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THE IMPACT OF EXCHANGE RATE FLUCTUATIONS ON PROFIT MARGINS: THE UK CAR MARKET, 1971-2002

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We investigate the impact on profit margins of exchange rate fluctuations in order to examine optimal pricing policy by source countries in the UK car market. We first estimate a nested logit demand model of new cars to calculate model-specific profit margins. Next we use these estimates to analyse the pricing-to-market (PTM) behaviour of car importers and local producers. The results show that: (1) profit margins fell over the period 1971-2002 as the UK car market moved from being a concentrated market to a looser oligopoly structure; (2) there is a positive association between exchange rate changes and mark-up adjustments of imported cars. Following a 10% pound depreciation, exporters' profit margins declined by up to 4% and local producers' profit margins increased by up to 2%; (3) PTM behaviour is asymmetric between appreciations and depreciations in bilateral exchange rates.

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I. Introduction

The degree of price discrimination in the UK car market has been a source of considerable ongoing debate. Consumer advocacy groups have been outspoken

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in their criticism of the pricing policy of car makers in the UK and from continental Europe (BEUC: 1981, 1989, 1992). Academic research has also provided evidence that price discrimination has occurred in the UK market (Cubbin 1975; Verboven 1996; Goldberg and Verboven, 2001). Price discrimination in the UK car market has also evoked scrutiny of the market by regulatory authorities both within the UK (House of Lords 1984; Monopolies and Mergers Commission 1992) and from the European Commission (EC 2000, 2004; Verboven and Degryse 2000). The industry, through its representative body, the Society of Motor Manufacturers and Traders, have vigorously argued discrimination is not at work citing currency movements as being responsible for substantial departures from prices charged for cars in Continental Europe (Competition Commission (UK) 1999). The industry's argument feeds into a substantial literature in observing that the local currency prices of imported goods are often insensitive to exchange-rate changes. On theoretical grounds, this phenomenon is often referred to as "pricing-to-market" (PTM) and reflects the view that exporters reduce their profit margins when faced with a depreciation against their own currency in order to stabilise the prices in destination currency (Krugman 1987).

An extensive body of literature has grown concerning the PTM phenomenon.[1] These studies suggest that pricing-to-market is a global phenomenon but that the main source of variation in their pattern is at the industry level (Knetter 1993) being most pervasive in differentiated product markets (Froot and Klemperer 1988; Knetter 1993, 1995; Marston 1990; Kasa 1992). Indeed, the finding that PTM is more important in differentiated product markets is reassuring since the ability firms have to segment markets through the imperfect substitutability of their products underlie violations in the "law of one price" in models of imperfect competition in international markets. As a substantive global industry and quintessential differentiated product, cars have been the most favoured market used to examine the extent of PTM behaviour (Le Cacheux and Reichlin 1992; Feenstra 1989; Kirman and Schueller 1990; Gagnon and Knetter 1995; Goldberg 1995; Irandoust 1998; Gross and Schmitt 2000; Goldberg and Verboven 2001; Gil-Pareja 2003).

In itself the UK car market is an interesting case study. The ability of firms to price discriminate at the beginning of the seventies was reflected in the UK market

[1] Knetter and Goldberg (1997) provide an excellent survey of the PTM literature.

being a cosy oligopoly: being founded on four manufacturers, whose production was based in the UK who were insulated from imports, through trade restrictions, and from exchange rate movements, by the Breton Woods fixed exchange rate regime.[2] By 2002 the market had witnessed considerable regulatory scrutiny and a number of direct initiatives including: British accession into the (then) EEC in 1973; intensifying pressure on manufacturers by consumer groups since the 1980s; the completion of the *Single Market Programme* in 1 January 1993, and the curtailment of Voluntary Export Restraints (VERs) on Japanese makers in December 1999, which were enforced since June 1977. Each of these factors may have contributed to reduce the degree of discrimination in an increasingly fragmented UK market.

Following Knetter (1989, 1993), past research has applied reduced form pricing models to investigate the impact of exchange rate fluctuations on source currency prices and has attempted to control for unobserved cost differences via the inclusion of intercept terms (to capture changes in marginal costs or common profit margin changes across source destinations) and a set of time dummies (to capture common marginal cost or profit margins changes over time).

We take a different approach by directly estimating the impact on profit margins of a change in exchange rates. First, we estimate a structural model of demand to calculate model-specific price elasticities. Second, we calculate model-specific profit margins (Lerner indices) expressed in local currency using information on prices, market shares and the estimated price elasticities. This approach has two advantages over previous research: (1) we do not require information about source-country prices since mark-ups are fully determined in the destination market; (2) we can model important features of the market, such as the multi-product nature of firms operating in the market and the product differentiated nature of the products. As will be shown in the analysis, explicitly modeling the multi-product nature of the car market implies substantive differences in firm’s mark-up behavior and so is a non-trivial issue. Finally, we examine the impact of exchange rate fluctuations on the model-specific profit margins: (1) How much do profit margins respond to exchange rate fluctuations? (2) Are all source-countries equally responsive to their bilateral exchange rate fluctuations? (3) Is there any evidence of asymmetric

[2] These four car makers were Ford UK, GM Vauxhall, Chrysler UK and British Leyland.

behaviour in the exchange rate pass-through, that is, do profit margins respond differently when the local currency appreciates than when the local currency depreciates? (4) Do local producers' profit margins also respond to exchange rate fluctuations? (5) Did voluntary export restraints have any effect on Japanese profit margins' response to fluctuations in exchange rates?

To preview results, profit margins over the period 1971-2002 fell as the UK car market moved from being characterised by a high degree of concentration to a considerably more fragmented oligopoly structure. The results indicate that manufacturers have implemented a 'pricing-to-market' policy in the UK as exporters reduce (increase) profit margins for foreign car models whose currencies have appreciated (depreciated) against the pound. On the one hand, the magnitude of the exchange rate pass through is different across countries and, on the other hand, importers exhibit asymmetric PTM behaviour with mark-ups adjustment being more pronounced during pound appreciation periods than when the pound depreciated. Another result is that local producers are also sensitive to exchange rate fluctuations. For example, following a depreciation of the pound, the profit margin of the non-Japanese domestic makers increased by up to 2%. We also find some evidence that voluntary export restraints for Japanese cars were binding.

The remainder of the paper is organised as follows. Section II describes the data and salient trends in the supply location of cars marketed in the UK. Section III presents a structural model of demand to estimate model-specific profit margins in a differentiated-product industry and relates profit margin changes to exchange rate changes. The results from model estimations are presented and interpreted in Section IV, and Section V provides concluding remarks.

II. Data and trends in the supply location of cars marketed in the UK

A. Data

We have collected annual data on prices and sales, for all new models of cars sold in the UK car market between 1971 and 2002. The highly differentiated nature of products marketed by firms was captured by employing a rich set of product attributes (power, size, fuel consumption and set of dummy variables that takes value of one if the car specification includes: diesel engine, fuel injection, turbo charging, air conditioning, ABS, PAS and air bags). We also collated the month of entry and exit in the market, when prices changed during the year and the source-country of production of each model. The product data set is merged with bilateral exchange rates for each of the countries that supply cars in the UK car market.[3] Further details concerning the construction and sources of the variables, as well as their related descriptive statistics, are provided in Appendix 1.

B. The supply of cars by production location and exchange rate fluctuations

Table 1 shows the distribution of car sales by year and by source country: UK, France, Germany, Italy, Spain, Sweden, Belgium, Netherlands, Japan and Korea. These 10 countries account for more than 97% of all new cars sold in the UK over the entire period. At the beginning of the 1970s production of cars marketed in the UK was predominantly domestically located. UK domestic production was

Table 1. Production location and distribution of sales (%) in the UK car market

	1971	1975	1980	1985	1990	1995	2002
UK	80.51	64.64	50.88	39.21	43.28	38.35	21.68
France	7.67	9.37	9.71	8.49	11.42	15.78	20.99
West Germany	4.55	7.59	13.00	22.82	17.51	16.38	27.16
Italy	3.00	4.83	3.83	3.70	2.83	3.55	3.54
Sweden	1.82	2.16	2.01	1.42	1.76	1.54	1.49
Japan	1.33	9.51	12.14	11.64	10.28	6.12	8.77
Netherlands	0.84	0.66	1.12	2.09	1.60	0.94	0.75
Spain*			4.65	6.26	3.64	6.67	8.90
Belgium*			0.94	1.79	4.85	6.14	2.92
Republic of Korea**				0.28	0.24	1.65	1.63
Others***	0.28	1.24	1.73	2.31	2.52	2.87	2.17
Number of new cars	1,036,396	1,117,040	1,496,932	1,705,235	1,936,388	1,922,996	2,462,489

Notes: * Supply from Belgium and Spain starts in 1977; ** Supply from Korea starts in 1982; *** USA, Poland, Czech Republic, East Germany, USSR, Australia, Malaysia, Yugoslavia, South Africa.

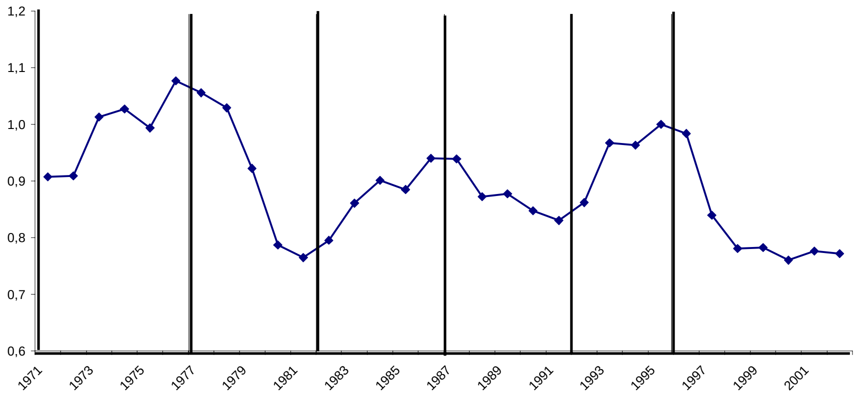
[3] We use monthly industry publications to find out the month(s) in which the price of a model changed to convert retail prices in units of the exporter's currency. On average firms change their price twice a year, with the larger changes being later in the year. Annual nominal exchange rates are calculated as the average of the end-of-the month exchange rate.

dominated by a group of three multinational operations, Ford UK, GM Vauxhall, Chrysler UK, and the last remaining UK mass producer, British Leyland (later Rover Group), with sales being roughly split between these two groups. By 2002 the location of production of cars sold in the UK had radically shifted. Less than one quarter of market sales stemmed from local production, with sales of cars emanating from West Germany eclipsing those in the UK, and the fraction of sales from France following close behind those produced in the UK. The reduced domestic production share in sales also reflected an expansion in market share by Asian manufacturers, initially via a rapid expansion in sales by Japanese manufacturers prior to the formalisation of Voluntary Export Restrictions agreements in 1977, but also to a lesser extent due to the entry of Korean producers. The firm distribution of UK production also shifted radically with the four firms that had dominated domestic production capturing an ever diminishing share of UK production. Chrysler UK was an early victim, exiting the UK market in 1979, with Chrysler's UK brands being discontinued by Chrysler Europe's acquirer, PSA Peugeot-Citroën by 1986. Rover Group sales have fallen precipitously to account for a mere 4 percent of domestic sales in 2002, while Ford UK's car production peaked in 1972 and ended in 2002, and GM Vauxhall expanded UK production until 1992, from which time the firm's production has more than halved. The market shifted from being a concentrated domestically based oligopolistic structure to one where a larger number of firms have carved out significant shares of the market. This alteration in market structure suggests that firm's ability to discriminate within the market may have declined over time.[4]

The volatile nature of UK's exchange rates between domestic and source currencies provided foreign manufacturers with ample opportunity to PTM. In each of the three decades we investigate the Sterling experienced dramatic swings against car manufacturers' local currencies. In 1973 and 1993, the pound, expressed as a real effective exchange rate, lost more than 10% of its value; in 1980 and 1997 the pound experienced an appreciation of 17% and 18%, respectively as is depicted in Figure I. While annual movements have been quite volatile they followed a strong cyclical pattern with three pairs of prolonged exchange rate shifts occurring over the period: pound depreciations between 1971-76, 1982-86 and 1992-95; and pound appreciations between 1978-82, 1987-1991 and 1996-2002.

[4] Firm concentration, as measured by the Herfindahl index, has fallen from 0.049 in 1971 to 0.021 by 2002.

Figure 1. Effective exchange rate of British pound sterling, 1971-2002



Source: Bank of England (www.bankofengland.co.uk). Normalised series (1995=1). A decrease in value represents an appreciation of the British pound. There are six periods, corresponding to depreciation (1971-77, 1983-86, 1993-96) and appreciation of the British pound (1978-82, 1987-92, 1997-02).

III. The model

A. Demand of cars

Following Berry (1994), household *i*'s utility of purchasing car *j* (U_{ij}) can be expressed as a linear function of car *j*'s characteristics and tastes idiosyncratic to household *i*:

$$u_{ij} = x_j\beta - \alpha p_j + \xi_j + \tau_{ij} \qquad (1)$$

where x_j is a vector of product *j's* attributes, and p_j is the car price. ξ_j represents car *j*'s characteristics that the household value, while τ_{ij} captures household *i*'s specific taste for car *j*, both of which are not observed by the econometrician. The mean utility level that product *j* yields to households is denoted by δj, so that $\delta_j = x_j\beta - \alpha p_j + \xi_j$. Consumers also have an option of not purchasing a car and purchasing the outside good.[5] Note that in this framework all variation in the valuation of cars across consumers stems from the unobserved additive taste term τ_{ij}. We allow consumer-specific tastes to be correlated across products with similar

[5] It is important to include an outside choice to make possible that a change in the price of all the cars affects the total demand of cars.

characteristics by using a nested logit demand model. Following Cardell (1997), the consumer taste parameter can be modelled as $\tau_{ij} \equiv v_{ig}(\sigma) + (1-\sigma)\varepsilon_{ij}$. The ε_{ij} term captures consumer tastes that are assumed to be identically and independently distributed across products and consumers according to the extreme value distribution. The term v_{ig} captures the common taste that household *i* has for all cars in market segment *g*. We group cars into eight distinct market segments *g*: mini, small, medium, executive, luxury, sport, jeep and minivan.[6] The common taste depends on the distribution parameter, $\sigma(0 \le \sigma < 1)$, which indicates the degree of substitutability between products within a market segment. When σ is zero, consumer tastes are independent across all cars and there is no market segmentation. The higher σ the more correlated the consumer tastes are for products within the same market segment and the competition among products is stronger within than across market segments.

Given the set of available cars, households are assumed to select the car that gives them the highest utility. Consumer *i* will choose car *j* if $u_{ij} > u_{ik}$, $\forall$k. Given the distributional assumptions on consumer tastes and functional form for utility, we can aggregate over individual consumer purchases to obtain predicted aggregate market share s_j of car *j*:

$$s_j(\delta,\sigma) = \frac{e^{\delta_j/(1-\sigma)}}{D_g} \frac{D_g^{1-\sigma}}{\sum_g D_g^{1-\sigma}} \text{ where } D_g = \sum_{j\in g} e^{\delta_j/(1-\sigma)} \tag{2}$$

The first term in this expression is car model *j's* market share in its market segment, while the second term is the market share of a market segment g in the overall car market. Since the outside good yields zero utility by assumption, δ_0 is 0 and D_0 is 1. From equation (2) we can derive the own and cross-price elasticities of demand for each model (see Appendix A2).

From the equation (2) it is easy to derive the following equation that links market shares to prices, car characteristics and the within-group share:

[6] The cars were allocated to each of these segments according to the Department of Trade and Industry (DTI) classification.

$$\ln S_j - \ln S_0 = x_j \beta - \alpha p_j + \sigma \ln S_{j/g} + \xi_j \tag{3}$$

where S_j is the observed market share of product j, S_0 is the observed market share of the outside good - in our case, following Berry, Levinsohn and Pakes (1995) and others, the total potential market consists of all households in a given year - $S_{j|g}$ is the observed market share of product j within its market segment g, x_j is a vector of observable attributes of car j, P_j is the price of car j and ξ_j represents the unobservable attributes of car j such as (unobserved) quality, prestige or reliability. This straightforward linear equation can be used to obtain the structural parameters of demand (α, σ).

B. The pricing-to-market equation

We assume that the industry competes in a Bertrand oligopoly setting of pricing behaviour.[7] Car makers market several models in a foreign destination market. In each period (omitting time subscripts), firm f maximizes its profits given by:

$$\pi_f = \sum_{j \in F_f} (ep_j - c_j) s_j(p) M \tag{4}$$

where p is the export price (expressed as price in the importer's currency); $s_j(p)$ is the product j^{th} market share (a function of the price vector p in the importer's currency) and M is (exogenous) market size; e is the exchange rate (in units of the exporter's currency per unit of the importer's currency); and c_j is the product's marginal cost. The profit function accounts for the fact that car makers are multi-product firms that simultaneously offer several products to the market at any one point in time. When a car maker considers lowering a price of one of its products, this will not only have the effect of reducing the market share of other rivals' products, but may also undercut the sales of its own other products. Hence we should explicitly capture the fact that a multi-product car maker might lower its prices by less than in a situation when it only sells one product.

Assuming that firms compete in prices, the first-order conditions for profit maximizing firm f with respect to product k yield:

[7] The assumption of price setting behaviour in the car market is common (Goldberg and Verboven, 2001) and consistent with industry wisdom.

$$\sum_{j\in F_f}\left(ep_j - c_j\right)\frac{\partial s_j}{\partial p_k} = -es_k \tag{5}$$

To derive a pricing equation for each product *k*, we use vector notation. Let *p* denote a *Jx1* price vector, *c* a *Jx1* vector of marginal costs, and *s* a *Jx1* vector of market shares of all products offered at time *t* (time subscript is omitted in the notation). Let Ω be a *JxJ* matrix whose element in row *k* and column *j* equals $-\partial s_j / \partial p_k$ if car *j* and *k* are produced by the same firm and 0 otherwise. We can then rewrite the first order profit maximizing conditions (or Lerner index) in vector form as

$$L = \frac{ep - c}{ep} = \Omega^{-1}\frac{s}{p} \tag{6}$$

Note that in the case of a single-product firm, the markup over price or profit margin equals the inverse of the products own price elasticity. Equation 6 reveals that the profit margin, expressed in source currency, is determined by the elasticity of demand in the foreign market, the market share and the price of the model.

Once we know the model-specific profit margins, we can investigate the effects of exchange rate fluctuations on profit margins. [8] Our empirical model based on Knetter (1989) is

$$L_{it} = \beta_i e_{it} + \theta_t + \theta_{brand} + \theta_{segment} + \varepsilon_{it} \tag{7}$$

where L_{it} is the log of the model-specific profit margin, calculated in (6), e_{it} is the log of the destination-specific exchange rate (expressed as units of the buyer currency per unit of the seller´s divided by the destination market price level) and $(\theta_t, \theta_{brand}, \theta_{segment})$ are vectors of dummy variables capturing year-specific, brand specific and segment specific fixed effects, respectively. These three set of dummy variables will control for differences in profit margins due to business cycle, firm characteristics such as prestige or luxury and segment features that may explain profit margins fluctuations not related to exchange rate fluctuations. The

[8] Since the average life of a new car is 8 years we did not explore the time-series properties of the model-specific profit margins.

interpretation of the coefficient on the exchange rate variable, β_1, is derived from Knetter (1989). The β_1 measure the destination-specific response of profit margins to destination-specific changes in exchange rates. A value of β_1 equal to zero means that the mark-up to a particular destination is independent of fluctuations in the value of the seller's currency against the buyer's. This implies that changes in currency values are fully passed through to the buyer. Negative values of β_1 indicate that mark-up adjustment is associated with stabilization of local currency prices. Positive values of β_1 imply that destination-specific mark-ups change in a way which amplifies the effect of destination-specific exchange-rate changes on the price in terms of the buyer's currency.

IV. Econometric issues and results

A. Demand and profit margin results

The estimation of the demand equation (3) presents one econometric problem. Its estimation by OLS will yield inconsistent estimates if car prices and within-group market share ($Sj|g$) are correlated with unobserved quality (ξ_j). We address the problem by estimating this equation using instrumental variable methods. We make use of the instruments usually used in this literature: (1) location of production dummies; (2) the number of models that a firm sells; (3) the number of models sold by rival firms within each market segment; (4) the characteristics of the rival cars averaged over models within each market segment. The key identifying assumptions is that cost of production, rival product attributes and intensity of competition measures are not correlated with unobserved quality. [9]

Table 2 displays the estimation results. Columns 1 and 2 report the OLS estimates of the demand parameters, while Column 3 reports the two-stage least squares estimates. In order to evaluate the performance of the instruments, we report the F-test of joint significance of the instruments of the regression of prices and segment market shares on the exogenous variables and the instruments. We do not have a weak instrumental problem as both F-tests are significant at 0.01 percent level. Accounting for the endogeneity of price and within segment market share affects

[9] For a detailed discussion about the validity of the selected instruments, see Berry, Levinsohn and Pakes (1995) and Bresnahan, Stern and Trajtenberg (1997) .

Table 2. Estimation of equation (3): Log (model market share/outside good market share)

Explanatory variables	(1)		(2)		(3)	
price (α)	-0.020	***	-0.028	***	-0.049	***
	(9.50)		(18.89)		(14.41)	
segment (σ)			0.681	***	0.331	***
			(79.63)		(20.02)	
power	-0.008	***	-0.006	***	0.001	*
	(8.66)		(11.07)		(1.72)	
size	0.009	***	0.008		0.082	***
	(6.41)		(0.01)		(7.62)	
mpp	0.009	***	0.008	***	0.007	***
	(13.72)		(19.50)		(14.21)	
inject	0.028		0.016		0.003	
	(0.52)		(0.47)		(0.09)	
diesel	-0.578	***	-0.427	***	-0.438	***
	(5.48)		(6.88)		(5.43)	
turbo	-0.005		0.003		-0.912	
	(0.06)		(0.07)		(1.29)	
aircon	-0.020		0.058	**	0.148	***
	(0.29)		(1.97)		(2.67)	
abs	-0.011		-0.359		-0.013	
	(0.17)		(0.81)		(0.26)	
pas	-0.378	***	-0.278	***	0.185	***
	(6.33)		(7.01)		(3.86)	
airbag	-0.317	***	-0.296	***	0.179	***
	(4.05)		(5.82)		(2.92)	
constant	-9.329	***	-5.913	***	-7.709	***
	(47.79)		(41.60)		(44.52)	
R squared	0.21		0.72		0.51	
Method of estimation	OLS		OLS		IV	
Period	1971-02		1971-02		1971-02	
F-test (p-value)					0.00 / 0.00	
Sargan test (p-value)					0.00	
Number observations	4,692		4,692		4,692	

Notes: t-ratios are reported in parenthesis. * Significant at the 90% level; ** Significant at the 95% level; *** Significant at the 99% level.

notably the estimated parameters. For example, the OLS estimate of the price coefficient in Column 2 is -.028, while the IV estimate is -.049 in Column 3. These estimates are in line with our expectation of upward bias in the OLS price coefficient. The coefficients on other product attributes are sensible. The IV estimated value of σ is 0.33 (compared to the OLS value of 0.68). The estimate is significantly different from zero, which suggests that cars within the same market segment are better substitutes for each other than cars across the market segments. The usual interpretation for the differences between the OLS and IV results is that cars with high unmeasured quality components will have (*ceteris paribus*) higher prices and higher market shares, making price and quantity positively correlated with the structural error term. The results provide a further indication that the instruments we use are effective.[10]

Table 3. Estimated price elasticities and profit margins

Period	Price elasticities			Profit margin *(ep-c)/ep*		
	(1) Own price	(2) Cross price same segment	(3) Cross price across segment	(4) Multiproduct Bertrand	(5) Single product Bertrand	(6) Deviation (4-5)/5
1971-75	-2.087	0.303	0.028	0.139	0.128	0.083
	(0.371)	(0.115)	(0.016)	(0.051)	(0.049)	(0.037)
1976-80	-2.146	0.245	0.036	0.126	0.114	0.105
	(0.336)	(0.124)	(0.016)	(0.050)	(0.048)	(0.038)
1981-85	-2.208	0.269	0.032	0.121	0.111	0.092
	(0.331)	(0.094)	(0.016)	(0.048)	(0.046)	(0.037)
1986-90	-2.251	0.333	0.042	0.118	0.108	0.090
	(0.315)	(0.103)	(0.017)	(0.045)	(0.044)	(0.032)
1991-95	-2.321	0.326	0.036	0.112	0.104	0.084
	(0.416)	(0.125)	(0.021)	(0.046)	(0.045)	(0.032)
1996-	-2.377	0.257	0.037	0.105	0.101	0.039
2002	(0.401)	(0.138)	(0.023)	(0.047)	(0.045)	(0.036)
1971-	-2.232	0.295	0.035	0.112	0.106	0.051
2002	(0.464)	(0.182)	(0.027)	(0.051)	(0.046)	(0.039)

Notes: Reported elasticities are period averages. Standard deviations are reported in parenthesis.

[10] The Sargan test for over-identifying restrictions is rejected at reasonable confidence values. The Sargan test is an omnibus specification test so there many reasons why it may be rejected. Nevo (2003) shows that it is fairly common to reject this test in models of differentiated-product demand on aggregate data.

We use the estimates for the coefficient on prices α and the substitutability parameter σ from Column 3 to calculate the own and cross-price elasticities of demand, as described in Appendix 2. Table 4 presents the means and standard deviations of the elasticities over time in Columns 1-3. First, the average estimate of the own-price elasticities reported in Column 1 suggests that a 10 percent increase in the price lowers a car's market share by 22 percent. The average demand elasticity increases in absolute value over time, averaging about –2.08 in the early 1970s to –2.37 in the late 1990s. Within a year, the own-price elasticities also differ significantly across products. Second, the estimates of the cross-price elasticities reported in Column 2 (for products in the same market segment) and 3 (for product in different market segments) suggest that products within each market segment are closer substitutes for each other than products across the segments. For example, the average cross-price elasticity suggests that a 10 percent increase in the price of a product leads on average to 2.9 percent increase in the market share of other products in the same segment and only .35 percent increase in the market share of other products in a different market segment.

With the estimated structural parameters (α, σ) from the demand equation, the prices and the markets shares, we have calculated model-specific profit margins, following equation (6). Columns 4-5 of Table 3 report the implied average profit margins over time. Column 4 presents the implied profit margins when we assume that a different firm produces each product, Column 5 presents profit margins that account for multi-product firms, and Column 6 shows the percentage difference between Column 4 and 5. First, the multi-product Bertrand estimates in Column 5 indicate that the average profit margins decline from .139 in the early 1970s to .102 in the late 1990s. Thus, competition in the UK car market has increased over time. For comparison, the mark-up over price estimated by Cubbin (1975) for the UK car passengers market during the period 1956-68 was .16; Verboven (1996) estimates a mark-up over price of .10 for the UK car market in 1990. Second, the multi-product firms' profit margins are higher than if we assume the case of single-product firms, and the differences have persisted over time. Therefore, it is important to account for the nature of the multi-product firm in order to calculate the profit margins.

B. The impact of exchange rate movements on profit margins

Now we investigate the impact of exchange rate fluctuation on profit margins, using equation (7). We begin examining the degree of exchange rate pass-through after pooling the data and allowing for different country-specific exchange rates associated to each of the nine source locations (after excluding UK). The results are reported in Table 4, column 1. The estimated value of -0.10 for Belgium car exports implies that in response to a 10% pound depreciation(appreciation) profit margins decreased (increased) by 1%. The range of estimated PTM coefficients

Table 4. Estimation of equation (7): Profit margins of exporters of cars to the UK.

Explanatory variables log bilateral exchange rate:	(1) whole period	(2) pound depreciation period	 pound appreciation period
Belgium	- 0.106 **	- 0.062 **	- 0.172 ***
	(2.19)	(2.01)	(4.78)
France	- 0.222 **	- 0.051	- 0.321 ***
	(2.30)	(1.15)	(3.93)
Germany	- 0.299 **	- 0.107 **	- 0.427 ***
	(2.47)	(2.23)	(4.62)
Netherlands	- 0.155 ***	- 0.082	- 0.279 ***
	(3.31)	(1.20)	(3.89)
Italy	- 0.071	- 0.055	- 0.098
	(1.43)	(0.63)	(1.57)
Spain	- 0.078	- 0.045	- 0.084
	(0.52)	(1.34)	(0.82)
Sweden	- 0.177 **	0.002	-0.146 *
	(2.21)	(0.44)	(1.88)
Japan	- 0.058	0.034	- 0.102 **
	(1.27)	(0.24)	(2.02)
Korea	- 0.041	0.001	- 0.022
	(0.37)	(0.45)	(0.48)
year dummies	yes	yes	
segment dummies	yes	yes	
brand dummies	yes	yes	
R squared adjusted	0.810	0.820	
N	3,763	3,763	

Notes: t-ratios are reported in parenthesis. * Significant at the 90% level; ** Significant at the 95% level; *** Significant at the 99% level.

range from –0.299 from German sourced cars, which obtained the largest share of imports by the end of the period analysed, to -0.041 for cars exported from Korea. The PTM coefficients are statistically significant at 10 percent level for all except two European countries, Spain and Italy, and two non-European countries, Japan and Korea. While German, French and Swedish cars´ profit margins seem to be more sensitive to exchange rate fluctuations, Japanese and Korean exhibit the lowest PTM coefficients.

It is possible that firms follow different pricing strategies when the sterling appreciates or depreciates. Knetter (1994) sets out the two arguments that justify an asymmetric response of export prices to appreciations and depreciations of the exporter's *vis-à-vis* the importer's currency. Under the first scenario, firms adjust profit margins more aggressively during *appreciations* of the exporter's currency (pound depreciation periods), a price strategy aimed at maintaining market share in foreign markets. A desire to build market share implies that during an appreciation of their currency, exporters prefer to reduce their markups and thus offset the implied increase in destination currency prices in order to maintain their market share in the foreign markets. However, when a depreciation of their currency occurs, exporters intent of building market share will adjust markups to a lesser degree permitting a larger proportion of the exchange rate shift to be passed-through in order to reduce export prices and increase market share. Therefore, profit margins tend to remain unchanged or increase marginally during pound appreciation periods. Under a second scenario, firms will fully adjust profit margins during *depreciations* of the exporter's currency (pound appreciation periods) due to binding quantity restrictions or volume trade restrictions. In the car industry, the existence of temporary bottlenecks in foreign markets, that is, instances where car exporters cannot expand their sales without also providing an expanded sales, distribution and service infrastructure abroad is a possibility. Moreover, Japanese car makers were subject to potentially binding voluntary export restrictions (VER) over the period 1977-1999. Under the bottlenecks scenario, the optimal price strategy of the exporters in response to a *depreciation* of their currency (pound appreciation period) is to adjust their profit margins upward in order to keep importer's currency prices stable and clear the market (i.e., PTM is complete). For the case of Japanese exporters, when quantity constraints bind and they are already charging the optimal price in pounds to achieve the quota sales level, profit margins will fully adjust upwards in response to a yen depreciation. However, since the number of cars shipped can be below the quota level, *appreciations* of the yen against pound may not elicit as much pricing-to-market, so profit margins will not fully adjust.[11]

Table 4, column 2, examines whether pricing behaviour have been asymmetric during the period analysed. Given the long run nature of our data set, the 31 years period incorporates three periods of sustained pound appreciation and pound depreciation (as Figure 1 shows). Then we allow the country-specific exchange rate coefficients to vary between periods of pound depreciation and periods of pound appreciation. The results shows that across each of the nine source countries the PTM elasticities are higher during pound appreciation periods and lower during pound depreciations periods.[12] The fact that profit margins among European makers seem to be less sensitive to bilateral exchange rates during pound depreciation periods than during pound appreciation periods strongly supports the hypothesis that temporary bottlenecks are important in the UK market.[13] Finally, the results are also consistent with the bottlenecks hypothesis in that Japanese mark-ups are more sensitive to changes in exchange rates during pound appreciation periods rather than during depreciation periods. [14]

Next we examine the mark-up response of local producers to British pound

[11] There is some evidence supporting the relevance of asymmetric behaviour in the exchange rate pass-through using industry-level data, however the findings are far from conclusive. Marston (1990) found an asymmetric response for five of the seventeen Japanese products exported to the US that he examined over the period 1980-1990. Of interest to our analysis, 'passenger cars' did exhibit a considerably greater PTM elasticities during the yen appreciation period (between February 1985 and December 1987). Knetter (1994) and Gil-Pareja (2000) seldom reject the hypothesis of a symmetric response of export prices to changes in exchanges rates on a wide sample of exporting industries in seven European countries between 1988 and 1996. In contrast, Ohno (1989), using quite aggregate industry data (2-digit) found PTM elasticities that were higher during yen *depreciations* in machinery and electrical equipment. Goldberg (1995) in simulations for the US car industry finds greater effect on import prices when the dollar depreciates than when it appreciates.

[12] F-tests showed these deviations to be statistically important at conventional levels for all the source countries.

[13] Gil Pareja (2000) also found evidence of temporary bottlenecks in other European markets for large engine size vehicles.

[14] However, Japanese car makers should adjust markups more than their European competitors if there are binding quota constraints. But compared to their European competitors, Japanese profit margins appear to fluctuate less, suggesting that voluntary export restraints on Japanese cars may be not been effective over the whole period 1977-1999.

exchange rate changes. In particular we wish to examine two issues. First, we ask whether local producers' profit margins are also sensitive to exchange rate fluctuations (in our case, the effective exchange rate of British pound sterling). Second, we ask whether Japanese cars made in the UK were also subject to the same quantity restriction as Japanese imports.[15]

Table 5 presents the results. A pound depreciation of 10% leads to an increase in profit margins among UK-based manufacturers of 1.1% during the period 1971-2002, rising to 1.8% for the sub-period 1987-2002 (before 1988 there is no Japanese car production in the UK). When we split the sample between Japanese makers and non-Japanese makers, Column 3 shows that mark-ups are responsive to exchange rate variations only for the first group; the profit margins of non-Japanese cars manufactured in the UK increase nearly 2% after a pound depreciation. Finally,

Table 5. Estimation of equation (7): Profit margins of car makers in the UK

Explanatory variable	(1)	(2)	(3)	(4)	
Effective pound exchange rate	1971-2002 period	1987-2002 period	1987-2002 period	pound depreciation	pound appreciation
All models	0.112	0.180 **			
	(1.34)	(2.36)			
Non-Japanese models			0.195 **	0.308 **	0.154
			(2.08)	(2.41)	(1.40)
Japanese models			0.098	0.075	-0.039
			(0.35)	(0.24)	(0.27)
segment dummies	yes	yes	yes	yes	
brand dummies	yes	yes	yes	yes	
R squared adjusted	0.85	0.90	0.90	0.90	
N	918	352	352	352	

Notes: t-ratios are reported in parenthesis. * Significant at the 90% level; ** Significant at the 95% level; *** Significant at the 99% level. Japanese makers started car production in the UK in 1988. The number of Japanese model-year observations is 60.

[15] In 1988 Nissan started to produce in the UK. In 1988 Japanese cars represented around 3% of total UK production and 12% of Japanese cars sold in the UK. In 2002 they represented 28% and 39%, respectively.

Column 4 shows that there is an asymmetric PTM behaviour in cars manufactured in the UK, as was the case with for imported cars.[16]

V. Concluding remarks

This paper examined the pricing policy of foreign car manufacturers in the UK market to reveal the degree of pass-through of exchange-rate fluctuations on profit margins over an extensive time horizon where the market witnessed substantive structural change. Rather than examining the relationship between prices and exchange rates, we derive profit margins directly using discrete choice modelling and then examine the effect of changes in the bilateral rate of exchange rates on profit margins.

The results reveal that profit margins adjust in the UK car market to changes in exchange rates. The estimated values of the exchange rate coefficients implied that pricing to market behaviour of German manufacturers was more pronounced than other European countries and Japan and Korea. The direction of the mark-up adjustments reveals that exporters try to stabilize local currency prices; this is particularly the case during periods of pound appreciation. The results also reveal that local producers are sensitive to exchange rate fluctuations; in particular, non-Japanese UK car models increase their profit margins more during pound depreciation periods than during pound appreciation periods.

Appendix I. Definition of variables, descriptive statistics and data sources

Price: Retail price divided by CPI. Nominal prices are derived from the *Motorists' Guide to New and Used Car Prices* (1971-1986) and *Parkers' Guide to New and Used Car Prices* (1987-2002). Since both sources use information provided by the industry there are no comparability problems. The data used for new car prices is the recommended retail price of new cars as reported by the car manufacturers, since there are no data on the discounts offered by the retailers and, hence, on the actual transaction prices. Prices of new cars change, on average, twice a year, but any large change usually occur late in the year.

[16] Domestic manufacturers include Ford UK, GM Vauxhall, Rover, Jaguar, Aston Martin, Daimler, Lotus, Rolls-Royce.

Sales: The demand for new car purchases is measured by annual new car registrations. Unit sales for each car model was originally compiled by the Society of Motor Manufacturers and Traders (SMMT) and provided by Renault UK and Global Insight Inc. (GII) strictly for academic use.

Product attributes: The variables employed are power, size, economy, diesel engine, fuel injection, turbo, air conditioning, PAS, ABS and front air bags. Power is defined as brake horse power (BHP) divided by weight (pounds), size is defined as length times width times height (in inches), and economy is defined as kilometres per £ (expressed in 2000 prices). The remainder of the variables are dummy variables. The product attributes refer to the baseline model. Sources: Augur Tech Ltd. data supplemented by aforementioned retail price guides.

Bilateral exchange rate: Bilateral exchange rates, defined as destination market currency per unit of the exporter's currency divided by the destination's CPI and multiplied by each respective source country's CPI. Sources: *International Financial Statistics* (various issues), Washington DC; *International Monetary Fund* (various issues), Washington DC. The effective Sterling exchange rate was obtained directly from *Bank of England* webpage.

Table A1. Descriptive statistics (N=4,692)

Variable	name	mean	s.d.	min	max
total market share	msh	0.001	0.001	0.00001	0.013
segment market share	segms	0.048	0.070	0.0004	0.623
price (in thousand pounds of 2000)	price	18.975	13.986	3.378	170.117
bhp divided by weight	power	90.72	30.73	28.17	280.39
length*width*heigth (/1000)	size	10.59	2.27	5.46	20.38
km per real pound of 2000	economy	115.5	23.41	29.04	157.94
dummy=1 if fuel injection	inject	0.437	0.496	0	1
dummy=1 if diesel engine	diesel	0.079	0.269	0	1
dummy=1 if turbo engine	turbo	0.077	0.267	0	1
dummy=1 if air conditioning	air	0.177	0.382	0	1
dummy=1 if automatic brake system	abs	0.228	0.420	0	1
dummy=1 if power assisted steering	pas	0.528	0.499	0	1
dummy=1 if front air bags	bag	0.117	0.321	0	1
production location dummies	UK	0.211		Italy	0.084
	Belgium	0.005		Spain	0.032
	France	0.124		Sweden	0.039
	Germany	0.211		Japan	0.248
	Holland	0.016		Korea	0.030

Appendix II. Price elasticities estimated in a nested demand logit model

The own and cross-price elasticities of demand are derived from market share equation (2),

$$\eta_{jj} = \frac{\partial s_j}{\partial p_j}\frac{p_j}{s_j} = -\alpha p_j s_j + \alpha p_j\left(\frac{1}{1-\sigma} - \frac{\sigma}{1-\sigma} s_{j|g}\right),$$
$$\eta_{jk} = \frac{\partial s_j}{\partial p_k}\frac{p_k}{s_j} = -\alpha p_k s_k \quad \text{if } \; j \neq k, \; k \notin g, \; j \in g,$$
$$\eta_{jk} = \frac{\partial s_j}{\partial p_k}\frac{p_k}{s_j} = -\alpha p_k s_k\left(\frac{\sigma}{1-\sigma}\frac{s_{k|g}}{s_k} + 1\right) \quad \text{if } \; j \neq k, \; k, j \in g,$$

where η_{jj} is product *j*'s own-price elasticity of demand, η_{jk} is the cross-price elasticity between product *j* and *k*, and differs depending upon whether the products belong to the same market segment.

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