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Does marketing widen borders? Cross-country price dispersion in the European car market

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ABSTRACT

We study cross-country price differences in the European market for new passenger cars based on detailed pricing and technical data. Car prices in Europe converged until the year 2003, but not thereafter. Even then the price range of the median model across EU15 countries was close to 20%. This cross-country price differentiation is systematically linked to common product features, varies significantly across models and increases systematically with the market segment. Identical cars are positioned individually by country, for example via tailored feature bundles. Both the convergence of prices in anticipation of a future reduction of barriers to arbitrage and the systematic price differentials point to active pricing-to-market strategies that treat countries as marketing regions.

1. Introduction

Pricing-to-market (PTM), the practice of differentiating the retail or wholesale price of a good across markets, is a well-known practice (e.g. Alessandria and Kaboski, 2011; Atkeson and Burstein, 2008; Berman et al., 2012; Burstein and Gopinath, 2014; Gron and Swenson, 1996; Simonovska, 2015; Strasser, 2013). Much less is known about the exact mechanisms through which PTM is implemented.[1] Price differentials between countries are often attributed to the structure of the economy, e.g. to differential distribution costs (Burstein et al., 2003; Corsetti and Dedola, 2005) or border costs (Engel and Rogers, 1996). But in advanced economies transaction and travel costs are low, and governments routinely promote competition through trade agreements and regulatory measures, so one would expect arbitrage to constrain the ability of firms to price to market. The persistence of PTM in these countries remains therefore something of a puzzle.

We examine the practice of PTM in what is perhaps the most studied example in the literature: the European car market (e.g. Auer, 2017; Gil-Pareja, 2003; Goldberg and Verboven, 2001, 2005; Mertens and Ginsburgh, 1985; Verboven, 1996a,b). Countries of the European Union (EU) are natural candidates for any discussion of market integration. They share a tightly integrated transport infrastructure, a common regulatory framework, and deep trade relations. Not least, most of them either use a common currency (the euro) or currencies which are credibly pegged to it.

A car is the most significant purchase of a tradeable good that households make. The car market is a highly visible indicator of European market integration and is as such the focus of intense scrutiny. For this reason, and despite exempting the passenger car

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[1] For example, a recent report of the Canada Senate on the persistent price gap with the U.S. with a special attention to car prices noted that after hearing extensive expert testimony and taking into account differences in regulation and taxation the committee "cannot offer an explanation as definitive as it would have liked for the price discrepancies for products between Canada and the United States" (Day et al., 2013, p. vi).

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0022-1996/

market from the unrestricted competition article of the EU treaty, the European Commission (EC) aims to increase market integration within Europe: car warranties must be respected across the EU; cross-border car buyers are exempt from taxes and fees in the country of purchase; car registration documents are valid EU-wide; even cross-border purchases to and from the British Isles are accommodated by requiring manufacturers to deliver upon request right-hand drive steering cars to dealers on the Continent (European Commission, 2002; European Commission DG-COMP, 2002). The explanations for price differences within Europe listed by Goldberg and Verboven (2004) have all more or less vanished since then.[2] And yet, significant price dispersion remains in the European car market. In this paper we trace some of these price differences to price differentiation by marketing: versioning an otherwise homogeneous product across countries. In particular, country-specific versions of a car can be created by changing the menu of included car features in each country.

Comparing car prices across countries is not a trivial exercise, neither for consumers nor for economists. A typical car buyer in Europe is presented with a menu of standard and optional features and auxiliary services which varies by country, rendering a direct "apples-to-apples" comparison difficult. A basic and necessary contribution of this paper is the creation of a data set which allows conducting international price comparisons of identical products, which requires pre-tax prices and technical characteristics. We then compare the pre-tax price of, for example, a particular Ford Focus purchased by a German buyer from a French dealership with the pre-tax price that same consumer would have paid in Germany.

Based on this new data set, we show that PTM in Europe was pervasive throughout the sample period (1993–2011), with little evidence of absolute convergence since the year 2004. This is true within the euro area as well as across the entire EU. It is a surprising finding given the decline in price dispersion in the 1990s, as carefully documented in earlier literature. It is even more surprising given the vigorous efforts by the European Commission to increase competition in the new car market and to reduce the obstacles to arbitrage.

Our data consists of pre-tax prices, P_t^{mc}, sampled for car model m in country c at time t. We define the real exchange rate for a given model m between a given country c and our base country, The Netherlands, as the logarithmic difference between the pre-tax, euro-denominated prices.[3] Denoting the natural logarithm by lowercase letters, the model-specific real exchange rate is given by $r_t^{mc} = p_t^{mc} - p_t^{m,NL}$. Fig. 1 presents histograms of this real exchange rate for two sets of years. Under the law of one price (LOP), these distributions would be concentrated tightly around zero. We see instead that real exchange rates are widely spread out, with no sign of (absolute) convergence to zero over time. If anything, real exchange rates diverge slightly from 2003 to 2011.

What can explain these features of the data? We identify mechanisms which allow PTM to take place, strengthening earlier findings that manufacturers' prices take advantage of existing market segmentation in Europe. We show that prices respond to differences in, for example, income and tax rates across countries. Our data allows us to go beyond previous studies, however, and uncover more nuanced practices: Car manufacturers seem to practice differential bundling of their products across markets. We find that the bundling of features systematically affects the price of a car and thus model-specific real exchange rates. Take air conditioning (AC): a common

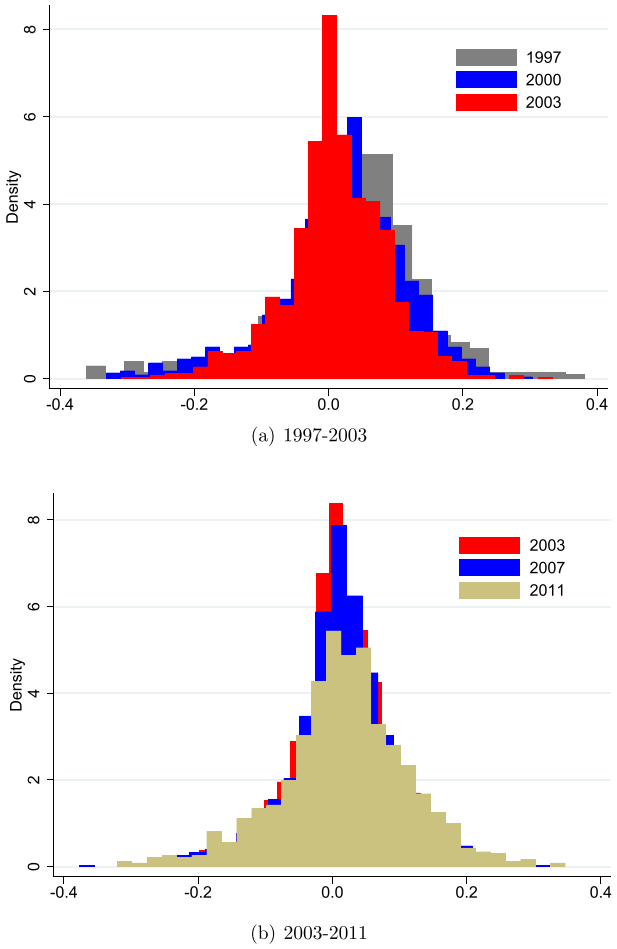

Fig. 1. Frequency distribution of model-specific real exchange rates. The histograms show the frequency distribution of model-specific real exchange rates, r_t^{mc}. Broad model definition, EU 15 countries only. The upper panel shows the months May 1997 (standard deviation 0.110), May 2000 (0.096), and May 2003 (0.076), whereas the lower panel shows the months November 2003 (0.071), May 2007 (0.078) and January 2011 (0.097).

car feature, but nevertheless not offered as standard everywhere. We find that the price difference between AC included in the car's price as standard and AC included as an option varies with the summer temperature in the respective country. Because we compare the prices of identical cars, all with AC, this amounts to price discrimination across countries. In other words, by exploiting the ability to offer different menus of options across countries car manufacturers create an artificial "border".

Due to its visibility and the regulatory attention it receives, the market for European new passenger cars has been the subject of many studies (Ginsburgh and Vanhamme, 1989; Kirman and Schueller, 1990; Mertens, 1990; Mertens and Ginsburgh, 1985). In the early 1990s, the price differences were still very large (Verboven, 1996a). In response to this apparent lack of market integration, the European Commission in 1993 started collecting pre- and post-tax prices for about 75 car models at least once a year. Beginning with the report of Degryse and Verboven (2000) to the Competition Directorate-General of the EC in 2000, this data set (henceforth "EC data set") forms the basis for most subsequent analyses of the European car market, including our own.

The papers that follow these seminal studies describe a car market characterized by substantial price dispersion, though declining over time (Gil-Pareja and Sosvilla-Rivero, 2008; Goldberg and Verboven, 2004, 2005), and by widespread PTM (Gil-Pareja, 2003).

[2] We discuss recent regulatory developments in the EU car market in detail in the Online Appendix.

[3] We choose The Netherlands as base country because of its intermediate car price level as well as its central location. Our choice is the same as the one of Goldberg and Verboven (2004, p. 503). See Online Appendix A.5.

We begin our analysis taking these latter papers as our starting point.[4]

Substantial price dispersion within and across countries is extremely common for products other than cars as well. It is often too large to fit common explanations, such as the cost of crossing a border or the differences in the cost of non-traded goods. These deviations from LOP have been the subject of intense debate in the international finance literature. This literature has, since the seminal paper by Engel and Rogers (1996), increasingly used micro data to examine cross-country price dispersion. Whereas for commodities LOP holds (Baffes, 1991), already within a global retailer such as IKEA deviations from LOP are large and cannot be explained with distribution costs or taxes (Baxter and Landry, 2012; Haskel and Wolf, 2001; Hassink and Schettkat, 2003). The IKEA results are based on prices quoted in different currencies. Within the euro area online stores of two large fashion chains, as well as of Apple and IKEA, however, seem to obey to the law of one price in more recent years (Cavallo et al., 2014).

Our paper revisits this debate but examines a very different market. Instead of small and easy-to-compare household items,[5] we compare large ticket items, namely cars. A car is the largest household expenditure item after buying a house, which renders comparing prices internationally a prudent effort for consumers. Compared to household items, cars are a very heterogeneous good, but with well-documented differences, which we exploit in this paper. Furthermore, we do not rely on online prices, but dealership prices for made-to-order cars.[6] Finally, the market we study has been explicitly deregulated to allow for cross-border purchases. That is not the case with online purchases for example, where cross-border purchases are often blocked.

We proceed as follows. The next section formulates the hypotheses we intend to test and describes our data. Section 3 examines the development of price dispersion in Europe over time. Section 4 shows that country-specific preferences help explain this persistence of international price differences. We discuss policy implications of our findings and conclude in Section 5.

2. Hypotheses and data

We start by detailing the four central hypotheses, which we test in this paper. Then we describe the key data series, introduce two definitions of a car model, and provide a brief overview of the data.

2.1. Hypotheses

For the past decades barriers to trade within the EU have continuously declined. This suggests

Hypothesis 1. Price convergence within an integrating single market is monotone and persistent.

The evidence in Section 3.1 rejects this hypothesis. First, (absolute) price convergence stopped in 2003. Second, on top of the underlying trends temporary bursts are possible, as during the 2009 crisis.

Because a common currency facilitates cross-border shopping, and thus arbitrage, we have

Hypothesis 2. A common currency reduces price dispersion.

Section 3.2 shows that this is true. Manufacturer list prices within the euro area are indeed less dispersed. However, most convergence occurred in advance of the introduction of the euro.

We conjecture that price dispersion is not a random outcome. Most specifically we have

Hypothesis 3. Price dispersion varies with the features of the product.

This hypothesis is accepted by the data. Section 3.3 shows that price dispersion is systematically linked to product features.

Our final hypothesis concerns the law of one price.

Hypothesis 4. Identical goods in two markets without barriers to trade have the same price.

This is rejected in our data. We discuss in Section 4 how country-specific marketing can create a price wedge when preferences differ by country.

2.2. The data

For this project we have collected data on car prices, technical specifications, taxation, plant locations, brand perception, and country properties.[7] The data sources and data cleaning procedure are described in more detail in the Online Appendix.

2.2.1. Car prices

Our car price data come from the European Commission's Directorate General for Competition.[8] This data set (henceforth "EC data set") was collected and distributed from 1993 until 2011 by the EC as a service to European consumers who wish to compare prices across countries. The data covers car models at the country level. Its scope are all EU member countries at the respective time, which translates into up to 27 countries. Until 2006 inclusive, the EC published semi-annual reports for May and November of each year. In 2007, the EC switched to annual reporting (for May of 2007 and then for January of 2008 and later years). Publication of the report

[4] Most studies of the European car market work with variants of the pre-2003 data. An exception are Gil-Pareja and Sosvilla-Rivero (2012), who select 45 models and 15 countries from an updated EC data set. Applying various panel unit roots test to the 1993–2008 data gives them only weak evidence of price convergence.

[5] These items typically have a unique identifying code. Broda and Weinstein (2008), Gopinath et al. (2011), and Gorodnichenko and Talavera (2017) for example, use Universal Product Codes (UPC) to ensure a comparison of identical products across countries. These studies exclude between 50% and more than 95% of UPCs, which are UPCs observed in only one country. Broda and Weinstein (2008) find no additional price dispersion across the border, whereas Gopinath et al. (2011) find a considerable price gap between identical products in stores belonging to the same retail chain but located across the USA-Canada border. This price gap is almost entirely driven by variation in wholesale costs borne by the retailer and consistent with full segmentation of markets.

[6] Online distribution of new cars has been extremely uncommon during the sample period. Online car brokers started entering the, for example, German market in 2005, but as of 2011 their market share remained negligible (Dudenhöffer and Neuberger, 2011).

[7] Data on population and on GDP per capita at constant international prices are from Eurostat, available at http://www.ec.europa.eu/eurostat. The indirect taxes on petrol paid at the pump by consumers are taken from the EC's Oil Bulletin, available at http://www.ec.europa.eu/energy/observatory/oil/bulletin_en.htm.

[8] The raw data is publicly available for download at http://ec.europa.eu/competition/sectors/motor_vehicles/prices/report.html. The Online Appendix A.1 describes the process we employed to standardize and clean the data. The years before 2000 are based on Goldberg and Verboven (2004).

ended in 2011.[9] Our data set contains the list prices of new cars, with and without tax, as well as information on standard features and the availability and pricing of several optional features. A distinguishing feature of this data set is that the prices are consistently collected across countries. This was essential for its original purpose: encouraging cross-border shopping within the EU.[10]

New cars in Europe are usually custom ordered at the dealership, where the buyer can choose from a menu of available features such as engine type, body color, AC, and an anti-lock braking system (ABS). List prices for the basic car model and for all available options are determined by the manufacturer, and updated periodically. The dealer usually stocks only a small number of new cars for immediate sale. Normally, customers need to wait weeks or months while the car which exactly fits their specifications is assembled and delivered to the dealership. Discounts and financing packages are typically determined by the manufacturer as well and apply throughout the country.[11] Price competition among dealers is quite limited as a result.

2.2.2. Car specifications

We obtain technical data on all car models sold in the United Kingdom (UK) from the website of the UK government's Royal Certification Agency (RCA). Every car model sold in Britain must undergo testing and certification by this agency, since each car's official emissions and fuel consumption data are determined in this way.[12] The RCA data set adds information on fuel consumption and emissions, augments the information on engine size and power in the EC data, and serves as a cross-check. We are able to match almost 90% of the models in our price data with the models in the RCA data set, which gives us more confidence that we are indeed comparing prices of technically identical cars.[13]

2.2.3. Taxation

Cars sales in Europe are subject to value added tax (VAT), whose rate differs by country and can change over time. Some countries tax new cars additionally at registration based on technical properties such as engine size, engine power, emissions (carbon dioxide CO_2, hydrocarbons HC, nitrate oxides NO_x, particles), or the overall EU emission standard. Less common are taxes based on fuel consumption, weight, or length of the car.

Cross-border car purchases are conducted on a pre-tax basis; buyers are required to pay VAT and registration taxes in their country of residence. We calculate effective registration tax rates from the pre- and after-tax prices recorded in the EC data set. We double-check their plausibility using a taxation manual published by PricewaterhouseCoopers (2011).[14]

2.2.4. Assembly plant locations

Price differences across countries may arise from transportation costs between countries. We collect annual data on the European assembly locations by car model, starting in the year 2000, from the industry publication "Automotive News Europe."[15]

Due to large economies of scale, a given car model is produced in very few locations. More than 84% of the observations are cars produced in a single country for the entire European market, and more than 74% are produced even in a single location.[16]

For each model-country pair, we calculate the distance from the nearest assembly plant to the country's capital city, using exact coordinates and applying the great circle formula. For models imported from Japan, South Korea, or the USA, we calculate the distance from the European port of entry where we know it. In cases where port of entry information is unavailable, we assume import through the port of Rotterdam. We choose Rotterdam, because it is located in our base country, and close to and between the main European ports for car handling, namely Antwerp and Zeebrugge in Belgium and Bremerhaven and Emden in Germany.

2.2.5. Brand centrality

Price differences across countries may also be driven by differences in consumers' elasticity of substitution between similar car models. We do not observe these elasticities directly; instead, we create a measure of brand centrality as a proxy. We collect data from an Internet search engine. Google Insights reports which search terms are most commonly entered jointly. In particular, we observe how often two brands are searched for together. Based on this information we calculate the centrality of each brand in a given country, relative to all other brands.[17] We interpret this measure as follows: if a brand is relatively central, it is seen by potential car buyers

[9] The EC's website offers the following reasoning for ending the survey: "Between 1993 and 2011, the Commission has published annually the […] Car Price Report. This report has been discontinued. When the report was launched, there were major car price differences among Member States, and it was much more difficult for consumers to compare prices across borders. Since then, the situation has improved greatly, in part due to enforcement action by the Commission, and also thanks to the increased availability of price information on the internet. This means there is no longer a need for the Commission to duplicate this information in the Car Price Report." (European Commission, 2013) The findings in this paper cast some doubt on this assessment of price differences in Europe.

[10] The EC maintains a website to educate European consumers about their rights to shop for cars anywhere in the EU: http://europa.eu/youreurope/citizens/vehicles/index_en.htm.

[11] Dealership discounts in Europe for newly built-to-order cars are small, rarely exceeding 10% (Degryse and Verboven, 2000). Based on undercover shoppers and manufacturer responses Degryse and Verboven (2000, p. 112) conclude that "the average discounts do not differ substantially across countries," and thus have a negligible effect on real exchange rates. Some dealers offer "near new" cars, usually last year's models or cars ordered but for any reason not claimed. This is a different market, however: the cars are sold as-is, and are already fully licensed. This market features much more robust price competition, with significant differences from list prices, similarly to dealer practices in the United States. Supply in this market, however, is limited; it is essentially a clearance market.

[12] The agency's website http://carfueldata.direct.gov.uk provides the year-by-year results of these tests. Because manufacturers treat Europe as a single market in terms of their choice of models, we apply the UK technical data to all countries.

[13] We match the cars based on time, brand, model name, engine capacity, engine power, fuel type and transmission, depending on which of these features were noted in the price data. Manual and automatic cars are tested (and thus matched) separately, because they differ in their emission and fuel consumption values. The brand Lancia was not sold in the UK during the sample period, therefore it cannot be matched with technical data and we exclude it from our analysis. Online Appendix A.2 describes the matching procedure in detail.

[14] Effective tax rates differ substantially between countries. On the lower end of the spectrum, the effective tax rate can be smaller than the VAT because of tax incentives. On the other end of the spectrum, some high-powered cars in Denmark are subject to an effective tax rate of more than 240%. The total tax can reach more than €150,000 for high-end Audi and Mercedes-Benz models in Denmark in some years. In 2011, the median effective tax rate across all models as a percentage of the pre-tax price was lowest in Luxembourg (15%) and Germany (19%) and highest Denmark (164%) followed by Finland and Malta with about 50%.

[15] The data is available at the website http://europe.autonews.com, which requires a subscription for some years. We have data for 2003–2008, and for 2012. We interpolate and extrapolate the missing years to cover the entire period 2000–2011. In this way we are able to determine the assembly location of more than 98% of the observations during these years. Assembly locations for a given model barely change over time.

[16] Notable exceptions are the high volume models Opel Astra and Volkswagen Golf with up to four production locations in some years. Only 8% of observations are cars produced simultaneously both within and outside the euro area in the boundaries as of the respective sampling date. Keeping these exceptions in mind it is fair to view car models as generally produced in one common location for all of Europe. In popular data sets of retail goods the assumption of a common production location is difficult to establish, because these goods are often produced locally or in multiple locations. An exception in the literature are Burstein and Jaimovich (2012), who control for the country of origin of the product. More similar to our data, Fitzgerald and Haller (2014) sample prices from individual Irish manufacturing plants. Unlike them we assign car models to plants indirectly, based on industry reports, exploiting the relatively small number of makes and manufacturing plants in the car industry.

[17] We describe the data collection and the calculation of the eigenvector centrality measure in more detail in Online Appendix A.3.

in that country as relatively substitutable to other brands. Therefore the manufacturer's ability to impose a high price relative to competitors in that country will be limited. The centrality measure varies by country and brand. It ranges from zero (about 15% of all brand-country pairs) to slightly more than 0.5 for Toyota in Malta. Overall, Toyota is the most central brand, with a centrality average of 0.36 across all countries, followed by Nissan and Citroen. The most idiosyncratic brands are MG Rover and Land Rover, with a centrality average close to zero, followed by Mini and Saab.

2.3. Model definition

From the year 2000 onwards, we are able distinguish models based on very detailed information, namely model name, an automatic gearbox indicator, engine size, engine power, fuel type, number of gears, euronorm, number of doors and a right-hand drive indicator. We refer to this as the *narrow* model definition. For comparability with other studies and with periods before the year 2000, we also use a coarser distinction between models, based only on model name and an automatic gearbox indicator, excluding any right-hand drive observations. We refer to this as the *broad* model definition. When comparing our post-2000 data with data for earlier periods, we break all series after December 1999, i.e. we use separate model definitions before the year 2000, in order to rule out the possibility that subtle differences in model definitions between the two subsamples might affect our results.

We subject the data to a rigourous cleaning and plausibility check. We exclude from our analysis a car (observation) if its price or key technical information after the year 2000 is missing, or if its recorded specification is uncommon and its existence unverifiable. We further exclude observations which are inconsistent across countries or across car properties, unless the correct value is obvious. The resulting data set covers Europe's most popular models within each segment, sold under 27 different brands, and comprising 204 models in an unbalanced panel.[18]

2.4. Decomposition into country and time effects

The data set covers a very diverse set of cars. To isolate the obvious price differences between car models from other effects, we study the residuals ρ_t^{mc} from the regression $P_t^{mc} = \alpha+\alpha_m+\alpha_t+\alpha_{mt}+X_t^{mc}+\rho_t^{mc}$ for the EU 27, where X_t^{mc} is the engine power measured in ccm. Next, we decompose these residuals, the not-model-specific variation, into cross-country dispersion and time variation by applying the conditional variance identity. Depending on time period and model definition, on average two-thirds to four-fifths of the variation at the model level is due to the dispersion of country long-run mean prices, rendering the other component, the average country-specific time variation $E[Var(\rho_t^{mc}|cm)|m]$, almost negligible.[19] For this reason, we study in this paper the determinants and causes of these long-run country effects.

3. Price dispersion

In this section, we document periods of price convergence and divergence, and the role of the euro. We identify segments of the car market that are particularly prone to price dispersion, and events that strongly affected price dispersion.

Model price dispersion, Ξ_t^m, is the standard deviation of log prices p_t^{mc} for a given model m at a given time t across countries c, i.e.

$$\Xi_t^m = 100 \times Std(p_t^{mc}|mt). \quad (1)$$

We use only Ξ_t^m values based on at least three countries, but a tighter criterion would not change the results.

The dispersion of car prices varies widely across models and over time. The upper panel of Fig. 2 shows the range of within-model price dispersion across EU15 countries for each survey period. Because this graph includes pre-2000 years, we use the broad model definition here. For the years 2000–2011, the graph under the narrow model definition looks similar.[20] The boxes represent the 25th to 75th percentile range, with the horizontal line marking the median. At any point in time, the price dispersion differs a lot between models. Compared to this large variation of dispersion across models, the time variation during these 19 years is rather small.

3.1. Convergence reversal

The years between 1995 and 2008 display a U-shaped time trend. First, beginning in 1998, prices converge, but around 2004 convergence comes to a stop. Most price convergence occurred during the years 2001–2003, around the time that the euro was introduced as circulating (and thus as invoicing and quoting) currency. Another, smaller decline is visible from 1998 to 1999, when the euro became the common accounting currency. This is in line with Cavallo et al. (2014), who show that a currency peg (as in Denmark) does not enforce LOP, not even on the Internet. Only a common currency (in this study the euro) does. The total decline in dispersion is sizeable. In total, the standard deviation of log prices between EU15 countries under the broad model definition is cut by almost one-half from 1995 to 2004.

The jump in price dispersion near the end of the sample, from (January) 2008 to (January) 2009, coincides with the more recent financial crisis. Since models differ in their dispersion in 2008 by about the same as in 2009, an important part of the overall jump in dispersion must be due to country factors.[21] The years 2010 and 2011 show a slow convergence towards the pre-2008 situation, but in 2011 the average dispersion was still higher than in 2008.

This result extends to price ranges, such as the difference between the maximum and the minimum price of a given model across EU15 countries, which are shown in the lower panel of Fig. 2. During the 1990s, price differences of 40% among EU15 countries were common. In the mid-2000s, the range shrunk to about 20%, and jumped up again to about 30% in the financial crisis. We see that manufacturers are able to maintain a 20% price difference permanently even within a market as tightly integrated as the EU 15. These international price differences are large compared with goods sold online. Take, for example, the real exchange rate between the USA and Canada calculated by Gorodnichenko and Talavera (2017), which is based on the best offers for consumer electronics on price comparison sites in the respective countries. Despite prices in different currencies and – compared to vehicles – much cheaper products, the average

[18] See the Online Appendix for additional summary statistics.

[19] Several papers focussing on relative purchasing power parity show that this common time variation traces the nominal exchange rate closely, for example Burstein and Jaimovich (2012) and Gopinath et al. (2011) based on retail chain scanner data. In our sample, where many countries share a common currency, this is the smaller component of international price dispersion; the country-level differences dominate. As Crucini and Telmer (2012) and Crucini and Yilmazkuday (2014) observe in a sample of global consumer goods prices, the idiosyncratic variation at the goods level, i.e. in our context the variation across countries for a given car model, dominates the (country-specific) time variation.

[20] Focussing on the EU15 subsample ensures that none of the time variation after the mid-1990s is due to the expansion of the set of countries over which the dispersion is calculated. In fact the lower dispersion in the first three surveys before mid-1994 stems from fewer EU countries and an incomplete coding of models in these years.

[21] This may be due to the heterogeneous performance of European economies during the recession, as well as to large exchange rate movements of some European currencies vis-à-vis the euro. Also, "cash for clunkers" programs may have temporarily decoupled car prices from the prices in countries without such programs.

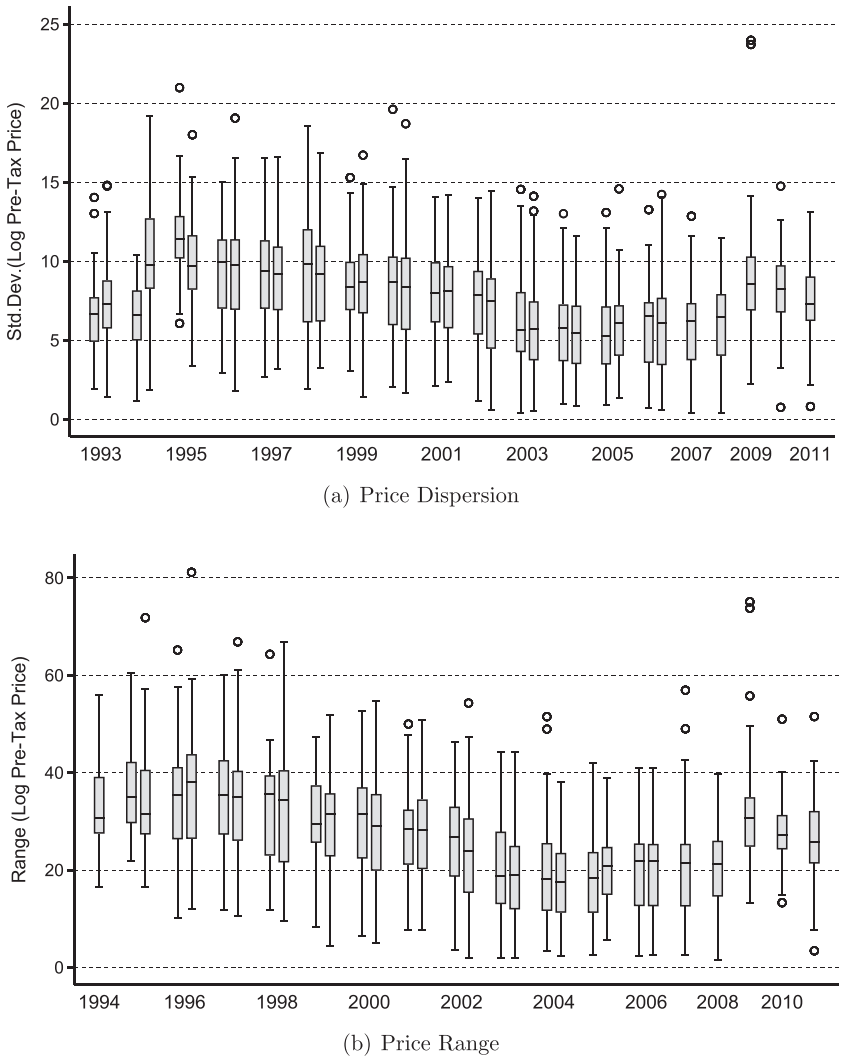

Fig. 2. Car price dispersion. The upper panel shows the distribution of Ξ_t^m across all models, i.e. of the model-specific cross-country dispersion of log prices. The lower panel shows the distribution of price ranges across models available in at least 10 countries, i.e. of the difference between the maximum and the minimum log price of a given model across countries. Broad model definition. EU15 countries only. Boxes represent the 25th–75th percentile range, with the horizontal line denoting the median. The lower whisker ends at the "largest observed value below the 25th percentile minus 1.5 interquartile ranges" threshold, and the upper whisker ends at the "smallest observed value above the 75th percentile plus 1.5 interquartile ranges" threshold. Circles represent outliers.

exchange rate adjusted price difference there was only 10% during the years 2008–2013.

We now turn to a more formal analysis of time trends in price dispersion. We first look at a specification that contains a quadratic time trend, controls for the recent EU enlargements and the financial crisis, and a model fixed effect α_m. The fixed effects regression

$$\begin{aligned}\Xi_t^m =&\alpha + \alpha_m + \beta_1 t + \beta_2 t^2 + \Lambda X_t^m \\ &+ \beta_{EU25}\mathbf{I}^{EU25}(t) + \beta_{EU27}\mathbf{I}^{EU27}(t) + \beta_{FC}\mathbf{I}^{FC}(t) + \beta_{AC}\mathbf{I}^{AC}(t) + \varepsilon_t^m,\end{aligned} \tag{2}$$

contains four binary time indicator variables, capturing important events during the sample period. The expansions of the EU are captured by the binary indicator variables $\mathbf{I}^{EU25}(t)$ and $\mathbf{I}^{EU27}(t)$, which take the value of one in all periods since the EU's expansion to 25 members and 27 members, respectively. The financial crisis is captured by the binary indicator variables $\mathbf{I}^{FC}(t)$ and $\mathbf{I}^{AC}(t)$, where the former takes the value one at the peak of the financial crisis, i.e. in January 2009, and the later in the two periods after that, i.e. in January 2010, and January 2011. X_t^m represents the price of a model in a given period averaged across countries and ε_t^m the idiosyncratic error.

Accordingly, α captures the average price dispersion, and β_1 and β_2 any quadratic time trend. Time t is measured in years from November 2003, which in Fig. 2 is one of the periods with the lowest dispersion. The coefficients β_{EU25}, β_{EU27}, β_{FC}, β_{AC} capture the impact of the respective events on price dispersion, and the coefficient Λ the effect of price changes over time.

On top of the overall steps towards an integrated European market, several regulations since the early 2000s have facilitated cross-border shopping of cars in particular, covering, for example, competition (European Commission, 2002), warranty (European Commission, 1999), and registration (European Commission, 2004). Hypothesis 1 implies a monotone decrease in the quadratic time trend in Eq. (2) towards the end of the sample ($t = 8$), i.e. a negative first derivative $H_0 : \beta_1 + 16\beta_2 \leq 0$. For samples starting in the year 2000, as in columns (1) and (2) of Table 1, this is rejected at the 5%

and 1% levels, respectively. This cannot be ascribed to the financial crisis. Column (4) shows that even before 2008 prices were already diverging. Only for the 1990s we accept this hypothesis, as in column (3).

Columns (1), (2) and (4) of Table 1 show that both EU enlargements increased dispersion. This reflects that the accession countries' markets had yet to integrate into the more homogenous EU15 market. This in turn is dwarfed by the jump in dispersion since late 2008.[22]

Overall, we have three distinctive episodes of price convergence and divergence.[23] The end of the period studied by Goldberg and Verboven (2004), 1993–2003, coincides with the end of the long convergence period around the turn of the century. As column (3) shows, prices indeed converged in that earlier subsample period from 1998 onwards. Also the specifications based on subsamples starting in the year 2000 shown in columns (1), (2) and (4) agree on an initial decline in dispersion until around the year 2004. After this, however, all three specifications report an increase. Whatever convergence to absolute price parity has been in this market in the 1990s and early 2000s, it has stopped and perhaps even reversed itself after 2004.[24]

How do these results for cars compare to other products? Several studies indicate a slowdown of price convergence in the EU since the turn of the century. Engel et al. (2004), for example, find considerable convergence among the prices of consumer goods in the 1990s, the period during which most intra-EU trade barriers were lifted, but no convergence after the year 1999. For washing machines in particular, Fischer (2012) finds hardly any price convergence during the period 1995 to 2005 in a study based on scanner data.[25] Compared to the consumer goods studied in these papers, the convergence trend of car prices lasted longer. We consider it likely that the implementation of additional EU regulation of the car market between 2002 and 2005 gave an additional incentive to car manufacturers to harmonize prices within the EU.

Table 1
Time trends in price dispersion.

	(1)	(2)	(3)	(4)
Sample period	2000–2011	2000–2011	1993–2003	2000–2008
Model definition	Narrow	Narrow	Broad	Narrow
Country sample	EU 27	EU 15	EU 15	EU 27
Time (years)	0.03	−0.03	−1.26***	0.01
	(0.09)	*(0.08)*	*(0.16)*	*(0.10)*
Time^2 (years^2)	0.03*	0.04**	−0.11***	0.08***
	(0.02)	*(0.02)*	*(0.01)*	*(0.02)*
EU 25	0.66***	0.27		0.56**
	(0.25)	*(0.23)*		*(0.26)*
EU 27	0.75***	0.33*		0.34
	(0.28)	*(0.18)*		*(0.27)*
Fin. crisis (2009)	3.58***	2.57***		
	(0.40)	*(0.37)*		
After crisis (2010+)	1.22**	1.48***		
	(0.56)	*(0.48)*		
Car price (log EUR)	−15.54***	−13.05***	−2.37	−11.93***
	(2.64)	*(2.18)*	*(1.73)*	*(2.84)*
Extremum	Min 2003	Min 2004	Max 1998	Min 2003
R^2 within	0.28	0.25	0.11	0.09
# observations	2779	2131	1732	2293

Dependent variable: 100× standard deviation of log pre-tax EUR prices across countries, Ξ_t^m. Fixed effects model Eq. (2). Time measured in years from November 2003. R^2 within is based on the mean-deviated regression. Constant and model fixed effects not reported. Bootstrap standard errors in parentheses. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% levels.

3.2. Effect of a common currency

The euro was introduced as bank money in a subset of EU countries in 1999. Did the adaption of a common currency reduce price dispersion among these countries? To understand the dynamics of price dispersion inside and outside of the euro area we define dispersion measures conditional on the currency area. Analogous to Eq. (1), we calculate dispersion separately for the set of countries with a common currency (EA), i.e. the euro area, and for a set of countries with different currencies (DC), which comprises all countries outside of the euro area and The Netherlands representing the euro. To distinguish these measures from overall dispersion Ξ_t^m we refer to them as $\Xi_t^{m,EA}$ and $\Xi_t^{m,DC}$, respectively. We use these in the regression

$$\Xi_t^{m,\sqsupset} = \alpha + \alpha_m + \beta_1 t + \beta_3 \mathbf{I}^{SC}(t) + \beta_4 \mathbf{I}^{DC}(\sqsupset, t) + \beta_5 \mathbf{I}^{DC}(\sqsupset, t)t + \beta_6 \mathbf{I}^{DC}(\sqsupset, t)\mathbf{I}^{SC}(t) + \beta_7 \mathbf{I}^{DC}(\sqsupset, t)\mathbf{I}^{EU25}(t) + \Lambda X_t^m + \varepsilon_t^{m,\sqsupset}, \quad (3)$$

where $\sqsupset \in \{EA, DC\}$. $\mathbf{I}^{SC}(t)$ is a binary indicator variable which takes the value one in the three sample periods since the financial crisis, i.e. in January 2009, January 2010, and January 2011. $\mathbf{I}^{DC}(\sqsupset, t)$ is a binary indicator variable which takes the value one for the set of countries $\sqsupset$ outside of the euro area in period t and $\varepsilon_t^{m,\sqsupset}$ is the idiosyncratic error for each set. Accordingly, β_1 captures any linear time trend, and β_3 an increase in price dispersion within the euro area since the financial crisis. Likewise, β_4 is the increment in the level, β_5 in the time trend, and β_6 in the financial crisis effect for countries without a common currency. Because all countries of the EU enlargement used their own national currency, we include the EU25 dummy with coefficient β_7 only for the group of countries without a common currency. An observation in specification Eq. (3) is identified by the model and the euro area indicators jointly. Because we include model fixed effects only, Table 2 does not show the common fixed-effects estimator, but the ordinary least squares estimator with model fixed effects. In Eq. (3), Hypothesis 2 shows up both in the levels and in the time trend. First, it implies higher dispersion outside the euro area, unconditionally, since the EU enlargement in 2004, and since the crisis, corresponding to a rejection of $H_0 : \beta_4 \leq 0$, $H_0 : \beta_4 + \beta_7 \leq 0$, and $H_0 : \beta_4 + \beta_6 + \beta_7 \leq 0$. Second, it suggests more price divergence outside the euro area, i.e. a rejection of $H_0 : \beta_5 \leq 0$.

The first column of Table 2 allows us to indeed reject all these subhypotheses, except for the period since the crisis. This column covers only years after the introduction of the euro, and therefore represents – apart from the accession of new countries to the EU and/or the euro area – more a cross-country than an intertemporal comparison. Comparing row 1 with row 2 reveals that in late 2003 the common currency cut price dispersion by about one third to one half. Since the crisis, however, the price dispersion in the two country

[22] In this fixed effects specification, the coefficient on car prices reflects time variation in prices. The negative coefficient reveals that price changes are not mirrored by proportional increases in dispersion across countries, which resembles the pattern documented already by Goldberg and Verboven (2001) and Goldberg and Verboven (2005). Price increases are in-between a level shift and proportional scaling.

[23] Estimated coefficients (not reported) of a quartic time trend for the EU15 sample over the full period 1993–2011 reflect the pattern visible in Fig. 2. First, price dispersion increases up to a peak in 1996. Then, for eight years, prices converge. But starting in 2004 dispersion starts to increase again, until the end of the sample, where the quartic time trend reaches its second maximum. Because this pattern holds in the EU15 subsample, it cannot be attributed to additional countries entering the sample. Even after controlling for the financial crisis with a dummy for observations since the summer of 2008 (January 2009, January 2010, January 2011) the increase in dispersion from 2004 to 2009 prevails. Dvir and Strasser (2017) explore the heterogeneity of price changes underlying the jump in price dispersion during the financial crisis.

[24] The studies of the late 1980s and early 1990s (Ginsburgh and Vanhamme, 1989; Kirman and Schueller, 1990; Mertens, 1990; Mertens and Ginsburgh, 1985) arrive at mixed conclusions about price convergence in Europe before 1990. The price differences in the early 1990s were still very large (Verboven, 1996a).

[25] For French exporters, however, Mèjean and Schwellnus (2009) find considerable convergence of export prices across EU export destinations between 1995 and 2004. A possible explanation for this is that lower trade barriers attracted smaller firms with no means of implementing PTM to enter the export market.

Table 2
Price dispersion and common currency.

	(1)	(2)	(3)	(4)
Sample period	2000–2011	2000–2011	1993–2003	2004–2011
Model definition	Narrow	Narrow	Broad	Narrow
Country sample	EU 25	EU 15	EU 15	EU 25
Constant	5.10***	4.71***	5.59***	4.00***
	(0.09)	*(0.07)*	*(0.23)*	*(0.22)*
Outside euro area constant	6.36***	2.00***	7.16***	2.16***
	(0.43)	*(0.55)*	*(0.44)*	*(0.21)*
Outside euro area × EU25	−4.69***			
	(0.53)			
Time	0.14***	0.28***	−0.04	0.34***
	(0.05)	*(0.05)*	*(0.07)*	*(0.07)*
Outside euro area × Time	0.25***	−1.00***	0.59***	0.12
	(0.07)	*(0.16)*	*(0.08)*	*(0.08)*
Since crisis (2009+)	1.57***	0.86***		1.07***
	(0.23)	*(0.19)*		*(0.27)*
Outside euro area × Since crisis	−1.30***	9.54***		−0.76*
	(0.40)	*(1.64)*		*(0.43)*
Car price (log EUR)	−7.97***	−15.38***	−6.13***	−4.69**
	(1.60)	*(1.84)*	*(1.16)*	*(2.00)*
R^2 within	0.40	0.55	0.35	0.34
# observations	3723	2239	2069	2703

Dependent variable: 100× standard deviation of log pre-tax EUR prices across countries, Ξ_t^m. Ordinary least squares regression with model fixed effects (Eq. (3)). Time measured in years from November 2003. R^2 within is based on the mean-deviated regression. Model fixed effects not reported. The constant is calculated with the sum of model fixed effects constrained to zero and car prices centered at the respective full-sample mean. Robust standard errors in parentheses. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% levels.

groups is not significantly different from each other. It is significantly lower in the euro area, though, when restricting the sample either to EU15 countries (column 2) or to the years since the EU enlargement in 2004 (column 4).

Despite dispersion among countries without a common currency in late 2003 being much larger than dispersion within the euro area, the price dispersion among the latter is significant (row 1). Obviously, the structure of the new car market in the euro area differs considerably from the one of Internet retail trade in standardized goods, which Cavallo et al. (2014) find to be essentially arbitrage-free.[26] We consider this a warning not to generalize findings for the products studied in Cavallo et al. (2014) to products that are more customized or distributed offline. Their price behavior, as we show here for cars, can be very different.

The entire price convergence effect of a common currency appears to occur around the time of its adaption. Row 4 of Table 2 provides no evidence of declining price dispersion within the euro area, especially not after 2004. However, given the larger contemporaneous increase in price dispersion among countries with individual currencies (row 5), this is a rather good track record.

The estimated one-time accession effect to the euro area is smaller after 2004. This is not due to a change in the euro area, but because the large group of new EU members, which initially all belonged to the group of countries without a common currency, was more homogenous in itself than the few incumbent EU countries not participating in the euro. In effect, the 2004 EU enlargement reduced dispersion among this group of countries without a common currency (row 3).

The financial crisis clouds the euro area's record somewhat (rows 6 and 7). At its onset the dispersion within the euro area jumps up, whereas it barely changes within the group of countries without a common currency. Column (4) confirms these findings for the years since 2004. The three countries with a separate currency in all years within the EU 15 (Denmark, Sweden, UK) appear to have converged internally and towards The Netherlands (column 2). During the crisis, however, this group diverged. It is the 2004 accession countries that move closely together and thus dampen divergence in column 1.

Overall, the euro appears to permanently lower price dispersion among its members, as noted in Simonovska (2015). During the financial crisis, however, the common currency area was subject to an increase in price dispersion not seen among most countries with individual currencies.

3.3. Effect of market segment

The magnitude and time pattern of price dispersion raises the question about its causes. If cross-country price dispersion was a purely mechanical effect of market frictions, such as asynchronous price adjustment or shipping costs, then dispersion would be similar in all market segments. If, however, price dispersion was the result of active price discrimination by manufacturers, then the underlying pricing strategy might depend on the market segment.

In this subsection, we look for such systematic differences in dispersion between market segments. An EC classification assigns each car model m to one of the following seven segments $s(m)$: *mini cars*, *small cars*, *medium cars*, *large cars*, *executive cars*, *luxury cars*, and *multi-purpose and sports utility cars*. Based on these seven segments, we include segment-specific intercepts $\alpha_{s(m)}$ in a random effects regression specified as

$$\begin{aligned}\Xi_t^m =& \alpha + \alpha_{s(m)} + \beta_1 t + \beta_2 t^2 + \beta_{EU25}\mathbf{I}^{EU25}(t) + \beta_{FC}\mathbf{I}^{FC}(t) + \beta_{AC}\mathbf{I}^{AC}(t) \\ &+ \Lambda X_t^m + \Lambda_{FC}\mathbf{I}^{FC}(t)X_t^m + \Lambda_{AC}\mathbf{I}^{AC}(t)X_t^m + \nu^m + \varepsilon_t^m \end{aligned} \quad (4)$$

with random effect ν^m and idiosyncratic error ε_t^m. Model-specific variables are collected in the vector X_t^m with corresponding coefficient vector Λ. This set of variables includes engine power, fuel type, average brand centrality, average car price, and the standard deviation of value added tax (VAT). The averages and standard deviations are taken over the set of countries in which the model is available in period t. A comparison of multiple specifications (not reported in the table) reveals that the effect of the crisis years is amplified by engine power, which renders segment-specific time trends largely redundant. For this reason, we include instead interactions of the crisis dummies with engine power, with corresponding coefficients Λ_{FC} and Λ_{AC}. Our Hypothesis 3 states that product features affect price dispersion and, more generally, that market segments matter, i.e. that we reject $H_0 : \Lambda = 0$ and $H_0 : \alpha_{s(m)} = 0$, respectively.

This is indeed the case. The joint test rejects the composite null at the 1% level. The upper block of Table 3 sends an even clearer message. In all specifications price dispersion is strongly correlated with the market segment. The more upscale a segment is, the higher is the dispersion.[27] This holds monotonically for the entire lineup of

[26] Cavallo et al. (2014) find an average absolute log good-level real exchange rate of 0.043 within currency unions for goods priced 200 USD and above. This number is decreasing with the price of the good, suggesting even less dispersion for more expensive products. Our paper shows that this extrapolation does not extend to the car market. The corresponding absolute real exchange rate in our sample restricted to the euro area in the years overlapping with Cavallo et al. (2014) is more than 70% larger (0.074).

[27] The coefficients on time and on car price levels mirror the results for the fixed effects model in Table 1.

Table 3
Determinants of price dispersion.

		(1)	(2)	(3)	(4)
Sample period		1993–2011	2000–2011		
Model definition		Broad	Narrow		
Country sample		EU 15	EU 15	EU 15	EU 25
Segment	Mini	−4.23***	−4.53***	−4.50***	−4.10***
		(0.66)	*(0.60)*	*(0.59)*	*(0.69)*
	Small	−2.66***	−3.29***	−3.33***	−2.33***
		(0.66)	*(0.52)*	*(0.53)*	*(0.62)*
	Medium	−0.79*	−0.89**	−0.95**	−1.01**
		(0.43)	*(0.39)*	*(0.40)*	*(0.46)*
	Large	0.65*	0.86***	0.82***	0.39
		(0.37)	*(0.31)*	*(0.31)*	*(0.36)*
	Executive	1.08**	1.22***	1.22***	1.47***
		(0.45)	*(0.40)*	*(0.40)*	*(0.43)*
	Luxury	1.41*	−0.09	−0.19	0.87
		(0.72)	*(0.41)*	*(0.40)*	*(0.55)*
Engine power (kW)			0.04***	0.03***	0.03***
			(0.01)	*(0.01)*	*(0.01)*
Fuel type (1 = diesel)			−0.69***	−0.81***	−0.18
			(0.23)	*(0.24)*	*(0.30)*
Brand centrality			3.25***	3.15***	2.35**
			(1.04)	*(1.01)*	*(1.21)*
Car price (log EUR)		−4.79***	−7.16***	−7.00***	−7.05***
		(0.54)	*(0.69)*	*(0.72)*	*(0.79)*
Dispersion of VAT		2.56***	0.95***	0.99***	0.73***
		(0.25)	*(0.21)*	*(0.21)*	*(0.26)*
Fin. crisis (2009)		3.45***	2.51***	−0.47	0.38
		(0.31)	*(0.34)*	*(0.77)*	*(0.83)*
Fin. crisis × Engine power				0.03***	0.03***
				(0.01)	*(0.01)*
After crisis (2010+)		2.64***	1.16***	−0.84	−1.99**
		(0.36)	*(0.44)*	*(0.59)*	*(0.87)*
After crisis × Engine power				0.02***	0.03***
				(0.01)	*(0.01)*
Time (years)		−0.02	−0.06	−0.05	−0.03
		(0.03)	*(0.05)*	*(0.05)*	*(0.06)*
Time^2 (years^2)		0.02***	0.05***	0.05***	0.04***
		(0.004)	*(0.01)*	*(0.01)*	*(0.01)*
EU 25					0.83***
					(0.23)
R^2 within		0.25	0.26	0.29	0.31
R^2 overall		0.41	0.45	0.46	0.28
# observations		3053	2078	2078	2713

Dependent variable: 100×standard deviation of log pre-tax EUR prices, Ξ_t^i, across countries. Constant not reported. Random effects GLS estimation of Eq. (4). Time measured in years from November 2003. Bootstrap standard errors in parentheses. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% levels.

mainstream segments, from mini cars to executive cars.[28] Whereas the obstacles to trading cars cross-border continuously declined, a comparison of columns (1) and (3) shows that nothing changed in the lineup of price dispersion with market segments. Furthermore, a look at columns (3) and (4) confirms that this pricing pattern has been inherited by the new EU member states as well.

The significant coefficients on engine power and fuel type reveal an additional dimension of price differentiation. Prices of powerful cars are more dispersed, prices of diesel cars less. These car features might distinguish customer segments differing in their price elasticity.[29] Columns (3) and (4) show for the EU 15 and the EU 25, respectively, that during the financial crisis the effect of engine power on dispersion became particularly pronounced. With the crisis price dispersion increased overall, but the increase was strongest for high-power cars. In fact, examining the crisis dummy and its interaction with engine power jointly, we see that for the cars with the weakest engines in the sample (about 40 kW), the impact of the financial crisis was about half of the average effect reported in columns (1) and (2), and insignificant since the year 2010. For cars with the strongest engines in the sample (more than 250 kW), however, price dispersion increased by more than twice the average

[28] Over the full sample period under the broad model definition in column (1) this even applies to luxury cars, which are insignificant in other specifications due to the relatively few observations in this segment. One might suspect that the insignificant coefficient on luxury cars in the other specifications is due to a particularly mobile customer base in the luxury segment. Degryse and Verboven (2000) observe a somewhat smaller variation in percentage (but not in absolute) terms in the luxury segment as well.

[29] For example, the choice of diesel over petrol might have rather rational motivations, such as cost and tax considerations. These rational buyers might be more inclined to compare prices internationally, rendering price differentiation across countries for diesel cars less attractive. The choice of a car with a high engine power might instead be driven more by impulse and lifestyle considerations than by need. These buyers might be less inclined to compare prices internationally before a purchase, which in turn makes international price differentiation for these cars feasible.

listed in columns (1) and (2), both in the crisis year 2009 and thereafter.

Centrally positioned brands (such as Toyota) tend to differentiate prices more across countries, whereas brands in niche markets (such as Mini) do not set widely different prices across Europe. Central brands are more substitutable with other brands, so they tend to face stronger competition. They might respond with an obfuscated description of features (Spiegler, 2006), which complicates cross-country price comparisons, and thus permits sustaining larger cross-country price differences.

Taking all these systematic differences between market segments into account suggests that manufacturer pricing does not merely follow relative macroeconomic conditions, but reflects active price differentiation between market segments. The source of price dispersion today is therefore in the realm of industrial organization. It is unlikely to be found in trade barriers and regulation, which apply to all market segments in the same way.

4. Determinants of country-specific car pricing

So far, we have looked a conditional moments, that is, on mean and standard deviations across countries conditional on model and time. Now we turn to the prices themselves, and study in particular their relationship to car features.

We first introduce our empirical approach and identify systematic determinants of car prices. We then document the heterogeneity of consumer preferences in the European car market reflected in these prices, and explain how country properties affect pricing. We close by describing how marketing can exploit preference differences within Europe, despite a prima facie integrated car market.

4.1. Empirical approach

Which factors determine the price of a car model in Europe? To answer this question, we study if and how the coefficients in a hedonic regression vary with country properties. Besides carving out differences in the pricing of car properties across countries, we want to examine how differences in the marketing across countries can affect the price.

Our data set provides an unique opportunity to do this, because it provides information on the pricing of AC in one of two ways. For some country-model pairs, AC is priced as part of the standard option bundle. For others, it has to be actively selected for an extra charge. This is captured by the indicator variable $\mathbf{I}_o^{opt}(m,c,t)$, which is one if the option o is included as standard in model m in country c in period t, i.e. whenever option o is included in the car's standard list price.

The price p_t^{mc} includes the same set of options in all countries. Although the models we compare are identical in terms of what the customer gets, they differ in terms of the menu of options offered to the buyer. Augmenting the regression with an indicator variable that reflects the offered option bundle allows us to measure the effect of including an option as standard – separately from the actual price of this option. It measures an effect that is solely based on an otherwise unobserved change in the presentation or positioning of the car within the market in question, potentially combined with a change in the menu of alternative offers.

Our starting point is the fixed effects regression

$$p_t^{mc} = \alpha+\alpha_{mc}+\alpha_t+\Lambda_1 X_t^m+\Lambda_2 X_t^{mc}+\Gamma Y_t^c+\sum_{o=1}^{3}\mu_o \mathbf{I}_o^{opt}(m,c,t)+\varepsilon_t^{mc}, \quad (5)$$

where we account for cross-sectional heteroskedasticity and within-panel serial correlation by clustering the idiosyncratic zero-mean error ε_t^{mc} at the model-country level. X_t^m is a vector of model-specific variables with corresponding coefficient vector Λ_1. These comprise mechanical properties that vary over time: emissions (HC, NO_x, particles) and measured fuel consumption.[30] The vector X_t^{mc} contains country-model-specific variables (distance to plant, registration tax, warranty) with corresponding coefficient vector Λ_2. The vector Y_t^c consists of country-specific variables with corresponding coefficient vector Γ. These include population, GDP per capita, euro area membership, and the rate of VAT.

Because our main interest rests on the interaction of country and model properties, we use for the main analysis the random effects specification

$$p_t^{mc} = \alpha+\alpha_c+\alpha_t+\alpha_m+\Lambda_1 X_t^m+\Lambda_2 X_t^{mc} + \Gamma_1 Y_t^c+\Gamma_2 Y^{mc}+\sum_{o=1}^{3}\mu_o \mathbf{I}_o^{opt}(m,c,t)+\lambda \mathbf{I}^{home}(m,c)+\nu^{mc}+\varepsilon_t^{mc}, \quad (6)$$

where ν^{mc} are the model-country random effects and the idiosyncratic errors ε_t^{mc} are again clustered at the model-country level. To control for differences of models across countries in the random effects specification, we augment the set of regressors by Y^{mc}, which are country-model-specific and time-invariant variables (brand centrality) with coefficient vector is Γ_2. The indicator variable $\mathbf{I}^{home}(m,c)$ is one if the brand of model m is associated with country c.

Table 4 presents the results, all under the narrow model definition for the years 2000 to 2011. In the fixed effects specification Eq. (5) shown in the first column, the inclusion of AC as standard comes with a significant surcharge, reflecting the cars' higher positioning in the market once AC is included.

As one would expect, cars subject to a high total registration tax are priced more modestly pre-tax, reflecting that manufacturers with market power absorb some of the tax in their price margin to reduce the substitution effect. Interestingly, despite controlling for the model-specific registration tax, time-variation in VAT itself remains significant. Pre-tax car prices start decreasing with VAT only at tax rates beyond the threshold of 22%. The increase of pre-tax prices at small VAT rates becomes plausible, if these VAT increases are seen as an opportunity to mask pre-tax price increases, dominated at higher VAT rates by the motive of keeping after-tax price changes small. Car prices increase significantly in distance to plant, albeit with an elasticity of only 0.01. By construction, this result rests on within identification, i.e. on changes in assembly locations of a given model.

Column (2) of the same table presents the analogous random effects specification Eq. (6). Neither the sign and significance of individual coefficients nor the overall explanatory power are greatly affected by the switch to random effects. As conjectured in Section 3.3, more central brands appear to have less market power. In fact, the price of a given car model is cheaper in those countries in which the brand is on average more central. The results are robust to the inclusion of country interaction terms in column (3) and to restricting the sample to the EU15 countries as in column (4).[31]

[30] The time variation stems from the redesign of engines of a given size and power, which changes their efficiency. CO_2 emissions are collinear with fuel consumption and thus omitted. For brand and segment effects please refer to the Online Appendix. The car options ABS and "airbag" do not vary sufficiently across countries to allow for interaction terms.

[31] Cars with a high in-city fuel consumption, an obvious follow-up cost for the consumer, are cheaper. For the majority of consumers in Europe, most trips cover short distances, and therefore in-city is for them the relevant consumption metric. For a given model, and therefore a given engine power, emissions affect prices. High NO_x emissions lower the price, for petrol and even more for diesel cars. HC have no effect on the price of diesel cars, but appear to proxy for some desirable property of petrol cars. Car prices increase in countries which grow in population or become richer.

Table 4
Price regression.

	(1) FE, EU 27	(2) RE, EU 27	(3) RE, EU 27	(4) RE, EU 15
Distance to plant (ln km)	1.03***	−0.01	0.16*	−0.18
	(0.34)	*(0.11)*	*(0.10)*	*(0.11)*
Brand centrality		−5.78***	−7.85***	−5.66***
		(1.08)	*(1.04)*	*(1.65)*
Home brand (1=domestic)		−0.68	Interacted	−0.90**
		(0.42)	with country	*(0.40)*
AC (1=standard)	1.32***	0.86***	Interacted	0.77***
	(0.30)	*(0.24)*	with country	*(0.25)*
NO_x (ratio to seg. median)	−0.32***	−0.31***	−0.25***	−0.28***
	(0.10)	*(0.10)*	*(0.08)*	*(0.10)*
NO_x if diesel (ratio to seg. median)	−0.58	−0.56	−0.55	−0.72
	(0.50)	*(0.50)*	*(0.42)*	*(0.55)*
HC (ratio to seg. median)	1.28***	1.22***	1.43***	1.04***
	(0.31)	*(0.31)*	*(0.25)*	*(0.33)*
HC if diesel (ratio to seg. median)	−1.28***	−1.18***	−1.43***	−1.14***
	(0.32)	*(0.32)*	*(0.26)*	*(0.35)*
Fuel consumption (city, l/100 km)	−0.81***	−0.78***	Interacted	−0.79***
	(0.26)	*(0.26)*	with country	*(0.29)*
Fuel consumption (highway, l/100 km)	1.72***	1.58***	Interacted	2.04***
	(0.56)	*(0.57)*	with country	*(0.60)*
Fuel type (1=diesel)			Interacted	
			with country	
Registration tax (%)	−0.17***	−0.11***	Interacted	−0.09***
	(0.02)	*(0.01)*	with country	*(0.01)*
VAT (%)	10.81***	9.04***		17.56***
	(1.27)	*(0.98)*		*(1.54)*
VAT^2 ($\%^2$)	−0.24***	−0.20***		−0.44***
	(0.03)	*(0.02)*		*(0.04)*
Population (*ln*)	22.50***	40.07***		59.05***
	(6.23)	*(3.51)*		*(4.36)*
GDP p.c. (*ln* EUR @ PPP)	9.77***	9.34***		11.77***
	(2.00)	*(1.34)*		*(2.38)*
Country, Model, Time effects	Yes	Yes	Yes	Yes
Country × Time effects	No	No	Yes	No
R^2 within	0.21	0.21	0.43	0.25
R^2 overall	0.99	0.98	0.99	0.98
# observations	28,182	28,182	28,182	20,451

Dependent variable: Log points of pre-tax EUR prices, P_t^{mc}. Estimation Eq. (5) for FE, and Eq. (6) for RE. Narrow model definition, 2000–2011. Constant and fixed effects are not reported. Further controls which are not statistically significant: euro area, particle emissions, warranty, bundled ABS, bundled airbag. Standard errors clustered at the model-country level in parentheses. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% levels.

Overall, the distance from the nearest assembly location does not play a big role here, implying that the classic scapegoat "transportation cost" has little relevance for price determination. Nor are prices in the euro area *on average* systematically different from other European countries. Domestic brands, however, are on average somewhat cheaper — an effect that is very heterogenous across countries, as the results in the next section will reveal.

4.2. Heterogeneous market

In this section, we focus on the drivers of price heterogeneity and discuss the interaction terms not shown in column (3) of Table 4. We lift the common assumption that consumers value a car property (or, more generically, "quality" as in Goldberg and Verboven, 2001) equally much in all countries. Specifically, we expand the random effects specification Eq. (6) with country interaction terms. We interact elements of X_t^m (fuel consumption), X_t^{mc} (registration tax), the AC indicator $\mathbf{I}_{AC}^{opt}(m,c,t)$, the home brand indicator $\mathbf{I}^{home}(m,c)$ and fuel type (otherwise absorbed by the model fixed effect) with country indicators and add interactions of the country and time effects, α_{ct}. Hypothesis 4, the law of one price, postulates the absence of home (brand) bias ($\lambda_c = 0$), and of systematic variation in feature pricing across countries (i.e. $\Gamma_{2,c} = \Gamma_2$, $\Lambda_{1,c} = \Lambda_1$, $\Lambda_{2,c} = \Lambda_2$, $\mu_{0,c} = \mu_0$, $\alpha_c^{fueltype} = 0\ \forall c$).

This hypothesis is clearly rejected by the data. Zooming into the home brand coefficients in Table 5 uncovers large heterogeneity across countries even in the home brand effect. In the Czech Republic, France and Italy, domestic brands sell at a premium. In contrast, they sell at a discount in Germany, Sweden, and the UK. Because we control for the actual assembly location, this home country effect is a pure demand side effect.[32]

Car demand strongly responds to fuel taxation (Klier and Linn, 2010), mirrored in our data in the lower prices charged for cars with high in-city fuel consumption in almost all countries. The pricing of (in-city) fuel consumption is strictly country- or region-specific, and in particular varies systematically with fuel taxation. In most countries, a reduction of fuel consumption comes with a price increase, reflected in the negative coefficient on the vertical axis in Fig. 3. The size of this reduction depends on the opportunity cost of the saved fuel. Fig. 3 shows that in high tax countries with a petrol tax above

[32] The domestic market share of brands is very stable. For example, the market share of French car brands in France was very close to 60% during the years 2000–2011. In Germany, the market share of German car brands was close to 57% during 2000–2011.

Table 5
Home brand effect.

France	5.29***
	(0.44)
Czech Republic	4.34***
	(1.43)
Italy	4.02***
	(0.81)
Germany	−1.78***
	(0.50)
Sweden	−3.73***
	(0.75)
United Kingdom	−6.54***
	(1.48)

Coefficient λ_c from column (3) of Table 4. Brands are assigned to home countries as follows: Peugeot, Renault, and Citroen (France); Fiat and Alfa Romeo (Italy); Audi, BMW, Mercedes-Benz, Opel, and Volkswagen (Germany); Skoda (Czech Republic), Volvo and Saab (Sweden); MG Rover, Land Rover, and Mini (UK).

55 cents per liter car prices increase by more than one percent for each saved liter per 100 km. This example demonstrates that the country-specific coefficients we estimate can be reasonably interpreted as demand shifters: in a country with high petrol taxes, there will be more demand for fuel-efficient models, hence their price will rise, all else equal.

This heterogeneity of consumers continues in the pricing of diesel cars. The average price difference between diesel and petrol cars varies widely between countries. The surcharge for diesel engines between the country with the lowest (UK) and the highest (Denmark) surcharge differs by more than 14%. It is strongly negatively correlated with the tax rate on diesel fuel (correlation coefficient −0.49), but not with the difference between petrol and diesel tax. And even the response of the pre-tax price to the registration tax displays large differences between countries. Whereas manufacturers offset taxation spikes strongly in Eastern Europe, they barely do so in Cyprus, Luxembourg and Denmark. Assuming that the market power of manufacturers is similar in all countries, this points towards large differences in demand elasticity in Europe.

This section presented some examples of how differently certain car features are priced within Europe and identified some determinants of price differences between countries, including preferences, brand centrality, and taxation.[33] Manufacturers follow a strategy already observed by Mertens and Ginsburgh (1985), who note that price discrimination is much larger than product differentiation in a hedonic price regression, and that car manufacturers "use product lines to discriminate across EU countries" (Ginsburgh and Weber, 2002).

4.3. Bundling and marketing

We have shown so far that cars are priced to market and take differences in preferences across countries into account. The cars in our sample are, however, mechanically identical, so that cross-country arbitrage should render any such price discrimination unsustainable. This begs the question how such price differentials can persist in an integrated, competitive market like the EU.

The examples of region-specific pricing in the previous section are based on observable features. Region-specific pricing is not limited to physical car features, though. It extends to soft factors, for example a car's marketing. This is usually not observable to researchers. Our data set allows us to look into one aspect of this, the bundling of AC.

Identical cars, i.e. cars with the same features, can differ in price if the features are priced in different bundles. Consider, for example, the pricing of a car with AC. The AC can either be included as standard equipment or be selected by the consumer from a list of optional, separately priced extras. The price of a car with AC purchased as bundle might differ from the price of a car with AC purchased as a separately priced option. But whether AC is included as standard or offered as an option has no effect on the production process, because the production process accommodates AC installation in either case. In this example the physical car is unchanged, only its marketing varies.

In our sample, 81% of the models in Italy include AC as standard, whereas the respective figure in Denmark is only 62%. Likewise, 9% of models in the UK had no AC option available, but only 1% in Italy. The fourth row of Table 4 shows that on average cars with bundled AC are more expensive than the estimated price of the separate components.[34] They appear to be marketed to a less price-sensitive customer segment.

Indeed, the surcharge is not randomly applied throughout Europe. A bundling surcharge can only be justified by a higher market positioning of cars with standard AC than of cars without standard AC. AC bundle surcharges are most prominent in Hungary, Slovakia and the UK, as shown in Fig. 4. This figure highlights a fairly ad hoc approach to differentiation: differentiation based on the utility derived from an AC, which depends on the climate. We measure this in a first approximation by the average temperature in the respective country's capital in the hottest month of the year. The plot is based on the coefficients on the AC bundle in column (3) of Table 4. It uncovers two clusters of countries. The first cluster consists of the Mediterranean countries Greece, Italy, Portugal and Spain. Their climate renders an AC a necessity, and there is almost no price effect of AC bundling. The second cluster covers the rest of Europe, where a car without AC might be considered acceptable. Within this cluster, the bundle surcharge increases significantly with the summer temperature (Table 6). Moving from the north to the center of Europe a car with bundled AC appears to be targeted at less and less price-sensitive customers — a strategy which might fail in the North because of the limited usefulness of AC in that region. The implied alignment of the bundling surcharge with latitude might also reflect an attempt to minimize the stimulus for active arbitrage, i.e. avoiding customers noticing much lower prices in a neighboring country. Excluding (in the right column of Table 6) the small-sample countries suggests that within the hot-summer country group the AC surcharge does not increase any further with temperature. If anything, it declines. In the South it is a necessity, so these countries show effectively no price response. The bundling surcharge is therefore exploiting the "desire for AC".

This type of country-specific marketing uses country differences to generate a differentiation without relevance for consumer utility. Its primary aim is reducing the probability of price comparison as described by e.g. Piccione and Spiegler (2012). And such differentiation does not stop at the pricing of feature bundles: In the Online Appendix, we compare the price lists of the Audi A3 for Germany and France in late 2009. These brochures differ completely in their layout, the structure of their price tables, and the provided details on car features — despite advertising the same car in two neighboring countries. Furthermore, many engine-transmission combinations are

[33] There are of course more determinants than the few that we can discuss in this paper, as differences in the country-time interaction terms indicate.

[34] More than one quarter of observations in our sample do not include AC as a standard feature. For each model, we observe either the price of the AC bundle, or separately the price of the car and the price of the AC option. We never observe both at the same time. Our estimate of the bundle surcharge is based on time variation in AC bundling and on cross-country differences of the bundle.

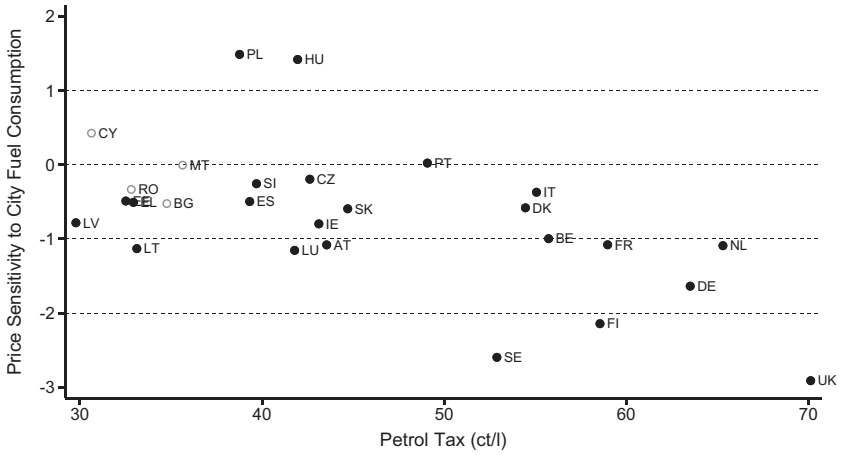

Fig. 3. Price sensitivity to fuel consumption by fuel tax. The graph plots the coefficients on city fuel consumption (l/100 km) against the tax on petrol fuel (ct/l). Based on specification (3) in Table 4. The estimates in light grey (Bulgaria, Cyprus, Malta, Romania) are based on a very small sample.

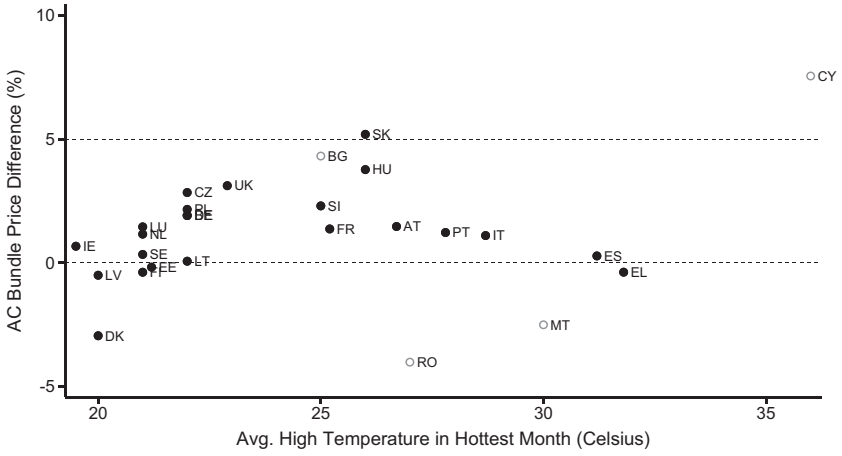

Fig. 4. Determinants of AC price difference. The graph plots the coefficients on bundled AC by country from specification (3) in Table 4 against the temperature by country. It shows the average discount (−) or surcharge (+) in percent when AC is included as standard option. The horizontal axis indicates the average (daily) high temperature in the country's capital in the hottest month measured in degrees Celsius. Estimates in light grey (Bulgaria, Cyprus, Malta, Romania) are based on a very small sample.

offered in only one of the two countries. Only three out of ten combinations for this model were available in both countries at that point in time (Online Appendix Table D.13). To further complicate a cross-border price comparison, the French price list does not report pre-tax prices, whereas the German one does. This apparently deliberate tailoring of the menu of versions to countries and the obfuscation of model features increase the cost of search for consumers shopping internationally. Such obfuscation is a rational behavior of oligopolistic firms, both in presence of rational (Ellison and Wolitzky, 2012) and boundedly rational consumers (Piccione and Spiegler, 2012). Under fairly general conditions it raises equilibrium prices.[35]

AC is of course only one example of a feature that can be exploited in country-specific marketing. Combined with other car features, missing in our data set, bundles can differentiate cars along multiple dimensions and thus can sustain larger price differentials. Overall, the evidence on AC bundling shows that pure marketing differences, and among them in particular country-specific bundling, can explain some of the international price differentials.

Table 6
AC bundle pricing and climate.

	EU 27	ex. BG, CY, MT, RO
Max. temperature × Cool country	0.58***	0.54***
	(0.18)	*(0.14)*
Max. temperature × Hot country	0.93***	−0.38
	(0.23)	*(0.39)*
Hot Country	−16.33*	22.56*
	(8.06)	*(12.18)*
Adj. R^2	0.50	0.39
# observations	27	23

Dependent variable: Coefficients on AC bundle from column (3) of Table 4. Constant not reported. Hot countries have an average high temperature in the hottest month of at least 27° Celsius.

4.4. Countries as marketing regions

The country-time effects in the price level regression (Eq. (6)) deserve further attention, because they might conceal additional systematic price differentiation across countries. Indeed, these average

[35] Spiegler (2006, p. 209) points out that "firms respond to greater competition with greater obfuscation, rather than with more competitive pricing." Whereas we cannot examine this with our data, it is indeed conceivable that the integration of the European car market spurred country-specific marketing.

price differences across countries are large and significant, even after controlling for registration tax. Large price differences are a common finding, for example in the study of LOP deviations between EU countries for retail goods and services during the years 1975–1990 by Crucini et al. (2005). This study also documents, however, that these price differences are centered around zero for each country pair after controlling for income and taxation differences. This is not the case within the product group "cars". Whereas in Crucini et al. (2005) overpriced and underpriced products average out, we add the worrying observation that the most expensive tradable good purchased by households, the car, is far from the median of the distribution.[36]

Obviously, passenger cars are a rather complex product. This provides many fulcra for price differentiation. 39% of the variation in the 27 country intercepts can be explained by only two variables:[37] The intercepts are decreasing in temperature, and increasing in the size of the economy, measured by real GDP. Allowing for lower prices in the East by including the longitude in the regression increases the R^2 to 44%. Income per capita captures less of the variation than any geographic or climatic factor alone.

Some car features, for example certain engine sizes, are offered in only a few countries, which is a direct way of segmenting the market. Engines could, in principle, be tailored to each individual market. Such cars would be different products, sustaining a price wedge between countries limited only by the elasticity of demand with respect to price and engine specifications. Tailoring a car directly to each country (marketing region) is more realistic today than ever before, as more and more car functions are handled by easy-to-replace software components. Changing the engine control software, for example, can radically change the engine's performance and emissions. This tailoring of software can be done without any loss of economies of scale in the production process. We would therefore expect an even more fragmented car market in the future.

The bottom line is that country effects are anything but random. Countries are marketing regions. The country effects vary systematically with observable specifics of the respective marketing regions, which for primarily historical reasons coincide with countries. The price difference between a pair of countries does not depend so much on their physical distance, but in how dissimilar they are from a marketing perspective. Accordingly, we suggest to include in discussions of border effects besides physical distance and cultural distance also metrics of market dissimilarity.

The price differentiation we observe is not limited to the car market. Already Haskel and Wolf (2001) suggest that "strategic pricing" might explain this price pattern. Burstein and Jaimovich (2012) show that consumer goods produced in the same location are subject to pricing-to-market. They detect differences in the wholesale price of the same product across regions, both in their data and based on interviews with retail managers. The car manufacturers in our sample do just the same.

[36] Our results for the European car market extend Crucini et al. (2005) to the big-ticket consumer goods segment. Despite the higher price of the products in our sample, and accordingly the larger incentive to collect information on cross-border arbitrage opportunities, we find significant price dispersion. This is even more striking when considering that our results are based on more recent data. During our sampling period the European market was more integrated than during the years 1975–1990 studied in Crucini et al. (2005). Cross-sectional price dispersion is negatively related to the tradability of the product, and positively related to share of non-traded content. Thus one might expect that in the car market the price dispersion would be smaller than in the retail market studied by Crucini et al. (2005), but this is not the case.

[37] Because the set of countries covered by our sample expands with time, it is an unbalanced sample. In this analysis, we first remove common time effects and then average across time.

5. Conclusion

Prices are widely dispersed across countries. Passenger cars are no exception, even in a market as integrated as the single market of the EU. Model-specific real exchange rates of cars vary significantly, and they vary differently for each model. In this paper, we show that these price differences are anything but random; they are systematic.

The magnitude of long-run country effects warrants a detailed investigation of its determinants. Shedding light on why international price *levels* differ permanently requires a data set that is sufficiently rich along three dimensions: country, time, and product. Our data set strikes the necessary balance. First, it covers multiple countries, which allows us to extract a relationship between country properties and the price level. Second, it covers multiple years, which enables us to rule out country-year idiosyncracies. Third, it covers a multitude of car models, which permits identifying car properties that support cross-country price differentiation. A novelty of our paper is studying the interplay of cross-country and cross-product differences.

Car features are priced very heterogeneously in Europe. These price differences ground on the heterogeneity of consumer preferences and regulation within the EU. We find evidence for price differentiation based on, e.g., regulatory (fuel tax), market (market power, market size) and climatic differences. But price differentiation does not stop at country differences that are exogenous to manufacturers. We find evidence that the marketing of identical products differs by country. Heterogenous brand positioning is reflected in large differences of the home brand effect across countries. Centrally positioned brands display lower price levels but wider price dispersion across countries. Even the market segment matters: Price dispersion grows monotonically with the market segment. Higher segments might have a less elastic demand, and we conjecture that the higher complexity of a car in upper segments is one reason for this. The higher complexity permits the marketing of a multiplicity of different car versions of a mechanically identical model. An extreme example of versioning might be price differentiation via bundling as described in this paper.

Overall, we find strong evidence of cross-country price differentiation actively managed by firms. The long-term violations of absolute LOP are founded on systematic pricing differences of individual product features.

In 2008, the European Commission (EC) revised the block exemption regulation, a central regulation governing the European car market, based on the notion that car prices within Europe have converged (European Commission, 2008). Using official EC data, we indeed find convergence of car prices until 2004. Since 2004, however, price convergence has come to a halt. Prices appear to have converged in anticipation of the regulatory push towards more market integration between 2002 and 2005, rather than adjusting to it thereafter. This suggests, again, a proactive price adjustment by manufacturers, well before international arbitrage might have kicked in.

We explain the lack of further price convergence in the European car market after 2004 with active product differentiation. At this point, market segmentation along country-specific versions and bundles appears to dominate market segmentation along administrative barriers. If the elimination of border effects was desired, EC competition policy would have go beyond regulating market access and removing administrative barriers. As already Adams and Yellen (1976) have suggested, it would have to ensure a "competitive supply of each decomposable good separately" (Adams and Yellen, 1976, p. 497f). This would require mandatory unbundling of non-essential car components (such as GPS, audio, AC, color, sunroof) and openly accessible interfaces, similar to the forced unbundling of Microsoft's Internet Explorer from its operating system, and offering the resulting menu of identical options in all countries. This would go much

further than the technical harmonization envisioned in the reform of the EC's vehicle type-approval system. It would, in effect, limit the scope for differential marketing.

Heterogenous marketing does not widen borders, but mirrors spatial diversity. Even integrated markets might contain regional differences in preferences. Often regions of common preferences coincide with countries. This renders countries natural marketing regions, even in an integrated market.

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Appendix A. Supplementary material

The main steps of assembling the data set, additional results, and background information to this article can be found online at https://doi.org/10.1016/j.jinteco.2018.02.008.

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