Working Paper no. 312

Exchange rate pass-through into UK import prices

Haroon Mumtaz, Özlem Oomen and Jian Wang

November 2006

Bank of England

Exchange rate pass-through into UK import prices

Haroon Mumtaz[*]

Özlem Oomen[**]

and

Jian Wang[†]

Working Paper no. 312

[*] Bank of England
Email: haroon.mumtaz@bankofengland.co.uk

[**] Bank of England
Email: ozlem.oomen@bankofengland.co.uk

[†] Federal Reserve Bank of Dallas
Email: Jian.Wang@dal.frb.org

The views expressed in this paper are those of the authors, and not necessarily those of the Bank of England or the Federal Reserve Bank of Dallas. The authors are grateful to Mark Astley, Charles Engel and Peter Sinclair for fruitful discussions and helpful suggestions. The paper also benefited from comments of seminar participants at the Bank of England and University of Wisconsin and two anonymous referees. This paper was finalised on 5 July 2006.

The Bank of England's working paper series is externally refereed.

Information on the Bank's working paper series can be found at www.bankofengland.co.uk/publications/workingpapers/index.htm.

Publications Group, Bank of England, Threadneedle Street, London, EC2R 8AH; telephone +44 (0)20 7601 4030, fax +44 (0)20 7601 3298, email mapublications@bankofengland.co.uk.

ISSN 1749-9135 (on-line)

Contents

Abstract

In this paper we estimate the rate of exchange rate pass-through (ERPT) into UK import prices using disaggregate data at the SITC-2 and SITC-3 digit level. Consistent with earlier studies, we find evidence for significant heterogeneity among the estimated industry-specific pass-through rates. In an environment where cross-sectional heterogeneity is significant the use of aggregate data can be misleading since aggregation may lead to heavily biased ERPT estimates at the economy-wide level. We demonstrate that the aggregation bias caused by this heterogeneity is not negligible for the UK data. Further, we investigate the source of the cross-sectional variation in the estimated industry-specific pass-through rates. For our sample, we find the industry-specific average inflation rates to be significant in explaining this variation. Furthermore, we find evidence for short-run and long-run partial pass-through into food and manufacturing sectors. As for the economy-wide ERPT the conclusion stands, possibly reflecting the relatively large weight of manufacturing goods in UK imports. Finally, we find a significant reduction in estimated ERPT rates since 1995 caused by increased stability of the UK economy over the past decade.

Key words: Exchange rate pass-through; aggregation bias; structural breaks.

JEL classification: F3; F4; C33.

Summary

Exchange rate pass-through (ERPT) is the percentage change in local currency import prices following a 1% change in the exchange rate between importing and exporting countries. A one-to-one response of import prices to exchange rate changes is known as *complete* ERPT while a less than one-to-one response is known as *partial* or *incomplete* ERPT. The rate of ERPT has important implications for the effect of monetary policy on domestic inflation as well as for the transmission of macroeconomic shocks and the volatility of the real exchange rate. As such, the relationship between exchange rates and goods prices has been studied extensively in previous work. In this paper, we focus on the pass-through of exchange rates into UK import prices, where these prices are measured for 57 industries. To the best of our knowledge, no research has been done to measure ERPT into UK import prices at this level of disaggregation, and this paper aims to fill this gap.

We use quarterly data from 1984 Q1 to 2004 Q1. Consistent with earlier studies, we find evidence for significant variation among the estimated industry-specific pass-through rates. This cross-sectional variation of pass-through rates poses an interesting problem for inference on the rate of ERPT at the economy-wide level. Our results show that ignoring this variation and simply using an aggregate import price index to estimate economy-wide pass-through rate can lead to a substantial upward bias in its measurement. Consequently, the aggregate ERPT rate can appear to be significantly higher than its true value. Using an estimation method that accounts for cross-sectional variation, we find evidence for short-run and long-run partial pass-through into import prices for the two import categories we construct using our industry-level data, namely food and manufacturing. Similarly, the economy-wide ERPT is also found to be partial, possibly reflecting the relatively large weight of manufacturing goods in UK imports. Further, we investigate the source of the cross-sectional variation in ERPT rates. Previous work on ERPT suggests that the variation of pass-through rates across industries relates to industry-specific factors such as the degree of competition, product differentiation, demand elasticities, trade barriers, inflation rates etc. For our sample, we find the industry-specific average inflation rates to be significant in explaining this variation. The final part of the paper examines whether the pass-through rates have varied across time. We find that there has been a significant decrease in the ERPT both at the economy-wide and the industry level. Our estimates suggest that this decrease can largely be explained by the increased stability of the UK economy over the past decade.

1 Introduction

Exchange rate pass-through (ERPT) is the percentage change in local currency import prices as a result of a 1% change in the exchange rate between importing and exporting countries. A one-to-one response of import prices to exchange rate changes is known as *complete* ERPT while a less than one-to-one response is known as *partial* or *incomplete* ERPT. The rate of ERPT has important implications for the effects of monetary policy on domestic inflation. Hence, in the literature, the relationship between exchange rate and goods prices has been studied extensively. Since the 1980s, ERPT research developed into estimation of pass-through rates at the industry level. These studies have emphasised the role of market structure, market segmentation and price discrimination across the destination markets as well as the convexity of demand schedules in explaining pass-through rates to prices using models of imperfect competition that take the exchange rate process as exogenous. Some examples include Feenstra (1989), Gross and Schmitt (2000), and Takeda and Katsumi (2003). Recently, studies on prices and exchange rates have focused on general equilibrium models where prices are assumed to be sticky in either the exporter's or the importer's currency. Some examples here include Obstfeld and Rogoff (1995), Obstfeld and Rogoff (2000), Betts and Devereux (1996), Betts and Devereux (2000), Chari, Kehoe and McGrattan (2002), and Engel (2003). In these studies, predictions on ERPT depend on assumptions concerning the currency of producer pricing, degree of rigidities, shocks hitting the economy as well as on market structure, market segmentation, and price discrimination across destination markets.[(1)]

In the 1990s, the observation that changes in exchange rates had only small effects on prices in many countries (eg Sweden in 1992 and the United Kingdom in 1996) led researchers to investigate the link between pass-through rates and macroeconomic variables, in particular monetary policy and exchange rate volatility. See, for instance, Taylor (2000), Choudri (2001), Devereux and Engel (2001), Gagnon and Ihrig (2001), Bailliu and Fujii (2004), Devereux, Engel and Storgaard (2004). Overall, these studies have suggested that the stability of monetary policy and exchange rates have led to lower pass-through rates and that pass-through rates might be endogenous to a country's macroeconomic performance. Campa and Goldberg (2005) (henceforth, CG), on the other hand, have emphasised the role of a change over time in the composition of import bundles towards goods with lower pass-through rates in explaining the

(1) See Goldberg and Knetter (1997) and Campa, Goldberg and Gonzalez-Minguez (2005) for a review.

estimated decline in ERPT rates of some OECD countries.

In this paper, we focus on the pass-through of exchange rates into UK import prices, where these prices are measured at the two-digit or three-digit SITC level. To the best of our knowledge, no research has been done to measure ERPT into UK import prices at the disaggregate level, and this paper aims to fill this gap. We use quarterly data from 1984 Q1 to 2004 Q1. Our data set includes import price indices of 57 UK industries at the two-digit or three-digit SITC level. Consistent with earlier studies, we find evidence for significant heterogeneity among the estimated pass-through rates of 57 industries involved in our analysis. This cross-sectional variation of pass-through rates poses an interesting problem for inference on the rate of ERPT at the economy-wide level. Our results show that ignoring this heterogeneity and simply using an aggregate import price index to estimate the economy-wide pass-through rate can lead to a substantial upward bias in its measurement. Consequently, the aggregate ERPT rate can appear to be significantly higher than its true value.

Further, we investigate the source of the cross-sectional variation in the estimated industry-specific pass-through rates. The ERPT literature suggests that the variation of pass-through rates across industries relates to industry-specific factors such as the degree of competition, product differentiation, demand elasticities, trade barriers, inflation rates, etc.[(2)] For our sample, we find the industry-specific average inflation rates to be significant in explaining this variation.

Furthermore, we find evidence for short-run and long-run partial pass-through into import prices for the two import categories we have constructed using our industry-level data, namely food and manufacturing. A similar result holds for the economy-wide ERPT, possibly reflecting the relatively large weight of manufacturing goods in UK imports. Finally, we find that ERPT rates have significantly decreased since 1995. And, unlike CG, in our sample this decrease is not caused by a change in the composition of imported products but by the more stable macroeconomic environment after 1995.

The rest of the paper is structured as follows. In Section 2 we present our data and discuss our results for the estimated ERPT rates. Section 3 attempts to explain the variation in estimated ERPT rates across industries while in Section 4 we try to explain the time variation on estimated

(2) For instance, see Knetter (1993) and Yang (1997).

ERPT rates. Section 5 concludes.

2 ERPT into disaggregated import prices

We consider the following generic regression model that has been widely estimated in the ERPT literature:[(3)]

$$p_t = c_t + \phi s_t + \gamma w_t^* + \eta d_t + \epsilon_t \quad \textbf{(1)}$$

All variables are in logs. The left-hand side variable, p_t, is the local currency price of imports. The right-hand side variables are the exchange rate, s_t, the exporters' cost variable, w_t^*, the real GDP of the importing country, d_t, and the error term, ϵ_t. The coefficient ϕ is the ERPT coefficient. ERPT is complete if $\phi = 1$ and incomplete if $\phi < 1$.

In this study, we are concerned with the estimates of ERPT rates into UK import prices at the industry level. Hence, we estimate the following regression equation for the i^{th} industry in our data set using ordinary least squares (OLS).

$$\Delta p_{i,t} = c_i + \phi_i \Delta s_t + \gamma_i \Delta w_t^* + \eta_i \Delta d_t + \Sigma_{j=1}^{J} \xi_{i,j} \Delta p_{i,t-j} + \nu_{i,t} \quad \textbf{(2)}$$

The regression equation is specified in first differences because we are unable to reject the hypothesis that the log of import prices and the variables on the right-hand side are non-stationary.[(4)] We use quarterly data from 1984 Q1 to 2004 Q1. Our data set includes free on board (f.o.b.)[(5)] import price indices of 57 UK industries at the two-digit or three-digit SITC level (source ONS), which are classified into 9 sectors defined at the one-digit SITC level. These import price indices are obtained from a survey completed by industrialists. c_i is the industry-specific constant with which we aim to capture any industry-specific effects. Due to data limitations we do not control for differences in exporters' cost of production across industries. Thus, the cost variable, w_t^*, in equation **(2)** does not have the subscript i. Following CG, we construct a consolidated exporter partners' cost proxy. The cost variable is measured as $W_t^* = \frac{NEER_t ULC_t}{REER_t}$, where ULC_t is the UK unit labour cost (source IFS), $NEER_t$ is the sterling nominal effective exchange rate (source IFS), and $REER_t$ is the sterling real effective exchange rate deflated by unit

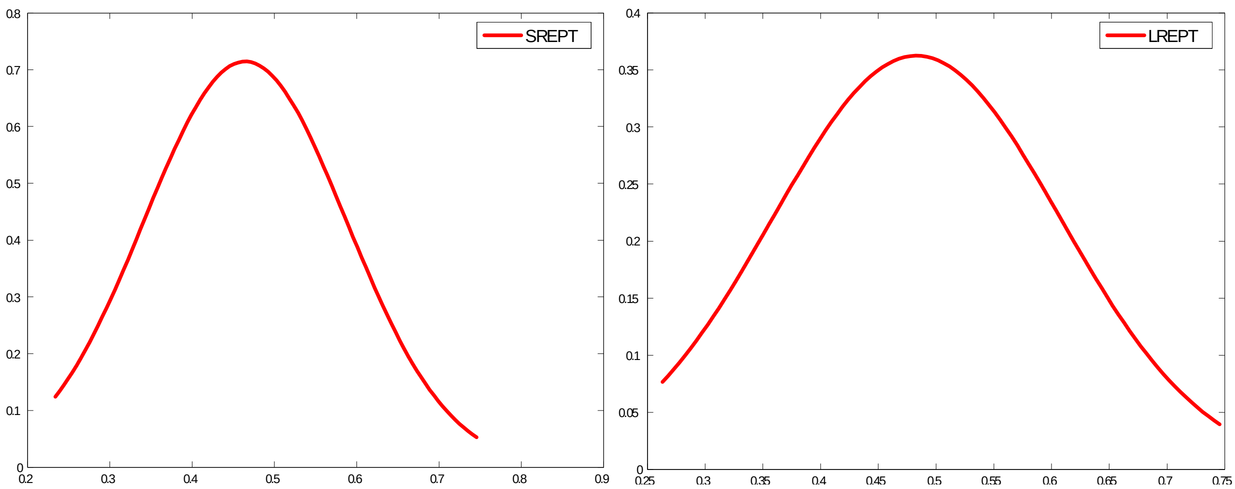
(3) See Goldberg and Knetter (1997).

(4) The unit root test is the augmented Dickey-Fuller test. We cannot reject the presence of a unit root for 95% of import prices at 95% confidence level. We also checked the appropriateness of a cointegration approach. Tests for cointegration revealed evidence of a long-run relationship in 11 cases. However, adding an error correction term in the regression equation for these sectors had little impact on the estimated ERPT coefficients. Therefore, we decided to ignore error correction models. These results are not reported here but they are available upon request.

(5) f.o.b. import prices do not include transportation and distribution costs. The inclusion of such costs would bias ERPT estimates downwards since these costs do not change with changes in exchange rates.

labour cost (source IFS). This provides us with a measure of the United Kingdom's trading partners' costs where each partner is weighted by its importance in UK trade. The real GDP of the importing country is used as a proxy for the total demand in the importing country. s_t is the sterling NEER. We include lagged import prices into the equation with the number of lags determined by the Akaike information criteria (AIC). This *ad hoc* specification aims to capture the reluctance of firms to adjust prices quickly, implying gradual adjustment of import prices to changes in exchange rates. Finally, the coefficient ϕ_i is the short-run ERPT rate for industry-i and $\Xi_i \equiv \frac{\phi_i}{1-\Sigma_{j=1}^{J}\xi_{i,j}}$ is the long-run ERPT rate for the same industry. We illustrate the estimation results from this regression in Chart 1 that plots the normalised probability distribution of the estimated ERPT rates (that are statistically significant) at the industry level. The left (right) panel shows the distribution of the estimated short-run (long-run) ERPT rates across industries.

Chart 1: Industry-specific ERPT rates



The left (right) panel shows the distribution of the estimated short-run (long-run) ERPT across industries.

We tabulate the estimation results in more detail in Table A. The table lists the industries in our data set together with the respective one-digit SITC classification under which they are listed. Notice that we do not have data at the industry level for SITC 4 (Oils & Fats). The estimation results suggest that the estimated short-run and long-run ERPT rates vary significantly across industries: we can clearly reject the hypothesis that the estimated ERPT rates are identical across industries based on a likelihood ratio test on the homogeneity of ϕ_i, ie $\phi_i = \phi$.[6]

Next, we group our industries under four import categories: Food (SITC 0 and 1), Raw Materials

(6) We obtain a test statistic of 199.1955 with a p-value of 0.000. This is the Swamy test for coefficient homogeneity.

Table A: Industry-specific short-run and long-run exchange rate pass-through rates

	Short Run	Long Run		Short Run	Long Run
SITC 0: Total Food & Live Animals	–	–	**SITC 6: Material Manufactures Inc. Precious Stones**	–	–
Live Animals	0.83 (0.54)	0.55 (0.55)	Leather	0.11 (0.15)	0.10 (0.18)
Meat & Meat Prep.	0.33 (0.10)	0.36 (0.17)	Rubber	0.34 (0.09)	0.38 (0.15)
Dairy Products & Eggs	0.41 (0.08)	0.49 (0.34)	Wood & Cork	0.46 (0.13)	0.46 (0.18)
Fish	0.64 (0.09)	0.69 (0.15)	Paper & Paperboard	0.29 (0.05)	0.55 (0.35)
Cereals & Cereal Prep.	0.41 (0.13)	0.37 (0.19)	Textile Fabrics	0.44 (0.06)	0.68 (0.26)
Fruit & Vegetables	0.23 (0.14)	0.15 (0.11)	Minerals Exc. PS	0.38 (0.05)	0.40 (0.10)
Sugar, Sugar Prep. & Honey	0.37 (0.12)	0.44 (0.19)	Iron & Steel	0.07 (0.08)	0.13 (0.19)
Coffee, Tea, Cocoa, etc.	0.41 (0.15)	0.56 (0.38)	Non-Ferrous Metals	0.14 (0.14)	0.23 (0.28)
Animal Feeding Stuff	0.67 (0.17)	0.83 (0.40)	Non-Ferrous Metals Exc. Silver	0.13 (0.15)	0.21 (0.27)
Misc. Edible Products & Prep.	0.25 (0.20)	0.18 (0.20)	Misc. Metal Manufacturers	0.51 (0.07)	0.54 (0.26)
SITC 1: Total Beverages & Tobacco	–	–	**SITC 7: Machinery & Transport Equipment**	–	–
Beverages	0.35 (0.09)	0.40 (0.28)	Machinery	0.42 (0.05)	0.61 (0.36)
Tobacco	0.55 (0.20)	0.45 (0.36)	Mechanical Machinery: Consumption	0.50 (0.15)	0.32 (0.17)
SITC 2: Total Crude Materials	–	–	Mechanical Machinery: Intermediate	0.53 (0.08)	0.51 (0.26)
Wood, Lumber & Cork	0.55 (0.13)	0.80 (0.34)	Mechanical Machinery: Capital	0.64 (0.08)	0.66 (0.12)
Pulp & Waste Paper	0.58 (0.19)	0.94 (0.74)	Electrical Machinery: Intermediate	0.32 (0.06)	0.48 (0.16)
Textile Fibres	0.41 (0.13)	0.93 (0.47)	Electrical Machinery: Consumption	0.30 (0.08)	0.24 (0.17)
Metal Ores	- 0.12 (0.21)	- 0.10 (0.17)	Electrical Machinery: Capital	0.23 (0.05)	0.36 (0.18)
SITC 3: Mineral Fuels & Related Materials	–	–	Road Vehicles	0.54 (0.05)	0.82 (0.44)
Oil	0.03 (0.51)	0.03 (0.61)	Other Road Vehicles: Consumption	0.75 (0.19)	0.53 (0.26)
Oil Products	- 0.01 (0.41)	− 0.01 (0.47)	Other Road Vehicles: Intermediate	0.59 (0.10)	0.56 (0.30)
SITC 4: Oils (Animal + Vegetable) & Fats	–	–	Other Road Vehicles: Capital	0.53 (0.08)	0.64 (0.32)
SITC 5: Chemicals & Related Products	–	–	Other Transport Equipment	0.14 (0.08)	0.16 (0.14)
Organic Chemicals	0.52 (0.10)	0.78 (0.30)	Railway Equipment: Intermediate	0.21 (0.24)	0.17 (0.24)
Inorganic Chemicals	0.16 (0.22)	0.10 (0.18)	Railway Equipment: Capital	0.08 (0.43)	0.09 (0.54)
Colouring Materials	0.63 (0.20)	0.79 (0.49)	**SITC 8: Misc. Finished Manufactures**	–	–
Medical Products	0.08 (0.07)	0.09 (0.11)	Clothing	0.41 (0.17)	0.37 (0.24)
Toilet Prep.	0.61 (0.07)	0.73 (0.34)	Footwear	0.55 (0.11)	0.41 (0.20)
Plastics	0.26 (0.08)	0.40 (0.19)	Scientific & Photographic: Consumption	0.24 (0.12)	0.13 (0.10)
Residual Chemicals	0.52 (0.10)	0.68 (0.30)	Scientific & Photographic: Intermediate	0.55 (0.15)	0.46 (0.25)
			Scientific & Photographic: Capital	0.47 (0.13)	0.45 (0.34)
			Residual Misc. Manufactures: Consumption	0.43 (0.10)	0.54 (0.24)
			Residual Misc. Manufactures: Intermediate	0.41 (0.05)	0.37 (0.08)
			Residual Misc. Manufactures: Capital	0.27 (0.16)	0.13 (0.10)

The table shows the estimated industry-specific short-run and long-run ERPT rates using equation **(2)**. White standard errors are in parentheses.

(SITC 2), Energy (SITC 3), and Manufacturing (SITC 4, 5, 6, 7 and 8). Then, we estimate ERPT rates at the level of these import categories:

$$\Delta\overline{p}_{k,t} = c_k + \phi_k \Delta s_t + \gamma_k \Delta w^*_t + \eta_k \Delta d_t + \Sigma^J_{j=1} \Delta\xi_{k,j} \overline{p}_{k,t-j} + \overline{v}_{k,t}. \quad k = 1, .., 4 \qquad \textbf{(3)}$$

where k denotes one of the four sectors and $\overline{p}_{k,t} = \sum^{n_k}_{i=1} m^k_i p^k_{i,t}$ is the aggregated UK import price index obtained by taking a weighted average over industries that fall under sector-k, where the number of those industries are denoted by n_k. We weight each industry's import price with that industry's trade weight in the sector under which it is listed. That is, the weight of industry-i in sector-k equals the ratio of the volume of imports in industry-i to the total volume of imports in sector-k. These results are shown in columns 2 and 5 in Panel A of Table B. For purposes of comparison, we have two other estimates for the ERPT rates at the sectoral level. These are obtained by taking an unweighted average (shown in columns 3 and 6 in Panel A) and weighted average (shown in columns 4 and 7 in Panel A) of industry-specific ERPT rates estimated by equation **(2)** across industries that fall under the respective sector. The panel shows that ERPT rates vary across sectors but not much across different methods of estimation. A number of results are immediately apparent. First, most product categories in our sample exhibit partial ERPT both in the short run and the long run. Starting with the short-run estimates, for each import category except energy, we reject the hypothesis of zero ERPT. For these sectors, we also reject the hypothesis of complete pass-through. Turning to the long-run estimates, for food and manufacturing, we reject the hypotheses of zero and complete pass-through. For the raw material sector, however, the findings are inconclusive: due to large standard errors attached to these estimates, we fail to reject either zero or complete pass-through. For the energy sector, the estimated pass-through rates are not significantly different from zero. This result is surprising since we would expect homogenous products, such as those listed under the energy sector, to have pass-through rates close to one. One important aspect of products listed under the energy sector is that they are traded in international commodity markets in US dollars. Hence, a more relevant exchange rate for these products is the dollar-sterling rate. Therefore, we re-estimated ERPT rates for this sector using the dollar-sterling rate in place of the sterling NEER. The point estimates of the short-run and long-run ERPT remain insignificant in this alternative specification. However, we prefer not to place too much weight on this particular result since the energy sector in our sample has only two industries listed under it and this might render ERPT estimates for this sector unreliable.[7] As for the overall pass-through estimates (shown in Panel B), the evidence suggests partial pass-through both in the short run and the long run, perhaps reflecting the relatively large

(7) As shown in Table A, these two industries are 'Oil' and 'Oil Products'.

Table B: Estimated short-run and long-run exchange rate pass-through rates

	Short Run			Long Run		
	AGGR	UW	TW	AGGR	UW	TW
Panel A:						
SITC 0-1: Food	0.38†	0.45†	0.38†	0.42†	0.45†	0.39†
	(0.08)	(0.17)	(0.13)	(0.18)	(0.28)	(0.23)
SITC 2: Raw Materials	0.30†	0.35†	0.29†	0.46‡	0.64‡	0.50‡
	(0.14)	(0.16)	(0.17)	(0.39)	(0.43)	(0.36)
SITC 3: Energy	0.02	0.01	0.02	0.02	0.01	0.02
	(0.47)	(0.46)	(0.48)	(0.56)	(0.54)	(0.56)
SITC 5-8: Manufacturing	0.43†	0.38†	0.42†	0.63†‡	0.42†	0.54
	(0.04)	(0.12)	(0.08)	(0.33)	(0.24)	(0.28)
Panel B:						
SITC 0-8: All	0.44†	0.38†	0.38†	0.66†	0.43†	0.49†
	(0.06)	(0.14)	(0.12)	(0.19)	(0.27)	(0.30)

[1] The table reports the estimated short-run and long-run ERPT rates at the sectoral level (Panel A) and for the overall economy (Panel B). In column 2 (5), we report the estimates of the short-run (long-run) pass-through rates based on aggregate import price data. In columns 3 and 4 (6 and 7), we report the unweighted and trade-weighted averages of industry-specific short-run (long-run) estimates of pass-through rates. White standard errors are in parentheses. [2] † Significantly different from 0 (10%). ‡ Not significantly different from 1 (10%).

weight of the manufacturing sector in UK imports. In general terms, our results are fairly similar to those reported in Table A1 in CG. That is, CG also finds partial ERPT for the food and manufacturing sector both in the short and the long run over the period 1975-2003. Unlike us, however, their findings also suggest incomplete pass-through for the raw material sector over this period. Also note that, for the energy sector, consistent with our results, CG reports pass-through estimates that are not significantly different from zero both in the short run and the long run.

2.1 Aggregation bias

As mentioned above, the estimated short-run and long-run ERPT rates vary significantly across industries in our data set. But what is the impact of this heterogeneity on the estimates of ERPT rates obtained using the aggregated import price index? In order to answer this question one could estimate the regression equation **(3)** for the full sample. That is

$$\Delta\overline{p}_t = c + \phi\Delta s_t + \gamma\,\Delta w_t + \eta\Delta d_t + \Sigma_{j=1}^{J}\xi_j\Delta\overline{p}_{t-j} + \overline{v}_t \qquad \textbf{(4)}$$

$\overline{p}_t = \sum_{i=1}^{N} w_i p_{i,t}$ denotes the aggregate UK import price index obtained by taking a trade-weighted average over all industries ($N = 57$ in our data set) and c is the regression constant. The estimates of ϕ (the short-run ERPT) and ξ_j's (the long-run ERPT) based on equation **(4)** will be biased and inconsistent if there is sufficient heterogeneity among industry-specific estimates of ERPT rates and/or estimated coefficient on the lagged dependent variable (see Pesaran and Smith

(1995)). For instance, consider the case where only the short-run ERPT varies across industries. And let $\phi_i = \phi + \tau_i$, where we assume τ_i to be a zero-mean random variable. Then, aggregating the data implies that, in regressions, this heterogeneity is pushed into the residual term. This can be seen by substituting $\phi_i = \phi + \tau_i$ into **(2)** and re-arranging the resulting equation to obtain

$$\Delta \overline{p}_t = c + \phi \Delta s_t + \gamma \Delta w_t + \eta \Delta d_t + \Sigma_{j=1}^{J} \xi_j \Delta \overline{p}_{t-j} + (\overline{v}_t + \tau_i \Delta s_t) \qquad \textbf{(5)}$$

From **(5)**, it is clear that $E[(\overline{v}_t + \tau_i \Delta s_t)\Delta s_t] \neq 0$. Moreover, if Δs_t is serially correlated then the error term will also be serially correlated implying that the OLS estimates of the coefficients will be biased and inconsistent. Note that instrumental variable estimation does not solve the problem here as any instrument that is correlated with Δs_t would also be correlated with the error term.[8] Pesaran and Smith (1995) show that if the true data generating process is heterogeneous and the assumption of homogeneity is imposed on the coefficients of the panel (eg in a fixed effects model), then the estimates of short-run coefficients will be biased downwards while the estimates of autoregressive coefficients will be biased upwards.[9] The authors also show that under these conditions, the estimates of the long-run coefficients will be biased upwards. The authors propose the 'mean group estimator' to solve this problem. The mean group estimator of the aggregate short-run and long-run ERPT rates can be obtained by taking an unweighted average of the industry-specific estimates of the ERPT rates as shown below

$$\hat{\phi}_{MG} = \frac{1}{N}\sum_{i=1}^{N} \hat{\phi}_i$$
$$\hat{\Xi}_{MG} = \frac{1}{N}\sum_{i=1}^{N} \hat{\Xi}_i = \frac{\hat{\phi}_i}{1 - \sum_{j=1}^{J} \hat{\xi}_{i,j}} \qquad \textbf{(6)}$$

And if N and T are sufficiently large, the mean group estimator will be unbiased and consistent. In Panel B of Table B we compare the mean group estimates of the aggregate ERPT rates to those obtained by estimating **(4)**. The panel shows that the estimated long-run ERPT based on the aggregate import price index is substantially larger than the corresponding mean group estimate.[10] On the other hand, the estimate of the short-run ERPT is found to be similar across estimation methods in our data set. This finding suggests that the bias in the aggregate estimates of

(8) This argument would also hold if there is heterogeneity among the estimated coefficients on the lagged dependent variable.

(9) Also see Imbs, Ravn, Rey and Mumtaz (2005) for results on the bias in autoregressive models estimated on heterogeneous panels.

(10) This result is preserved even when we correct for the small sample bias in the autoregressive coefficient. Following Pesaran and Zhao (1999)we use non-parametric bootstrap methods to correct for the small sample bias present in the estimated long-run coefficients. The bias corrected mean group estimate for the long-run aggregate ERPT rate is 0.46 and it is 0.70 when we use the aggregated import price data. In addition, correcting for cross-sectional correlation does not alter the results greatly. For example, a SURE-Mean Group estimator produces a long-run pass-through estimate of 0.43.

the long-run ERPT seems to stem from the estimated coefficients on the lags of the dependent variable. The mean group estimate suggests that the sum of the estimated coefficient on the lagged dependent variable is 0.03 while this sum is estimated to be 0.33 when aggregate data are used. This result is consistent with Pesaran and Smith (1995) and Robertson and Symons (1992) where the authors show that averaging data in heterogeneous panels may lead to an upward bias in the estimates of persistence.

3 The cross-sectional variation in the estimated ERPT rates

In previous sections we argued that ERPT rates vary substantially across industries. But what explains this cross-sectional variation? In this section we try to shed some light on this issue.

3.1 What causes ERPT rates to vary across industries?

The following models are estimated in order to understand the factors that may explain the variation of ERPT rates across industries

$$\hat{\phi}_i = c_s + \kappa_s Z_i + e_i \tag{7}$$

$$\frac{\hat{\phi}_i}{1 - \sum_{j=1}^{J} \hat{\xi}_{i,j}} = c_l + \kappa_l Z_i + \varsigma_i \tag{8}$$

where the industry-specific short-run and long-run ERPT rates are obtained from the first-stage OLS regressions described above.[(11)] Here, we only consider the pass-through coefficients that are statistically significant. The matrix Z_i contains variables that reflect characteristics of different industries. The choice of variables included in Z_i is similar to that in Yang (1997). Specifically, Z_i includes the following variables:

Capital to labour ratio (KLR). Industries with a high capital to labour ratio may find it harder to change their output as it is usually more difficult to acquire capital than labour, especially in the short run. Thus, industries with a high capital to labour ratio tend to have high elasticity of marginal cost with respect to output. In other words, industry-specific capital to labour ratios can

(11) Frankel, Parsley and Wei (2005) conduct a similar exercise for a multi-country panel. They consider the impact of cross-country differences by adding interactions of the nominal exchange rate and country characteristics in the first-stage pass-through regression. This is a possible alternative to the two-step approach adopted here. Note, however, that our approach allows us to cleanly examine the issues in a ‘sequential’ manner. Our first-stage regression identifies significant cross-sectional heterogeneity, while the second-stage regressions reported in this section attempt to explain this heterogeneity.

be used as a proxy for the output elasticity of marginal cost. This elasticity will be positive if the underlying cost function is convex. That is, the marginal cost production will increase when output produced increases. A depreciation in the importing country's currency makes the local currency price of imports relatively more expensive, which, in turn, reduces the demand for imports. Under the assumption of a convex cost function, a reduction in output lowers the marginal cost of production and the price of imports. Hence, the increase in the price of imports following the depreciation is partially offset. The higher the elasticity of marginal cost with respect to output, the larger this offsetting effect will be. Therefore, we expect industries with higher capital to labour ratios to have lower ERPT rates. Data on capital and labour are obtained from the Bank of England industry data set. The data set covers 34 industries for the period between 1969 and 2000. The data on capital include nominal capital in buildings, computers, intangibles (excluding software), plant and machinery (excluding software and communications), communication equipment, vehicles, and software. The data on labour are total hours worked (not adjusted for quality). We use the average capital labour ratio over this period for each industry.

Intra-industry trade (IIT). IIT is defined as

$$IIT_{i,t} = 1 - \frac{|X_{i,t} - M_{i,t}|}{X_{i,t} + M_{i,t}} \qquad \textbf{(9)}$$

where $M_{i,t}$ and $X_{i,t}$ are calculated as the quarterly averages of import and export volumes in industry-i. IIT is an important component in international trade, especially among the industrialised countries.(12) In the trade literature, IIT has been associated with product differentiation.(13) Hence, we expect industries with higher levels of IIT to have lower elasticity of substitution between domestically produced and imported goods and lower ERPT rates. Note that the degree of ERPT will be positively related to elasticity of substitution: a firm with relatively lower elasticity of substitution has a higher mark-up and it is therefore more able to absorb shocks by varying its profit margin. The quarterly data on import and export volumes run from 1984 Q1 to 2004 Q1 and cover 8 UK sectors (at the one-digit SITC level) and 57 UK industries (at the two or three-digit SITC level). The source for these data is ONS.

Change in demand elasticity (CDE). In models of monopolistic competition where each monopolistic competitor is assumed to be too small to affect the aggregate price level, the price elasticity of demand facing each firm will be constant. However, when it is assumed that each firm

(12) See Ruffin (1999) for more details.
(13) See, for instance, Krugman (1981), Helpman (1981), and Chiarlone (2000).

is large enough to affect the industry price, the demand elasticity facing any individual firm will be a function of a sequence of prices charged in the market. One implication of this is that ERPT rates in each industry will now be related to price-induced movements in that industry's demand elasticity. Hence, the difference in ERPT rates across industries, to some extent, can be explained by differences across industries in how the price elasticity of demand moves with movements in price. The level of IIT in each industry can be used as a proxy for the price elasticity of demand in that industry. As noted above, high levels of IIT can be linked to high degrees of product differentiation and low substitution elasticity, and the price elasticity of demand tends to be low when the degree of substitution is low. Therefore, the estimated coefficient from a regression of $(1 - IIT_{i,t})$ on $p_{i,t}$ in each industry can provide us with a measure of the sensitivity of demand elasticity to price movements in each industry. That is

$$ln\epsilon_{i,t} = c_i + \psi_i p_{i,t} + \omega_{i,t} \tag{10}$$

where we use $\epsilon_{i,t}$ to denote the price elasticity of demand in industry-i and we proxy this demand elasticity by $(2 - IIT_{i,t})$. We use 2 for convenience in taking logarithms. $p_{i,t}$ is the (log) import price index of industry-i at time-t. $\omega_{i,t}$ is the error term with a mean of zero and a constant variance. $\hat{\psi}_i$ will be our proxy for the response of demand elasticity to price movements in industry-i.(14) We expect industries with higher $\hat{\psi}_i$ to be associated with higher ERPT rates.

Tariff (TRF). We include industry-specific tariff rates to capture the impact of trade barriers on ERPT rates. We assume exporters who face high tariff rates will face a higher degree of local competition in the markets to which they export and hence will be more limited in passing exchange rate changes onto the prices that they charge. Therefore, we expect industries protected with higher tariff rates to have lower rates of ERPT. Tariff rates are obtained from the United Nations Conference on Trade and Development (UNCTAD). The tariff rates we use are the average tariff rates among the European countries.

Inflation (INF). We include industry-specific average inflation rates in order to capture the impact price rigidities might have on ERPT rates. It is documented, for instance, in Taylor (2000) that when inflation is high it is more likely to be persistent. This implies that forward-looking firms could be more willing to pass any cost changes into their prices in an environment with high and persistent inflation. Hence, we expect higher inflation to be associated with higher ERPT rates.

(14) In our sample, the correlation coefficients between the variables IIT and DE are 0.2 in both short and long run.

Estimation results from **(7)** and **(8)** are shown in Table C. The first (second) row presents our results when the short-run (long-run) estimated ERPT rates, after eliminating any statistically insignificant estimates, from first round of regressions are used as the dependent variable. The table shows that the variable INF is significant (at 1%) with the correct sign in explaining the cross-sectional variation across estimated short-run and long-run ERPT rates. All other variables are found to be insignificant (or wrongly signed) in explaining the cross-sectional variation in both short and long run.

Table C: Cross-sectional variation in exchange rate pass-through rates

	CDE	INF	KLR	TRF	IIT	R^2	N
Short-run ERPT	0.07 (0.09)	0.14 (0.04)	0.02 (0.10)	0.001 (0.001)	-0.05 (0.08)	0.27	41
Long-run ERPT	-0.35 (0.13)	0.21 (0.05)	-0.10 (0.13)	-0.0003 (0.005)	0.003 (0.08)	0.47	22

The table reports the results from regressing the estimated short-run and long-run ERPT rates on industry-specific capital to labour ratio (KLR); volume of intra-industry trade (IIT); change in demand elasticity (CDE); tariff rate (TRF); and inflation rate (INF). White standard errors are in parentheses.

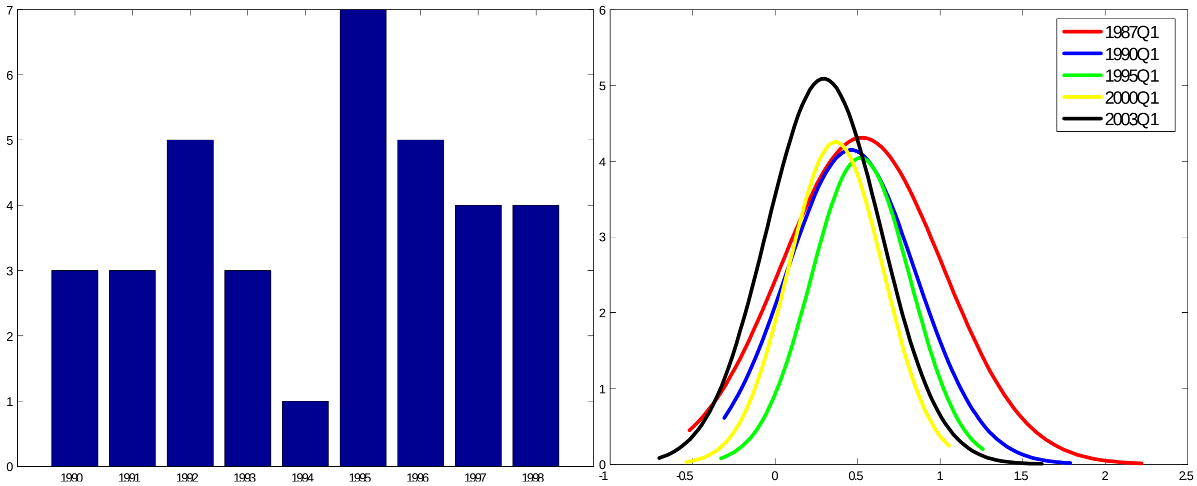
4 The time variation in the estimated ERPT rates

In this section we relax the assumption that ERPT is constant over time and explore the possibility of structural breaks over our sample.

4.1 Testing for the stability of the estimated ERPT rates

In this section, we focus on the estimated short-run ERPT rates since the time-series variation in the estimated long-run ERPT rates would also capture any time-series variation in the estimated coefficients on the lagged dependent variable. Two methods are employed to test for a structural change. The first method employs the Andrews (1993) test for a structural break with an unknown break point. We estimate the unknown break date for industry-specific short-run ERPT rates calculated using equation **(2)**. The left panel of Chart 2 plots the distribution of dates where a structural break is detected in the estimated industry-specific short-run ERPT rates. The x-axis is the break date and the y-axis is the number of industries for which a break is detected. We ignore any estimated dates before 1990 and after 1998, as small sample problems make them unreliable. The first quarter of 1995 appears to be the most important break date across our panel. The second method considers a simple time-varying parameter model to capture any variation in the estimated industry-specific short-run ERPT rates over time. That is we estimate the time-varying ERPT coefficients via a simple random coefficients model that allows these coefficients in equation **(2)** to vary over time. The unobservable parameters are assumed to follow a driftless random walk and are estimated via the Kalman filter. The right panel of Chart 2 plots the Kernel densities of the estimated short-run ERPT coefficients across industries at different dates that we chose randomly. The estimates indicate that the ERPT into import prices has decreased substantially over time.

Chart 2: Short-run ERPT rates over time: disaggregated import price data



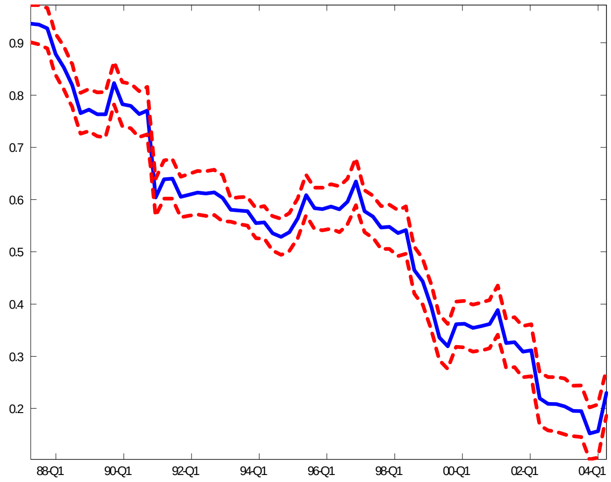
The left panel shows the distribution of dates for which a break is detected in the estimated short-run ERPT rates across industries. The right panel shows the Kernel densities of the estimated short-run ERPT rates across industries at selected dates.

The results are similar when we apply the two methods to the aggregate import price index. The structural break test indicates a change in the estimated aggregate short-run ERPT coefficients in the first quarter of 1995.[(15)] This result is consistent with that obtained using the disaggregated data. Chart 3 plots the estimated aggregate short-run ERPT coefficient over time using a simple time-varying parameter model. As in the disaggregated data, the estimated short-run ERPT has declined over the sample period.[(16)]

(15) The Sup F statistic rejects the hypothesis of stability at the 10% level (P-value 0.09). The estimated break date is 1995 Q1.

(16) Note that 1995 was characterised by a change in ONS conventions regarding import price data. Before 1995, the ONS published import price data based on unit value indices. After 1995, the ONS data was based on company quotes. This raises the possibility that the structural break test may be picking up this change in the definition of the import price index. However, the fact that the time-varying parameter model indicates a *gradual decline* in ERPT over the *entire sample* casts doubt on this idea.

Chart 3: Short-run ERPT rates over time: aggregate import price data



The chart plots the estimated aggregate short-run ERPT coefficient over time using a simple time-varying parameter model. The dotted lines are the standard errors.

4.2 What can lead to a change in ERPT rates over time?

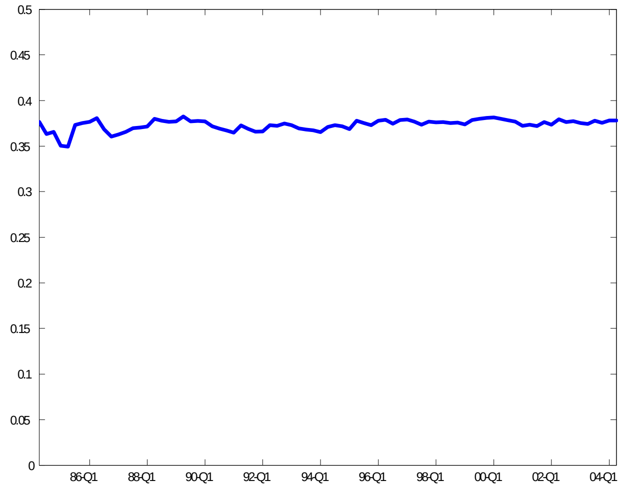
What can explain this decline in ERPT rates? To answer this question, we focus on the aggregate import price data as the estimated variation in the pass-through is broadly consistent across the aggregate and disaggregated data. Specifically, we regress our estimates of the time-varying short-run aggregate ERPT rates on the following variables:

Structure of imports (impute). One simple explanation for the decline in the estimated ERPT rates over time could be a change in the composition of imports, with the share of sectors with low pass-through rates increasing over time. As in CG we construct an index, *impute*, that reflects the change in estimated short-run ERPT rates due to a change in the weights attached to each industry over time. In each period, this variable is set equal to the trade volume weighted average of industry-specific short-run ERPT rates estimated using equation **(2)**. Hence, a decrease in the index reflects an increase in the weight on industries with low pass-through rates. In Chart 4 we plot this variable against time.[17] The chart reveals that the decline in the ERPT rate caused by a shift in the import structure is negligible for our data set.

Macroeconomy. The ERPT literature suggests that the stability of monetary policy and low

(17) In our sample, the impute variable has a mean of 0.37 and a standard deviation of 0.01.

Chart 4: Structure of imports



The chart shows the trade volume weighted average of industry-specific short-run ERPT rates estimated using equation **(2)**. A decrease in the index reflects an increase in the weight on industries with low pass-through rates.

exchange rate volatility can lead to lower pass-through rates. This is because importing countries with high macroeconomic stability are likely to have their currencies chosen for international transactions or greater macroeconomic stability is likely to make importers less willing to change prices. In order to proxy the stability of macroeconomy, in our regressions, we use the conditional variance of the exchange rate returns, consumer price index (CPI) inflation, and import price inflation, all estimated using the method of exponentially weighted moving average (EWMA) as well as the rate of GDP growth in the importing country.[(18)]

Exchange rate surprise. The estimated errors from an AR(4) model fitted to the sterling NEER are used as a proxy for unexpected changes in the exchange rate. Here, the idea is to determine whether errors in forecasting the exchange rate have played a part in the reduction of the ERPT rates in the post-1995 period. For example, if an appreciation in the exchange rate is greater than expected, the ERPT rate may decline if firms reduce prices to offset the effects of the unexpected change in the exchange rate.

The first column of Table D shows our benchmark specification. Not surprisingly, the coefficient

(18) We do not include the variance of GDP growth as a proxy for macro stability in our regressions since in our sample this variable is highly correlated with the variance of import price inflation.

on *impute* is insignificant indicating that, in our sample, the fall in the ERPT rate cannot be explained by a change in the structure of imports. We find the variance of the import price inflation to be significant (at 1%) with a positive sign. However, the exchange rate variance has a negative and significant coefficient, which would suggest that a fall in this variable has increased the ERPT rate. This might be due to the high correlation coefficient (0.87 for our sample) between the variance of the exchange rate and import price inflation. In order to mitigate the effects of multi-collinearity, the third column presents the estimates when we exclude the import price inflation variance from the regression. The coefficient on the variance of the exchange rate is now positive and significant (at 1%). This implies that the decrease in exchange rate variance over the 1990s has reduced pass-through to import prices. The coefficient on GDP is also positive and significant (at 1%). When we run our regressions excluding the exchange rate variance instead, we find only import price inflation to be significant (at 1%) with a positive sign. The coefficient on the variance of CPI inflation and on our proxy for unexpected exchange rate changes is not found to be significant in either of the three specifications in our sample.

Table D: Time-series variation in ERPT

		Exc. IMP-Inf Var	Exc. ER Var
GDP	-0.775 (1.347)	6.883 (1.726)	-0.348 (1.521)
Impute	-0.441 (2.050)	-1.383 (3.906)	-0.091 (2.202)
ER Var.	-0.061 (0.016)	0.112 (0.016)	–
IMP-Inf Var	0.380 (0.024)	–	0.289 (0.014)
CPI-Inf Var	0.040 (0.112)	0.152 (0.210)	-0.046 (0.130)
ER-Surprise	-0.003 (0.003)	-0.007 (0.005)	-0.004 (0.003)
Adj. R^2	0.92	0.70	0.90
N	70	70	70

The table shows the results from regressing the estimated time-varying short-run aggregate ERPT rates on the rate of GDP growth in the importing country; the variance of the Exchange Rate (ER Var); Import Price Inflation (Imp-Inf Var); the CPI inflation (CPI-Inf Var); and a measure of unexpected exchange rate changes (ER-Surprise). White standard errors are in parentheses.

5 Conclusion

In this paper we estimate the rate of ERPT into UK import prices using disaggregated import price data at the two or three-digit SITC level using quarterly data over the period 1984-2004. To the best of our knowledge, no research has been done to measure ERPT into UK import prices at the disaggregate level, and this paper aims to fill this gap. Consistent with earlier studies, we find evidence for significant heterogeneity among the estimated pass-through rates of 57 industries involved in our analysis. Further, we investigate the source of the cross-sectional variation in the estimated industry-specific pass-through rates. For our sample, we find the industry-specific average inflation rates to be significant in explaining this variation. In an environment where cross-sectional heterogeneity is significant the use of aggregate data can be misleading since aggregation may lead to heavily biased ERPT estimates at the economy-wide level. We demonstrate that the aggregation bias caused by this heterogeneity is not negligible for the UK data. For instance, when we use aggregate import price index we find the short-run (long-run) ERPT rate to be 0.44 (0.66) but when we use disaggregated data instead, the pass-through rate for the overall economy drops to 0.38 (0.43). Furthermore, we find evidence for partial short and long-run pass-through into food and manufacturing sectors. A similar conclusion holds for the economy-wide ERPT possibly reflecting the relatively large weight of manufacturing goods in UK imports. Finally, we find a significant reduction in estimated ERPT rates since 1995 possibly caused by the increased stability of the UK economy over the past decade.

References

Andrews, D (1993), 'Test for parameter instability and structural change with unknown change point', *Econometrica*, Vol. 61, No. 4, pages 821–56.

Bailliu, J and Fujii, E (2004), 'Exchange rate pass through and the inflation environment in industrialized countries: an empirical investigation', *Bank of Canada Working Paper no. 2004-21*.

Betts, C and Devereux, M B (1996), 'The exchange rate in a model of pricing to market', *European Economic Review*, Vol. 40, pages 1,007–21.

Betts, C and Devereux, M B (2000), 'Exchange rate dynamics in a model of pricing to market', *Journal of International Economics*, Vol. 50, pages 215–44.

Campa, J M and Goldberg, L S (2005), 'Exchange rate pass-through into import prices', *Review of Economics and Statistics*, Vol. 87, pages 679–90.

Campa, J M, Goldberg, L S and Gonzalez-Minguez, J M (2005), 'Exchange rate pass-through to import prices in the euro area', *NBER Working Paper no. 11632*.

Chari, V V, Kehoe, P J and McGrattan, E (2002), 'Can sticky price models generate volatile and persistent real exchange rates?', *Review of Economic Studies*, Vol. 69, pages 533–63.

Chiarlone, S (2000), 'Evidence of product differentiation and relative quality in Italian trade', *CESPRI Working Paper 114*, Universita Bocconi, Milano, Italy.

Choudri, H E U (2001), 'Exchange rate pass through to domestic prices: does inflationary environment matter?', *IMF Working Paper no. 01/194*.

Devereux, M B and Engel, C (2001), 'Endogenous currency of price setting in a dynamic open economy model', *NBER Working Paper no. 8559*.

Devereux, M B, Engel, C and Storgaard, P E (2004), 'Endogenous exchange rate pass through when nominal prices are set in advance', *Journal of International Economics*, Vol. 63, pages 263–91.

Engel, C (2003), 'On the relationship between pass through and sticky nominal prices', *mimeo*, University of Wisconsin.

Feenstra, R (1989), 'Symmetric pass-through of tariffs and exchange rates under imperfect competition: an empirical test', *Journal of International Economics*, Vol. 27, pages 25–45.

Frankel, J A, Parsley, D C and Wei, S-J (2005), 'Slow pass-through around the world: a new import for developing countries?', *NBER Working Paper no. 11199*.

Gagnon, J E and Ihrig, J (2001), 'Monetary policy and exchange rate pass-through', *International Finance Discussion Papers 704*, Washington: Board of Governors of the Federal Reserve System.

Goldberg, P K and Knetter, M M (1997), 'Good prices and exchange rates: what have we learned?', *Journal of Economic Literature*, Vol. 35, pages 1,243–92.

Gross, D and Schmitt, N (2000), 'Exchange rate pass through and dynamic oligopoly', *Journal of International Economics*, Vol. 52, pages 89–112.

Helpman, E (1981), 'International trade in presence of product differentiation, economies of scale, and monopolistic competition: a Chamberlin-Heckscher-Ohlin approach', *Journal of International Economics*, Vol. 11, pages 305–40.

Imbs, J, Ravn, M, Rey, H and Mumtaz, H (2005), 'PPP strikes back. Aggregation and the real exchange rate', *Quarterly Journal of Economics*, Vol. 120, pages 1–44.

Knetter, M M (1993), 'International comparison of pricing to market behavior', *American Economic Review*, Vol. 83, pages 473–86.

Krugman, P R (1981), 'Intra-industry specialization and the gains from trade', *Journal of Political Economy*, Vol. 89, pages 959–73.

Obstfeld, M and Rogoff, K (1995), 'Exchange rate dynamics redux', *Journal of Political Economy*, Vol. 103, pages 624–60.

Obstfeld, M and Rogoff, K (2000), 'New directions for stochastic open economy models', *Journal of International Economics*, Vol. 50, pages 117–53.

Pesaran, M H and Smith, R (1995), 'Estimating long run relationships from dynamic heterogenous panels', *Journal of Econometrics*, Vol. 68, pages 79–113.

Pesaran, M H and Zhao, Z (1999), 'Bias reduction in estimating long run relationships from dynamic heterogenous panels', in Hsiao, C, Lahiri, K, Lee, L and Pesaran, M (eds), *Analysis of panels and limited dependent variables: A volume in honour of G.S. Maddala*, Cambridge: Cambridge University Press.

Robertson, D and Symons, J (1992), 'Some strange properties of panel data estimators', *Journal of Applied Econometrics*, Vol. 7, pages 175–89.

Ruffin, R (1999), 'The nature and significance of intra-industry trade', *Economics and Financial Review*.

Takeda, F and Katsumi, M (2003), 'Exchange rate pass through and strategic pricing: evidence from Japanese imports of DRAMs', *Economics Bulletin*, Vol. 6, pages 1–13.

Taylor, J (2000), 'Low inflation, pass through, and the pricing power of firms', *European Economic Review*, Vol. 44, pages 1,389–408.

Yang, J (1997), 'Exchange rate pass through in U.S. manufacturing industries', *The Review of Economics and Statistics*, Vol. 79, pages 95–104.