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SCHWEIZERISCHE NATIONALBANK
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BANCA NAZIONALE SVIZZERA
BANCA NAZIUNALA SVIZRA
SWISS NATIONAL BANK

2012-11

Swiss National Bank Working Papers

ISSN 1660-7716 (printed version)
ISSN 1660-7724 (online version)

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May 2012

Abstract

We document that in the European car industry, exchange rate pass-through is larger for low than for high quality cars. To rationalize this pattern, we develop a model of quality pricing and international trade based on the preferences of Musa and Rosen (1978). Firms sell goods of heterogeneous quality to consumers that differ in their willingness to pay for quality. Each firm produces a unique quality of the good and enjoys local market power, which depends on the prices and qualities of its closest competitors. The market power of a firm depends on the prices and qualities of its direct competitors in the quality dimension. The top quality firm, being exposed to just one direct competitor, enjoys the highest market power and equilibrium markup. Because higher quality exporters are closer to the technological leader, markups are generally increasing in quality, exporting is relatively more profitable for high quality than for low quality firms, and the degree of exchange rate pass-through is decreasing in quality.

*An earlier version of this study was titled "How do the Prices of Different Goods Respond to Exchange Rate Shocks? A Model of Quality Pricing-to-Market." We thank Ariel Burstein, Gianpaolo Corsetti, Linda Goldberg, Paul Krugman, Frank Verboven, an anonymous referee at the Working Paper Series of the Swiss National Bank and seminar participants at the ASSA Annual Meeting 2008, Austrian National Bank, the Bank of Spain, The CEPR/UPF/CREI Third Annual Workshop on Global Interdependence, the CEPR/SNB Conference of Quality Heterogeneity in International Trade, Columbia University, the European University Institute, Humboldt University, Magiar Nemzeti Bank, Paris School of Economics, University of Munich, and the 2007 Princeton IES Summer Workshop. The views expressed in this study do not necessarily reflect those of the Swiss National Bank.

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1 Introduction

Empirical evidence suggests that vertical product differentiation is a key determinant of international trade patterns. Richer nations tend to both export (Schott (2004); Hummels and Klenow (2005)) and import (Hallak (2006)) goods with higher unit values. Also direct estimates of product "quality" point at vertical product differentiation being of first order importance for our understanding of international trade flows (see Khandewal (2010), Hallak and Schott (2011), and Manova and Zhang (2012)).

While existing work has analyzed the role of good quality for the international product cycle (see Flam and Helpman (1987)), for the selection of goods and firms into exporting (see Hummels and Skiba (2004), Baldwin and Harrigan (2011), Johnson (2012), Kugler and Verhoogen (forthcoming), Crozet et al. (forthcoming), and Manova and Zhang (2012)) and for the direction of net trade flows (see Foellmi et al. (2010), Fieler (2011), Hallak (2010), and Fajgelbaum et al. (2011)),[1] the importance of vertical differentiation on firms' pricing-to-market (PTM) decisions and competitive pressure has received little attention in the literature. This gap is striking, as quality has been identified as a main dimension of product differentiation and pricing decision (see for example Mussa and Rosen (1978) and Shaked and Sutton (1982)).

In the current paper, we argue that good quality is also a key determinant of firms' pricing-to-market (PTM) decisions. To motivate our analysis, we first document that good quality is an economically important determinant of pricing in the European car industry. We examine a panel of cars sold in five markets from 1970 to 1999. Our data is from Goldberg and Verboven (2001 and 2005), and includes car characteristics, based on which we can construct several indices of car "quality". Second, the data includes prices of the same car model sold in different markets, allowing us to analyze export pricing of one and the same good differs along the quality dimension and how it responds to the exchange rate changes.

We analyze whether the degree of exchange rate pass through (ERPT) differs between high and low quality cars.[2] First, we document that pass-through rates of exchange rate

[1] Further see Linder (1961), Verhogen (2008), Choi et al. (2009), and Hallak and Sivadasan (2009).

[2] Exchange rate movements are endogenous to productivity, wages, and other macroeconomic shocks.

changes into nominal prices are higher for low quality cars than for high quality cars. Our empirical estimates suggest that this differential effect is large: the short term pass-through rate is below 10 percent for the highest decile of car quality, while it is around 20 percent for the lowest decile of car quality. Second, we evaluate the impact of exchange rate shocks on export over local prices for the same car model. We find that the relative pass-through rate is significantly larger for low quality than for high quality cars. The magnitude of this difference is larger than the difference we document for nominal prices and it holds over various horizons.

To rationalize these patterns, we propose a model of how firms price to market in an industry that is differentiated by good quality in the second part of the paper. Our model is motivated by the literature emphasizing price complementarities (see Atkeson and Burstein (2008), Melitz and Ottaviano (2008), Chen et al. (2009), Gust et al. (2010), and Auer and Schoenle (2012)).

The main focus of our analysis is on analyzing how firms producing goods of heterogeneous quality compete for consumers with heterogeneous preference for quality, how this competition leads to a direct price interdependency between firms producing goods adjacent in the quality space, and how the equilibrium degree of price complementarities is determined by the reverberation of direct price interdependencies through the chain of firms lined along the quality space.

We thus draw on the literature of quality competition in the field of industrial organization and adopt the preference structure from the seminal works by Mussa and Rosen (1978) and Shaked and Sutton (1982), in which goods of heterogeneous quality are sold to consumers with heterogeneous valuation for quality. Specifically, we postulate that consumers differ in their valuation for quality in the sense that, while all of them strictly prefer higher quality levels over lower ones, individuals differ in their willingness to pay for a marginal increase of quality. This type of consumer heterogeneity can lead to non-degenerate equilibria (see Anderson et al. (1992)), where a countable number of firms coexist, each selling to a strict subset of the total market. In our setup, the industry is populated by a large set of firms each producing a good of unique quality. Each firm holds a blueprint of

An advantage of focusing on the difference in the pass-through rate of different car models is that while the exchange rate may be endogenous, the difference in the pass-through rate itself should not be biased.

a certain quality and has market power over a narrow set of consumers. The degree of this market power depends on the prices and qualities of adjacent competitors.[3]

We nest our model in an economy featuring transportation costs. Trade, by increasing the density of firms in the quality spectrum, intensifies competition and thus puts downward pressure on prices. This effect operates even if the volume of trade is low: the "toughening" of spatial competition in the quality dimension brought about by entry of foreign firms can have a sizeable effect on markups and prices.

We next turn to rationalize the empirical observations presented before that relate pricing to market decision to good quality. These predictions are derived from one additional assumption that quality is “scarce” in the sense that the upper bound of valuations is high enough so that there would also be demand for even higher quality goods and that therefore, the technological leader enjoys higher relative markups than all other firms.

We first show that if markets are opened to trade between symmetric countries, profit margins in the export market are more increasing in quality than is the case in the domestic market – i.e. exporting is relatively more profitable for high quality firms than for low quality firms. The reason for this is that high quality exporters benefits more from the vicinity to the technological leader (who charges an additional markup) and that this benefit is not much affected by trade costs. The reasoning also implies that the bundle of exported goods is generally of higher quality than the bundle of domestically produced goods - a prediction also observed in our data.

Second, we evaluate the rate to which a cost shock (probably stemming from an exchange rate movement) is passed through into domestic prices. We document that pass through is always incomplete and also, that exchange rate pass-through is larger for low quality exporters than for high quality exporters. Any firm’s optimal price depends on the marginal costs of production, the prices of the two competitors producing the next highest and next lowest quality, and the quality differentials between these three firms. In equilibrium,

[3] We note that this preference specification is related to the models of spatial differentiation in Lancaster (1980) and Helpman (1981), who examine Hotelling’s classic ‘location’ paradigm in open economy settings. However, such models of "spatial" competition, although widely used to reflect generic product characteristics, do not apply to competition in quality: by its very definition, quality requires that individuals agree on the ranking of varieties so that, in particular, their individually preferred "ideal variety" coincide and only the higher price tag of the universally preferred higher-quality goods causes different consumers to buy distinct qualities.

the price of a given firm depends on the cost structure and quality spacings in the entire economy, with a larger weight given to the market environment in the vicinity of the firm's quality. Because higher quality exporters are closer to the technological leader, their markups are higher and respond less to the exchange rate.[4]

Our findings are related to the literature examining the degree of ERPT using micro data sets and, in particular, the studies examining why the rate of ERPT differs so much across different sectors, goods, or countries. For import prices measured at the dock (that is, net of distribution costs), the main dimensions along which the heterogeneity of pass-through rates have recently been identified[5] include the currency choice of invoicing as in Gopinath et al. (2010b) and Goldberg and Tille (2008 and 2009); inter- versus intra-firm trade as in Neiman (2010); multi-product exporters as in Chatterjee et al. (2012); the sectoral import composition as in Goldberg and Campa (2010); market share and firm productivity (Krugman (1987), Dornbusch (1987), Feenstra et al. (1996), Yang (1997), and Berman et al. (2012), who use free on board prices) and the overall market structure of a sector affects real rigidities (see Gopinath and Itskhoki (2010a) and Auer and Schoenle (2012)); and nominal price rigidities (see Gopinath and Rigobon (2008) and Gopinath and Itskhoki (2010b)). When evaluating retail prices, also the share of the distribution costs matters for pass-through (see Bacchetta and van Wincoop (2003), Burstein et al. (2003), and Corsetti and Dedola (2005), as well as Hellerstein (2006), Nakamura and Zerom (2009), and Goldberg and Hellerstein (forthcomming) for detailed industry studies). More generally, also the size and origin of the exchange rate movement may matter for pass-through (see, for example, Michael et al. (1997) and Burstein et al. (2005 and 2007)).

Against this vast literature, the contribution of our paper is to study how the characteristics of the traded good itself affect the rate of pass through, which is novel to this literature to the best of our knowledge.[6] Our finding of ERPT being decreasing in good

[4]To the best of our knowledge, the predictions of our model of how monopolistically competing firms price to market are new to the literature. Note, however, that Shaked and Sutton (1984) and Sutton (2007) have analyzed product differentiations and price setting decisions in vertically differentiated open economies characterized by the entry of a monopolist or few oligopolists. Feenstra et al. (1996) analyze how market share and oligopoly interact in the car industry, although their model is not focused on good quality.

[5]Goldberg and Knetter (1997) survey an earlier literature on exchange rate pass through.

[6]An exception to this is Auer and Chaney (2009), who analyze how firms set their prices in a model of perfectly competitive markets featuring a firm- and market-specific distribution cost schedule that is convex in quantity. The intuition underlying this modeling strategy is that each firm owns a market-specific

quality is closely related to Berman et al. (2012), who document that the rate of ERPT is decreasing in relative firm productivity. In combination with the fact that high productivity firms also tend to produce higher quality goods, our findings agree with the ones of Berman et al. (2012) and we also document the particular relevance of one of their hypothesized channels.

The second strand of literature our model relates to is the literature on industry dynamics with heterogeneous firms in the open economy, deriving from Melitz (2003) (see also Bernard et al. (2003) and Chaney (2008)). While Melitz (2003), Bernard et al. (2003), and – in a model allowing for variable markups – Melitz and Ottaviano (2008) assume that the intrinsic difference of firms is in physical productivity, Kugler and Verhoogen (2008), Baldwin and Harrigan (2011), and Johnson (2012) assume that the key heterogeneity of firm survival is the difference in the quality of the goods these firms produce.

Last, our paper also connects to the literature on Schumpeterian growth in the spirit of Grossman and Helpman (1991 a) and Aghion and Howitt (1992), and in particular the application of the latter to the international product cycle in Grossman and Helpman (1991 b and 1991 c). Our paper delivers a rich market structure to this literature as our setup allows to analyze how multiple firms compete in the quality spectrum, thus enabling us to analyze how changes in the spacing of firms affects equilibrium prices.

The remainder of the paper is organized as follows. Section 2 examines pricing to market and good quality in a panel of car prices. Section 3 presents a theoretical model of quality pricing and derive predictions for exchange rate pass-through and pricing-to-market rationalizing the presented empirical patterns. Section 4 nests these preferences in an international economy and derives predictions for exchange rate pass-through and pricing-to-market. Section 5 concludes.

distribution network that is partly fixed in the short run, hence giving rise to such a firm- and market-specific convexity. If this convexity affects high and low quality firms differently, Auer and Chaney (2009) document that exchange rate pass through is quality dependent. In contrast, in this paper, we primarily aim to explain how price setting is affected by the very nature in which firms compete for consumers with heterogeneous preference for quality and how trade-induced changes in the "density" of quality competition affects pricing decisions. We believe that given the importance of quality differentiation in international trade, it is worth providing such a more general theoretical foundation of quality pricing-to-market.

2 Quality and Pricing-to-Market in the European Car Industry

In this section, we briefly document that good quality determines pricing-to-market decisions in the European car industry. As our data includes only few markets but 30 years, we focus on price *changes* rather than levels and document that also the degree of ERPT is quality dependent.

With our reduced-form estimations, we ignore a sophisticated literature that identifies structural demand and supply parameters from observed car characteristics and aggregate sales (see Verboven (1996), Goldberg and Verboven (2001 and 2005), Benkers and Verboven (2006 a and b)), and the literature deriving from Berry et al. (1995)). We view our regressions as complimentary to these exercises in that they point out the importance of a further aspect - good quality - for PTM decisions.[7]

2.1 What is "Quality"?

The data on car prices, quantities, and quality attributes used in this study is from Goldberg and Verboven (2001 and 2005). Their data set also includes relevant macroeconomic information such as exchange rates and inflation rates.[8] It covers cars sold on five European Markets (Belgium, France, Germany, Italy, and the UK) in the period from 1970 to 1999. Although we only have prices for cars sold in these markets, the cars originate from 14 countries.

Before describing the data in more detail, we first construct a measure of car quality. Following Goldberg and Verboven (2005), we construct hedonistic indices of quality that relate the price of a car to its characteristics such as weight, horse power, and fuel efficiency. Since customers are willing to pay a higher price for more of an attribute such as "maximum speed", these attributes reveal a car's quality.

In Table 1, the dependent variable is the natural logarithm of the car price net of VAT and in Special Drawing Rights (SDR).[9] All car prices in our sample are for the basic

[7] Also see Knetter (1989) and (1993), who also examines pricing to market in the car industry.

[8] The data is described in detail in Goldberg and Verboden (2005). It can be accessed on the webpages of either author.

[9] SDRs are a basket of major currencies with weights updated every 5 years.

configuration of each car model, i.e. the cheapest version actually offered on a market. We estimate random effects panels since including fixed effects by car model would account for nearly all of the quality variation in our sample. Goldberg and Verboven (2001 and 2005) find significant evidence of price discrimination across the European markets and we thus include market fixed effects to the regression. We also include consumer price inflation to the specification. Last, we include a trend to account for the fact that technological progress might make car production cheaper in general.

In Table 1, and unless otherwise stated also in the rest of the paper, we take the model definition "co" of Goldberg and Verboven. But in order to properly reflect changes in the exchange rate, we count a car model as a new observation when the location of production changes.[10] In the panel, a group is defined as one car model sold in one market so that we have 1554 groups and 379 car models.

In Column 1 of Table 1, we regress the logarithm of a car's price on a Luxury Dummy that equals 1 if the car is either counted as "Intermediate Class" or "Luxury Class" in official car guides. The interpretation of the coefficient of the luxury dummy is the following. If two car models are sold on the same market and in the same year, yet one is a Luxury or Intermediate car while the other one is not, the price differential is on average 0.698 log points (around 2−fold).

In Column 2 of Table 1, we relate car prices to "measurable" quality characteristics. We include horsepower, fuel efficiency, cylinder volume, size, weight, and maximum speed. All measures have the expected sign except height, which has a negative coefficient, potentially because expensive sport cars tend to be flat. Conditional on the other car characteristics, a one KW stronger engine is associated with a 0.55% higher price. The overall fit of the model is very high, with an R^2 of 92.6%, but we can do even better by also including "soft" car attributes such as the car brand. In Column 3, we thus add brand dummies and class dummies to the estimation.

We next predict two indexes of car quality. We predict "Quality Index 1" from Column 2 of Table 1. Since conditional on the car characteristics, where and when a car is sold should not influence its quality, and since the level of consumer prices does not affect the

[10] This happens in less than 20 instances. Moreover, a change of the production location is mostly a Japanese firm re-locating production to Europe. In the sample of cars that are both produced and sold in our five markets, there are only 3 car models that are counted twice.

quality of a car, we partial out these variables when predicting the quality index. We next predict "Quality Index 2" from the model in Column 3 of Table 1. For Quality Index 2, we again partial out the effect of when, where, and at what level of consumer prices a car was sold, but we include the brand and class dummies. After predicting, we standardize both indices of quality for better interpretability of the results.

2.2 Data Description: What Kind of Cars are Traded?

Having constructed the hedonistic quality indices, we can describe our data in detail, which is done in Tables 2 and 3. Table 2 lists the summary statistics of our sample of cars. The structure of Table 2 is the following. We first summarize the whole sample in Panel A and then split this sample up into cars that are produced in one of our five markets (BEL, FRA, GER, ITA, and UK) and sold in the market of production (Panel B), cars that are produced in one of the five markets and exported to at least one of the other four markets (Panel C), and cars that are sold in at least one of the five markets, but that are produced somewhere else (Panel D).

For these four groups of cars, we report the summary statistics for the quantity sold, prices, and quality. In addition to the usual statistics (un-weighted mean, un-weighted standard deviation, minimum, and maximum), we also report the weighted mean quality index. As smaller, less expensive car models tend to have much higher sales than luxury cars, the weighted average quality is negative on average.

The most salient fact emerging from Table 2 is that high quality cars are exported more often. For this, one needs to compare the average quality in Panel B to the one in Panel C: the weighted average of Quality Index 1) of those cars exported and sold domestically is -0.348, while the same average in the group of cars produced in one of the five markets and exported to the other four markets is 0.04 higher than that. Also when evaluating the alternative quality index and/or the unweighted means, exported cars tend to be of higher quality than domestically sold cars.

We present some more information about the variability of our changes in Table 3. The upper part of Table 3 presents summary statistics for the annualized change in the natural logarithm of a model's price, changes in the exchange rates, and annual CPI inflation. We also display the annual change in the logarithm of the relative price. The relative price is the ratio of the price of a car in the importer market divided by the price of the same car in the market of production. In the main specifications that we present below, we focus on car models that are produced in Belgium, Italy, Germany, France, or the UK and sold on one of the other four markets. We thus present the summary statistics only for this group of observations.[11]

2.3 Quality and Nominal ERPT

In this subsection, we document that pass-through rates of exchange rate changes into nominal prices are higher for low quality cars than for high quality cars. Our empirical estimates suggest that this differential effect is economically large: the one year pass-through rate is below 10% for the top decile of car quality, while it is around 20% for the lowest decile of car quality. To our knowledge, this finding is novel to the literature on pricing-to-market and on exchange rate pass-through.[12]

Table 4 documents that high quality cars are characterized by a lower degree of exchange rate pass through. Throughout the table, the dependent variable is the change in the natural logarithm of the car price in the respective market. Unless otherwise noted, all specifications are weighted by the number of a model's sales, include fixed effects, and heteroscedasticity robust standard errors are reported in brackets below the coefficient point estimates.[13] In Columns 1 to 6, we include fixed effects for all model and market

[11] There are no outliers for the annual exchange rate fluctuation or for the annual inflation rates. However, some of the year-to-year price changes are quite large. The lower part of Table 4 lists any observation where either the nominal or the real price changed by more than 0.5 log points (a 64% change) from year to year. Such a large price change does never occur for the exact same configuration of a model. The underlying reason for these fluctuations is that the base model is sometimes discontinued, while other versions are still offered. Since Goldberg and Verboven always use the price of the base model that is actually available on a market (and do not treat version changes as a new car models) the price can jump from year to year. However, after discussing this issue with Penny Goldberg and Frank Verboven, we include these observations in the main regression to avoid a product replacement bias in the pass through rate (see Nakamura and Steinsson (2010)). Note also that when we observe a drastic change in the nominal price, the car quality also changes considerably in the same year. All regressions presented below account for that change in quality, and hence the quality-adjusted price change is much smoother that the nominal one.

[12] One exception to this is an interesting finding of Gagnon and Knetter (1995) of the differential pass though rate for large engine and small engine cars.

[13] In Table 5, we only use those cars that are produced in the five markets under consideration. This is done in order to ensure that we can compare our results of nominal and relative price pass-through: when

combinations. The exchange rate is always the bilateral year end value from Goldberg and Verboven and we estimate one-year pass through regressions of the type

$$\Delta p_{i,t} = \alpha_i + \beta\Delta e_t + \gamma_j q_i \Delta e_t + \delta\Delta x_t + \epsilon_{i,t}, \tag{1}$$

where $\Delta p_{i,t}$ is the annual percentage change of the car's price, α_i the model-market fixed effect, Δe_t the annual percentage change in the bilateral exchange rate, q_i the car's hedonistic quality index, Δx_t the set of included covariates, and $\epsilon_{i,t}$ the error.

Columns (1) to (3) of Table 4 compare our approach to a standard ERPT regression that does not take into account the role of quality. In Column 1 of Table 4, we include only the exchange rate change and consumer inflation to the regression. The (contemporaneous) pass-through rate is estimated at 13.1%. We add car quality (Quality Index 1) to this specification in Column 2. Although quality itself is a significant determinant of price changes, this does not affect the pass-through rate by much, which is estimated at 14%.[14]

Accounting for a car's quality has a large effect on pass-through rates. In Column 3 of Table 4, we allow pass through rates to be quality-dependent and add the interaction of Quality Index 1 and the exchange rate change. While the average pass-through rate is not much affected (it does not stay exactly the same since we have standardized quality for the sample of all cars but use only cars from our five markets), the interaction is negative, significant, and economically large. A one standard deviation difference in quality is associated with a 6.3 percentage point different pass-through rate. For example, compare the $10th$ percentile of car quality to the $90th$ percentile. The respective percentiles are -1.26 and 1.37, so that the pass through rate of these two car qualities is 21.8% versus 5.3%, i.e. four times as large.

We next document the robustness of this result. Inflation, average car quality, and car prices might all be subject to common trends. We thus include a trend to the equation in

we estimate relative price pass through below, we need a price in the home market which we do not have for cars that are produced outside of Belgium, France, Italy, Germany and the UK.

[14]Because we include fixed effects for each model sold on each market, the coefficient of quality has to be interpreted with care: if the quality of a model does not change during its life cycle, the fixed effects absorb all the variation associated with quality differences between cars. However, car manufacturers often upgrade the engine and other features of a model during its life cycle, and therefore the quality of a model can change slightly. Thus, the coefficient of "Quality Index 1" has the interpretation of how much a change in the quality of a car affects its price during its life cycle.

Column (4). While the year trend is significant, this does not affect any other coefficient in our model (in fact the interaction coefficient is larger and significant at higher levels compared to the previous estimation). The trend itself has a negative coefficient, which might reflect productivity advances in the car industry. Next, in Column (5), we take into account that car prices are auto-correlated and add the lagged price change to the estimation. Indeed, prices are mean-reverting, but accounting for the mean reversion results in a larger coefficient for the interaction of quality and exchange rate changes (this estimation uses the dynamic panel estimator developed by Arellano and Bond (1991) instead of a fixed effects panel regression). The estimations in Column (6) repeats the baseline estimation of column (3), but the regression is unweighted.

Goldberg and Verboven use two different definitions of a car model. In our main specification, we use their narrow model definition "co." Their second model definition, "zcode" is somewhat broader than the main definition. For example, Daimler Benz discontinued the Mercedes 300 in 1992/3 and introduced the similar Mercedes E Class shortly thereafter. Our main definition classifies these two cars as two different models, but zcode counts them as one. Because car companies offer both the new and the old model of a car in the same year and on the same market, zcode does not uniquely define observations. We thus include market dummies and model dummies (by zcode) as fixed effect in Column (8). For better comparability, we also present the same specification (fixed effects by markets and models, but not all combinations) for our main model definition "co" in Column 7. Again, the interaction of exchange rate changes and car quality is negative, significant, and the coefficient is large.

Columns (9) and (10) document that it is unlikely that local distribution costs explain the heterogeneous pass through response along the quality dimension. For this, we follow Goldberg and Verboven (2001) and use the importer nation's producer price index as a gauge of the evolution of the local distribution costs. We first add producer price instead of consumer price inflation in Column (9) showing that ppi inflation does substantially affect the price of all car models, thus pointing to the importance of local distribution costs.

We note that it is possible that these findings could also be explained by the fact that local distribution costs are increasing as a share of total costs in car quality: when evaluating retail prices such as the one we observe, also the share of distribution costs has been shown to be one of the main determinants of pass-through.[15] Indeed, local distribution costs are a substantial share of total costs in this industry, by some estimates accounting up to 35% of total costs (see, for example, Verboven (1996)), although this number also includes fixed overhead cost such as marketing, while only per-unit costs should affect vehicle pricing.

If the share of local distribution costs is increasing in the quality of a car, the response of the local price to domestic PPI changes should be increasing in the quality, i.e. one needs to include not only the change in the local PPI change, but also its interaction with the quality index. Column (10) then documents that while ppi inflation does substantially affect the price of all car models, this response does not differ across cars of different quality (the interaction coefficient is estimated insignificantly). Second, the rate of ERPT is highly quality dependent also conditional on the inclusion of the PPI inflation and its interaction with car quality.

We also believe that it is ex ante unlikely that distribution costs are increasing as a share of costs in the car's quality. Indeed, given that many of the tasks involved in selling a car to the final consumer – such as transporting it in the country – are roughly the same for any type of car, it is probably more reasonable to assume that if at all, the share of distribution costs as a percentage of total costs are decreasing in car quality. Also the use of additional information from external sources does *not* point toward distribution costs being higher in the luxury car segment. For example, in Germany, the Volkswagen company has a rule to pay a margin of 15% to dealers on all its models and brands (VW, Audi, Seat, and Skoda) whereas Opel, the German subsidiary brand of General Motors, gives its dealers margins ranging from 13.85% to 15.85%, again mostly irrespective of the type of the car sold. It is generally true that foreign low-quality importers pay higher margins than the domestic luxury car producers: Richartz (2009) documents that the margins of car dealers are on average 15.9% for German producers, 16.9% for brands originating from other European countries (and US brands, but their share is minim in the European car industry), and 17.6% for Asian car producers. The same study, using car data from Jato Dynamics argues

[15] See Bacchetta and van Wincoop (2003), Burstein et al. (2003), Goldberg and Campa (2010), and Goldberg and Hellerstein (forthcoming). Note that Gopinath et al. (forthcoming) however document that in a rich dataset of matched retail and wholesale prices for multiple products sold by a single retailer in the U.S. and Canada, incomplete pass through can to a large extent be explained by pricing to market at the wholesaler level rather than by the share of local non-traded goods.

that margins are roughly constant across cars of different classes.[16]

We thus conclude that the fact that nominal pass through rates in our sample of European cars vary considerably with quality, and this is not explained by differences in the distribution cost intensity.

2.4 Quality and Relative ERPT

In this section, we evaluate the response of the relative price of the same car in the importer market and the exporter market to exchange rate movements. We test whether this "relative pass-through rate" is higher for low quality than for high quality cars.

For this, we first define the relative price of a car model as the price in the importing nation compared to price of the same model in the exporting nation and adjusted for the exchange rate:

$$P_i^{rel} = LN\left[\frac{\text{Local Cur. Price in Importing Nation}_i}{\text{Local Cur. Price in Exporting Nation}_i} Exr^{-1}_{\text{Imp Currency/Exp Currency}}\right]$$

The relative price thus measures the price (net of taxes) of the same car and expressed in the same currency in two different markets. We note that the relative price is slightly below unity (0.997).

We believe that examining how relative prices react to the bilateral exchange rate can add useful information as the evolution of the price of the identical car model at home can add useful information on the evolution of the marginal cost of producing the good. Of course, unlike the data of Fitzgerald and Haller (2010) (also see Burstein and Jaimovich (2009)), our data is polluted by the presence of local distribution costs so that the exchange rate should have less than a one-to-one effect on the price we observe even if firms pass

[16] The numbers in this paragraph were obtained from the below sources (accessed on 26.01.2012):
www.kfz-betrieb.vogel.de/neuwagen/handel/articles/180387/
www.stern.de/wirtschaft/geld/autokauf-was-der-haendler-verdient-547617.html
automobilwoche.de/article/20110818/REPOSITORY/110819925/1279/neue-opel-ci-wird-teuer
In addition to the stated number, for the US, the car website edmunds.com provides data allowing to directly direct test whether high quality cars are characterized by higher distribution cost. The site lists, for all model sold on US, the invoice price, i.e. the price that car dealers themselves pay and it also lists the Manufacturer's suggested retail price (MSRP). For example, the baseline BMW 3 series model carries an invoice price of USD 31,830 and a MSRP of USD 34,600, leaving the dealer with a margin of 8.7%. A comparison of 30 imported car models reveals that the car dealer margin is neither dependent on the invoice price or the class of a car (edmunds.com was accessed on 26.01.2012).

through cost fluctuations one-to-one. However, this relative strategy can still shed light on our understanding of how exchange rate differs along the quality dimension as long as the price of the model in its home market carries some information about the evolution of the (non-traded component) of the marginal cost of producing the car.

Throughout Table 5, the dependent variable is P_i^{rel}, the change in the natural logarithm of the relative price of a car, defined as the ratio of the before-tax price in the importer market over the before tax price in the country where the car is produced and both expressed in the same currency. Instead of testing how absolute nominal prices responds to changes in the exchange rate, we test how relative nominal prices react to the exchange rate.

In Column 1 of Table 5, to reflect the fact that we are looking at relative prices, we do not include consumer price inflation at home to the estimation, but relative consumer price inflation, i.e. the change in the natural logarithm of the ratio of CPI(importing nation)/CPI(exporting nation). The effect of the exchange rate on the relative price, the "relative pass through-rate" is estimated at 16.5%, somewhat higher than the nominal rate in Table 4. This difference between relative and nominal pass through nearly vanishes once we also control for quality in Column 2. Again, to reflect the fact that we consider not the absolute but the relative price, we include an index of the relative quality (Quality Index 1 in the Importer Country– Quality Index 1 in the Exporter Country) to the regressions. This index varies quite a lot since manufacturers introduce different model configurations to different markets in different years.

Next, in Column 3 of Table 5, we document our main finding that relative price pass-through is much lower in the high quality car segment. Low quality cars are characterized by a much higher degree of relative pass through. This finding is even more pronounced than for nominal pass through. A one standard deviation in quality is associated with a 9.1 percentage points lower rate of pass through. As we will show below, the fact that the relative pass-through-differential is larger for than the nominal pass-through-differential is in accordance with our theory.

To establish the robustness of this result, we add a time trend (Column 4), the lagged change in the price (Column 5, using the relevant dynamic panel estimator), both (Column 6), and we use the alternative definition of car models (Columns 7 and 8). We present one additional robustness test in Column 9, where instead of only controlling for relative quality and relative inflation, we add quality in the importing market and quality in the exporter market separately, and we also add the two measures of consumer prices separately.

Column (10) finally documents that it is unlikely that local distribution costs explain the heterogeneous pass through response along the quality dimension. For this, we follow Goldberg and Verboven (2001) and use the importer nation's producer price index as a gauge of the evolution of the local distribution costs. If the share of local distribution costs is increasing in the quality of a car, the response of the local price to domestic PPI changes should be increasing in the quality, i.e. one needs to include not only the change in the local PPI change, but also its interaction with the quality index.

Column (10) documents that while ppi inflation does substantially affect the price of all car models (as the main effect is estimated positively and significant), this response does not differ across cars of different quality (the interaction coefficient is estimated insignificantly). Second, the rate of ERPT is highly quality dependent also conditional on the inclusion of the PPI inflation and its interaction with car quality.

In Table 6, we repeat these specifications, but we use our second measure of quality (Quality Index 2). In all specifications except in Column 9, relative exchange rate pass through is significantly higher for low quality cars, and in Column 9 our specification is only marginally not significant.

Table 7 next documents that pass through rates vary along the quality dimension also at longer horizons. Following Rigobon and Gopinath (2008), we measure pass-through by estimating a stacked regression where we regress monthly import price changes on monthly lags of the respective measure of the exchange rate.

$$\Delta p_{i,t} = \alpha_i + \sum_{j=1}^{n} \beta_j \Delta e_{t-j+1} + \sum_{j=1}^{n} \gamma_j \left(q_i \Delta e_{t-j+1} \right) + \sum_{j=1}^{n} \delta_j \Delta x_{t-j+1} + \epsilon_{i,t} \tag{2}$$

We estimate this models up to the $5-$year horizon.

There is statistically significant evidence of the ERPT rates differing between high and low quality exporters at all horizons. Table 7 reports the sum of coefficients (i.e. $\sum_{j=1}^{n} \beta_j$ and $\sum_{j=1}^{n} \gamma_j$ for main and interaction coefficient respectively). Panel A does this for the case of using quality measure 1. Here, the average rate of exchange rate pass through (equal to the main effect since the quality measure is of mean 0) is increasing from 13.2% at the one year horizon to 53.4% after 5 years. Also the difference in the ERPT rate between high and low quality exporters seems to increase with the time horizon. The magnitude of the interaction coefficient increases from 11% at the one-year horizon to 14.7%, 15%, and 23% at the 2, 3, and 4 year horizon respectively. However, the at the five year horizon, the interaction coefficient is estimated at only -15.6%. When using quality measure 2 in panel B, the effect of quality on pass through is empirically smaller in magnitude, but still significant.

We thus conclude that in response to an exchange rate shock, the ratio of the relative nominal prices in the importing nation and in the home country (exporter) moves more for low quality cars.

3 The Model

In this section, we build a model of quality-pricing-to-market. On the supply side, different firms produce different qualities of the same consumption good. On the demand side, we postulate that consumers differ in their valuation for quality in the sense that, while all of them strictly prefer higher quality levels over lower ones, individuals differ in their willingness to pay for a marginal increase of quality. This type of consumer heterogeneity can lead to non-degenerate equilibria, where a countable number of firms coexist, each selling to a strict subset of the total market.

Our entry game is based on Auer and Saure (2011).[17] We then embed this model in an international economy setting to study the interaction between production of quality, trade integration and the exchange rate path through.

3.1 The Setup

3.1.1 Preferences

Consumers either consume one unit of the differentiated good $\mathcal{Q}$ or none at all. A consumer with the valuation v for quality who consumes the quality level q of the $\mathcal{Q}$-good and a units of good $\mathcal{A}$ derives utility $U_v(q, a) = vq + a$. Normalizing the price of good $\mathcal{A}$ to unity and

[17] Vogel (2008), in a closed economy setup, analyzes how firms differentiate themselves in the spatial dimension and simultaneously set their prices.

writing $p(q)$ for the price of quality q, we can rewrite the utility of this consumer in the following reduced form

$$U_v(q) = v \cdot q - p(q) \tag{3}$$

An important property of these preferences is that valuation and quality are complementary. The higher a consumer's valuation for quality, the more she is willing to pay for a given quality level. By focusing on the reduced form (3) we implicitly assume that the consumers with valuation v choose to purchase the $\mathcal{Q}$-type good, which is the case if and only if

$$v \geq \min_q \{p(q)/q\} \tag{4}$$

holds. Throughout the paper, we will focus on situations where the expression on the right of (4) is zero and the condition is trivially satisfied for all positive v. Also, we assume that the individuals' expenditure is high enough to generate positive demand for good $\mathcal{A}$. In so doing, we rule out corner solutions in individual demand.

Consumers differ in their valuation v for quality q. In particular, valuation among the individuals of total mass L is uniformly distributed on the interval $[0, v_{\max}]$:

$$v \sim U([0, v_{\max}])$$

This dispersion of valuation across individuals will make firms serve different market segments and allow them to charge monopolistic prices.

3.1.2 Production

Production of the $\mathcal{A}$-type good takes place at constant returns to scales with labor as the only factor. We normalize productivity in the $\mathcal{A}$-sector to one, which implies, together with price normalization of good $\mathcal{A}$ above, that wages equal unity.

Production technologies of the $\mathcal{Q}$-type good exhibit increasing returns to scale and depend on the quality level produced: while the marginal cost of producing the good is constant, entry is subject to a one time fixed cost. A firm established in the $\mathcal{Q}$-market produces at constant marginal cost of

$$c(q) = \varphi q^\theta \tag{5}$$

labor units. The parameter $\varphi > 0$ governs the marginal production cost. We assume that both the fixed cost of entry as well as the marginal cost are increasing and convex in quality ($\theta > 1$).

Firms compete in prices, *i.e.* each firm sets the price for its quality to maximize its operating profits, while taking total demand and the other firms' prices as given. In the equilibrium of the entry game to which we turn later, firms need to cover their setup cost with monopoly rents. Under Bertrand competition and positive setup cost this implies that firms must be located at positive distance to each other. Hence, the number of firms is countable and we can index firms by $n \in \mathcal{N}_0 = \{0, -1, -2, ...\}$. The quality level produced by firm n is denoted by q_n. Without loss of generality we order firms by the quality level they produce so that firm 0 produces the highest quality level q_0 and all further quality levels satisfy $q_{n-1} < q_n$. Finally, we assume that the quality ratio of either pair of neighboring firms is constant

$$q_{n+1} = \gamma q_n \tag{6}$$

with $\gamma > 1$.

3.1.3 Optimality Pricing

We begin by characterizing the general pricing solution. Under the preferences determined by (3) a consumer with valuation v is indifferent between two goods q_n and q_{n+1} if and only if their prices p_n and p_{n+1} are such that $v = (p_{n+1} - p_n) / (q_{n+1} - q_n)$. Thus, given $v_{\max}$ and given the prices $\{p_n\}_{n \leq 0}$, the n^{th} firm sells to all consumers with valuations v in the range $[\underline{v}_n,\ \overline{v}_n]$, where[18]

$$\underline{v}_n = \frac{p_n - p_{n-1}}{q_n - q_{n-1}} \qquad \text{and} \qquad \overline{v}_n = \begin{cases} v_{\max} & \text{if } n = 0 \\ \dfrac{p_{n+1} - p_n}{q_{n+1} - q_n} & \text{if } n < 0 \end{cases} \tag{7}$$

As a consumer with valuation $v \in (\underline{v}_n, \overline{v}_n)$ demands one unit of the variety produced by firm n, total demand of firm n equals $D_n(p_n) = [\overline{v}_n - \underline{v}_n] L/v_{\max}$. The optimal price p_n maximizes the operating profits, solving

$$\max_{p_n} (p_n - c_n) [\overline{v}_n - \underline{v}_n] L/v_{\max} \qquad s.t.\ (7) \tag{8}$$

so that the optimality condition is

$$[\overline{v}_n - \underline{v}_n] + (p_n - c_n) \left[\frac{d\overline{v}_n}{dp_n} - \frac{d\underline{v}_n}{dp_n} \right] = 0. \tag{9}$$

[18] We will rule out undercutting, where firm n sets its quality-adjusted price to take the market share of a directly neighboring firm and compete with second-next firms.

The second order condition is quickly checked to grant a local maximum. Combining conditions (9) and (7) leads to the recursive formulation of prices

$$p_n = \begin{cases} \frac{1}{2}\left[c_0 + \left(1-\gamma^{-1}\right) q_0 v_{\max} + p_{-1}\right] & \text{if } n = 0 \\ \frac{1}{2}\left[c_n + \frac{1}{1+\gamma} p_{n+1} + \frac{\gamma}{\gamma+1} p_{n-1}\right] & \text{if } n < 0 \end{cases} \tag{10}$$

These conditions describe the optimal prices only if they exceed marginal costs c_n. A sufficient condition for this requirement to be satisfied is that marginal production costs (5) are increasing and convex in quality.

Lemma 1 *Assume conditions*

$$c(q)|_{q=0} = 0 \qquad \left.\frac{\partial c(q)}{\partial q}\right|_{q=0} = 0 \qquad \left.\frac{\partial c(q)}{\partial q}\right|_{q=q_0} \leq v_{\max} \qquad \frac{\partial^2 c(q)}{(\partial q)^2} > 0$$

hold. Then, the optimal price for all firms $n \in \mathcal{N}$ is determined by (10).

Proof. *Consider firm $n < 0$. None of its direct competitors sells below marginal costs: $p_{n-1} \geq c_{n-1}$ and $p_{n+1} \geq c_{n+1}$. Hence*

$$p_n - c_n \geq \frac{1}{2}\frac{q_n - q_{n-1}}{q_{n+1} - q_{n-1}}\left(c_{n+1} - c_{n-1}\right) - \frac{1}{2}\left(c_n - c_{n-1}\right)$$

and firm n has a nonnegative margin if $\frac{c_{n+1}-c_{n-1}}{c_n - c_{n-1}} > \frac{q_{n+1}-q_{n-1}}{q_n - q_{n-1}}$, which is satisfied if $c(q)$ is convex. Further, the lowest quality firm with $q \to 0$ sells its good if $c(q)|_{q=0} = 0$ and $\frac{\partial c(q)}{\partial q}|_{q=0} = 0$ (compare (4)). Last, consumers with highest valuation $v_{\max}$ prefer to buy the highest quality q_0 rather than the second highest q_{-1} if $v_{\max} q_0 - p_0 \geq v_{\max} q_{-1} - p_{-1}$. Using (10) for $n = 0$ and rearranging this condition is

$$v_{\max}\left(q_0 - q_{-1}\right) \geq c_0 - p_{-1}$$

With $p_{-1} \geq c_{-1}$ the condition $\partial c(q)/\partial q|_{q=q_1} \leq v_{\max}$ is a sufficient one. ■

Apart from imposing conditions on the borders (at $q = 0$ and $q = q_0$) the Lemma states that marginal production costs need to increase more than linearly in quality to generate the interior pricing solution defined by (10). This condition is quite intuitive given our preference structure (3): any individual who is consuming good $\mathcal{Q}$ at a given quality level $\bar{q}$ prefers an increase of x percent in consumed quality that comes about with an increase in price of less than x percent. When costs are convex, higher quality firms can offer exactly this deal. Consequently, the highest quality firm q_0 can, by charging a price moderately above its marginal costs attract the entire market, in which case all consumers purchase the highest quality available on the market and the equilibrium collapses to a corner (see Figure 1). Ruling out linear costs as the limit case of concavity, we are left with the requirement that costs be convex. In this sense, convexity of quality costs is a natural condition for the market to generate non-degenerate allocations.

We turn to equilibrium pricing next.

Proposition 1 *Under equal relative spacing (6) the equilibrium prices are*

$$p_n = A\lambda^n + \alpha c_n \qquad \forall \;\; n \leq 0 \tag{11}$$

where

$$\alpha = \frac{\gamma+1}{2(\gamma+1)-\gamma^{\theta}-\gamma^{1-\theta}} \tag{12}$$

$$\lambda = \gamma+1+\sqrt{\gamma^2+\gamma+1} \tag{13}$$

$$A = \frac{\lambda}{2\lambda-1}\left(1-\alpha\left(2-\gamma^{-\theta}\right)+\frac{\gamma-1}{\gamma}\frac{q_0 v_{\max}}{c_0}\right)c_0. \tag{14}$$

Proof. Substituting $u_n = p_n - \alpha c_n$ and ignoring the border condition, the recursive formulation of the prices (10) is

$$2\left[u_n + \alpha c_n\right] = c_n + \frac{1}{\gamma+1}\left[u_{n+1}+\alpha c_{n+1}\right] + \frac{\gamma}{\gamma+1}\left[u_{n-1}+\alpha c_{n-1}\right]$$

for $n > 1$. With $\alpha = (1+\gamma)/\left[2(1+\gamma)-\gamma^{\theta}-\gamma^{1-\theta}\right]$ this is $2(\gamma+1)u_n = u_{n+1} + \gamma u_{n-1}$. The equation

$$X^2 - 2(\gamma+1)X + \gamma = 0 \tag{15}$$

has two roots, $\lambda = \gamma+1+\sqrt{\gamma^2+\gamma+1}$ larger than unity and $\mu = \gamma+1-\sqrt{\gamma^2+\gamma+1}$, smaller than unity. The general solution to the recursive series is thus

$$p_n = A\lambda^n + B\mu^n + \alpha c_n \tag{16}$$

where $B = 0$ because of $\mu < 1$ and the transversality condition $\lim_{n\to-\infty} p_n = 0$. Equation (10) for $n = 0$ is $2p_0 = c_0 + (q_0 - q_{-1})\,v_{\max} + p_{-1}$ and implies

$$2\left[A + \alpha c_0\right] = c_0 + q_0\left(1 - 1/\gamma\right)v_{\max} + A/\lambda + \alpha c_{-1}.$$

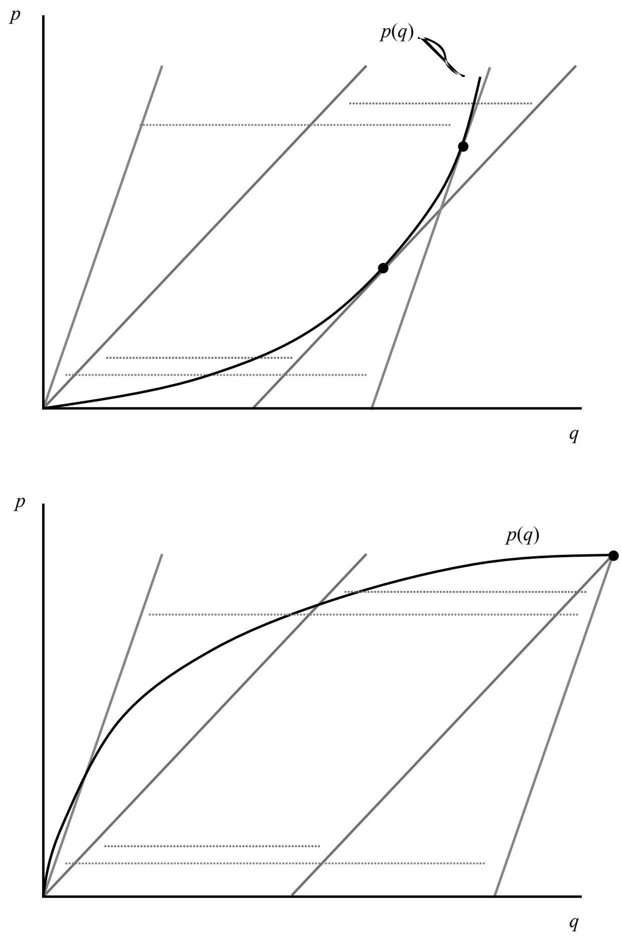

Figure 1: Price schedule (black line) in the price-quality space. Red lines represent indifference curves for high valuation, green those for low valuation. The arrows point in the direction of increasing utility. If prices are convex in q (top panel), there are interior equilibria for any individual with positive valuation. If, instead, prices are concave in q, no interior equilibrium exist (bottom panel).

Solving A proves (14). ■

Notice that the term α from (11), which is common to firms' markups, might be positive or negative, depending on whether or not

$$2 > \frac{\gamma^{\theta} + \gamma^{1-\theta}}{\gamma + 1} \tag{17}$$

holds. Nevertheless, expression (11) defines positive markups in either of the cases provided that the highest quality firm is active in the market. To verify this statement, write

$$p_n/c_n = A\left(\lambda/\gamma^{\theta}\right)^n + \alpha$$

and observe that[19]

$$\alpha > 0 \qquad \Leftrightarrow \qquad \lambda/\gamma^{\theta} < 1. \tag{18}$$

Next, consider the case $\lambda > \gamma^{\theta}$ and $A \geq 0$, in which case $A\left(\lambda/\gamma^{\theta}\right)^n + \alpha > 1$ holds since $\alpha > 1$. If, instead, $\lambda > \gamma^{\theta}$ and $A < 0$ then $A\left(\lambda/\gamma^{\theta}\right)^n + \alpha > 1$ holds for all $n \leq 0$ if it does so for $n = 0$. Similarly, in the case $\lambda < \gamma^{\theta}$ we have, by the above considerations, $\alpha < 0$ and hence $A > 0$ so that, again, $A\left(\lambda/\gamma^{\theta}\right)^n + \alpha > 1$ holds for all $n \leq 0$ if it does so for $n = 0$.

The crucial condition for markups to be positive is thus $A + \alpha - 1 > 0$. This condition is satisfied as long as $v_{\max}$ is large enough to generate positive demand for the firm producing the highest quality. In sum, if under equal relative spacing (6) a firm with quality q sells positive quantities, then all firms with minor qualities do so.

Obviously, the highest quality firm does not produce under all circumstances, *e.g.*, if the highest valuation is small so that $v_{\max}q_0 < c_0$ demand for the highest quality is zero even if q_0 is sold at marginal cost (compare (4)). In this case, however, the highest quality firm remains idle and we can drop it from the set of firms considered. Doing so successively for all idle top firms, the ratio $q_0 v_{\max}/c_0$ increases up to the point where $A + \alpha - 1$ is positive, which then defines positive markups throughout.

The equilibrium prices (11) consist of two parts. First, there is the part described by (12) which describes a constant markup over marginal production costs. Second, there is the auxiliary term A that stems, just as in the closed economy, from the distorted price

[19] This relation is quickly done by verifying that both inequalities $\gamma^{\theta} + \gamma^{1-\theta} < 2(\gamma + 1)$ and $\lambda/\gamma^{\theta} < 1$ hold (are violated) for small (large) $\gamma > 1$ and that, moreover, $\lambda = \gamma^{\theta}$ if and only if γ solves (15), i.e. $\gamma^{\theta} + \gamma^{1-\theta} = 2(\gamma + 1)$.

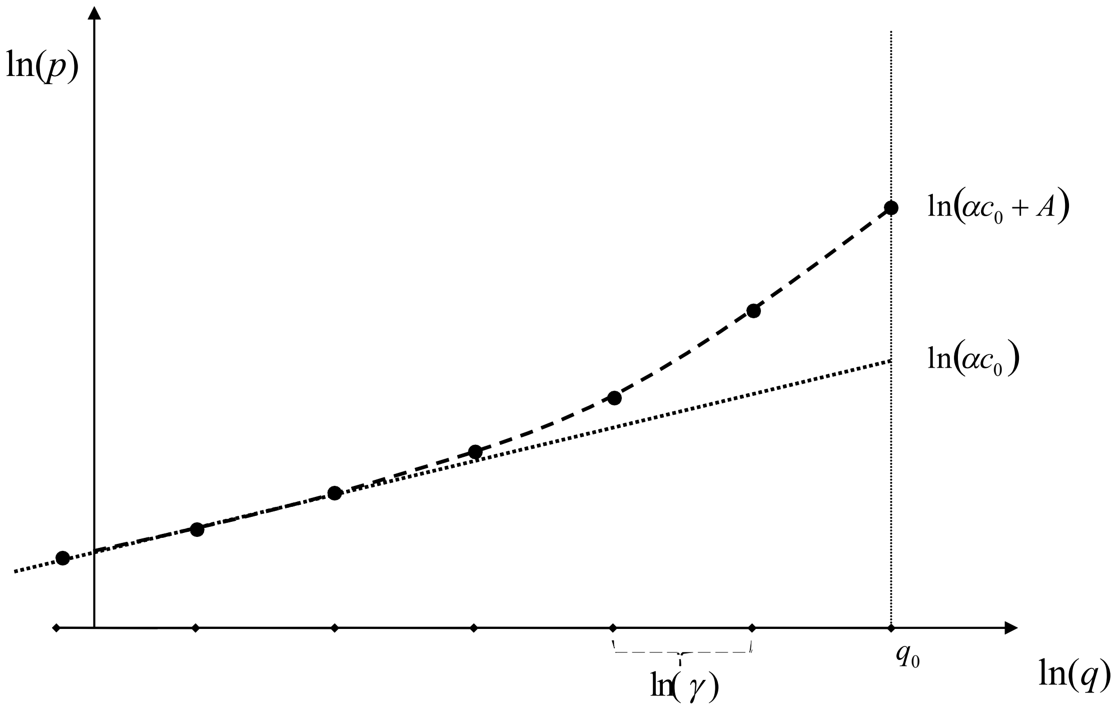

Figure 2: Equilibrium prices of quality in a closed economy. Markups consist of a constant times marginal productivity (represented by the straight line) plus a variable part that increases in quality (the difference between the bent and the straight line).

elasticity of the top quality firm. Intuitively, all firms have the same first order condition (9), but the top quality firm, which has just one direct competitor and an inelastic demand margin at the top end. Therefore, all firms tend to charge similar markups, except the top firm with its asymmetric position. Therefore, the second best firm, having a direct competitor with non-standard pricing behavior, prices its product in a non-standard way as well, but slightly less than the top quality firm. This logic applies to the third and the fourth best firm as well, finally explaining the perturbation term $A\lambda^n$ that is added to the constant markups α and which, moreover, vanishes for firms very distant to the quality frontier. Figure 2 illustrates the two components of prices by plotting them as a function of quality q.

For further intuition of the pricing formula (11), consider a situation where $A > 0$ holds, which is a case we will be especially interested in. Notice that this condition is satisfied when the maximal valuation $v_{\max}$ is large. In that case, the expression for the equilibrium prices (11) shows that the markup is higher for high quality firms. This implications of Proposition 1 is quite intuitive, when reading them in light of market shares and demand elasticities. In particular, recall that a price increase of a given firm induces its consumers at the upper and lower end of its market share to purchase qualities of competing firms (compare (7)). Obviously, the smaller the firm's market share, the severer is the drop of demand in percentage terms and therefore the demand elasticity. This effect is particularly obvious when considering the limit case of a vanishing market share, in which case any discrete price increase entirely eradicates the firm's demand. In sum, a higher market share comes along with a lower demand elasticity and thus with higher markups. Thus, for large $v_{\max}$ the top quality firm supplies an especially large market segment, enjoys a low demand elasticity, and thus charges markups above the industry average. This pricing behavior is precisely reflected by the positive value for A.

With a good understanding of equilibrium pricing in the quality dimension, we turn next to the case of trade between two economies.

4 International Trade

We now consider a world of two countries, Home and Foreign (denoted by a *), which are populated, respectively, by L and L^* individuals. The homogenous good $\mathcal{A}$ is costlessly traded, thus equalizing wages in both countries, as the according production technology is assumed to be equal worldwide. Trade in the $\mathcal{Q}$-type good is subject to standard gross iceberg trade costs $\tau \geq 1$. The monopolistically competitive firms price discriminate between the export and domestic market. Preferences in both countries are identical, which implies, in particular, that the maximum valuations coincide ($v_{\max} = v^*_{\max}$ holds).

Nothing of the following analysis changes in presence of a larger number of $\mathcal{Q}$-type industries, which may differ in costs and maximum valuations $v_{\max}$. Potential trade imbalances between the aggregate of these industries are offset by costless trade in the homogeneous good $\mathcal{A}$, whose consumption levels are assumed to be high enough to do so.

In order to avoid excessively many different cases, we will impose the restriction that guarantees that α from (12) is positive, i.e. (18) holds. Notice that this is a condition on the markup under autarky, yet it will be relevant for the trade case as well. It requires that firms populate the quality space rather densely, as condition (18) holds for γ close to one.

Consider an industry producing the $\mathcal{Q}$-type good described above. We assume that qualities of firms satisfy the pattern (6) and firms are alternating in their location on the quality line. Specifically, firm n is located in Home if and only if firm $n-1$ is located in Foreign.

Figure 3 depicts the industry equilibrium in Home assuming that the current technological leader with quality q_0 resides in home. In this figure, each solid dot represents a Home firm and each lined dot represents a foreign firm. Home and foreign Firms are placed at alternating locations on the quality spectrum. Each firm serves a range of consumers, yet because foreign firms have to pay the transportation cost, they serve a relatively smaller group of consumers.

We adopt the notation $c_n = \varphi q_n^\theta$ if n is located in Home and $c^*_n = \varphi^* q_n^\theta$ if n is located in Foreign. Adapting the firms' optimal pricing condition (10) to trade costs, consumer prices

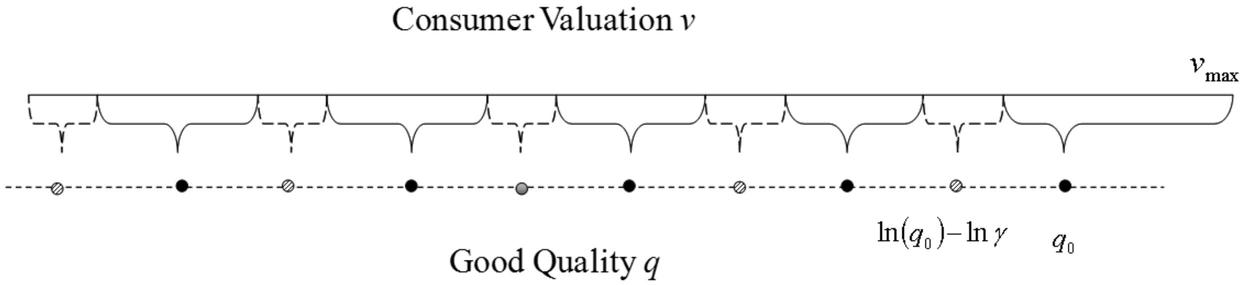

Figure 3: Equilibrium market segments for qualities produced by foreign firms (represented by lined dots) and domestic firms (solid dots).

in Home are determined by the system

$$p_n = \begin{cases} \frac{1}{2}\left[c_0 + \left(1-\gamma^{-1}\right) q_0 v_{\max} + p_{-1}\right] & \text{if } n = 0 \text{ and firm 0 is in Home} \\ \frac{1}{2}\left[\tau c_0^* + \left(1-\gamma^{-1}\right) q_0 v_{\max} + p_{-1}\right] & \text{if } n = 0 \text{ and firm 0 is in Foreign} \\ \frac{1}{2}\left[c_n + \frac{1}{1+\gamma} p_{n+1} + \frac{\gamma}{\gamma+1} p_{n-1}\right] & \text{if } n < 0 \text{ and firm 0 is in Home} \\ \frac{1}{2}\left[\tau c_n^* + \frac{1}{1+\gamma} p_{n+1} + \frac{\gamma}{\gamma+1} p_{n-1}\right] & \text{if } n < 0 \text{ and firm 0 is in Foreign} \end{cases} \tag{19}$$

Just as in a closed economy we can derive the equilibrium prices explicitly.

Proposition 2 *Assume that (6) holds and firm locations alternate in n. Then, consumer prices in Home are*

$$p_n = \begin{cases} A\lambda^n + \alpha c_n & n \text{ in Home} \\ A\lambda^n + \alpha^* c_n^* & n \text{ in Foreign} \end{cases} \tag{20}$$

where

$$\alpha = \frac{2 + \tau \frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma+1} \frac{\varphi^*}{\varphi}}{4 - \left(\frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma+1}\right)^2} \qquad \alpha^* = \frac{2\tau + \frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma+1} \frac{\varphi}{\varphi^*}}{4 - \left(\frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma+1}\right)^2} \tag{21}$$

$$\lambda = \gamma + 1 + \sqrt{\gamma^2 + \gamma + 1} \tag{22}$$

and

$$A=\begin{cases}\dfrac{\lambda}{2\lambda-1}\left(1-2\alpha+\alpha^{*}\gamma^{-\theta}\frac{\varphi^{*}}{\varphi}+\frac{\gamma-1}{\gamma}\dfrac{q_0 v_{\max}}{c_0}\right)c_0 & n=0 \text{ in Home}\\ \dfrac{\lambda}{2\lambda-1}\left(\tau-2\alpha^{*}+\alpha\gamma^{-\theta}\frac{\varphi}{\varphi^{*}}+\frac{\gamma-1}{\gamma}\dfrac{q_0 v_{\max}}{c_0^{*}}\right)c_0^{*} & n=0 \text{ in Foreign}\end{cases} \tag{23}$$

and λ *is from (13).*

Proof. Set $p_n = u_n+\alpha c_n$ if firm n is located in the domestic market and $p_n = u_n+\alpha^* c_n^*$ if not. Then, ignoring the border condition, the system (19) for the consumer prices in Home is

$$\begin{aligned} 2\left[u_n+\alpha c_n\right] &= c_n+\frac{1}{\gamma+1}\left[u_{n+1}+\alpha^* c_{n+1}^*\right]+\frac{\gamma}{\gamma+1}\left[u_{n-1}+\alpha^* c_{n-1}^*\right] && n \text{ in Home}\\ 2\left[u_n+\alpha^* c_n^*\right] &= \tau c_n^*+\frac{1}{\gamma+1}\left[u_{n+1}+\alpha c_{n+1}\right]+\frac{\gamma}{\gamma+1}\left[u_{n-1}+\alpha c_{n-1}\right] && n \text{ in Foreign}\end{aligned}$$

The terms multiplied by c_n vanish iff

$$\begin{aligned} 2\alpha &= 1+\left\{\frac{\gamma^{\theta}}{\gamma+1}+\frac{\gamma^{1-\theta}}{\gamma+1}\right\}\frac{\varphi^*}{\varphi}\alpha^* && n \text{ n Home}\\ 2\alpha^*\frac{\varphi^*}{\varphi} &= \tau\frac{\varphi^*}{\varphi}+\left\{\frac{\gamma^{\theta}}{\gamma+1}+\frac{\gamma^{1-\theta}}{\gamma+1}\right\}\alpha && n \text{ n Foreign}\end{aligned}$$

Solving for α and α^* leads to (21). The remaining problem is

$$2u_n=\frac{1}{\gamma+1}u_{n+1}+\frac{\gamma}{\gamma+1}u_{n-1} \qquad n<0$$

with the general solution

$$u_n = A\lambda^n + B\mu^n$$

where $\lambda=\gamma+1+\sqrt{\gamma^2+\gamma+1}$ and $\mu=\gamma+1-\sqrt{\gamma^2+\gamma+1}$. The transversality condition $\lim_{n\to-\infty} p_n=0$ and $\mu<1$ imply $B=0$. Equation (19) leads to

$$\begin{aligned} 2A+2\alpha c_0 &= c_0+\frac{\gamma-1}{\gamma}q_0 v_{\max}+A/\lambda+\alpha^*\gamma^{-\theta}\frac{\varphi^*}{\varphi}c_0 && \text{if } n=0 \text{ in Home}\\ 2A+2\alpha^* c_0^* &= \tau c_0^*+\frac{\gamma-1}{\gamma}q_0 v_{\max}+A/\lambda+\alpha\gamma^{-\theta}\frac{\varphi}{\varphi^*}c_0^* && \text{if } n=0 \text{ in Foreign}\end{aligned}$$

Solving for A proves (23). ■

For the rest of the section, we will focus on the case where $A>0$, i.e. where the maximal valuation $v_{\max}$ is large enough. Moreover, by the inequality (17), we know that

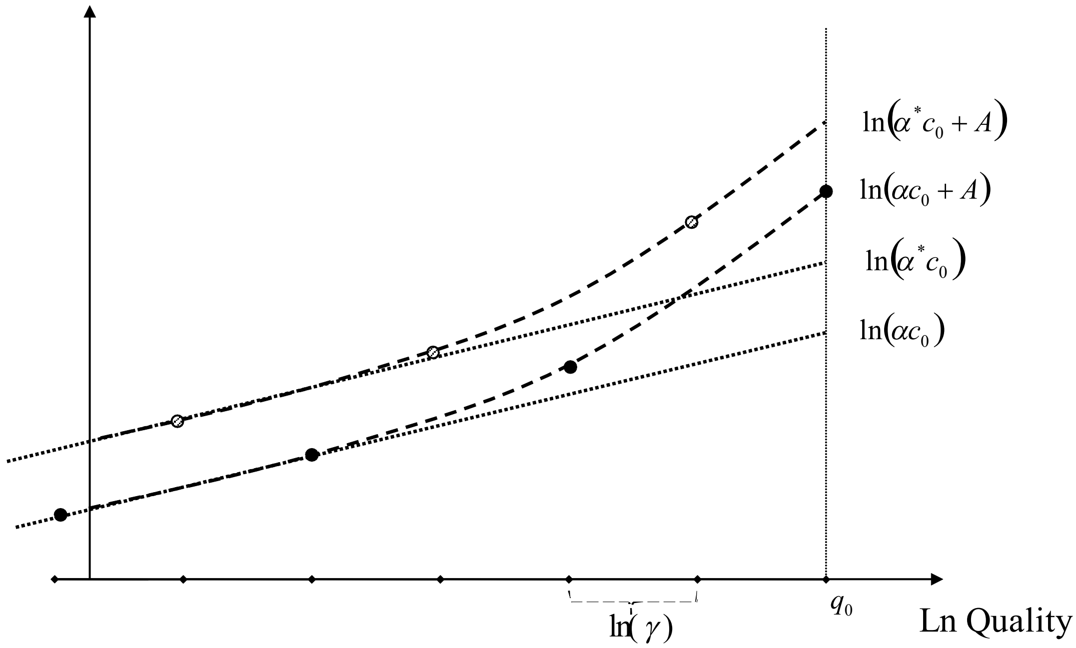

Figure 4: Equilibrium consumer prices of quality with costly trade between two economies. Lined dots represent qualities produced by foreign firms, solid dots represent those produced by domestic firms.

$\alpha, \alpha^* > 0$, implying that prices (20) actually exceed production costs for all firms (and thus constitutes the equilibrium prices) are $\alpha \geq 1$ and $\alpha^* \geq \tau$. With expressions (21), these conditions can be written as

$$\begin{aligned} \frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma + 1}\left[\frac{\varphi^*}{\varphi}\tau + \frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma + 1}\right] &\geq 2 \\ \frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma + 1}\left[\frac{\varphi}{\varphi^*} + \tau\frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma + 1}\right] &\geq 2\tau \end{aligned}$$

Notice that in the limit $\gamma \to 1$ the two conditions become $\tau\varphi^*/\varphi \geq 1$ and $\varphi/\varphi^* \geq \tau$. These are jointly satisfied if and only if $\varphi = \tau\varphi^*$. Clearly, in this limit of a competitive market, the transport costs must be exactly offset by a productivity advantage of the exporter. Since the ratio $(\gamma^\theta + \gamma^{1-\theta})/(\gamma + 1)$ is increasing in γ, the conditions are less strict with larger γ: a wider spacing allows less productive firms – or firms with a disadvantage due to transport costs – to sell into a market niche.[20]

[20]Notice also that at $\varphi = \tau\varphi^*$ the consumer prices under trade (20) are identical to those in the closed economy (11).

Looking at firms' optimal prices (20), we observe that quality pricing in export markets is quite similar to pricing in domestic markets in the sense that the markups consist of two parts (see Figure 4). First, there is the part described by (21) which describes a markup that is common among all domestic (foreign) firms. It is quick to check that for domestic firms this term α is increasing in foreign firms' effective supply cost $\tau\varphi^*$. Intuitively, if foreign products become more expensive due to higher production or transport costs, competition in the domestic market becomes less tough, which allows domestic firms to charge higher markups. Conversely, the markup of foreign firms' effective supply costs (α^*/τ) decreases in the expression $\tau\varphi^*$: as the foreign firms' effective supply costs increase, their market share drops and the reduced market power forces them to charge lower markups.

In addition, there is the perturbation term A that stems, just as in the closed economy, from the distorted price elasticity of the top quality firm. Consider the case when the top quality firm is located in foreign. In this case, one can expect that the negative impact of an increase in foreign production costs φ^* is mitigated by the top firm's privileged position: having only one direct competitor in the export market, the perceived competitive pressure for the top quality producer is less severe and its markup reacts less strong than those of its fellow exporters. Conversely, if the top quality firm is located in the domestic market, an increase in foreign production costs φ^* affects only one (instead of two) of its direct competitors, so that the effect on markup might be positive, but only moderately so. Indeed, it can be shown that[21]

$$\frac{d}{d\varphi^*}A < 0 \tag{24}$$

holds, irrespective of the location of the top firm.

In our analysis we are interested in the degree of the exchange rate pass through and how it depends on good quality. We can think of a shock to the exchange rate as a change in the effective supply costs $\tau\varphi^*$. The exchange rate pass through is then measured through the response in Homes's import prices p_n (n in Foreign). In particular, it is quick to check with (21) that the term $\alpha^* c_n = \alpha^* \varphi^* q_n^\theta$ is increasing in foreign firms' effective supply costs $\tau\varphi^*$. At the same time, $\alpha^* c_n/\tau\varphi^*$ is decreasing in the effective supply costs $\tau\varphi^*$. Together, these observations show that the degree of exchange rate pass through to the common markup α^* is positive but incomplete.

[21] See Appendix.

But we are not only interested the exchange rate pass through of the common markup. Instead, we aim to analyze the full pass-trough and specifically, how the pass-through rate varies with quality. Formally, this task is accomplished by determining the sign of the cross derivative

$$\frac{d}{dn}\frac{d}{d\varphi^*}\ln(p_n)$$

Indeed, under our assumption $A > 0$ we can show that this cross-derivative is always negative. We can summarize our results in the following lemma.

Lemma 2 *If $A > 0$ then,*

(i) relative markups over gross production costs $\left(\frac{p_n}{c_n} - 1\right)$ are increasing in quality q.

(ii) the degree of the exchange rate pass through is decreasing in quality q.

Proof. (i) Follows directly from $A > 0$, $\lambda/\gamma^\theta > 1$ and (20).

(ii) see Appendix. ■

The results of the Lemma are quite intuitive, when reading them in light of market shares and demand elasticities. Thus, a price increase of a given firm induces its consumers at the upper and lower end of its market share to purchase qualities of competing firms (compare (7)). The smaller the firm's overall market share, the severer is the percentage drop of demand and thus of revenues. This effect is particularly obvious in the limit of vanishing market shares, when any discrete price increase entirely eradicates the firm's demand. By this effect, a higher market share comes along with a lower demand elasticity and thus with higher markups.

Part (i) restates that, under the assumption that the maximal valuation $v_{\max}$ is large enough, demand for top quality is high. Thus, the top quality firms have a particularly large market share, and the according low demand elasticity allows them to charge markups above the industry average.

Part (ii), in turn, states that for high quality firms, the effect of an increase in supply costs is less strong than for lower quality firms. This observation reflects the relatively insensitive pricing behavior at the top end of the quality spectrum, which, in turn, is driven by the relatively price-insensitive demand that the top quality producer faces.

Lemma 3 *Assume $A > 0$ and technologies are equal across countries ($\varphi = \varphi^*$). Then,*

(i) if firm $n = 0$ is located in Home, the markup charged in the export market over the markup charged in the domestic market is increasing in quality q for all Home firms.

(ii) if firm $n = 0$ is located in Foreign, the markup charged in the export market over the markup charged in the domestic market is increasing in quality q for all Home firms if

$$\frac{q_0 v_{\max}}{c_0} > (\tau + 1) \frac{\gamma}{\gamma - 1} \frac{\frac{\gamma^{\theta}+\gamma^{1-\theta}}{\gamma+1} - \gamma^{-\theta}}{\left(2 - \frac{\gamma^{\theta}+\gamma^{1-\theta}}{\gamma+1}\right)\left(\frac{\gamma^{\theta}+\gamma^{1-\theta}}{\gamma+1} + 1\right)}.$$

Proof. See Appendix. ■

Lemma 3 derives an interesting implication of our pricing theory for how the incentives to export vary across firms producing goods of heterogeneous quality: if technology is scarce relative to consumer valuations (which implies $A > 0$), profit margins in the export market are more increasing in quality than they are in the domestic market – i.e. exporting is relatively more profitable for high quality firms than for low quality firms. We note that this result is akin to the "shipping the good apples out" conjecture, but it is not derived from the assumption that the ratio of transportation costs over the marginal cost of production is decreasing in quality (a feature which Hummels and Skiba (2004) derive from fixed per-unit shipping costs). Rather, in our analysis markups are increasing in quality, so that even with iceberg transportation costs, the ratio of the profit margin of an exported good divided by the profit margin of the same good when sold domestically is increasing in quality.

We note that in the second case of Lemma 3 the technological leader is domiciled in Foreign, we require an additional restriction on technology to hold. The reason for this is that transportation costs then make the top-level technology q_0 more expensive at Home than abroad, which leads to the constant of the price schedule in Foreign (the equivalent of A from (23) in Foreign) being higher than the constant A of the pricing schedule in Home. As we document in the Appendix, in the case of $n = 0$ being located in Foreign, the markup charged in the export market over the markup charged in the domestic market is increasing in quality q for all Home firms under a condition on the scarcity of technology that is slightly more stringent than $A > 0$.

5 Conclusion

This paper starts by documenting that in the European car industry, firms systematically differ in their pricing to market behavior along the good quality dimension. We document that pass-through rates of exchange rate changes into nominal prices are higher for low quality cars than for high quality cars and that low quality cars also tend to be traded more often in our sample. We also evaluate the response to exchange rate shocks of the relative prices of the same car in the importer market and the exporter market. We find that the relative pass-through rate is significantly larger for low quality than for high quality cars. The magnitude of the uncovered effects are economically very large.

To rationalize these patterns, we propose a model of how firms set prices to market in an industry that is differentiated by good quality in the second part of the paper. Our preferences are based on the seminal works of Mussa and Rosen (1978) and Shaked and Sutton (1982), where goods of heterogeneous quality are sold to consumers with heterogeneous valuation for quality. In our setup, the industry is populated by a large set of firms each producing a good of unique quality and foreign and domestic firms compete in the quality space.

In this setup, we show that if markets are opened to trade between symmetric countries, profit margins in the export market are more increasing in quality than is the case in the domestic market – i.e. exporting is relatively more profitable for high quality firms than for low quality firms. The reason for this is that high quality exporters benefits more from the vicinity to the technological leader (who charges an additional markup) and that this benefit is not much affected by trade costs. The same reasoning also implies that the bundle of exported goods is generally of higher quality than the bundle of domestically produced goods. Second, we evaluate the rate to which a cost shock is passed through into domestic prices. We document that pass through is always incomplete and also, that exchange rate pass-through is larger for low quality exporters than for high quality exporters.

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Appendix – Proofs

Proof of (24). Case I ($n = 0$ in Home): The term A from (23) is proportional to

$$A \sim 1 - 2\alpha + \alpha^* \gamma^{-\theta} \frac{\varphi^*}{\varphi} + (1 - 1/\gamma) \frac{q_0 v_{\max}}{c_0}$$

the only terms that vary with $\tau\varphi^*$ are those involving the $\alpha^{(*)}$ from (21). The sum of there, in turn, is proportional to

$$\begin{aligned} -2\alpha + \alpha^* \gamma^{-\theta} \frac{\varphi^*}{\varphi} &\sim -2\frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma + 1} \tau \frac{\varphi^*}{\varphi} + (2\tau\varphi^*) \frac{\gamma^{-\theta}}{\varphi} + const \\ &\sim 2\tau \frac{\varphi^*}{\varphi} \left[-\frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma + 1} + \gamma^{-\theta} \right] + const \end{aligned}$$

The expression in brackets is negative for $\gamma > 1$ and $\theta > 1$. Hence, A is decreasing in φ^*.

Case II ($n = 0$ in Foreign): The term A from (23) is proportional to (recall that $c_0 = \varphi^* q_0^\theta$)

$$A \sim \tau\varphi^* - 2\alpha^* \varphi^* + \alpha\gamma^{-\theta}\varphi + const$$

The sum of the terms that vary with $\tau\varphi^*$ is proportional to

$$\begin{aligned} \tau\varphi^* - 2\alpha^*\varphi^* + \alpha\gamma^{-\theta}\varphi &\sim \left[\tau \left(4 - \left(\frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma + 1} \right)^2 \right) - 4\tau + \frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma + 1} \tau\gamma^{-\theta} \right] \varphi^* + const \\ &\sim \left[-\left(\frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma + 1} \right) + \gamma^{-\theta} \right] \tau \frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma + 1} \varphi^* + const \end{aligned}$$

Again, the expression in brackets is negative so that A is decreasing in φ^*. This shows (24). ■

Proof of Lemma 2 (ii). For all n in Foreign, we rewrite prices (20) as

$$p_n = \left[\frac{A(\lambda/\gamma^\theta)^n / q_0^\theta}{\alpha^* \varphi^*} + 1 \right] \alpha^* \varphi^* q_n^\theta$$

With the expression, we compute

$$\begin{aligned} \frac{d}{dn}\frac{d}{d\varphi^*} \ln(p_n) &= \frac{d}{dn}\frac{d}{d\varphi^*} \ln \left[\frac{A(\lambda/\gamma^\theta)^n}{\alpha^*\varphi^* q_0^\theta} + 1 \right] + \frac{d}{dn}\frac{d}{d\varphi^*} \ln \left[\alpha^*\varphi^* \right] + \frac{d}{dn}\frac{d}{d\varphi^*} \ln \left[q_n^\theta \right] \\ &= \frac{d}{dn}\frac{d}{d\varphi^*} \ln \left[\frac{A/q_0^\theta}{\alpha^*\varphi^*} (\lambda/\gamma^\theta)^n + 1 \right] \end{aligned}$$

Since $\lambda > \gamma^\theta$ and $A > 0$ this last derivative is negative if and only if

$$\frac{d}{d\varphi^*} \left(\frac{A}{\alpha^*\varphi^*} \right) < 0$$

holds, which is true by (24). ■

Proof of Lemma 3. (i) Under $\varphi = \varphi^*$ and setting $\xi = \left(\gamma^\theta + \gamma^{1-\theta}\right) / (\gamma + 1)$ we have

$$\alpha = \frac{2 + \tau\xi}{4 - \xi^2} \qquad \text{and} \qquad \alpha^* = \frac{2\tau + \xi}{4 - \xi^2}$$

and

$$A = \begin{cases} \dfrac{\lambda}{2\lambda - 1}\left(1 - 2\alpha + \alpha^*\gamma^{-\theta} + \frac{\gamma-1}{\gamma}\dfrac{q_0 v_{\max}}{c_0}\right) c_0 & n = 0 \text{ in Home} \\ \dfrac{\lambda}{2\lambda - 1}\left(\tau - 2\alpha^* + \alpha\gamma^{-\theta} + \frac{\gamma-1}{\gamma}\dfrac{q_0 v_{\max}}{c_0}\right) c_0 & n = 0 \text{ in Foreign} \end{cases}$$

Formally, the statement of this lemma (markup charged in the export market over the markup charged in the domestic market is increasing in quality q for all Home firms) is that

$$\frac{\frac{A\lambda^n + \alpha^* c_n}{\tau c_n} - 1}{\frac{A\lambda^n + \alpha c_n}{c_n} - 1}$$

is increasing in n. Thus, considering both cases of the top firm's location, it is sufficient to show

$$\frac{|A_{n=0 \text{ is Home}}}{|A_{n=0 \text{ is Foreign}}} > \frac{\alpha^* - \tau}{\alpha - 1} \qquad \text{and} \qquad \frac{A|_{n=0 \text{ is Foreign}}}{A|_{n=0 \text{ is Home}}} > \frac{\alpha^* - \tau}{\alpha - 1}$$

It is quick to check that

$$\frac{1 - 2\alpha + \alpha^*\gamma^{-\theta}}{\tau - 2\alpha^* + \alpha\gamma^{-\theta}} \qquad \text{and} \qquad 1 > \frac{\alpha^* - \tau}{\alpha - 1}$$

so that the first condition holds always thus proving Lemma (3).

(ii) Consider next the case where $n = 0$ is based in Foreign. To have export markups compared to domestic markups being increasing in quality requires

$$\frac{\tau - 2\alpha^* + \alpha\gamma^{-\theta} + \frac{\gamma-1}{\gamma}\frac{q_0 v_{\max}}{c_0}}{1 - 2\alpha + \alpha^*\gamma^{-\theta} + \frac{\gamma-1}{\gamma}\frac{q_0 v_{\max}}{c_0}} > \frac{\alpha^* - \tau}{\alpha - 1}$$

which can be reformulated as

$$\frac{\gamma - 1}{\gamma}\frac{q_0 v_{\max}}{c_0} > \frac{(\alpha^* - \tau)\left(1 - 2\alpha + \alpha^*\gamma^{-\theta}\right) - (\alpha - 1)(\tau - 2\alpha^* + \alpha\gamma^{-\theta})}{\alpha - 1 - (\alpha^* - \tau)}.$$

Simplifying by using

$$\alpha^2 - \alpha^{*2} = -\frac{\tau^2 - 1}{4 - \xi^2} \qquad \alpha\tau - \alpha^* = \frac{(\tau^2 - 1)\xi}{4 - \xi^2} \qquad \alpha - \tau\alpha^* = -\frac{2(\tau^2 - 1)}{4 - \xi^2}$$

the numerator on the right hand side is equal to

$$\begin{aligned}\frac{1}{\gamma^{\theta}}\left(\alpha-\alpha^{2}-\gamma^{\theta}\alpha^{*}+(\alpha^{*})^{2}-\tau\alpha^{*}+\alpha\tau\gamma^{\theta}\right) &= \frac{1}{\gamma^{\theta}}\left(\alpha-\tau\alpha^{*}+\gamma^{\theta}\left(\alpha\tau-\alpha^{*}\right)+\frac{\tau^{2}-1}{(4-\xi^{2})}\right)\\ &= \frac{\tau^{2}-1}{\gamma^{\theta}(4-\xi^{2})}\left(\gamma^{\theta}\xi-1\right)\end{aligned}$$

while the denominator is equal to

$$\alpha-1-(\alpha^{*}-\tau)=(\tau-1)\frac{\xi+2-\xi^{2}}{4-\xi^{2}}=(\tau-1)\frac{(2-\xi)(\xi+1)}{4-\xi^{2}}$$

Hence, the relevant condition for relative markups being increasing in quality is

$$\frac{q_{0}v_{\max}}{c_{0}}>(\tau+1)\,\frac{\gamma}{\gamma-1}\frac{\xi-\gamma^{-\theta}}{(2-\xi)(\xi+1)}. \tag{25}$$

Restriction (25) is equivalent to a restriction of A to be positive. We note that in the limit for very dense spacing $\gamma\to1$,

$$\frac{\xi-\gamma^{-\theta}}{\gamma-1}=\frac{\xi-1}{\gamma-1}-\frac{\gamma^{-\theta}-1}{\gamma-1}\overset{\gamma\to1}{\to}0-(-\theta).$$

so that in the limit $\gamma\to1$, the restriction on technological scarcity becomes $\frac{q_{0}v_{\max}}{c_{0}}>(\tau+1)\,\frac{\theta}{2}$. ■

Table 1 - Quality Attributes and Prices: Random Effects Estimations

	(1)	(2)	(3)
	Luxury Dummy	*Quality Index 1*	*Quality Index 2*
	Dependent variable is Ln price in SDR, net of taxes		
Luxury Dummy (Cla= 4,5)	0.698		
	[0.017]**		
Horsepower (in kW)		0.0055	0.0047
		[0.0003]**	[0.0003]**
Fuel efficiency (L/100 km)		-0.0143	-0.0138
		[0.0016]**	[0.0016]**
Cylinder volume (in l)		0.18467	0.16784
		[0.0122]**	[0.0119]**
Weight (in t)		0.2145	0.10811
		[0.0282]**	[0.0282]**
Length (in m)		0.2316	0.1474
		[0.0149]**	[0.0169]**
Width (in m)		0.0464	-0.1031
		[0.0547]	[0.0539]
Height (in m)		-0.4514	-0.3620
		[0.0603]**	[0.00058639]**
Maximum speed (km/hour)		0.0013	0.0011
		[0.0003]**	[0.0003]**
Trend (year)	y	y	y
CPI Inflation	y	y	y
Market Dummies	y	y	y
Class Dummies			y
Brand Dummies			y
Observations	11510	11510	11510
Number of Groups	1554	1554	1554
R-Sq.within	82.8%	84.6%	84.8%
R-Sq. between	82.1%	94.4%	96.3%
R-Sq. total	81.9%	92.9%	94.5%

Notes: In Table 1, the dependent variable is the Ln(price) in Special Drawing Rights and net of taxes. All models include a year trend, CPI inflation, and import market dummies. A group is identified by a model (co_loc) sold on one market. The measure of fueld efficiency used is Li (average of Li1, Li2, Li3); robust standard errors in paranthesis; * significant at 5%; ** significant at 1%

Table 2 - Data Description (Cars and Quality)

	(1)	(2)	(3)	(4)	(5)
Variable	***Mean***		***Std. Dev.***	***Min***	***Max***
	weighted	***unweighted***	***unweighted***		
Panel A: All models, all markets, and all years					
(11510 Model-Market-Years, 1554 Model -Years, and 379 Models)					
Price in SDR	6010	6627	4512	681	39665
Quality Index 1	-0.337	0	1	-2.247	3.927
Quality Index 2	-0.331	0	1	-1.949	3.855
Quantity (per Market and Year)	-	19868	37771	51	433694
Panel B: Models produced and sold domestically in market of production (BEL, FRA, GER, ITA, or UK)					
(2097 Model -Years and 255 Models)					
Price in SDR	5785	6214	4330	681	35398
Quality Index 1	-0.348	-0.055	1.005	-2.247	3.927
Quality Index 2	-0.288	-0.006	0.993	-1.949	3.855
Quantity (per Market and Year)	-	65505	65660	300	433694
Panel C: Models Produced in BEL, FRA, GER, ITA, or UK and Exported to other 4 markets					
(6161 Model-Market-Years, 833 Model - Years, and 241 Models)					
Price in SDR	6345	6518	4698	691	39665
Quality Index 1	-0.304	-0.009	1.022	-2.247	3.927
Quality Index 2	-0.277	0.047	1.013	-1.949	3.854
Quantity (per Market and Year)	-	10726	15196	51	175812
Panel D: Models Produced Outside of BEL, FRA, GER, ITA, or UK					
(3252 Model Market Years, 466 Model-Years, and 110 Models)					
Price in SDR	6354	7099	4223	963	34561
Avg. Quality Index 1	-0.36	0.052	0.950	-2.020	3.396
Avg. Quality Index 2	-0.48	-0.086	0.973	-1.913	2.956
Quantity (per Market and Year)	-	7759	13602	53	157612

Notes: In Table 2, there are in total 379 models, of which 14 are only exported and not sold in the home market. The quality indexes are predicted from the respective model in Table 1 partialing out the effect of inflation, year, and market. The quality indexes are also standardized. For the Relative Avg. Quality Index, we weight each car quality by the quantity sold and then demean this average by year (but not by market).

Table 3 - Summary Statistics of Yearly Fluctuations and List of Outliers

Sample consists of all car models that are produced in BEL, FRA, ITA, Ger, and UK and exported to the other 4 markets

	Observations	Mean	St Dev.	Min	Max
dExrate =ΔLn(Bilateral Exchange Rate)	5216	-0.0005858	0.0703469	-0.266955	0.266955
dPrice = ΔLn(Car Price in Local Currency)	5216	0.0700733	0.0869908	-0.8905315	0.8134804
dPrice_Relative= ΔLn(Price Import Market/ Price Home Market), Prices in local currencies	4976	-0.0041548	0.1012984	-0.9666461	0.7753934
dCPI = ΔLn(CPI Importer)	5216	0.0592325	0.0440829	-0.0024832	0.2170054
dCPI_Relative= ΔLn(CPI Import Market / CPI Home Market)	5216	0.0004058	0.0435519	-0.1593031	0.1593031

List of Observations with |dPrice|>0.5 or |dPrice_Relative|>0.5

Year	Importer (ma)	Exporter (loc)	Car Model	dPrice	dPrice_Relative	Change of Q1	Level of Q1
74	Italy	Germany	Opel Record	0.6032	0.4798	0.0000	0.3566
75	Italy	Germany	Opel Record	0.5163	0.4440	0.4816	0.8382
75	Belgium	Italy	Fiat 124	0.5991	0.1291	0.5722	0.0898
75	France	Italy	Fiat 124	0.5728	0.1028	0.5722	0.0898
75	UK	Italy	Fiat 124	0.6705	0.2005	0.5722	0.0898
76	UK	Germany	VW Beetle 1200	0.3793	0.5065	0.0000	-1.0821
77	UK	Italy	Fiat Argenta	0.5054	0.1929	0.4228	0.8267
79	Belgium	Germany	VW Beetle 1200	0.6118	na	0.3029	-0.7792
81	Germany	France	Peugeot 504	0.7080	0.6024	0.5107	0.8290
84	Italy	Germany	Audi 100/200	0.7056	0.6729	0.7017	1.3252
93	Belgium	Italy	Lancia Delta	0.8135	0.7754	1.5782	1.6892
94	Belgium	Italy	Lancia Delta	-0.8905	-0.9666	-1.6259	0.0632
95	Belgium	France	Renault 19	-0.1199	-0.6930	0.0000	-0.2130
95	Germany	France	Renault 19	0.0123	-0.5608	-0.2066	0.0171

Notes: The upper part of Table 3 presents summary statistics for changes of exchange rates, prices, and CPI inflation. The summary statistics are presented for all cars that are produced in BEL, FRA, ITA, GER, and the UK and that are sold on at least one of four possible export markets in our sample; when presenting the summary statistics for relative prices, we drop the models that are not sold in the country of production and thus have no "Home Market Price"; In the lower part of Table 3, we list outliers that had year-top-year price changes of more than 0.5 log points or relative price changes of more than 0.5 log points.

Table 4 - Nominal Exchange Rate Pass Through (Fixed Effects or Dynamic Panel Regressions)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Baseline ERPT	Adding Quality	Quality-dep. ERPT	Trend	Mean Reversion	Unwgted Estimation	No Change of Loc	zcode as Group	PPI Inflation	Local Distrib.
Estimation:	FE Panel	FE Panel	FE Panel	FE Panel	Dyn. Panel	FE Panel	FE Panel	FE Panel	FE Panel	FE Panel
	Sample: All Models that are produced in & exported to BEL, FRA, ITA, GER and UK									
	Dependent Variable is the Change of Ln Car Price (Local Currency, net of Taxes)									
dExrate = % Change of Exrate	0.159	0.17	0.147	0.135	0.116	0.139	0.142	0.136	0.066	0.069
	[0.032]**	[0.031]**	[0.028]**	[0.028]**	[0.028]**	[0.023]**	[0.029]**	[0.027]**	[0.027]*	[0.027]*
dExrate* Quality Index 1			-0.076	-0.076	-0.062	-0.063	-0.059	-0.055	-0.064	-0.061
			[0.030]*	[0.029]**	[0.026]*	[0.023]**	[0.025]*	[0.024]*	[0.025]*	[0.025]*
Quality Index 1		0.046	0.046	0.095	0.251	0.075	0.071	0.041	0.091	0.092
		[0.008]**	[0.008]**	[0.010]**	[0.030]**	[0.010]**	[0.011]**	[0.007]**	[0.012]**	[0.012]**
Trend (year)				-0.003	-0.008				-0.006	-0.006
				[0.000]**	[0.001]**				[0.001]**	[0.001]**
Lag 1 of % Price Change					-0.186					
					[0.028]**					
CPI Inflation Importer	0.796	0.959	0.948	0.806	0.861	0.941	0.911	0.924		
	[0.038]**	[0.044]**	[0.043]**	[0.046]**	[0.069]**	[0.048]**	[0.047]**	[0.045]**		
PPI Inflation Importer									0.27	0.245
									[0.051]**	[0.054]**
PPI Inf * Quality Index 1										-0.056
										[0.052]
Market Dummies	na	na	na	na	na	na	y	y	na	na
Observations	5216	5216	5216	5216	3730	5216	5216	5216	4012	4012
Number of groups	736	736	736	736	578	736	212	150	596	596
R-squared (within)	0.15	0.16	0.16	0.18	na	0.12	0.18	0.19	0.09	0.09

Notes for Table 4: specifications (1) to (6) include fixed effects by Market-Co-Location (all combinations) where "Co" is the narrow car model definition of P. Goldberg and Verboven (2005); (7) includes fixed effects for Markets and Co separately; (8) includes fixed effects by Markets and zCode, where "zCode" is the wide definition of a car model in P. Goldberg and Verboven (2005). In Columns (2) to (8), the respective quality index is included to capture changes of the quality of a car during the lifecycle of a model; the interpretation of the quality index coefficient is the effect a change in a model's quality has on the price; robust standard errors reported in parentheses * significant at 5%; ** significant at 1%.

Table 5 - Relative Exchange Rate Pass Through (Fixed Effects Results for Quality 1)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Baseline ERPT	Adding Quality	Quality-dep. ERPT	Trend	Mean Reversion	Unwgted Estimation	No Change of Loc	zcode as Group	Home and For Variables	Local Distrib.
Estimation:	FE Panel	FE Panel	FE Panel	FE Panel	Dyn. Panel	Dyn. Panel	FE Panel	FE Panel	FE Panel	FE Panel
Sample: all models that are produced in & exported to BEL, FRA, ITA, GER and UK										
Dependent Variable is the percentage change (dLn) of the ratio of importer over exporter price (local currencies)										
dExrate = % Change of Exrate	0.171	0.167	0.132	0.129	0.116	0.144	0.158	0.151	0.13	0.092
	[0.044]**	[0.042]**	[0.038]**	[0.037]**	[0.033]**	[0.028]**	[0.038]**	[0.038]**	[0.041]**	[0.036]*
dExrate * Quality Index 1			-0.111	-0.111	-0.046	-0.091	-0.083	-0.087	-0.088	-0.126
			[0.037]**	[0.037]**	[0.035]	[0.027]**	[0.034]*	[0.034]*	[0.037]*	[0.032]**
Difference in Relative Quality 1		0.243	0.244	0.244	0.217	0.235	0.236	0.237		0.259
(Importer Q1-Exporter Q1)		[0.023]**	[0.023]**	[0.023]**	[0.023]**	[0.020]**	[0.023]**	[0.023]**		[0.023]**
Trend (year)				0	0					
				[0.000]	[0.001]					
Lag 1 of Change in					-0.232					
Ln (Relative Price)					[0.018]**					
Change in Ln Relative CPI	0.803	0.788	0.757	0.732	0.895	0.757	0.761	0.802		
(Importer Infl. - Exporter infl.)	[0.051]**	[0.047]**	[0.048]**	[0.054]**	[0.089]**	[0.044]**	[0.044]**	[0.042]**		
Quality 1 Exporter									0.177	
									[0.024]**	
Quality 1 Importer									-0.202	
									[0.032]**	
Change in Ln CPI Importer									0.697	
									[0.072]**	
Change in CPI Exporter									-0.808	
									[0.078]**	
PPI Inflation Importer										0.103
										[0.051]*
PPI Inf * Quality Index 1										-0.044
										[0.055]
Market Dummies	na	na	na	na	na	na	y	y	na	na
Observations	4976	4976	4976	4976	3499	4976	4976	4976	4976	3855
Number of groups	719	719	719	719	555	719	204	144	719	582
R-squared (within)	0.08	0.22	0.22	0.22		0.21	0.25	0.26	0.14	0.19

Notes for Table 5: in all specifications, the dependent variable is the change in the natural logarithm of the relative car price in local currencies (Importer Price divided by Exporter Price); the independent variable "Change in Ln CPI" measures the change in the ln of the ratio of importer CPI to the exporter CPI; in Columns (2) to (9), the relative quality index is included to reflect changes of the relative quality of a car during the lifecycle of a model; the interpretation of the relative quality index coefficient is the effect a relative change in a model's quality (in the importer relative to the exporter) has on the relative price; Columns (1) to (6) and (9) include fixed effects by Market-Co-Location (all combinations); (7) includes fixed effects for Markets and Co; (8) includes fixed effects for Market and zCode; robust standard errors reported in parentheses * significant at 5%; ** significant at 1%.

Table 6 - Relative Exchange Rate Pass Through (Using Quality Index 2)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Baseline ERPT	Adding Quality	Quality-dep. ERPT	Trend	Mean Reversion	Unwgted Estimation	No Change of Loc	zcode as Group	Home and For Variables	Local Distrib.
Estimation:	FE Panel	FE Panel	FE Panel	FE Panel	Dyn. Panel	Dyn. Panel	FE Panel	FE Panel	FE Panel	FE Panel
	Sample: all models that are produced in & exported to BEL, FRA, ITA, GER and UK									
	Dependent Variable is the percentage change (dLn) of the ratio of importer over exporter price (local currencies)									
dExrate = % Change of Exrate	0.171 [0.044]**	0.167 [0.042]**	0.146 [0.039]**	0.143 [0.039]**	0.119 [0.033]**	0.149 [0.028]**	0.162 [0.038]**	0.155 [0.039]**	0.142 [0.042]**	0.099 [0.036]**
dExrate * Quality Index 2			-0.074 [0.035]*	-0.075 [0.035]*	-0.03 [0.034]	-0.072 [0.027]**	-0.066 [0.033]*	-0.071 [0.032]*	-0.054 [0.036]	-0.099 [0.030]**
Difference in Relative Quality 2 (Importer Q2-Exporter Q2)		0.3 [0.029]**	0.302 [0.029]**	0.302 [0.029]**	0.27 [0.029]**	0.292 [0.026]**	0.294 [0.029]**	0.295 [0.029]**		0.321 [0.030]**
Trend (year)				0 [0.000]	0 [0.001]					
Lag 1 of Change in Ln (Relative Price)					-0.233 [0.018]**					
Relative CPI Inflation (dCPI Importer Infl. - Exporter in	0.803 [0.051]**	0.787 [0.047]**	0.772 [0.047]**	0.745 [0.053]**	0.9 [0.089]**	0.765 [0.044]**	0.769 [0.044]**	0.809 [0.041]**		
Quality 2 Exporter									0.215 [0.029]**	
Quality 2 Importer									-0.251 [0.040]**	
Change in Ln CPI Importer									0.709 [0.072]**	
Change in CPI Exporter									-0.823 [0.078]**	
PPI Inflation Importer										0.133 [0.048]**
PPI Inf * Quality Index 2										0.011 [0.047]
Market Dummies	na	na	na	na	na	na	y	y	na	na
Observations	4976	4976	4976	4976	3499	4976	4976	4976	4976	3855
Number of groups	719	719	719	719	555	719	204	144	719	582
R-squared (within)	0.08	0.22	0.22	0.22	na	0.2	0.25	0.26	0.14	0.19

Notes for Table 6: in all specifications, the dependent variable is the change in the natural logarithm of the relative car price in local currencies (Importer Price divided by Exporter Price); the independent variable "Change in Ln Relative CPI" measures the change in the ln of the ratio of importer CPI to the exporter CPI; in Columns (2) to (9), the relative quality index is included to reflect changes of the relative quality of a car during the lifecycle of a model; the interpretation of the relative quality index coefficient is the effect a relative change in a model's quality (in the importer relative to the exporter) has on the relative price; Columns (1) to (6) and (9) include fixed effects by Market-Co-Location (all combinations); (7) includes fixed effects for Markets and Co; (8) includes fixed effects for Market and zCode; robust standard errors reported in parentheses * significant at 5%; ** significant at 1%.

Table 7 - The Time Profile of ERPT and Quality

No. of Included Lags	Sum of Coefficients on Exchange Rate	Sum of Coefficients on Exchange Rate * Quality Index 1
	Panel A - Using Quality Index 1	
0	0.132	-0.111
	[0.038]**	[0.037]**
0-1	0.248	-0.147
	[0.049]**	[0.045]**
0-2	0.447	-0.150
	[0.050]**	[0.054]*
0-3	0.483	-0.230
	[0.070]**	[0.061]**
0-4	0.534	-0.156
	[0.116]**	[0.078]*
	Panel B - Using Quality Index 2	
0	0.146	-0.074
	[0.039]**	[0.035]*
0-1	0.269	-0.099
	[0.050]**	[0.040]*
0-2	0.465	-0.121
	[0.049]**	[0.050]*
0-3	0.502	-0.220
	[0.070]**	[0.062]**
0-4	0.539	-0.166
	[0.112]**	[0.075]*

Notes for Table 7: robust standard errors reported in brackets * significant at 5%; ** significant at 1%.

LIST OF LOC Changes when Car is in the Full sample

Obs. No.	ye	type		Produciton Change
1437	93	nissan	micra	Japan to UK
1454	93	nissan	micra	Japan to UK
1471	93	nissan	micra	Japan to UK
1497	93	nissan	micra	Japan to UK
1607	89	nissan	bluebird	Japan to UK
1619	89	nissan	bluebird	Japan to UK
1634	89	nissan	bluebird	Japan to UK
1654	89	nissan	bluebird	Japan to UK
2760	**90**	**peugeot**	**309**	**Fro UK to FRA**
2808	**94**	**peugeot**	**405**	**Fro UK to FRA**
5330	98	seat	toledo	From Spain to Belgium
5337	98	seat	toledo	From Spain to Belgium
5345	98	seat	toledo	From Spain to Belgium
5353	98	seat	toledo	From Spain to Belgium
5797	94	toyota	carina	Jap to UK
5807	94	toyota	carina	Japan to UK
5817	94	toyota	carina	Japan to UK
5833	94	toyota	carina	Japan to UK
9959	**91**	**ford**	**sierra**	**UK to BEL**
10420	95	honda	civic	Japan to UK
10446	95	honda	civic	Japan to UK
10473	95	honda	civic	Japan to UK
10484	95	honda	civic	Japan to UK
10511	95	honda	civic	Japan to UK
10628	93	honda	accord	Japan to UK
10651	93	honda	accord	Japan to UK
10673	93	honda	accord	Japan to UK
10684	93	honda	accord	Japan to UK
10707	93	honda	accord	Japan to UK

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