1 and Figure 2 show leading importers in world trade. The U.S. and the euro area are by far the two largest destination markets. We therefore expect high pricing-to-market for these two destinations and less so for smaller advanced

economies.

[TABLE 1 HERE]

[FIGURE 2 HERE]

Concerning the role of the types of exporters, Table 2 shows the revealed comparative advantages of EEs and DEs with respect to two broad types of goods, i.e. capital goods and consumption goods (following the U.N. Broad Economic Categories). The table shows that DEs tend to have comparative advantages in capital goods (Balassa index greater than one for these goods), while EEs would be more specialised in consumption goods. This therefore justifies the proposed grouping of countries (EEs and DEs) as they are specialised in different types of goods for which pricing behaviours related to exchange rate changes are different. Given Gaulier et al. (2006) results, we could therefore expect EEs to follow more the pricing-to-market strategy than DEs.

[TABLE 2 HERE]

Moreover, as shown in Table 1, out of the ten leading exporters, nine are DEs. We could therefore expect low pricing-to-market from exporters coming from DEs as their market shares are already sufficiently large. On the contrary, EE exporters would tend to adopt pricing-to-market strategy in order to increase their market shares in the advanced economies' markets.

Concerning the time-varying dimension, several empirical studies show that exchange rate pass-through to import prices has declined in major advanced economies over the past decades (e.g. Ihrig et al., 2006). This decrease in pass-through has been noticed mostly from the 1980s to the 1990s. As our analysis only concerns the period 1991-2007, we do not expect necessarily a further reduction in the degree of pass-through. However, as the theory shows that the rate of pass-through depends on the type of shocks, we expect to see noticeable changes over the period. Those changes should be evident at the aggregate level but also as regards the distinction between DEs and EEs. Table 2 also

shows the evolution over time of the Balassa index. While the overall results reported above still hold for the most recent period, some converging trends have emerged, with EEs losing slightly comparative advantages on consumption goods and gaining some on capital goods. These developments might be of relevance for our time-varying analysis.

3 Empirical results

The empirical analysis is conducted for the five major advanced economies: the U.S., the euro area (extra-euro-area trade only), Japan, Canada and the U.K., using monthly data on a sample from 1991 to 2007. Before showing the estimation results, we provide in Section 3.1 some details about the data used and about the construction of foreign price and exchange rate series. The empirical results have been conducted in two different steps. First, we estimate the parameters of the import price equation detailed above over the whole sample (Section 3.2). Second, to account for possible changes in the parameters, we estimate on a rolling window a simpler dynamic equation, linking changes in import prices to their own lags and the current and lagged values of the change in the (log) exchange rates and foreign prices (Section 3.3). Finally, we discuss the results in Section 3.4.

3.1 Data

The monthly series for import prices come from national sources (see Appendix 2 for exact definitions) and correspond to the price of imported goods excluding petroleum products or, in some cases, the price of manufactured goods. The exchange rate variable is an index of the national currency nominal value against the currencies of 27 partners weighted by their time-varying share in the country's total imports. As the measure of foreign costs, we use foreign headline CPIs, aggregated in a similar manner than for exchange rates[4]. Out of the 27

[4] As Marazzi et al. (2005), we use CPIs rather than PPIs because the CPI data are available for more countries and in longer time series.

foreign countries, 10 are considered as DEs and 17 as EEs. The complete list of countries is available in Appendix 2. The grouping follows the distinction between high-cost and low-cost countries defined in ECB (2006). As some EEs have moved during the period to DEs (like the Republic of Korea or Singapore), we also perform some robustness checks with an alternative grouping.

Figure 3 illustrates the data we use on a basis of year-on-year growth rates. The figure shows that import prices are much more volatile than foreign costs and some correlation with the exchange rate changes can be visually detected. The split of exchange rates between EEs and DEs also shows some differences in exchange rate changes across the two groups of countries.

[FIGURE 3 HERE]

In the theoretical framework, the variables in Eq. (1) are understood as (logarithm) deviations from their steady-state (see Appendix 1). In our empirical study, the variables are therefore detrended using a Hodrick-Prescott filter (smoothing parameter = 14400). Stationarity tests clearly reject the presence of a unit root in the term $[s_t + mc_t - p_t]$ as well as in the first differences of the dependent and independent variables for the five developed economies (see Appendix 3).

Other control variables are included in the estimation: commodity prices (to control for additional cost variables) and output gaps (to control for cyclical fluctuations), defined as the deviation of industrial production from a trend computed using a Hodrick-Prescott filter (smoothing parameter = 14400).

3.2 Estimation over the whole sample

3.2.1 Specification and estimation method

We estimate Eq. (1), defined in the theoretical framework, with maximum likelihood (ML).

We start by estimating Eq. (1) without distinguishing among the types of

exporting countries. As R, the discount factor, is close to unity, we set it equal to one[5] and estimate the remaining parameters ζ, and α.

Following Fuhrer and Rudebusch (2004), the ML estimation is conducted by solving for the expectations of import prices and exchange rates that are consistent with the rational expectations solution of Eq. (1). An unrestricted vector autoregressive (VAR) model for foreign marginal costs and exchange rates represents the dynamics of the rest of the model in a general, agnostic fashion. The VAR equations can be interpreted as a completing model. As Fuhrer and Rudebusch (2004), the completing model is a first-differenced VAR without feedback from import prices[6].

In other words, the model is represented by the system (2)-(3):

$$\begin{aligned} \Delta p_t &= RE_t \Delta p_{t+1} \\ &\quad + \left(\frac{(1-\zeta)(1-\zeta R)}{\zeta} \right) [s_t + mc_t - p_t] \\ &\quad + \alpha [\Delta s_t - RE_t [\Delta s_{t+1}]] + \varepsilon_t \end{aligned} \tag{2}$$

$$x_t = A x_{t-1} + \omega_t \tag{3}$$

where $x_t = [\Delta s_t, \Delta mc_t]'$. It is assumed that ε_t and ω_t are independently distributed and are serially uncorrelated with zero means and finite variances.

Then, the likelihood of the solved model can be computed for any set of parameters under the assumption that the innovations in the model are joint normally distributed with mean zero. The ML estimates are obtained using the algorithms for estimation of rational expectations models implemented in Dynare (Juillard, 2005).[7]

In a second step, we confront these results with another set of estimates

[5] To test whether $R = 1$ is a valid assumption, we re-estimate Eq. (1), with various values for R, varying between 0.9 and 1 with a step of 0.01. Looking at the value of the likelihood function, we verify that $R = 1$ corresponds to the optimum of the likelihood function, validating our assumption.

[6] When estimating the model using higher order VARs, the results remain very similar.

[7] Contrary to Bache (2006), the VAR is estimated together with the Rational Expectations equations with ML. Bache fixes the VAR coefficients at their OLS estimates prior to the ML estimations.

where the effective exchange rate (s_t) is split into a DE (s_t^D) and EE component (s_t^E), so that $s_t^D + s_t^E = s_t$. In this case Eq. (2) becomes Eq. (4):

$$\begin{aligned} \Delta p_t &= RE_t \Delta p_{t+1} \\ &+ \left(\frac{(1-\zeta)(1-\zeta R)}{\zeta} \right) [s_t^D + s_t^E + mc_t - p_t] \\ &+ \alpha^D \left[\Delta s_t^D - RE_t \left[\Delta s_{t+1}^D \right] \right] \\ &+ \alpha^E \left[\Delta s_t^E - RE_t \left[\Delta s_{t+1}^E \right] \right] + \varepsilon_t \end{aligned} \tag{4}$$

The procedure used to estimate the system (2)-(3) is also applied to the system (4)-(3).

3.2.2 Estimation results

The ML estimates of Eq. (2) are reported in Table 3.

[TABLE 3 HERE]

The Calvo parameter (ζ) is between 0.85 for the euro area and 0.96 for Japan. In terms of average duration of prices, the U.S. shows a price duration of 16 months. The average duration is lower for the U.K. (around 12 months) and for the euro area (7 months) and higher for Canada and Japan (more than 20 months).

The share of PCP firms is not significant for the U.S. and the euro area, confirming that large destination market should see more pricing-to-market (or LCP) behaviours from the exporters. These shares are higher and significant for the U.K. (around 25%), Japan (around 70%) and Canada (around 80%). It is important to note that in the Canadian case, the import price measures may artificially bias pass-through rate to the upside. The Canadian import price series suffer from measurement problems in that a number of Canadian import prices are constructed by multiplying the foreign currency price by the nominal exchange rate.

Estimating Eq. (4) allows us to distinguish between DE and EE exporters. These estimation results are reported in Table 4. In most cases, the share of PCP firms is higher for DE exporters than for EE ones although for the U.S., the share of PCP firms is not significant. The share of PCP firms in EEs is much higher for the other countries (between 30 and 45% for the euro area, Japan and Canada and around 100% for the U.K.). The share of PCP firms in DEs exporting to the euro area is negative and is less than 20% for the U.K. The share of PCP firms from DE exporting to Canada is close to 90%, reaching 100% for those exporting to Japan. The Calvo parameters are similar to those obtained with aggregated data.

[TABLE 4 HERE]

Finally, to investigate the issue of parameter instability over the period considered, we perform stability tests suggested by Ploberger and Krämer (1992), based on the maximal cumulative sum (CUSUM) statistic, which is similar to the CUSUM test suggested by Brown et al. (1975), although the latter is based on recursive rather than full-sample residuals. Tables 3 and 4 (column "PK test") show that we reject the presence of structural break in the sample considered.

3.2.3 Impulse responses

Although the share of PCP firms matters in determining the degree of exchange rate pass-through, it does not provide any information about the speed at which exchange rate changes affect import prices. Moreover, these estimates indicate the share of PCP firms within each group. To assess the effective degree of pass-through, we also need to account for the share of each group in total trade.

To go from the estimating shares of PCP firms to the degree of pass-through, we need to solve the rational expectation model represented by Eq. (2) and Eq. (3). In other words, if we call y the vector of endogenous variables, we need to find for the model $E_t\left[f\left(y_{t+1}, y_t, y_{t-1}, u_t\right)\right] = 0$ an unknown function,

$y_t = g(y_{t-1}, u_t)$ that could be plugged into the original model and satisfy the implied restrictions (the first order conditions). The function g is a time recursive (approximated) representation of the model that can generate time series that will approximately satisfy the rational expectation hypothesis contained in the original model. We derive g from Dynare for each estimation and use these functions to compute the dynamic response of import prices to an exogenous, permanent increase in exchange rates. These responses represent our measure of the exchange rate pass-through. We also compute error bounds by bootstrapping the model. The error bounds allow us to assess the degree of precision of the estimated responses and to check whether the estimated differences between DE and EE exporters' behaviours are significant.

Figure 4 shows these measures of the degree of pass-through for the five countries of the sample, together with the error bounds.

[FIGURE 4 HERE]

As found previously in the literature, the short-run pass-through is overall rather low in the United States. Overall, cumulating the two responses, the total degree of pass-through is around 5% after 6 months and around 60% after 2 years. It is higher for the other countries, where full pass-through is reached by the two-year horizon. Only the U.K. exhibits lower pass-through. The large error bounds however suggest that the estimates for the U.K. are surrounded by large uncertainty. The dynamics of the pass-through is also different across countries. It rises very fast in the euro area and to a lesser extent in Canada and the U.K., while it is more sluggish in Japan and the United States. This is also consistent with the estimates of the price stickiness as suggested by the Calvo parameter.

The dynamics of exchange rate pass-through are also different across groups of exporters. In all cases, import prices related to EE goods have a very low degree of pass-through, while DE-related pass-through responses are significantly higher in most cases.

3.2.4 Robustness checks

To check the importance of the grouping in our empirical analysis and also to account for the fact that some EEs at the start of our sample could now be considered as DEs, we have re-estimated the previous model with an alternative grouping. In this robustness check, two countries (Singapore and the Republic of Korea) have been included in the DE group. The results are presented in Appendix 4.

Table (11) shows that the results are not dramatically different from those obtained with the original grouping. The only noticeable difference concerns the share of PCP firms, which tends to be lower for EE firms exporting to the euro area, Japan and the U.K. (and even not significant for Canada), underlying that the Singapore and Korea might indeed have behaved more like DEs than EEs during the period. The main conclusions drawn from the previous results however remain.

3.3 Evidence on rolling regressions

While the findings reported above do not show any structural break, this does not mean that the import price determination has not been subject to any gradual changes over time. This leads us to adopt a more flexible approach, and estimate a simple dynamic equation linking import prices to their own lags and the current and lagged values of the change in the (log) exchange rates and foreign costs. We estimate such an equation on a moving window of six years. However, before showing the time-varying estimation, we start showing the full-sample results of this simple dynamic equation.

3.3.1 A simple dynamic equation for import prices

Although Eq. (2) is very close to our theoretical model and brings informative results, it remains constrained by the theoretical framework. Moreover, the large parameterisation prevents us from estimating it on shorter samples, a necessary

condition to time-varying estimations. This drawback is overcome with variants of this equation that are similar to the closed-form solution of the RE model (function g above) and closer to specifications usually found in the literature on exchange rate pass-through (see for instance Devereux and Yetman, 2002), where changes in import prices depend on changes in exchange rates and in foreign prices[8].

As above, we start with estimating equations without distinguishing between DE and EE exporters.

Following Marazzi et al. (2005), we estimate the following equation:

$$\Delta p_t = a_0 + \sum_{i=1}^{s} a_{1i}\Delta p_{t-i} + \sum_{i=0}^{s} a_{2i}\Delta s_{t-i} + \sum_{i=0}^{s} a_{3i}\Delta mc_{t-i} + v_t \qquad (5)$$

Given the lag structure (s is the number of lags), we can derive from this estimation a "long-run" pass-through coefficient $\widetilde{a}$ using the following formulas : $\widetilde{a} = \frac{\sum_{i=0}^{s} a_{2i}}{\left(1-\sum_{i=1}^{s} a_{1i}\right)}$.[9]

Table 5 gives the results obtained from estimating Eq. (5) and using 6 lags[10].

[TABLE 5 HERE]

The degree of pass-through ($\widetilde{a}$) is 22% in the U.S., 40% in the euro area, 58% in Japan, 77% in Canada and 44% in the U.K. Table 6 reports the results of tests for equality of pass-through across destination markets. We can see that we reject such an equality jointly. Bilateral equality can also be rejected except in the cases of U.S.-euro area, euro area-Japan, euro area-U.K. and Japan-U.K. Such results clearly show significant differences in the degree of pass-through to import prices across developed economies. The fact that we cannot reject

[8] De Bandt et al. (2008) are however sceptical about such specification and rather favour estimations including cointegrating relationships. As we have not been able to find any cointegrating relationships among the variables of our sample, we have disregarded such specifications.

[9] It is somehow abusive to call it "long-run pass-through" and it would rather be more correct to call it "pass-through after s periods".

[10] Alternative specifications omitting the lagged dependent variable have been also estimated. Different lag structures have also been tested. Overall, the results obtained are very close to those presented in the paper. The results of these alternative estimations are available upon request.

equality between U.S. and euro area as well as between U.K. and Japan could indicate that the degree of pass-through is very close for similar market's size.

As before, we estimate in a second step the same equations but by distinguishing DE and EE components in the right-hand-side variables . This allows us to estimate degrees of pass-through that are specific to the exporter type. These results are also reported in Table 5. $\widetilde{a}^D$ ($\widetilde{a}^E$) is in this case the long-run pass-through coefficient for DE (EE) exporters. The overall degree of pass-through ($\widetilde{a}^T$) is then the sum of $\widetilde{a}^D$ and $\widetilde{a}^E$.[11]

The results for the overall degree of pass-through ($\widetilde{a}^T$) are very similar to the results obtained when not distinguishing across types of exporters ($\widetilde{a}$). Confirming the results of the previous section, the estimates show however clear and significant differences between DE and EE exporters (see test results in column "diff" in Table 5). All the estimates show very low pass-through coefficients for EE exporters (not significantly different from zero). The degree of pass-through related to EEs is between 3% and 8% according to the countries considered, while the pass-through related to DEs is in all cases significant and varies between 15% and 74%.

[TABLE 6 HERE]

Testing for equality of pass-through among DE partners shows again significant differences across destination markets (Table 6). However, we cannot reject equality between pass-through coefficients for the same pairs as above.

When testing among EE partners, we cannot reject such equality in all cases. This result means that DE exporters might change their pricing strategy

[11] As in the estimations we now use two aggregated measures for the exchange rate and for the price level (i.e. distinction between DE and EE countries), we check whether possible co-movements of theses variables among high- and low-cost trading partners do not cause severe multi-collinearity. Appendix 4 shows that in all cases, the estimations should not be subjected to multicollinearity, except for the highest order lags in the models for the euro area and Japan.

according to the destination markets, while EEs adopt more pricing-to-market whatever market considered.

Of course the degree of pass-through depends on the share of DE/EE in total imports. Table 5 also reports the degree of pass-through within each category of firms (comparable to the share of PCP firms). In the U.S., the degree of pass-through is between 7% for EE and 24% for DE exporters after 6 months. The degree of pass-through of EE exporters is also very low in Japan (17%). For Japan, however, there is almost full pass-through for DE exporters. Concerning the euro area, 47% of DE firms pass through exchange rate changes, while this share for EE firms is around 30% after 6 months. The degree of pass-through of EE firms is the highest in Canada (54%). This is also the case for DE firms exporting to Canada (85%) but this elevated pass-through might simply reflect the problem in the measurement methodology for import prices in Canada. For the U.K., the pass-through from DE firms is 49% and 37% for EE firms.

Finally, we also perform robustness check according to the grouping chosen. Appendix 5 shows that the alternative grouping described above do not change dramatically the above results.

3.3.2 Estimations on a rolling window

The previous estimations have been realised over the full sample 1991-2007. To assess whether the pricing behaviours of firms have changed during this period, we have estimated the previous equations on a rolling window of six years (72 observations).

Concerning the pass-through parameters, we prefer showing the time-varying profile of the cumulated pass-through as computed from Eq. (5). In Figure 5, we show the dynamics of the pass-through over a six-month period[12]. Although, the exchange rate pass-through tends to increase with the number of lags, Figure

[12] To improve the readability of Fig. 5, we report only pass-through coefficients averaged over one year (i.e. the 1998 figures corresponds to the average of estimates over windows going from 1992M1-1998M1 to 1992M12-1998M12).

5 confirms that most of the impacts tend to occur in the first months following the changes in exchange rates.

[FIGURE 5 HERE]

We can also see that there is no clear trend in the change in pass-through parameters. For the euro area and the U.K., a downward trend observed up to the end of 2001 (i.e. 1996-2001) seems to have reverted in the subsequent periods. In Japan and Canada, a similar observation can be made regarding the degree of pass-through from EEs, which increased rapidly in the most recent periods. In the U.S., although the degree of pass-through remains the lowest among the five major advanced economies, no clear trend can be found. Some decrease in the pass-through parameters from the period ending in 2000 (i.e. 1995-2000) to the one ending in 2003 (i.e. 1998-2003) seems to have reverted since then.

Looking at the difference in the pricing behaviours between DEs and EEs, the pass-through tends to be much higher for the former category. This tends to remain so also when looking at the evolution over time. As shown before, no clear and common trend can be detected over the period considered. In the U.S., the degree of exchange rate pass-through for DEs has continuously decreased from the first period to the one ending in 2002 (i.e. 1997-2002). It has increased again in the most recent period. The opposite pattern can be found for EEs, whose exchange rate pass-through peaked in the period ending in 2002 (i.e. 1997-2002), decreasing significantly thereafter. A similar pattern can be found for the euro area. In Japan, we have already shown that the degree of pass-through is very high. It is also interesting to see that the pricing behaviours between DEs and EEs are reversed during the period considered, with a sharp decrease in the DE pass-through concomitant with a sharp increase in the EE pass-through. A sharp increase in the EE pass-through is also found for Canada (full pass-through for the most recent periods), while the DE pass-through remains elevated whatever period considered. The same observation

also applies for the U.K., where EE firms seem to have changed their pricing behaviour from low pass-through for most of the period considered to full pass-through in the most recent period.

3.4 Discussion of the results

The previous estimations give interesting results in terms of pricing of exports to major advanced countries. The results show that the pricing behaviours vary according to the destination, across types of exporters (DE vs. EE) and over time.

3.4.1 Differences in the degree of exchange rate pass-through across countries

First, the results presented above indicate differences in terms of import price stickiness as shown by estimates of the Calvo parameter. Our results show that the U.S., the U.K. and Japan exhibit high degrees of stickiness. The average duration derived from our estimates is around a year for the U.S. and the U.K. and around two years for Japan, while it is much shorter for the euro area and Canada (half a year). For the U.S., these results are in line with those found in the literature. For instance, using micro data on U.S. import prices for the period 1994-2005, Gopinath and Rigobon (2007) estimate the median import price duration to be 10.3 months. For the U.K., Bache (2006), using similar estimation techniques than those employed in this paper, also finds an average duration for import prices ranging between a year and a year and a half for the U.K.

Second, the estimates of the exchange rate pass-through also vary across countries. Our estimates show lower pass-through coefficients for the U.S. (less than 20%). The coefficients of pass-through into euro area and U.K. import prices are higher (between 40% and 50%) and the results for Japan and Canada show a very high degree of pass-through (between 60% and 85%). These results are in line with those found for instance by Campa and Goldberg (2005) and

Ihrig et al.(2006).

We have seen that differences in pass-through rates across countries could be related to the conditions in the destination market, especially in terms of size and competitive environment. These differences could also be related to the choice of the invoicing currency.

Gopinath et al. (2007) find for U.S. import prices that the pass-through into U.S. dollar (non-U.S. dollar) priced goods is close to 0 (1) in the short-run and is 0.14 (0.92) after 24 months. They show that conditioning on a price change, there is a large difference in the pass-through of the average good priced in U.S. dollars (25%) versus non U.S. dollars (95%). They also show that the aggregate level of pass-through varies substantially across countries. In short, the higher the share of local currency in the invoicing of imported goods, the lower the degree of pass-through.

Looking at estimates of the share of invoicing currencies, we can see that the percentage of imports priced in local currency is equal to 90% for the U.S. (Gopinath and Rigobon, 2007), 45% for the euro area (based on ECB, 2007), 40% for the U.K. (HM Customs and Excise, 2002), around 20% for Japan (Bacchetta and van Wincoop, 2002) and between 2 and 25% for Canada according to the industries considered (Donnenfeld and Haug, 2003). Our results are therefore consistent with previous findings by Bacchetta and van Wincoop (2002) or Otani et al. (2003), who also show the negative relationship between the share of imports invoiced in the local currency and the degree of exchange rate pass-through.

3.4.2 The role of the EEs on the degree of exchange rate pass-through

We find for most countries that exchange rate pass-through into import prices has been much lower for imports from EEs compared to those from DEs (Tables 4 and 5). Therefore, the combination of higher shares of these countries in the trade of major advanced economies together with their lower degree of pass-

through has certainly helped to keep overall pass-through relatively low.

Clear differences across major advanced economies however appear regarding the impact of EEs in the overall exchange rate pass-through. While the degree of pass-through from EEs to the U.S. is close to zero, it is between 30 and 40% in the other advanced economies considered.

Exchange rate regimes might also strongly affect the difference in pass-through coefficients first between DE and EE exporters and also between the U.S. and the other major advanced economies. The relative large share of EEs that have (or had during the period) a fixed peg vis-à-vis the U.S. dollar might indeed partly explain the fact that EEs have a degree of pass-through to U.S. import prices close to zero. In particular, this might have influenced the competitors of such countries in their pricing behaviours, as they might have been reluctant to pass through exchange rate changes in order to remain competitive on the major advanced economies' markets.

Concerning the pricing behaviours on other advanced economies, it appears that the size of the market plays a large role as regards the degree of pass-through of EE firms. While the degree of pass-through for the euro area remains relatively low, it is much higher in the relatively smaller advanced economies. The time-varying estimates also show that EE-related pass-through tends to increase in these economies in the most recent periods. This is clear in Canada and Japan, and to a lesser extent in the U.K. During the emergence of EEs as partners of advanced economies, the EE firms tend to follow pricing-to-market behaviours to gain market shares. On smaller markets, these market shares might reach more quickly a level where there is less incentives to gain further market shares and therefore less incentives to follow pricing-to-market strategy (as noted by Feenstra et al., 1996).

3.4.3 Changes in exporters' behaviours over time

While there is a wide consensus regarding the decline in the exchange rate pass-through between the 1980s and the 1990s, our empirical analysis does not

suggest any further decline during the 1990s-beginning of 2000s. Opposite patterns can even be noticed between DE and EE exporters. In particular, for the U.S. and the euro area, it seems that the exchange rate pass-through has decreased gradually up to the period ending in 2002-2003 (i.e. 1997-2003) before subsequently increasing. The profile for EEs is opposite with a gradual increase in exchange rate pass-through up to a peak reached when estimating the relationships over 1997-2003 and a decrease for most recent periods. It seems clear that periods including the Asian crisis tend to feature higher degree of pass-through for imports from EEs than those which exclude it. On the contrary, the degree of pass-through related to the DE exporters tended to decline during this period.

This result provides some evidence on the link between export pricing behaviours and the size of exchange rate changes. If the appreciation is very large, exporters may find it increasingly difficult to lower their prices since it implies falling profit margins. Analysing exchange rate pass-through to U.S. import prices for 30 industries, Pollard and Coughlin (2004) find that the size of the exchange rate change is more important than the direction of the change[13].

Consistently with this conclusion, our results show some correlation between the standard deviation of exchange rates and the degree of pass-through from EE exporters to U.S. import prices, and to a lesser extent to euro area import prices (Table 7). Some evidence can also be found for DEs exporting to the euro area and Japan. The link between the standard deviation of exchange rates and the degree of pass-through related to EEs is however negative for Japan, Canada and the U.K. Table 7 also shows the correlation between exchange rate changes and degree of pass-through. The very low correlation coefficients show that it remains difficult to identify any link between the direction of exchange rate movements and pass-through coefficients. Nevertheless, we do find some positive correlation between EE exchange rates and pass-through in the euro area, Japan, Canada and the U.K. In other words, an appreciation in EE exchange rates

[13] For the role of non-linearities and asymetries in exchange rate pass-through to trade prices, see Bussiere (2007).

would partly be associated with an increase in exchange rate pass-through. The results are more mixed for DE exchange rates.

4 Concluding remarks

In this paper, we have considered heterogeneity in the pricing of exports to major advanced economies at three different levels 1) across destination markets; 2) across types of exporters (distinguishing developed economy from emerging economy exporters); and 3) over time.

The results show first evidence of differences in exchange rate pass-through to import prices across major advanced economies. The U.S. has the lowest degree of pass-through, while Japan and Canada have the highest. Pass-through to European economies' import prices lies somewhere in between. This result has been explained by the tendency for exporters to adopt a pricing-to-market strategy for large, competitive markets like the U.S. These results also confirm the negative relationship between the share of imports invoiced in the local currency and the degree of exchange rate pass-through. Second the results show that the degree of pass-through for EE exporters is in general lower than for DE ones. This allows to break the assumption usually followed in the literature on exchange rate pass-through of homogenous behaviours in price setting. Finally, no clear trend in the degree of pass-through (whether downwards or upwards) has been identified over the period considered (1991-2006). However, particular events, like large exchange rates depreciations during the Asian crisis, seem to have greatly influenced the degree of pass-through.

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Tables and Figures

Table 1: Leading exporters and importers in world merchandise trade, 2006 (Billions of USD and percentage)

Rank	Leading exporters			Leading importers		
	Exporters	Value	Share	Importers	Value	Share
1	Germany	1112.0	9.2	United States	1919.4	15.5
2	United States	1038.3	8.6	Germany	908.6	7.3
3	China	968.9	8.0	China	791.5	6.4
4	Japan	649.9	5.4	United Kingdom	619.4	5.0
5	France	490.4	4.1	Japan	579.6	4.7
6	Netherlands	462.4	3.8	France	534.9	4.3
7	United Kingdom	448.3	3.7	Italy	437.4	3.5
8	Italy	410.6	3.4	Netherlands	416.4	3.4
9	Canada	389.5	3.2	Canada	357.7	2.9
10	Belgium	369.2	3.1	Belgium	353.7	2.9
11	Rep. of Korea	325.5	2.7	Hong Kong	335.8	2.7
12	Hong Kong	322.7	2.7	Spain	316.4	2.5
13	Russia	304.5	2.5	Rep of Korea	309.4	2.5
14	Singapore	271.8	2.2	Mexico	268.2	2.2
15	Mexico	250.4	2.1	Singapore	238.7	1.9
16	Taiwan	223.8	1.9	Taiwan	203.0	1.6
17	Saudi Arabia	209.5	1.7	India	174.8	1.4
18	Spain	205.5	1.7	Russia	163.9	1.3
19	Malaysia	160.7	1.3	Switzerland	141.4	1.1
20	Switzerland	147.5	1.2	Austria	140.3	1.1

Source: WTO.

Table 2: Revealed Comparative Advantage by type of goods and by market

Market	Type of goods	Developed Economies (DE)				Emerging Economies (EE)			
		1995	2000	2006	Av.95-06	1995	2000	2006	Av.95-06
US	Capital goods	1.06	1.07	1.15	1.07	0.66	0.79	0.89	0.81
	Consumption goods	0.86	0.88	0.91	0.89	1.75	1.37	1.06	1.36
euro area	Capital goods	1.08	1.09	1.17	1.08	0.84	0.86	0.93	0.89
	Consumption goods	0.70	0.74	0.79	0.77	1.61	1.42	1.09	1.33
Japan	Capital goods	1.23	1.23	1.08	1.15	0.72	0.79	0.96	0.86
	Consumption goods	0.74	0.69	0.88	0.80	1.31	1.28	1.08	1.18
Canada	Capital goods	1.04	1.05	1.07	1.06	0.71	0.73	0.82	0.77
	Consumption goods	0.89	0.89	0.86	0.87	1.80	1.72	1.31	1.55
UK	Capital goods	1.06	1.36	1.45	1.26	0.66	0.82	0.77	0.76
	Consumption goods	0.83	1.05	1.03	0.98	1.93	1.89	1.33	1.69

Source: COMTRADE, Authors' calculations Note: The Balassa index of revealed comparative advantage indicates that a country has a comparative advantage on a type of goods relative to its competitor on a particular market when the index is greater than one.

Table 3: Estimation results of Eq. (2) over 1991M01-2007M12

	Eq. (2) + VAR(1)		
Country	ζ	a	PK test
US	0.938***	0.012	0.56
euro area	0.852***	0.028	0.75
Japan	0.958***	0.676***	0.65
Canada	0.949***	0.820***	0.56
UK	0.914***	0.256***	0.40

***/**/* indicate significance at 1%/5%/10%. The critical value of the Ploberger-Krämer test is equal to 1.36 at 5%, under the null hypothesis of no structural break.

Table 4: Estimation results of Eq. (4) over 1991M01-2007M12

	Eq. (4) + VAR(1)			
Country	ζ	a^D	a^E	PK test
US	0.938***	0.049	-0.079	0.60
euro area	0.841***	-0.256**	0.443***	0.79
Japan	0.965***	1.031***	0.308***	0.73
Canada	0.903***	0.879***	0.477***	0.56
UK	0.924***	0.162***	1.059***	0.42

***/**/* indicate significance at 1%/5%/10%. The critical value of the Ploberger-Krämer test is equal to 1.36 at 5%, under the null hypothesis of no structural break.

Table 5: Estimation results of Eq. (5) over 1991M01-2007M12

	Eq. (5)	Eq. (5) with distinction DD/EE				Degree of PT within each group	
Country	$\widetilde{a}$	$\widetilde{a}^D$	$\widetilde{a}^E$	$\widetilde{a}^T$	diff	$\widetilde{a}^D/\delta_t$	$\widetilde{a}^E/(1-\delta_t)$
US	0.222***	0.151***	0.026	0.177	0.049	0.243	0.069
euro area	0.402***	0.344***	0.080	0.424	0.131	0.470	0.300
Japan	0.577***	0.514***	0.078	0.592	0.008	0.964	0.167
Canada	0.765***	0.742***	0.067	0.809	0.000	0.847	0.543
UK	0.435***	0.433***	0.045	0.478	0.001	0.493	0.373

***/**/* indicate significance at 1%/5%/10%. "diff " refers to the p-value of a Wald test for equality of $\widetilde{a}^D$ and $\widetilde{a}^E$.
Note: δ_t is the share of DE partners in total trade.

Table 6: Tests for equality of pass-through across destination markets

	Equality across $\widetilde{a}$				Equality across $\widetilde{a}^D$				Equality across $\widetilde{a}^E$			
	US	e.a.	Jap.	Can.	US	e.a.	Jap.	Can.	US	e.a.	Jap.	Can.
US	–	–	–	–	–	–	–	–	–	–	–	–
euro area	0.10	–	–	–	0.16	–	–	–	0.51	–	–	–
Japan	0.00	0.15	–	–	0.00	0.30	–	–	0.57	0.98	–	–
Canada	0.00	0.00	0.04	–	0.00	0.01	0.04	–	0.49	0.87	0.90	–
UK	0.01	0.77	0.14	0.00	0.00	0.56	0.52	0.00	0.78	0.69	0.73	0.74
joint	0.00				0.00				0.94			

p-values of a Wald test for equality of total pass-through among countries. "joint" refers to the p-value of the hypothesis of joint equality.

Table 7: Correlation between the standard deviation of exchange rates and the degree of pass-through estimated over rolling windows

	correl. (std(neer), pass-through)		correl. (delta(neer), pass-through)	
Country	DE	EE	DE	EE
US	-0.152	0.618	0.138	-0.060
euro area	0.136	0.222	-0.031	0.369
Japan	0.843	-0.679	-0.274	0.298
Canada	-0.451	-0.421	0.275	0.150
UK	-0.026	-0.730	0.012	0.357

Appendix 1 - Theoretical framework

Import prices are modelled following Betts and Devereux (1996, 2000). It is assumed that part of the exporters price their exports in the currency of the importing country (local currency pricing - LCP) and the remaining exporters price their products in their own currency (producer currency pricing - PCP). Moreover, frictions in the price setting process à la Calvo (1983) are introduced, i.e. only part of the exporters are allowed to change their price in the current period. The aggregation of pricing behaviours over these two types of exporters gives an import price Euler equation where import prices depend on expected future import price inflation, current and expected future change in foreign exchange rates and on the real marginal costs of the exporters.

An importer aggregates the various types of exports.

Aggregate imports

An importing firm aggregates the products of the exporter firms. The goods are produced in a number of varieties defined over a continuum of unit mass. Varieties of goods by PCP exporters are indexed by $j \in [0, \alpha)$ and those of LCP exporters by $j \in [\alpha, 1]$. Aggregate imports M is defined by:

$$M = \left[\int_0^{\alpha} M^P(j)^{-\rho} dj + \int_{\alpha}^{1} M^L(j)^{-\rho} dj \right]^{-1/\rho}$$

where M^i is the imports coming from the i exporter ($i = P, L$) and $1/(1+\rho)$ is the constant elasticity of substitution between the individual goods.

The aggregate import price P is defined by:

$$P = \left[\int_0^{\alpha} SP^P(j)^{\frac{\rho}{1+\rho}} dj + \int_{\alpha}^{1} P^L(j)^{\frac{\rho}{1+\rho}} dj \right]^{\frac{1+\rho}{\rho}} \quad (6)$$

where P^i is the import price corresponding to goods produced by exporter i ($i = P, L$), S is the bilateral exchange rate between the exporting country and the importing country. Assuming symmetric equilibria and log-linearising the

price equation (6) around the steady-state gives:

$$p_t = \alpha p_t^P + (1-\alpha)\, p_t^L + \alpha s_t \tag{7}$$

The cost minimisation implies the following demand functions:

$$M^i(j) = \left[\frac{P^i(j)}{P}\right]^{-\frac{1}{1+\rho}} M, \qquad i = L, P \tag{8}$$

Exporter price behaviours

Assuming imperfect competition, exporters price their products by taking into account the demand function (8). All firms share the same cost function $C(j)$, assumed to be homogenous of degree one in output. They also share the same discount factor $R_{t,t+k}$. Firms are assumed to change their price level when they receive a random "price-change signal" (see Calvo, 1983). Probability of receiving a price change signal is given by $1-\zeta$ ($\zeta \in [0,1]$). It is assumed to be identical to all (both LCP and PCP) firms[14]. Since there is a continuum of firms, $1-\zeta$ also represents the share of firms that has received such a signal and, consequently, got an opportunity to change their prices. The average time between price changes is given by $1/(1-\zeta)$. The firms' maximisation problem is as follows:

$$\max_{\left\{\overline{P}_t^i(j)\right\}} E_t \sum_{k=0}^{\infty} \zeta^k R_{t,t+k} \Pi_{t+k}^i \left[\overline{P}_t^i(j)\right], \qquad i = P, L \tag{9}$$

where $\Pi_{t+k}^i \left[\overline{P}_t^i(j)\right], i = P, L$ is momentary profits of a firm type i.

PCP firms

[14] This assumption has some empirical support. Using micro data for traded goods prices at the docks for the US, Gopinath and Rigobon (2006) find that the stickiness of prices invoiced in foreign currencies is similar to the stickiness of prices invoiced in dollars.

Given the momentary profits of PCP firms

$$\begin{aligned}\Pi^P_{t+k}\left[\overline{P}^P_t(j)\right] &= \overline{P}^P_t(j)M^P_{t+k}(j) - S_{t+k}C_{t+k}(j)M^P_{t+k}(j) \\ &= \left[\overline{P}^P_t(j) - S_{t+k}C_{t+k}(j)\right] S_{t+k}\left[\frac{S_{t+k}P^P_t(j)}{P_{t+k}}\right]^{-\frac{1}{1+\rho}} M_{t+k}\end{aligned} \tag{10}$$

the first-order-condition of the profit maximizing problem (9) is given by

$$\overline{P}^P_t(j) = -\frac{1}{\rho}\frac{E_t\sum_{k=0}^{\infty}\zeta^k R_{t,t+k}S_{t+k}P^{\frac{1}{1+\rho}}_{t+k}M_{t+k}MC_{t+k}(j)}{E_t\sum_{k=0}^{\infty}\zeta^k R_{t,t+k}S_{t+k}P^{\frac{1}{1+\rho}}_{t+k}M_{t+k}} \tag{11}$$

where $MC(j) = C'(j)$.

The aggregate price level P^P_t evolves according to the following equation of motion:

$$S_tP^P_t = \left\{\zeta\left(S_tP^P_{t-1}\right)^{\frac{\rho}{1+\rho}} + (1-\zeta)\left[S_t\overline{P}^P_t(j)\right]^{\frac{\rho}{1+\rho}}\right\}^{\frac{1+\rho}{\rho}} \tag{12}$$

Assuming symmetric equilibirum and log-linearising the Eq. (11) and Eq. (12) gives the Euler equation for PCP firms in high-cost countries.

$$\Delta p^P_t = RE_t\Delta p^P_{t+1} + \frac{(1-\zeta)(1-\zeta R)}{\zeta}\left(mc_t - p^P_t\right) \tag{13}$$

LCP firms

Given the momentary profits of LCP firm

$$\begin{aligned}\Pi^L_{t+k}\left[\overline{P}^L_t(j)\right] &= \overline{P}^L_t(j)M^L_{t+k}(j) - S_{t+k}C_{t+k}(j)M^L_{t+k}(j) \\ &= \left[\overline{P}^L_t(j) - S_{t+k}C_{t+k}(j)\right]\left[\frac{P^L_t(j)}{P_{t+k}}\right]^{-\frac{1}{1+\rho}} M_{t+k}\end{aligned} \tag{14}$$

the first-order-condition of the profit maximizing problem (9) is given by

$$\overline{P}^L_t(j) = -\frac{1}{\rho}\frac{E_t\sum_{k=0}^{\infty}\zeta^k R_{t,t+k}P^{\frac{1}{1+\rho}}_{t+k}M_{t+k}S_{t+k}MC_{t+k}(j)}{E_t\sum_{k=0}^{\infty}\zeta^k R_{t,t+k}P^{\frac{1}{1+\rho}}_{t+k}M_{t+k}} \tag{15}$$

where $MC(j) = C'(j)$.

The aggregate price level P_t^L evolves according to the following equation of motion:

$$P_t^L = \left\{ \zeta \left(P_{t-1}^L \right)^{\frac{\rho}{1+\rho}} + (1-\zeta) \left[\overline{P}_t^L(j) \right]^{\frac{\rho}{1+\rho}} \right\}^{\frac{1+\rho}{\rho}} \tag{16}$$

Assuming symmetric equilibrium and log-linearising the Eq. (15) and Eq. (16) gives the Euler equation for LCP firms.

$$\Delta p_t^L = RE_t \Delta p_{t+1}^L + \frac{(1-\zeta)(1-\zeta R)}{\zeta} \left(s_t + mc_t - p_t^L \right) \tag{17}$$

Aggregate import prices

Using the aggregation equation (7) and Euler equations (17) and (13), the aggregated import price equation is as follows:

$$\begin{aligned} \Delta p_t \quad = \quad & RE_t \Delta p_{t+1} + \left(\frac{(1-\zeta)(1-\zeta R)}{\zeta} \right) [s_t + mc_t - p_t] \\ & + \alpha \left[\Delta s_t - RE_t \Delta s_{t+1} \right] \end{aligned} \tag{18}$$

The Euler equation is the equation to be estimated. The unknown parameters are the discount factor (R), the percentage of firms that can change their price ($1-\zeta$), the share of firms that price in local currency (α).

Appendix 2 - Statistical annex

Import price series:

United States: Import price index in US dollar excluding petroleum products, not seasonally adjusted. Source: Bureau of Labor Statistics.

Euro area: Unit value index in euros for manufactured products (SITC 5 to 8), seasonally adjusted. Source: Eurostat

Japan: Import price index in Japanese Yen for "Other primary products & manufactured goods" (i.e. excluding Foodstuffs & feedstuffs, Textiles, Metals & related products, Wood, lumber & related products, Petroleum, coal & natural gas , Chemicals & related products and Machinery & equipment), not seasonally adjusted. Source: Bank of Japan.

Canada: Import prices for manufactured goods, balance of payments basis, seasonally adjusted, January 2005 = 100. Source: Bank of Canada

United Kingdom: Import price index in British Pound for manufactures less erratics (SITC 5 to 8), not seasonally adjusted. Source: National Statistics.

Foreign price series:

Foreign price series are derived from an aggregation of headline CPIs for 27 countries (Source: IMF International Financial Statistics- series 64). The weights are computing using country-specific import shares (time-varying computed as 3 year moving-average). The share are computed using bilateral trade weights (Source: IMF Direction of Trade Statistics). As the weights are available on an annual frequency, they have been linearly interpolated to obtain monthly weights.

The 27 countries considered are listed below:

10 developed economies (high-cost): euro area, United States, Japan, United Kingdom, Canada, Switzerland, Norway, Sweden, Australia and New Zealand.

17 emerging markets and developing economies (low-cost): Argentina, Brazil, Chile, China, Egypt, India, Indonesia, South Korea, Malaysia, Mexico,

Peru, Philipines, South Africa, Saudi Arabia, Singapore, Thailand and Turkey. As in ECB (2006), the low-cost countries also include 2 Newly Industrialised Economies (i.e. South Korea and Singapore) that were considered as emerging markets for most of the period.

Exchange rates:

Effective exchange rates are derived from an aggregation of nominal exchange rates in national currency (Source: IMF International Financial Statistics- series are converted in national currency using the value of the national currency in USD). The weights are computed similarly to foreign price series using the same geographic coverage and the same weighting schemes (see above).

Commodity price index:

The commodity price index include prices of raw materials belonging to categories 0 (Food and live animals), 1 (Beverages and tobacco), 2 (Crude materials, inedible, except fuels), 3(Mineral fuels, lubricants and related materials), 4 (Animal and vegetable oils, fats and waxes) and 68 (Non-ferrous metals) in the SITC (Revision 3) classification. (USD). Source: HWWA.

Output gaps:

Output gaps are computed as deviations of industrial production (Source: IMF International Financial Statistics) from a trend derived from a Hoddrick-Prescott filter (smoothing parameter = 14400).

Appendix 3 - Stationarity tests

Table 8: ADF (1st line) and KPSS (2nd line) Tests for Dependent Variables

	US	euro area	Japan	Canada	UK
Δp	-10.710	-10.681	-11.196	-11.789	-14.799
	0.041	0.031	0.033	0.060	0.023
relative prices	-4.935	-4.448	-3.657	-6.708	-4.037
	0.045	0.058	0.045	0.051	0.033
Δs^H	-10.069	-9.929	-10.625	-11.544	-11.767
	0.038	0.030	0.030	0.097	0.023
Δs^L	-11.175	-9.964	-10.912	-12.944	-10.171
	0.033	0.027	0.043	0.032	0.028
Δmc^H	-11.289	-4.194	-10.803	-11.961	-4.385
	0.250	0.271	0.123	0.240	0.500
Δmc^L	-3.417	-4.864	-4.565	-3.457	-5.101
	0.063	0.146	0.035	0.045	0.198
Δs^{H*}	-9.901	-9.886	-10.475	-11.540	-11.656
	0.037	0.030	0.027	0.099	0.023
Δs^{L*}	-11.046	-10.022	-11.071	-12.451	-10.102
	0.030	0.027	0.040	0.050	0.037
Δmc^{H*}	-11.241	-4.065	-10.707	-11.963	-4.371
	0.247	0.274	0.096	0.265	0.490
Δmc^{L*}	-3.475	-4.693	-4.473	-3.533	-4.100
	0.056	0.135	0.037	0.058	0.142
Δp_c	-12.326	-12.480	-12.073	-12.372	-13.340
	0.041	0.041	0.040	0.039	0.049
output gap	-4.752	-7.177	-4.537	-5.540	-4.319
	0.051	0.0212	0.031	0.032	0.034

Critical values	1%	5%	10%
ADF	-3.47	-2.88	-2.58
KPSS	0.74	0.46	0.35

Note: "relative price" refers to $\left[(\alpha+\beta)\left(s^H+mc^H-p\right)+(1-\alpha-\beta)\left(s^L+mc^L-p\right)\right]$, Δp_c denotes price changes of total primary commodities. The "*" means that the corresponding variables have been pre-multiplied by the share in total imports as defined in equation (4).

For the Augmented Dickey-Fuller (ADF) test, the null hypothesis is: the series has a unit root.

For the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test, the null hypothesis is: the series is stationary. See Kwiatkowski et al. (1992).

Appendix 4 - Multicollinearity tests

To check whether possible co-movements of aggregated exchange rates and prices between high- and low-cost countries do not cause severe multi-collinearity, we report in this appendix two measures of multicollinearity: the Variance Inflation Factor (VIF) and the condition number.

Variance Inflation Factor (VIF)

The VIF of the ith independent variable is given by $\text{VIF}_i = \frac{1}{1-R_i^2}$, where R_i^2 is the coefficient of determination of the auxiliary regression of the ith independent variable (i. e. the ith independent variable regressed on the remaining independent variables). The VIF is the reciprocal of the tolerance, whereas the tolerance represents the proportion of variance in the ith independent variable not being related to the other independent variables in the model. The VIF is therefore a reasonable measure for the degree of multi-collinearity. A widely applied rule of thumb is $\max_{i=1,\ldots,K}(\text{VIF}_i) \leq 5$ (with K the number of independent variables).

In Table 9, we report the maximum of the VIF among countries for Eq. (5) The results indicate that multi-collinearity should not be a concern in the models for the US and the UK. However, interpretations drawn from the models with higher lag order on the euro area and on Canada and Japan should be treated with caution.

Table 9: Maximum of VIF for equation (5)

	number of lags					
Country	1	2	3	4	5	6
US	1.47	1.70	1.95	2.00	2.23	2.37
euro area	2.33	2.65	2.95	3.82	4.55	5.33
Japan	6.46	6.75	6.96	7.14	7.35	7.89
Canada	10.27	11.38	11.92	12.62	13.52	15.31
UK	2.14	2.45	2.74	3.10	3.44	3.54

Condition Number

Another measure for multicollinearity that is specifically targeted at the nature of the matrix of the covariates is the condition number. The condition number κ is defined to be the square rooted ratio of the largest and smallest eigenvalue of the squared matrix of the covariates (with each column vector rescaled to unit lenght), i.e. $\kappa = \sqrt{\frac{\lambda_{\max}}{\lambda_{\min}}}$. Belsley et al. (1980) state that values of κ exceeding 20 are suggestive for multicollinearity.

In Table 10 we report condition numbers among countries for Eq. (5). According to the condition number, results should not be subject to multicollinearity.

Table 10: Condition number for equation (5)

	number of lags					
Country	1	2	3	4	5	6
US	3.91	3.50	4.31	3.72	7.92	8.95
euro area	2.51	3.50	3.71	4.40	17.16	4.92
Japan	3.64	10.53	7.22	7.40	8.76	9.31
Canada	6.80	5.63	10.96	10.42	9.41	11.81
UK	2.93	3.82	3.77	9.17	9.85	7.23

Appendix 5 - Robustness checks:
Results for alternative grouping

Table 11: Estimation results of Eq. (4) over 1991M01-2007M12

	Eq. (4) + VAR(1)			
Country	ζ	α^D	α^E	PK test
US	0.960***	0.057**	-0.046	0.59
euro area	0.868***	-0.137	0.337**	0.63
Japan	1.023***	0.980***	0.210***	0.80
Canada	0.667***	0.889***	0.405	0.84
UK	0.920***	0.173***	1.158***	0.41

***/**/* indicate significance at 1%/5%/10%. The critical value of the Ploberger-Krämer test is equal to 1.36 at 5%, under the null hypothesis of no structural break.

Table 12: Estimation results of Eq. (5) over 1991M01-2007M12

	Eq. (5)				Degree of PT within each group	
Country	$\widetilde{\alpha}^D$	$\widetilde{\alpha}^E$	$\widetilde{\alpha}^T$	diff	$\widetilde{\alpha}^D/\delta_t$	$\widetilde{\alpha}^E/(1-\delta_t)$
US	0.158***	0.003	0.162	0.001	0.234	0.010
euro area	0.382***	0.062	0.444	0.024	0.494	0.274
Japan	0.599***	-0.061	0.538	0.000	0.970	-0.159
Canada	0.754***	0.032	0.786	0.000	0.843	0.303
UK	0.488***	0.002	0.491	0.000	0.539	0.024

***/**/* indicate significance at 1%/5%/10%. "diff " refers to the p-value of a Wald test for equality of $\widetilde{\alpha}^D$ and $\widetilde{\alpha}^E$

Table 13: Tests for equality of pass-through across destination markets

	Equality across $\widetilde{\alpha}^D$				Equality across $\widetilde{\alpha}^E$			
	US	e.a.	Jap.	Can.	US	e.a.	Jap.	Can.
US	–	–	–	–	–	–	–	–
euro area	0.08	–	–	–	0.28	–	–	–
Japan	0.00	0.19	–	–	0.41	0.17	–	–
Canada	0.00	0.00	0.21	–	0.45	0.61	0.25	–
UK	0.00	0.46	0.43	0.01	0.98	0.35	0.46	0.57
joint	0.00				0.63			

p-values of a Wald test for equality of total pass-through among countries. "joint" refers to the p-value of the hypothesis of joint equality.

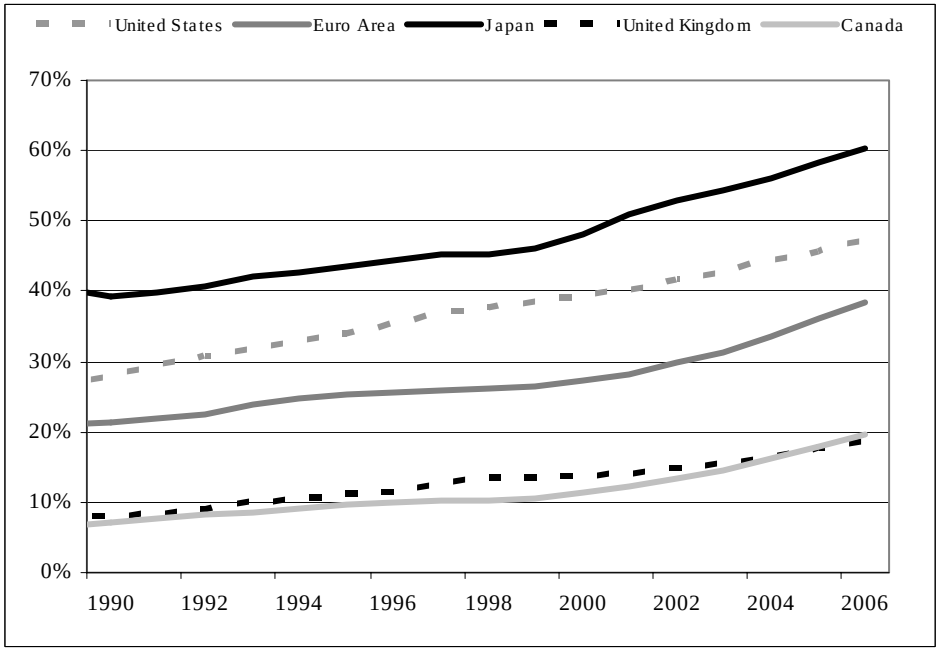

Fig. 1 – Share of low-cost countries in total imports of selected developed economies

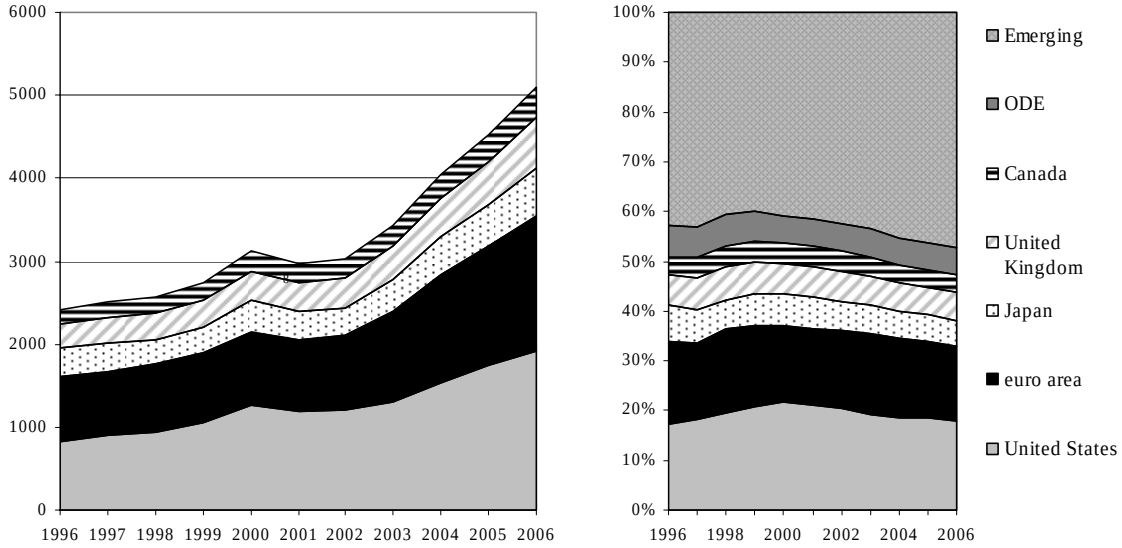

Fig. 2 – Size of import markets, in USD bn – left – and in percentage of total trade – right –

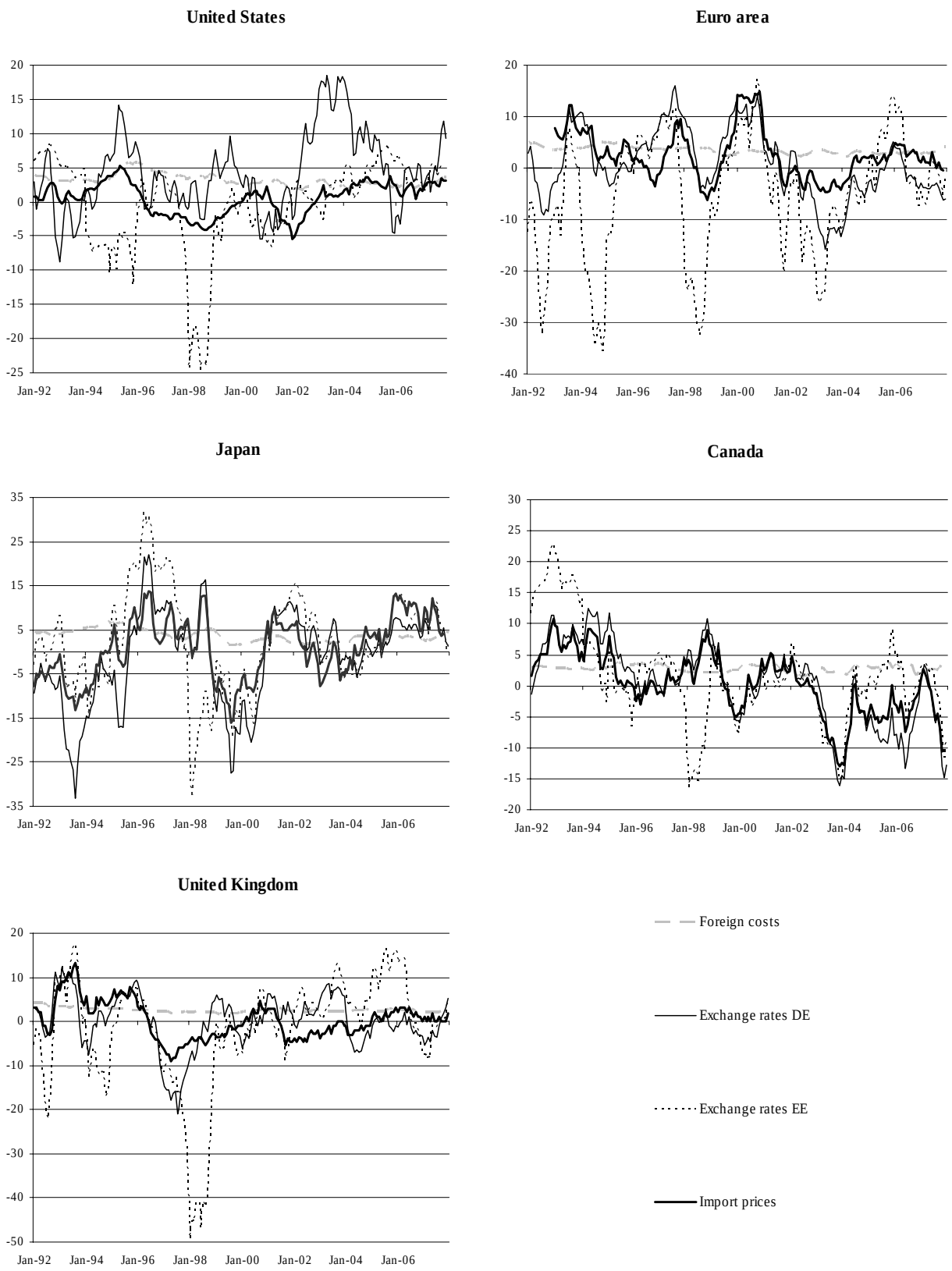

Fig. 3 – Series of import prices, foreign costs and exchange rates used in the empirical study (year-on-year changes, %)

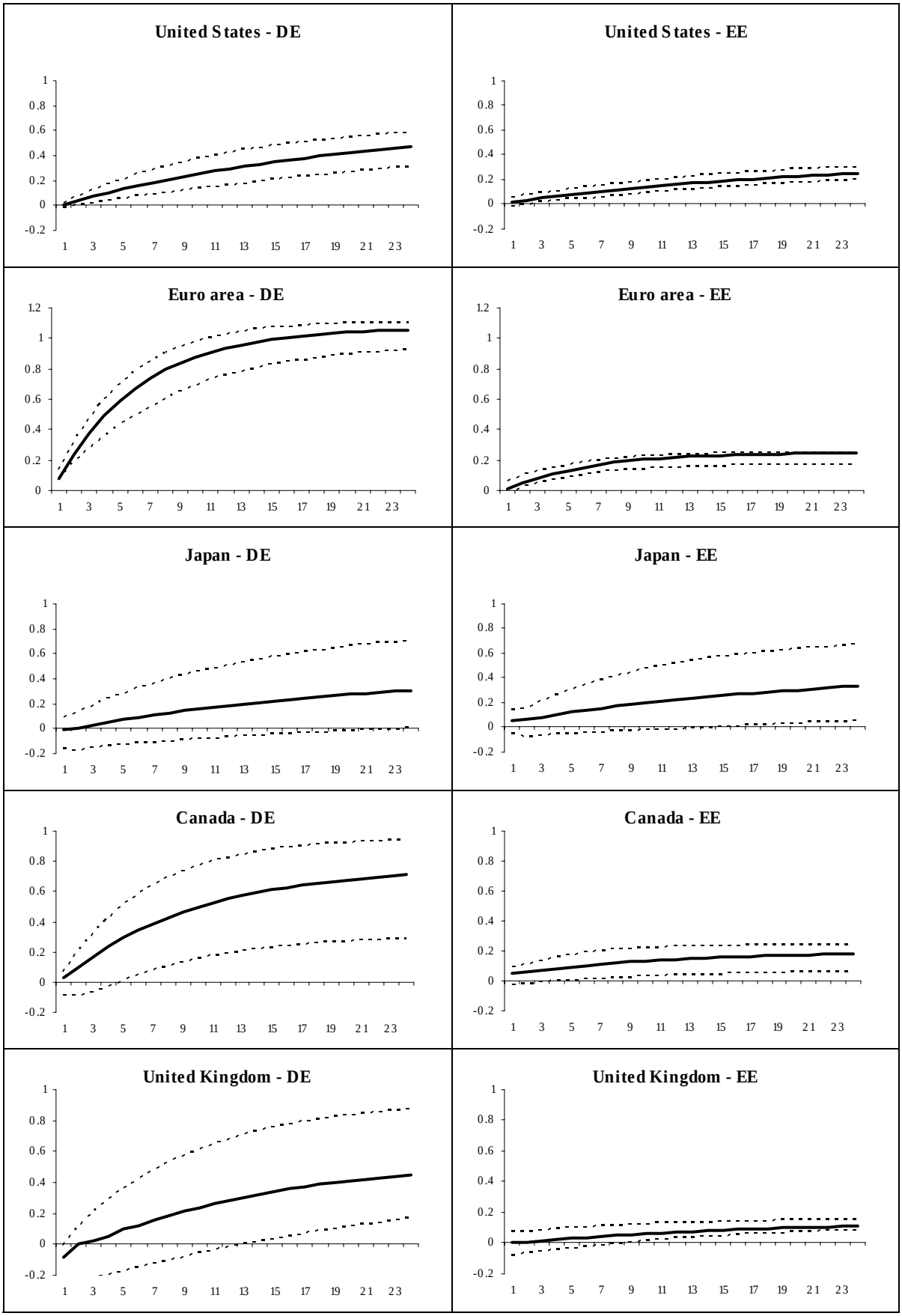

Fig. 4 – Exchange rate pass-through to import prices in months after the shock across destination and type of firms (bootstrap mean estimates with 90% bootstrap error bounds)

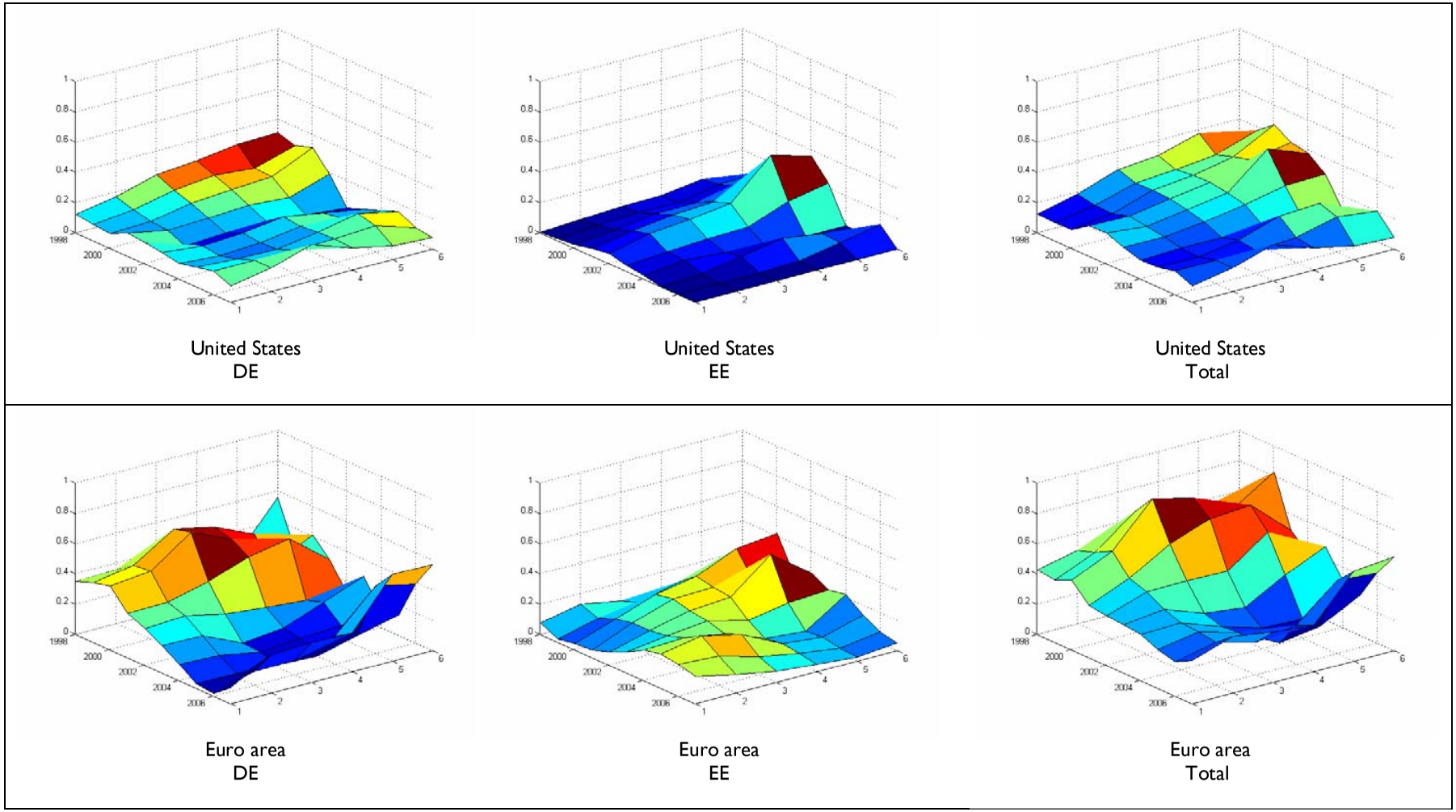

Fig. 5 – Exchange rate pass-through dynamics and time evolution (United States and euro area)

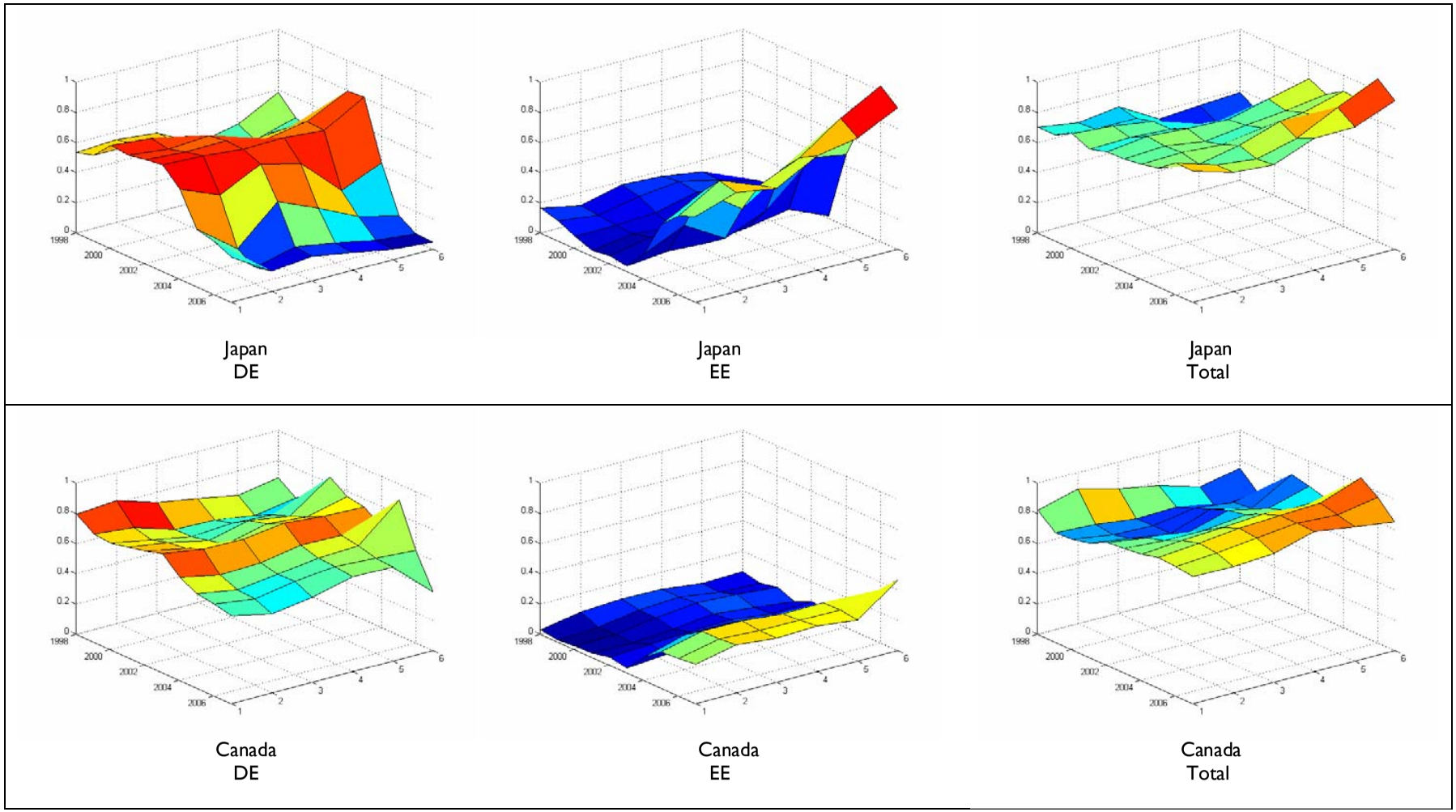

Fig. 5 (cont'd)– Exchange rate pass-through dynamics and time evolution (Japan and Canada)

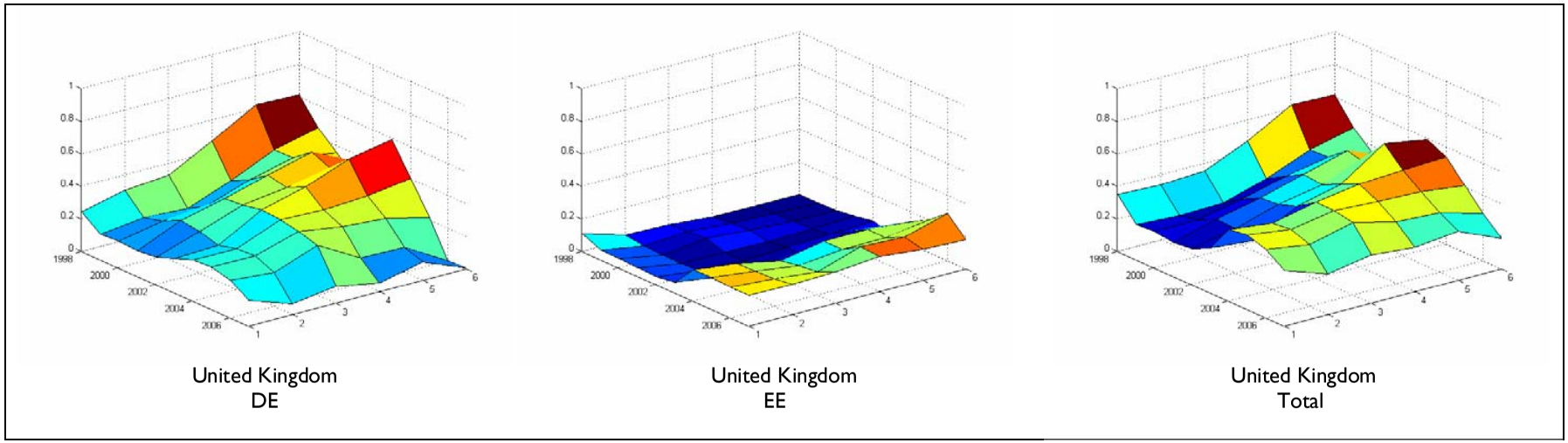

Fig. 5 (cont'd)– Exchange rate pass-through dynamics and time evolution (United Kingdom)

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