International Journal of Industrial Organization 52 (2017) 30–62

Contents lists available at ScienceDirect

International Journal of Industrial Organization

www.elsevier.com/locate/ijio

The impact of online sales on consumers and firms. Evidence from consumer electronics ☆

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ARTICLE INFO

Article history:
Received 29 October 2015
Revised 11 January 2017
Accepted 30 January 2017
Available online 10 February 2017

JEL classification:
L13
L63
L81

ABSTRACT

In this paper we estimate a differentiated products demand model to ask three questions regarding the introduction of e-commerce. First, we ask whether the online distribution channel has increased total sales, or only diverted sales from traditional channels. We find that there is a market expansion effect but also a considerable sales diversion. Second, we ask to which extent consumers and firms benefited from the introduction of the online sales channel. We find that consumers benefited proportionately more, and this is entirely due to the appearance of an additional distribution channel and not due

☆ We thank Marc Ivaldi, Lapo Filistrucchi, Ulrich Laitenberger, and participants at the 2015 ICT Conference at Telecom ParisTech, the Digital Economy Workshop in Turin, the Ninth IDEI-TSE-IAST Conference on The Economics of Intellectual Property, Software and the Internet in Toulouse, the 2016 FSR C&M scientific seminar at the Florence School of Regulation, and the 4th ERSA Workshop on the Economics of Competition and Industrial Organization in Cape Town. We are grateful to two anonymous referees and to the editor for valuable comments. All errors are our own. The views and opinions expressed in this paper are the authors' and do not necessarily reflect those of the European Commission.

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http://dx.doi.org/10.1016/j.ijindorg.2017.01.009

Keywords:
Online sales
Offline sales
Nested logit
BLP

to increased competition. Third, we ask how the online channel has affected European market integration. We find that price differences between the EU countries for identical products are large both in the traditional channel and online. Therefore, the introduction of e-commerce did not influence price levels and international price dispersion in the traditional channel.

1. Introduction

The rapid dissemination of information and communication technologies (ICT) and particularly the massive adoption of the Internet in the past decades have boosted the use of e-commerce as a distribution channel. The growing role of e-commerce resulted in unprecedented structural changes in many industries. These transformations are already generating a major reorganization in the way some products are manufactured, marketed and purchased, as exemplified by the travel and tourism or media industries. Today business to consumer e-commerce represents only a small segment of total retail in most developed countries. But it has been showing impressive growth rates even during the recent economic downturn, auguring a rapid expansion in the years to come.

The expected benefits of e-commerce are manifold. For consumers, it provides a useful and convenient platform to buy an enlarged set of products and services from more vendors at presumably better prices. Consumers can use search engines and price comparison sites, which significantly reduce search costs, to find and compare many different offers for the same product. In addition, electronic markets allow consumers to shop at anytime from anywhere, avoiding the problem of opening hours, distance to shop or availability of items. E-commerce also benefits firms by providing a channel to better promote and distribute their products. Electronic markets allow sellers to efficiently transfer relevant product information to potential buyers, which reduce their search costs. Moreover, firms can use digital technologies to increase product differentiation and soften price competition; to differentiate themselves by superior interfaces with respect to competitors and create switching costs. Furthermore, electronic-mediated transactions offer new ways to gauge customer preferences more truthfully and hence offer opportunities for targeted advertising, personalized marketing, product customization and price discrimination. Hence, numerous reasons suggest that e-commerce can positively affect social welfare, although the question of who benefits more remains a matter of empirical analysis (Bakos, 2001).

In May 2015, the European Commission recognized that e-commerce plays a critical role for the economic integration of the European markets and launched a sector inquiry into e-commerce with the aim to better understand the nature of the barriers that obstruct online trade between EU Member States.[1] This inquiry poses a number of policy questions, some of which we try to address in this paper. First, it is important to understand to which extent e-commerce is considered as a substitute to traditional sales channels. A related question concerns the impact of e-commerce on prices in traditional shops. A better understanding will provide insights as to whether total sales from the traditional brick-and-mortar channels are diverted to online, or whether there is a total market expansion effect, with implications for total employment and growth. Second, as we discussed above, e-commerce may bring benefits to both consumers and producers. But most research has focused on consumer benefits, and has not compared this with the benefits to producers and hence total welfare. A more complete understanding can also better guide policies towards e-commerce. Finally, as noted by the Commission, the European market appears to be segmented due to existing barriers in purchases of products online across borders. It is therefore important to assess whether the online channel affects European market integration in that prices in both online and traditional stores converge across countries.

In this paper, we analyze the above questions with a focus on three different consumer electronics products, namely digital cameras, portable media players and portable computers, which are sold through both the traditional and online channel in several European countries.[2] We estimate differentiated products demand models for each product category separately, and obtain the implied price elasticities and diversion ratios. Our estimates suggest that there is considerable substitution between the online and traditional channels, but at the same time, the introduction of the online channel also resulted in total market expansion. We subsequently use the demand estimates and the firms' first-order conditions under the assumption of Bertrand-Nash competition to simulate equilibrium prices in the absence of the online distribution channel. Our results can be summarized in three main findings.

First, we consider the impact of the online distribution channel on total sales. Although the introduction of the online channel has not led to lower prices in general, there is a considerable positive effect on total sales because a significant fraction of consumers considers the online channel to be more convenient. The online distribution channel thus swipes away some traditional sales, but it also activates consumers who find the online channel more appealing. On average, 36.5% of online sales of digital cameras, 28.5% of online sales of media players and, depending on the demand model, between 36.7% and 52.4% of online sales of portable computers would be lost without the online channel. At the prevailing level of online market shares, this implies that e-commerce increased total

[1] The Digital Single Market Strategy pursued by the European Commission should create a single EU-level market for products sold and bought online.

[2] The sales of consumer electronics in the EU offer an interesting case to study the effects of the introduction of the online distribution channel. Consumer electronics is the second largest industry in e-commerce -just behind apparel and footwear – representing around 15% of total online sales in the EU as of 2014 (Duch-Brown and Martens, 2015). The three different product categories used in this study represent about 30% of consumer electronics sales but with large differences across the Member States.

sales by, respectively, 2.4%, 5.0% and 7.0–10.0% for these three consumer electronics products. Hence, e-commerce partly complements traditional sales rather than replacing them entirely.

Second, we look at the relative gains from the online channel to consumers and producers. We find that the increase in consumer surplus due to the introduction of online sales is much larger than the increase in firms' profits: about twice as large for portable media players, 2.7 times larger for portable computers and 3.6 times larger for digital cameras. Since all brands available online are also present via the traditional channel, these consumer benefits are not due to increased price competition, but they mainly stem from the fact that a significant fraction of consumers has a positive valuation of the additional distribution channel.

Finally, we use our model to investigate whether the introduction of the online distribution channel reduces price dispersion in the selected European countries. We find that for products which are sold through both distribution channels there is still substantial market segmentation in the online channel between the EU countries. Furthermore, the introduction of the online channel did not influence the price levels and international price dispersion in the traditional channel. We conclude that the online channel has not led so far to an improvement in market integration, either directly or indirectly through the traditional channel.

Our paper contributes to the literature on the effects of e-commerce and electronic markets in general. There is a large body of literature analysing the effects of the Internet on prices and sales of different products based on reduced form models. However, to the best of our knowledge, there are no empirical studies which use a structural model of differentiated demand and supply to analyze how the diffusion of e-commerce has influenced the market equilibrium outcomes and welfare.

The early literature on e-commerce focused almost exclusively on studying how it impacts the level of prices and price dispersion. The initial empirical evidence showed that Internet markets did not exhibit smaller price dispersion than traditional markets (see Pan et al., 2003 for a review of the early literature). More recent empirical evidence, however, tends to point to lower price dispersion online than in the traditional channel. Still, substantial online price differences persist (see Duch-Brown and Martens, 2014). There is also an ongoing debate on the effects of e-commerce on market structure and welfare. Some empirical papers deal with competition effects (Goolsbee, 2001; Hackl et al., 2014); others focus on the analysis of the complementarity or substitutability of the online channel (Prince, 2007; Pozzi, 2013). Less abundant is the literature on the welfare effects of e-commerce, and this literature has typically focused on consumer surplus gains without comparing this with possible gains to producers (Brynjolfsson et al., 2003; Gentzkow, 2007; Ellison and Ellison, 2014). Also, there are limited contributions regarding international online price differences (Duch-Brown and Martens, 2014; Gorodnichenko and Talavera, 2014) and European integration (Duch-Brown and Martens, 2015).

The remainder of the paper is organized as follows. Section 2 discusses the data used in the estimation and shows some descriptive statistics. Section 3 introduces the econometric framework. Section 4 presents the estimation results and discusses the different questions we pointed out above. Finally, Section 5 concludes.

2. Data

We use data collected by the Gesellschaft für Konsumforschung (GfK), which contains price and sales information on three different types of consumer electronics products in several EU countries: digital cameras, portable media players and portable computers.[3] The data comes from a representative number of traditional and online retailers and was provided to us as total sales during one year, namely the period between April 2008 and March 2009.[4] In addition, for portable computers we have monthly panel data between January 2012 and March 2015. We estimate nested logit demand models for the digital cameras and portable media player categories using the cross-sectional data for 2008/2009. For portable computers we use the richer panel data to also estimate a nested logit model as well as a more flexible random coefficient logit model as in Berry et al., (1995; henceforth BLP).

The unit of observation is described by two identifiers: brand and model, which can be sold online or in the traditional channel. The first identifier corresponds to brands such as Canon or Nikon for digital cameras, Apple or Creative for portable media players, and Acer or Sony for portable computers. The second identifier corresponds to models, for instance in the case of portable computers Acer offers Aspire 8920 G or Travelmate 7720 G among other models. The additional dimension for the panel data on portable computers is the month.[5]

The data sets include 24,939 observations for digital cameras, 17,952 of portable media players and 931,509 for portable computers. The last number is much higher due to the time dimension. We cleaned the data, which involved aggregating sales for duplicated products and dropping observations with missing values for key variables. Moreover, since the vast majority of products has very small sales, for each category we dropped

[3] We also have information on other product categories: flat screen TVs, vacuum cleaners, irons, refrigerators, micro waves, washing machines, coffee makers, which except for flat screen TVs fall into the category of household appliances. Our intention in this paper was to focus on a group of similar products, which are purchased online more frequently.

[4] The data covers a comprehensive sample of all retailers and resellers in the following channels in different countries: system houses; office equipment retailers; computer shops; consumer electronics stores; mass merchandisers; pure internet players; mail orders/online catalogues. It does not include: duty free shops; gas stations; door to door; street markets; discounter stores and direct sales (to staff, hotels, schools, hospitals, etc.). Although we do not know the coverage by country, we know that the average market coverage in the EU is 87%. The sample is representative both for the smaller independent sellers as well as for the large chain-stores.

[5] GfK uses a “point of sales tracking” technology, which reports which products are sold, when, where and for how much, both at online and offline outlets on a monthly (or sometimes weekly) basis. The data was collected directly from the electronic point of sales systems from retailers and resellers. Sales were tracked at the individual stock keeping unit level and coded with a full set of features using a cohesive international methodology to allow for accurate comparison both within and across European markets. Any brand or model which was found to be sold in the covered countries is tracked, unless the brand is exclusive, in which case it is still audited but with a label which hides its exact origin. Sales volumes and turnover per item were gathered at the same time as the model specification information. The price of the item was calculated as turnover divided by units sold.

25% of products with the smallest sales, which represent only about 0.1% of sales of digital cameras in terms of units, 0.1% of sales of portable media players and 0.15% of sales of portable computers. Next, we dropped observations for unbranded products and a number of brands with small total sales. For each product category there is a large price variation and there are niche products which have very low or high prices. We further removed observations from the top and bottom 5% of the price distribution. The purpose of this trimming is to focus on the brands and products which are at the core of consumer demand and competition. The final data set consists of 15,909 observations for digital cameras and 6,435 observations for portable media players, where the observation is a product sold either online or offline in a particular European country. The number of different digital cameras sold in a country ranges between 116 and 812 with an average of 575, and the number of portable media players range between 165 and 463 with an average of 330, as shown in Table A.1. The overall number of unique products is 1322 for digital cameras and 1010 for portable media players.

For portable computers we further reduced the number of observations by aggregating sales for similar products. There are a large number of portable computers offered by the same manufacturer with slight differences in model names, which we aggregate up to the series name. To simplify the estimation of the BLP model, we limit the number of months to the second, fifth, eight and eleventh month of each year. The estimation results are not influenced by this choice. The final data set thus consists of 17,645 observations for portable computers, where the observation is a product (series name) sold online or offline in a particular country, during 13 different months. The number of different portable computers sold in a country in a particular month ranges between 43 and 117 with an average of 77, as shown in Table A.1. The overall number of unique portable computers is 264.

The final data sets used in the estimations represent, respectively, 81%, 73% and 82% of sales of digital cameras, portable media players and portable computers in the original data sets.[6] As shown in Table A.1, some of the products are sold both online and offline, while others are available only offline. With a few exceptions, which were dropped from the data, there are no products which are available only online. There may be however products sold online in one country and offline in another one, in which case they are classified as available both online and offline.

Table A.2 reports the descriptive statistics for the variables used in the estimation by product category. These variables are the determinants of consumers' indirect utility of a product, namely the price and various non-price characteristics. The other main variable used in the empirical model is sales, from which we construct, as explained in the next section, the market shares as a fraction of the whole market and as a fraction of specified market segments.

[6] Besides, the original data covers – according to the data provider – around 87% of the total EU market for the products considered. Hence, the coverage of the market is substantial.

3. Model

In this section we describe the model used to analyze the impact of the online distribution channel on demand, prices and consumer and producer surplus. We first describe the demand models and then explain the supply side of the market.

3.1. Demand

We consider the demand for three electronic products: digital cameras, portable media players and portable computers. Consumers can choose among a large variety of products that are differentiated in quality. Furthermore, they can either purchase these electronic products in a traditional brick-and-mortar shop (offline) or they can purchase the products through an online distribution channel. Finally, consumers can also decide not to buy an electronic product at all, in which case they can spend their money on other goods. To model the substitution patterns, we specify a two-level nested logit model which allows for market segmentation according to two discrete dimensions: quality, which can be either high or low, and the distribution channel, which is either offline or online. In addition, we use the panel data for portable computers to estimate a more flexible random coefficient logit model, which we specify at the bottom of this section.

The nested model can be described as follows. In a country c there are L_c potential consumers. Each consumer i in a country c can choose among J_c differentiated products, where a "product" refers to the combination of the electronic product and the distribution channel. Note that not every electronic product is necessarily sold through both the offline and the online channel. The choice set is divided into different groups or nests g, which refer to (at least) two quality categories and one remaining category for the outside good. Each group (except the outside good category) is further divided in subgroups h of g. These subgroups refer to the distribution channel within the quality category. For example, in the case of digital cameras, the groups are categories of pixels per inch, and the subgroups indicate the offline or online sales channel within each quality category.

A consumer i in country c has the following indirect utility for product j:

$$u_{ijc} = \underbrace{x_{jc}\beta - \alpha p_{jc} + \gamma_c on_{jc} + \xi_c + \xi_{jc}}_{\delta_{jc}} + \zeta_{igc} + (1-\sigma_2)\zeta_{ihgc} + (1-\sigma_1)(1-\sigma_2)\varepsilon_{ijc} \quad (1)$$

The first part, δ_{jc}, is the mean utility for product j in country c. For the outside good, $j=0$, we normalize the mean utility to zero, $\delta_{0c}=0$. For the other goods, the mean utility depends on a vector of observed product characteristics x_{jc} (such as a dummy variable for optical zoom in the case of digital cameras) including a set of brand dummy variables, on the price of product j in country c, p_{jc}, on an online sales dummy variable on_{jc} with country-specific valuations, and on unobserved quality terms: ξ_c and ξ_{jc}. The second part is the individual specific-deviation of utility around that mean, modeled as a weighted sum of three random variables: ζ_{igc} is a common valuation across products in the same group g, ζ_{ihgc} indicates a common valuation for all products in the same subgroup h of g, while ε_{ijc} is an individual-specific valuation for product j. The random variable ε_{ijc} is i.i.d. extreme value, and ζ_{ihgc} and ζ_{igc} have a distribution such that the appropriate sums are i.i.d. extreme value (see Cardell, 1997). The nesting parameters σ_1 and σ_2 (with $0 \leq \sigma_2 \leq \sigma_1 \leq 1$) measure the degree of preference correlation for products of the same subgroup and group. At one extreme, if $\sigma_1 = 1$, consumers perceive all products of the same subgroup as perfect substitutes. If in addition $\sigma_2 = 1$, consumers view all products of the same group as perfect substitutes. At the other extreme, if $\sigma_1 = \sigma_2 = 0$, there is no preference correlation within subgroups and groups. The model then simplifies to a simple logit model and consumers consider all products as symmetric substitutes. When only $\sigma_2 = 0$, the model simplifies to the one-level nested logit model. More generally, for $0 < \sigma_2 < \sigma_1 < 1$, products in the same quality category and distribution channel are the closest substitutes; products in a different distribution channel but the same quality category are weaker substitutes; and products of a different quality category are the weakest substitutes. The nesting parameters thus enable one to assess to what extent consumers view products in the same distribution channel and/or quality category as closer substitutes.

Assuming that consumers choose the product with the highest utility, one can obtain the well−known choice probabilities for every product j in every country c, including the probability of purchasing the outside good (see e.g. McFadden, 1978). At the aggregate level, these choice probabilities can be equated to the market shares (relative to the potential market L_c). We assume that the market size for each product represents 40% of a country's population.[7] As shown by Berry (1994) for the nested logit, and extended by Verboven (1996) for a two-level nested logit, the market share system can be inverted to obtain the following estimating equation:

$$\ln s_{jc}/s_{0c} = x_{jc}\beta - \alpha p_{jc} + \gamma_c on_{jc} + \sigma_1 \ln s_{j|hgc} + \sigma_2 \ln s_{h|gc} + \xi_c + \xi_{jc} \tag{2}$$

where $s_{jc} = q_{jc}/L_c$ is the market share of product j (sales volume divided by potential market of country c); s_{0c} is the market share of the outside good; $s_{j|hgc}$ is the market share of product j in the subgroup h of g; and $s_{h|gc}$ is the market share of the subgroup h within the group g.

The demand model is used to compute consumer surplus based on the formulas shown in the Appendix. We also compute the own- and cross-price elasticities of demand which have the following expressions. Let $D^1_{jk} = 1$ if $j = k$ (and 0 otherwise). Similarly, let $D^2_{jk} = 1$ if j and k are in same subgroup, $D^3_{jk} = 1$ if j and k are in same group. The elasticity of demand for product j with respect to the price of product k is then given by (omitting the country subscript c):

$$\frac{\partial s_j}{\partial p_k}\frac{p_k}{s_j} = -\alpha\left(\frac{1}{1-\sigma_1}D^1_{jk} - \left(\frac{1}{1-\sigma_1} - \frac{1}{1-\sigma_2}\right)s_{j|hg}D^2_{jk} - \frac{\sigma_2}{1-\sigma_2}s_{j|g}D^3_{jk} - s_j\right)p_j \tag{3}$$

[7] Alternative definitions of the market size of 20% and 80% of country population give similar results.

This elasticity expression illustrates how the preference correlations translate into aggregate substitution patterns. Products in the same subgroup have a higher cross-price elasticity than products in a different subgroup, especially if the gap between σ_1 and σ_2 is high. We can therefore assess to which extent the online distribution channel substitutes for the traditional brick-and-mortar channel, or to which extent it provides a new source of differentiation that raises total sales for consumer electronics rather than displaces existing sales.

3.1.1. BLP demand model specification for portable computers

As discussed in the data section, for portable computers we have monthly panel data, which allows us to estimate a random coefficient logit model, in addition to a nested logit model. In this way we can estimate more flexible substitution patterns (Petrin, 2002). In the specification with random coefficients, consumer i in country c and month t has the following indirect utility function for product j:

$$u_{ijct} = x_{jct}\beta_i - \alpha_i p_{jct} + \gamma_c on_{jct} + \xi_j + \xi_c + \xi_{jct} + \varepsilon_{ijct} \tag{4}$$

Here, x_{jct} is a row vector of observed product attributes, namely processor speed, the diagonal of the screen, the resolution of the screen or pixel density, the weight and the amount of RAM. Furthermore, p_{jct} is the price of product j in country c in month t, and on_{jct} is the online distribution dummy, with country-specific valuations. To model the unobservable product characteristics in a flexible way, we include a full set of product fixed effects ξ_j, and country fixed effects ξ_c. In addition, we include a common linear time trend and month fixed effects in x_{jct}. The latter allow us to capture seasonal variation in total sales within each year. The remaining unobservable characteristic is ε_{ijct}, the model's structural error term.

The random variable ε_{ijct} represents a consumer-product specific match value, that is i.i.d. and has a Type I extreme value distribution. The random coefficients β_i and α_i denote consumer-specific valuations of product characteristics and price. We specify β_i and α_i as:

$$\begin{pmatrix}\beta_i \\ \alpha_i\end{pmatrix} = \begin{pmatrix}\beta \\ \alpha\end{pmatrix} + \Sigma v_i,\ \ v_i \sim N(0,1) \tag{5}$$

where (β, α) refers to a vector of mean valuations of the product characteristics and price; v_i is a vector of independent random draws from a normal distribution, capturing unobserved individual heterogeneity; and Σ is a diagonal matrix of parameters, containing the standard deviations of the random coefficients (σ^k for the k-th characteristic and σ^p for price).

In the estimation, we include two random coefficients: (i) one for price to account for individual-specific price sensitivity; (ii) one for the online distribution dummy to account for individual-specific preferences for purchasing products online. We have also estimated specifications with up to four random coefficients, including a random coefficient on the constant and on the other observable laptop attributes. None of these additional random coefficients were statistically significant and did not alter our results in a substantial way. We therefore base our estimations and counterfactuals on the more parsimonious specification (4).

Assuming random utility maximization, one can again obtain the aggregate market shares, i.e. the logit choice probabilities aggregated over the individual-specific taste parameters. The resulting market share system can be inverted using the contraction mapping of BLP to obtain a numerical solution for the error term ξ_{jct}. For further details on the model estimation and identification, see BLP and Nevo (2001).

3.2. Supply

For both demand models, we add an oligopolistic supply side to infer marginal costs and current economic profits, and to perform policy counterfactuals to compute the impact of removing the online distribution channel. For simplicity, we remove the country subscript c and the time subscript t in this section. Let F_f be the set of products sold by firm f. The profits of firm f are given by:

$$\Pi_f(\mathbf{p}) = \sum_{k \in F_f} (p_k - c_k) s_k(\mathbf{p}) L \tag{6}$$

where c_k is the marginal cost of product k in country c, and $s_k(\mathbf{p})$ is product k's market share in country c as a function of the price vector in country c. Assume firms choose prices to maximize profits. The first-order conditions that define the Bertrand-Nash equilibrium are given by:

$$s_j(\mathbf{p}) + \sum_{k \in F_f} (p_k - c_k) \frac{\partial s_k(\mathbf{p})}{\partial p_j} = 0 \tag{7}$$

for products $j = \mathbf{1}, \ldots, J$. This can be written in vector notation as:

$$s(\mathbf{p}) + \left(\theta^F \odot \Delta(\mathbf{p})\right)(\mathbf{p} - \mathbf{c}) = 0 \tag{8}$$

where $\mathbf{p}$ and s($\mathbf{p}$) are $J \times 1$ price and market share vectors, $\Delta(\mathbf{p}) \equiv \partial \mathbf{q}(\mathbf{p}) / \partial \mathbf{p}$' is a $J \times J$ matrix of own- and cross-price derivatives, θ^F is a $J \times J$ block-diagonal matrix, with ones for products of the same firm and zeros otherwise, and $\odot$ denotes element-by-element multiplication of two matrices.

The system of first-order conditions (8) can be inverted at the current price and market shares to compute the current marginal costs $\mathbf{c}^0$:

$$\mathbf{c}^0 = \mathbf{p} + \left(\theta^F \odot \Delta\right)^{-1} \mathbf{s} \tag{9}$$

Furthermore, the system of first-order conditions (8) can be used to perform policy counterfactuals. In particular, we solve the system of equations (8) after removing the equations for products sold through the online distribution channel. The solution gives the counterfactual equilibrium price vector $\mathbf{p}^1$, which contains only prices for products sold through the traditional distribution channel. We can then, in turn, compute the counterfactual sales $\mathbf{s}^1 L$, profits given by (6), and consumer surplus given by the "log sum" or logit inclusive formula normalized by the price coefficient, as shown in the Appendix. In the calculation of consumer surplus we include the error term ξ_j as it captures unobserved quality of a product (e.g. Nevo, 2003).

4. Empirical results

In this section we discuss the empirical results of the demand model for the three categories of consumer electronics products: digital cameras, portable media players and portable computers. We use the parameter estimates to calculate the price elasticities and diversion ratios, and we comment on the degree of substitution between online and traditional sales channels. We then simulate the equilibrium prices and sales in the absence of the online distribution channel. The counterfactual simulations are used to assess the benefits from the introduction of the online distribution channel to producers and consumers. Finally, we use the results to evaluate the impact of the online distribution channel on price convergence in the European markets.

4.1. Demand and substitution

For digital cameras and portable media players we estimate the two-level nested logit demand model specified by Eq. (2), which segments products into groups and subgroups at the upper and lower level, respectively.

First, digital cameras at the upper level are grouped according to four pixel bands: (i) below 8.0 mega pixels; (ii) between 8.0 and 8.9 mega pixels; (iii) between 9.0 and 9.9 mega pixels; and (iv) above 9.9 mega pixels. Products within a group are allowed to be closer substitutes than products of different groups. The number of pixels is one of the main decision factors when buying a digital camera and in general a higher number of pixels correspond to a higher price. At the lower level, the four groups of digital cameras are subdivided into subgroups according to whether they are sold online or offline. This allows for a higher substitution of products sold in the same distribution channel.

Second, portable media players at the upper level are grouped according to storage capacity bands: (i) below 2GB; (ii) between 2GB and 3GB; (iii) between 3GB and 5GB; and (iv) above 5GB. Storage is one of the main decision factors when buying a media player and a higher storage is reflected in a higher price. At the lower level, the grouping is again according to whether products are sold online or offline.

Third, portable computers at the upper level are grouped according to RAM memory size, which is one of the main factors considered by consumers when buying a computer, where more expensive computers tend to have a higher RAM memory. Since we use monthly panel data between January 2012 and March 2015, and the range of products changes over time, we specify two computer segments based on RAM memory bands in the following way: (i) below mean RAM memory size in a given month; and (ii) above mean RAM memory size in a given month. We also considered other continuous variables to define the upper nest level, such as processor speed, and this gave similar results. At the lower level, we again allow for the possibility that the two groups are subdivided into two subgroups according to whether they are sold online or offline. Moreover, as discussed in the previous section, we use the data on portable computers to estimate a random coefficient logit model, with random coefficients for price and for the online channel dummy variable.

The demand equations for the three product categories are estimated using instrumental variables (IV) to account for the endogeneity of the price variable p_{jc} and the within group market shares in logarithm $\ln(s_{j|hgc})$ and $\ln(s_{h|gc})$, which may all be positively correlated with the error term. A positive unobserved shock to demand for a given product will result in a higher within group market share and at the same time in a higher price. As instruments we use the variables suggested by BLP: sums of the characteristics and counts of the number of products over all of the firm's products and over all of the competing firms' products. For the nested logit models, we add instruments suggested by Verboven (1996): the sums and counts of the products by groups. According to a Hausman specification test, the null hypothesis of the exogeneity of prices and within group market shares may be rejected at a significance level of 1%.

The estimation results are reported in Table A.3. For digital cameras and portable media players we find a significant and negative price coefficient and significant and positive nesting coefficients σ_1 and σ_2. These satisfy the inequalities $1 > \sigma_1 > \sigma_2 > 0$, consistent with the restrictions for the model to comply with random utility maximization. Intuitively, this implies that products of the same quality category and distribution channel (same subgroup) are the closest substitutes; products of a different distribution channel but the same quality category (same group) are weaker substitutes, and products of a different quality category are the weakest substitutes. The difference in the substitution between subgroups is greater when the gap between σ_1 and σ_2 increases.[8]

For portable computers, we found that the two-level nested logit is not supported by the data (i.e. we estimate $\sigma_1 < \sigma_2$). This implies that according to the nested logit model, the type of distribution channel does not constitute a separate source of market segmentation.[9] We therefore estimate a constrained one-level nested logit model (with $\sigma_1 = \sigma_2$), which satisfies the necessary condition for consistency with random utility maximization, $1 > \sigma_1 > 0$. Hence, products of the same quality category are closer substitutes

[8] We also considered two alternative nesting structures. In the first alternative, the upper level is the online/offline distribution channel and the lower level is the quality category. This specification was rejected because the order condition $\sigma_1 > \sigma_2$ was not satisfied. Hence, we find that the quality category is a more dominant form of segmentation than the distribution channel, which is consistent with intuition. In the second alternative, the upper level is the quality category, and the lower level is the model, consisting of either the offline or online version. This specification was also rejected, implying that the distribution channel is a more dominant form of segmentation than the model.

[9] In a previous version of the paper, we estimated the model with older data for a single year (as the other two categories). We then found that $\sigma_1 > \sigma_2$, consistent with a two-level nested logit, but the difference was very small.

than products of a different quality category. We also find a significant and negative price coefficient. Regarding the BLP specification, both random coefficients are significant, which confirms that there is consumer heterogeneity with respect to the valuation of the price and the online distribution channel.

Apart from the price parameter and the nesting parameters (or random coefficients), the models include parameters representing the valuations of other product characteristics, brand and country dummy variables.[10] In addition, we use a linear time trend and month dummies to account for the seasonal and panel dimension of the portable computers data. The parameters of the product characteristics are usually significant and with the anticipated signs. For instance, as shown in the first column in Table A.3, the utility of a digital camera increases with a higher pixel resolution and when the camera has an optical zoom, allows for color photos, has a single-lens reflex and includes image stabilization technology. As shown in the second column, the utility of portable media players increases with a higher storage capacity, built-in photo viewer, digital rights manager, mpeg4, microphone and video playback features. Finally, the mean utility of a mobile personal computer increases with a higher processor speed, a greater size of the screen, a greater number of pixels per inch and a greater RAM memory size.

The parameters of the country and brand dummies are significant as well, as are most of the product dummies for portable computers. Hence, there are significant differences in the utility of particular brands, which may be due to brand and product perception, quality and other factors which are not controlled for by the included product characteristics. There are also differences in the valuation of the product categories across the EU countries. These differences may be due to income effects or other country-specific factors. For instance, there may be a higher utility from having portable computers in Germany than in Romania because of higher income but also because consumers in Germany may in general value computers more since access to high speed broadband Internet is more widespread.

Finally, the utility specifications include country-specific parameters for the online dummy variable. These parameters are highly significant and negative for all categories. This reflects the fact that the share of products sold online is much lower than offline during the considered time period. As shown in Table A.4, online sales in the selected EU countries represent on average only 6.7% for digital cameras and 17.6% for portable media players in 2008/2009, and 19.1% for portable computers in 2012. The estimated online parameters combine the costs and benefits of e-commerce. This may include the disutility from shopping online due to lack of customer support and the utility gain from saved travel costs. The negative parameters therefore indicate that for an average consumer the costs outweigh the benefits at this point in time. Forman et al. (2009) also find that there is disutility from purchasing products online and that offline transportation costs matter,

[10] For portable computers, since the number of unique products is smaller (264), we include in the estimation a full set of product dummies instead of brand dummies. As discussed in Section 2, we could sensibly aggregate model-level observations to the series name level.

which they identify from examining the impact of local retail entry on local online book sales.

Our online valuation parameters are significantly negative for all countries, but there are large differences across countries: this reflects the fact that e-commerce is at different stages of development across European countries. These differences may be due to differences in the households' access to broadband and computers across countries, or they may be due to differences in preferences or in the quality of online retailing (such as websites) or traditional retailing (store availability) across countries.[11]

Note that the negative average valuation for the online channel in the considered time period does not rule out that there is a positive consumer surplus effect from the introduction of online. This is because there is consumer heterogeneity in the valuation of online. Our estimates of the country-specific mean valuations of the online channel relative to the standard deviation imply that in the whole sample of countries, 14.8% of consumers have a positive valuation of online (under the normal distribution of the random coefficient). It would be interesting in future research to obtain more detailed data on observed heterogeneity, for instance from consumer surveys, to understand the sources of the unobserved heterogeneity in the valuation of e-commerce which we document in this paper.[12]

The demand estimates are used to compute own- and cross-price elasticities at the product level. The own-price elasticities at the product level are in general always greater than one in absolute terms. They are on average equal to −4.46 for digital cameras and −3.4 for portable media players for two-level nested logit estimation. The cross-price elasticities are the highest for products in the same subgroup, which indicates that there is strong substitutability between products which are in the same quality segment and channel. The average own-price elasticities at the country level differ by product category due to differences in the estimates of the parameters α, σ_1, σ_2, and the level of prices. The differences in the values of the own-price elasticities for the same product category across countries are due to a different range of products, which are available in particular countries and their price levels. For portable computers the estimated price elasticities are on average higher, equal to −10.4 for the nested logit model and −12 for the random coefficient logit model. Also, in this case the cross-price elasticities are higher for products in the same quality category.

[11] The sample of countries is different for each product category and therefore the estimates of online coefficients are not fully comparable. But, as shown in Table A.3, among countries which are represented in all three product categories, France, Germany and UK tend to have smaller negative coefficients than Italy and Spain. The last two countries have a bit lower GDP per capita and much lower broadband penetration. The share of e-commerce in total sales is also much lower in these two countries. But it is also much lower in Italy and Spain than in Poland and Slovakia, which both have lower GDP per capita and broadband penetration. This suggests that, while income and broadband infrastructure matter for online sales, there must be also idiosyncratic country-specific preferences for e-commerce, perhaps also stemming from a less well-developed traditional retail sector.

[12] See for example, Gómez-Herrera et al. (2014) who use consumer survey data in 27 EU countries to analyze the determinants of online cross-border trade.

We use the estimates of demand elasticities to compute marginal costs for profit-maximizing multi-product firms under the assumption of Nash-Bertrand equilibrium using the system of equations (9). Since the prices used in this calculation are the final retail prices, the estimates of marginal costs include both the costs of manufacturing and sales. The imputed marginal costs are used to calculate mark-ups, which on average for all the brands and models sold in the selected EU countries are 37% for digital cameras, 54% for portable media players, and 12% for portable computers in the nested logit model and 10% in the BLP model.

4.2. Impact of the online channel

4.2.1. Diversion ratios

We use the demand parameter estimates and the marginal costs (obtained from our system of first-order conditions) to assess the impact of the introduction of the online distribution channel on equilibrium prices and sales. More specifically, we simulate the equilibrium prices and sales in the situation in which the online sales channel is not available at all. We then compute diversion ratios from online to offline for each country and for all EU countries together: they measure the fraction of online sales that would go to offline if the online distribution channel is removed. In the Appendix we provide the expression for the diversion ratio, and its relation with the diversion ratio from small price increases.

Table A.4 shows the share of online in total sales in the considered EU countries, the diversion ratios from online to offline, the estimated loss in offline sales and the estimated total sales increase due to the introduction of the online distribution channel.

The total diversion ratios across all considered EU countries measure the fraction of online sales that would go to offline if the online distribution channel would be removed. For digital cameras, the diversion ratio is 63.5%: this means that 63.5% of online consumers would purchase a digital camera through a traditional channel if the online channel is no longer available, while 36.5% of the online shoppers would no longer purchase a camera (e.g. perhaps postpone a replacement purchase because of the reduced convenience). For portable media players the diversion ratio is 71.5%, implying that 28.5% of the online sales would be lost if the online channel is no longer available. For portable computers, the diversion ratio is 63.3% for nested logit model and 47.6% for BLP model, implying that 36.7% and 52.4% of the online sales would be lost in the respective demand models.

The online distribution channel thus reduces traditional sales from brick-and-mortar shops, but at the same time it creates a market expansion effect by activating new consumers. The percentage increase in total sales is equal to the share of online multiplied by one minus the diversion ratio. In the case of digital cameras, the online distribution channel reduced traditional sales by −4.3%, but it raised total sales by 2.4% (=6.7%×(1−0.635)). For portable media players the online channel reduced offline sales by −13.2%, but it raised total sales by 5.3%. For portable computers, the online channel reduced traditional sales by −13% according to the nested logit model and −10.1% according to the BLP model. At the same time total sales increased by 7.0% and 10.0%, respectively.

The above numbers refer to the total diversion ratios and total sales effects across all included European countries. There are however significant differences across countries, as shown in Table B.1 in the Appendix. In general, the loss in traditional sales is greater in countries with a higher current share of online sales. For example, for digital cameras the share of online sales is twice as high in the UK and Denmark as compared to the whole sample of European countries. On the other hand, the share of online sales is particularly low in Bulgaria and Greece. These differences may be due to differences in Internet coverage and in interest or possibility (websites) to purchase products online. Hence, comparatively more consumers in the UK and Denmark may be active online. This implies a stronger market expansion effect, namely 5.3% in both countries, as compared with only 2.4% for Europe as a whole. Similar cross-country differences apply to the other two consumer electronics categories.

4.2.2. Consumer surplus and profit

Another important question is who benefits more from the introduction of online sales: consumers or producers? This question is also relevant to policy makers when designing policies to promote e-commerce. To answer this question we compare consumer and producer surplus under the observed situation, where the online distribution channel is available, to a counterfactual situation, in which the online channel is removed.

Table A.5 shows the changes in total consumer and producer surplus (in absolute value) across all considered EU countries. For all three product categories, both consumer surplus and gross profits increase because of the introduction of the online distribution channel. It is interesting to compare the relative benefits to consumers and producers. For portable media players, the increase in consumer surplus is about twice as large as the increase in profits. For digital cameras, it is about 2.7 times larger and for portable computers it is even about 3.6 times larger. These ratios show that consumers benefit more than firms from the introduction of the online distribution channel. Firms have only limited benefits, because much of the online sales are mainly diversion from traditional sales. For the three product categories, consumers obtain on average between 67% and 78% of the gross total welfare gains induced by e-commerce. Given that firms also need to invest fixed cost resources to set up online distribution channels, consumers obtain an even larger share of the net total welfare gains. Finally, note that there are differences in gains in consumer and producer surplus across countries, as shown in Table B.2 in the Appendix.

Given that consumers reap a larger part of the benefits, it is of interest to consider the sources of consumer welfare gains in further detail. We used the random coefficients logit model to break-down the consumer welfare changes in two parts: a part due to heterogeneity in the valuation of the online channel, and a part related to other factors including the idiosyncratic logit error (in the spirit of Petrin, 2002).[13] According to Table A.5, the overall consumer welfare drop from removing the online channel is 467 million Euro. The consumer welfare drop would be only 23.4 million Euro if there would be no heterogeneity in the valuation of online. Hence, 443.6 million Euro or 95% of the consumer welfare drop is due to heterogeneity in the valuation of the online channel, and only 5% is due to other factors including the logit error. Intuitively, this follows from the fact that without consumer heterogeneity only a small fraction of consumers would purchase online (stemming from the logit error).

It is also useful to discuss the consumer benefits from the online channel in relation to the average price they pay. For digital cameras, consumer surplus increases by 66 Euro per unit of online sales, compared with an average price of 180 Euro. For portable media players and portable computers the consumer surplus increases are, respectively, 34 Euro and 124 Euro per unit of sales, compared with average prices of 88 Euro and 714 Euro. Hence, although the average consumer has a negative valuation for the online distribution channel as discussed above, the online distribution channel provides a moderate increase in total consumer surplus per unit sold, as compared with the average price to be paid.

In sum, the gains in consumer welfare from the online channel mainly come from consumer heterogeneity: despite the negative mean valuation for online a considerable fraction of 14.8% of consumers have a positive valuation for online. In principle, the consumer welfare gains from the introduction of new products could also come from reduced prices due to more competition. However, it turns out that this source of gain is not relevant in our setting. The price effects are very small, since almost all the products which are sold online are also present in the traditional distribution channel.

4.2.3. Price convergence

Finally, we analyze whether the introduction of the online distribution channel led to convergence of prices in the EU market. As discussed in the introduction, the purpose of this analysis is to comment on whether e-commerce contributes to the economic integration of the European markets in relation to the market inquiry launched by the European Commission. Since prices become more easily comparable with the presence of an online distribution channel, one may expect that prices become less dispersed, as compared with the traditional channel. Because of competition between online and traditional sales, prices in the traditional channel may also become more dispersed after

[13] To do this, we computed the consumer welfare change from removing the online channel when there would be no consumer heterogeneity in the valuation of online, i.e., when the standard deviation on the online dummy is set to zero (while other parameters remain the same), and we compare this with the consumer welfare change under consumer heterogeneity. Note that this approach requires computing two new price equilibria and the corresponding consumer welfare: an equilibrium after setting the standard deviation to zero and keeping the entire product set, and an equilibrium after both setting the standard deviation to zero and eliminating all online products.

the online distribution channel is introduced. To assess the impact of the online distribution channel on international price differences, for each product category we estimate three hedonic price regressions to construct quality-adjusted prices. The first two regressions consider the prices of products sold online and offline, respectively, as a function of product characteristics and country-specific dummy variables. The coefficients of the country-specific dummy variables are then used to construct the quality-adjusted price differences across the selected EU countries. The third regression is similar to the regression for offline products, but now based on the predicted offline prices when the online distribution channel is removed (instead of the actual offline prices). This third regression enables us to assess whether the removal of the online distribution channel would imply larger international price differences for products sold offline.

As shown earlier in Table A.1, all the products which are sold online are also available offline, but there are many products which are only sold offline. To compare identical products, the hedonic price regressions are estimated for products which are available both online and offline. The dependent variable in the first regression is the logarithm of online prices and in the second regression it is the logarithm of offline prices. In the third regression, the dependent variable is the logarithm of offline prices, which are predicted using our equilibrium model of demand and supply under the assumption that the online channel is not available. The set of explanatory variables is the same as in the demand estimation, including product characteristics and dummy variables for brands and countries. The regression for portable computers includes product dummy variables instead of brand dummy variables, as well as a time trend and monthly dummy variables. The estimation results of the three hedonic price regressions for each product category are reported in Table A.6.

In an integrated European market we should expect that price differences between identical products are small or non-existent. This does not seem to be the case for the selected consumer electronics products. We first consider digital cameras. The parameters of all product characteristics in the three regressions are significant with positive signs, except the image stabilization dummy variable. Most of the brand dummy variables are also significant. After controlling for product characteristics and brand dummies, significant coefficients on the country dummies indicate that on average there are differences in the quality-adjusted prices between countries, where the reference country is the UK. The estimated coefficients of the country dummies in the regressions for the observed online and offline prices (first and second regressions) are comparable. This means that international price differences are not smaller for products sold online than for products sold offline. Furthermore, the estimates in the third regression for the predicted offline prices after removing the online distribution channel are almost identical to the second regression. This means that the introduction of the online channel did not induce firms to reduce international price differences for their offline products. Fig. B.1 in the Appendix plots the estimated country effects for the three regressions, after taking exponents to transform the coefficients into a hedonic index. The values show price differences in percentage terms relative to the country with the lowest prices which is the UK.

The estimation results for portable media players lead to similar conclusions. The estimates of product characteristics and brand dummies tend to be significant. The coefficients on the country dummies are in general also significant, which indicates that prices differ significantly across countries. As in the case of digital cameras, these price differences apply both to products sold offline and online. Furthermore, also for this product category the introduction of the online distribution channel has almost no effect on international price differences. Fig. B.2 in the Appendix shows the estimates of country effects for the three regressions for portable media players. The values show price differences in percentage terms relative to the country with the lowest prices which is the UK. Finally, similar conclusions can be drawn for portable computers, even though in this case we use panel data for a different time period. Fig. B.3 in the Appendix shows the estimates of the country fixed effects for the three regressions for portable computers. The values also show price differences in percentage terms relative to the country with the lowest prices which is Italy for this product category.[14]

5. Conclusion

Many arguments support the idea that the existence of digital markets may provide benefits to both producers and consumers. The Internet offers much more information to the consumer and at a lower cost, hence making price comparisons easier. A better informed consumer is more likely to find a product that exactly matches her preferred characteristics. Since in principle the Internet has no borders, a larger market enhances competition as the number of suppliers bidding for a consumer's expenditure increases. At the same time, suppliers who successfully exploit this larger market can benefit from economies of scale to reduce production costs. Hence, in theory, the use of digital markets should reduce market prices and increase welfare for both consumers and producers. In practice, however, there are many sources of market segmentation which may effectively impede the realization of these potential benefits. Among these the most relevant are transport costs for the physical delivery of goods, regulatory barriers to cross-border trade and persistent language barriers to cross-border online shopping, which hamper the full geographical integration of online markets in the EU.

In this paper we estimate a differentiated products demand model to analyze some of the effects related to the introduction of e-commerce. We use a rich dataset on prices, quantities and characteristics of three different consumer electronics products: digital cameras, portable media players and portable computers in several European countries. In this setting, we ask three questions. First, we are interested in determining whether the introduction of e-commerce increases total sales or, on the contrary, only crowds out sales

[14] We have also looked into price dispersion within a selected country. We come to similar conclusions. At the country level, the dispersion of quality-adjusted prices is similar for products sold online and offline and it is not affected by the introduction of the online distribution channel.

from traditional channels. Second, we would like to know whether consumers or firms benefited most from online sales. Finally, we ask whether the adoption of e-commerce has had any effect on the European integration process.

Our estimation results for these three product categories indicate that offline sales decrease to some extent due to the appearance of the online channel; this is the business stealing effect. However, there is also a market expansion effect because selling products online allows retailers to expand their total sales. Moreover, our results indicate that consumers capture a much larger fraction of the surplus created by the online distribution channel than firms. For the three product categories which we study in the selected EU countries, consumers obtain on average between 67% and 78% of the total welfare gains induced by e-commerce, which is due to the benefits from increased product differentiation (rather than reduced prices). Our results hold for both the nested logit model and a more flexible BLP model, which we estimate for portable computers using monthly panel data.

Finally, our results also point out to persistent quality-adjusted international price differences for offline products even when e-commerce is introduced. This means that the adoption of e-commerce does not induce international price convergence of offline products. One reason could be that price dispersion in online prices is also high, although the pattern is different from offline.

If e-commerce expands the market, as our results show, then any barrier to e-commerce would have substantial negative effects in terms of revenue for producers and welfare for consumers. There is then a clear role for policy to design appropriate measures to help e-commerce thrive which should help to generate jobs and boost economic growth.

Appendix A

Tabel A1, Tabel A2, Tabel A3, Tabel A4, Tabel A5, Tabel A6.

Table A1.
Number of products.

	Number of unique products by category			Average per market
	Total	Offline only	Offline + online	
Digital cameras	1,322	707	615	575
Portable MPs	1,010	506	504	330
Portable PCs	264	24	240	77

The total number of unique products which are sold in selected EU countries by distribution channel. The average number of unique products sold in a country in year 2008/2009 for digital cameras and portable media players; and in a country in a month between years 2012 and 2015 for portable computers.

Table A2.
Summary statistics.

	Description	Obs.	Mean	Std.	Min	Max
Digital cameras						
Price	Price	15,914	194	100	70	574
Sales	Sales (in 000 units)	15,914	3.37	13.91	0.002	520
Online	Online sales dummy	15,914	0.31	0.46	0	1
Pixels	Pixels	15,909	8.63	2.16	4	15.1
Type	Color dummy	15,914	0.95	0.22	0	1
Single-lens	Single-lens reflex dummy	15,914	0.04	0.20	0	1
Stabilization	Image stabilization dummy	15,914	0.24	0.43	0	1
Optical	Optical zoom	15,914	0.40	0.49	0	1
Portable MPs						
Price	Price	6,435	72	46	20	233
Sales	Sales (in 000 units)	6,435	3.24	24.24	0.001	1,020
Online	Online sales dummy	6,435	0.32	0.47	0	1
Storage	Storage capacity (MB)	6,435	3,269	2,549	512	8,192
Mic	Microphone dummy	6,435	0.68	0.46	0	1
Photoviewer	Photo viewer dummy	6,435	0.56	0.50	0	1
drm	Digital rights manager dummy	6,435	0.41	0.49	0	1
mpeg4	MPEG4 format dummy	6,435	0.25	0.43	0	1
videoplaybk	Video playback dummy	6,435	0.49	0.50	0	1
colordisplay	Color display dummy	6,435	0.59	0.49	0	1
Portable PCs						
Price	Price	17,645	826	341	400	1,999
Sales	Sales (in 000 units)	17,645	1.16	3.28	0.001	52
Online	Online sales dummy	17,645	0.49	0.50	0	1
Proc speed	Speed of processor (GHz)	17,645	2.58	0.47	0.80	3.67
Diag	Diagonal screen size (in.)	17,645	428	44	203	530
ppi	Pixels per inch	17,645	104	21	74	217
Weight	Weight (kg)	17,645	2.12	0.68	0.56	4.68
Ram	RAM memory (MB)	17,645	6,937	3,401	1,024	16,384

Summary statistics for the sample used in estimation. GHz and MB, respectively, denote giga hertz and mega bytes.

Table A3.
Estimation results.

	Digital cameras		Portable MPs		Portable PCs			
	Nested logit		Nested logit		Nested logit		BLP	
	Est.	Std.	Est.	Std.	Est.	Std.	Est.	Std.
Price	-0.008^{***}	(0.001)	-0.010^{***}	(0.001)	-0.006^{***}	(0.000)	-0.012^{***}	(0.001)
Upper nest	0.650^{***}	(0.012)	0.785^{***}	(0.012)	0.529^{***}	(0.018)		
Lower nest	0.499^{***}	(0.043)	0.710^{***}	(0.027)				
Price std							0.004^{***}	(0.001)
Online std							3.365^{***}	(1.427)
Type	0.572^{***}	(0.037)						
Single-lens	1.765^{***}	(0.145)						
Stabilization	0.220^{***}	(0.021)						
Optical	0.513^{***}	(0.033)						
Pixels	0.155^{***}	(0.012)						
Storage			0.000^{***}	(0.000)				
Mic			0.064^{***}	(0.021)				
Photoviewer			0.154^{***}	(0.052)				
drm			0.086^{***}	(0.019)				
mpeg4			0.195^{***}	(0.029)				
Videoplaybk			0.203^{***}	(0.030)				
Colordisplay			-0.075	(0.049)				
Proc speed					0.928^{***}	(0.099)	1.155^{***}	(0.215)
Diag					0.004^{***}	(0.002)	0.015^{***}	(0.003)
ppi					0.013^{***}	(0.002)	0.020^{***}	(0.005)
Weight					0.093	(0.096)	-0.358^{*}	(0.184)
Ram					0.018^{**}	(0.007)	0.115^{***}	(0.014)
Country online dummies								
Austria	-1.075^{***}	(0.123)	-0.477^{***}	(0.072)				
Belgium	-1.204^{***}	(0.148)	-0.785^{***}	(0.116)	-0.965^{***}	(0.060)	-5.351^{**}	(2.227)
Bulgaria	-3.095^{***}	(0.400)						
Czech Republic	-1.015^{***}	(0.110)	-0.461^{***}	(0.073)				
Denmark	-0.651^{***}	(0.103)			-0.385^{***}	(0.048)	-2.833^{**}	(1.294)
Finland	-1.579^{***}	(0.224)						
France	-0.774^{***}	(0.109)	-0.375^{***}	(0.067)	-0.680^{***}	(0.054)	-4.304^{**}	(1.864)
Germany	-0.919^{***}	(0.117)	-0.403^{***}	(0.061)	-0.294^{***}	(0.044)	-2.749^{**}	(1.365)
UK	-1.036^{***}	(0.119)	-0.301^{***}	(0.073)	-0.189^{***}	(0.050)	-2.866^{*}	(1.589)
Greece	-3.021^{***}	(0.387)						
Hungary	-0.970^{***}	(0.123)	-0.905^{***}	(0.090)				
Ireland	-1.287^{***}	(0.159)						
Italy	-1.360^{***}	(0.153)	-0.609^{***}	(0.094)	-1.047^{***}	(0.071)	-5.984^{**}	(2.490)
Netherlands	-1.079^{***}	(0.131)	-0.354^{***}	(0.072)	-0.446^{***}	(0.048)	-3.230^{**}	(1.511)
Poland	-1.167^{***}	(0.126)	-0.607^{***}	(0.090)	-0.765^{***}	(0.055)	-4.581^{**}	(2.038)
Portugal	-1.267^{***}	(0.153)	-0.961^{***}	(0.136)				
Romania	-1.187^{***}	(0.156)	-0.657^{***}	(0.128)				
Slovakia	-1.212^{***}	(0.136)	-0.806^{***}	(0.097)	-0.106^{**}	(0.052)	-2.724	(1.671)
Slovenia	-0.923^{***}	(0.124)	-0.621^{***}	(0.103)				
Spain	-1.432^{***}	(0.164)	-0.677^{***}	(0.110)	-0.911^{***}	(0.065)	-5.576^{**}	(2.372)
Sweden	-0.821^{***}	(0.121)						
Country dummies	Yes		Yes		Yes		Yes	
Brand dummies	Yes		Yes		No		No	
Product dummies	No		No		Yes		Yes	
Month dummies	No		No		Yes		Yes	
Observations	15,909		6,435		17,645		17,645	
Wald stat.							58.2	

Standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A4.
Diversion ratios.

	Digital cameras (%)	Portable MPs (%)	Portable PCs (%)	Portable PCs (BLP) (%)
Online share	6.7	17.6	19.1	19.1
Total sales change (%)	2.4	5.0	7.0	10.0
Diversion ratio	63.5	71.5	63.3	47.6
Loss of offline	−4.3	−13.2	−13.0	−10.1

Online share: the share of online in total sales. Total sales change: change in total sales due to introduction of online channel. Diversion ratios: share of online sales which would go to offline if there was no online distribution channel. Loss of offline: percentage loss of offline sales due to the introduction of online.

Table A5.
Changes in consumer surplus and profits after removing online channel.

	Digital cameras	Portable MPs	Portable PCs	Portable PCs (BLP
Consumer surplus (M€)	−235	−124	−331	−467
Producer surplus (M€)	−66	−62	−121	−172
Share of CS (%)	78	67	73	73
Average price (€)	180	88	714	714
CS per unit of online sales (€)	66	34	88	124

The changes in consumer and producer surplus after removing online sales channel in million Euros. The changes in consumer surplus per unit of online sales after removing online sales channel in Euros.

Table A6.
Hedonic price regressions.

Cameras	Online	Offline	Pred. offline	Portable MPs	Online	Offline	Pred. offline	Portable PCs	Online	Offline	Pred. offline
Type	0.068***	0.088***	0.088***	MIC	−0.002	0.013	0.013	Proc speed	0.245***	0.280***	0.280***
	(0.022)	(0.022)	(0.022)		(0.019)	(0.019)	(0.019)		(0.040)	(0.037)	(0.037)
Single-lens	0.749***	0.712***	0.712***	Photoviewer	0.187***	0.208***	0.208***	Diag	0.002**	0.001*	0.001*
	(0.022)	(0.021)	(0.021)		(0.061)	(0.057)	(0.057)		(0.001)	(0.001)	(0.001)
Stabilization	−0.011	−0.007	−0.007	Drm	0.121***	0.145***	0.145***	Ppi	0.006***	0.004***	0.004***
	(0.013)	(0.013)	(0.013)		(0.017)	(0.017)	(0.017)		(0.002)	(0.001)	(0.001)
Optical	0.259***	0.262***	0.262***	Mpeg4	0.061***	0.097***	0.097***	Weight	−0.000	−0.000**	−0.000**
	(0.013)	(0.013)	(0.013)		(0.022)	(0.021)	(0.021)		(0.000)	(0.000)	(0.000)
Pixels	0.088***	0.088***	0.088***	Videoplaybk	0.132***	0.182***	0.182***	Ram	0.000	−0.000	−0.000
					(0.026)	(0.026)	(0.026)		(0.000)	(0.000)	(0.000)
				Colordisplay	0.072	0.068	0.068	Time trend	−0.000***	−0.000***	−0.000***
					(0.058)	(0.054)	(0.054)		(0.000)	(0.000)	(0.000)
				Storage	0.000***	0.000***	0.000***				
					(0.000)	(0.000)	(0.000)				
Austia	0.145***	0.144***	0.144***	Austria	0.074**	0.218***	0.217***				
	(0.030)	(0.029)	(0.029)		(0.034)	(0.033)	(0.033)				
Belgium	0.159***	0.199***	0.199***	Belgium	0.226***	0.232***	0.231***	Belgium	0.014	0.059***	0.059***
	(0.031)	(0.030)	(0.030)		(0.038)	(0.038)	(0.038)		(0.014)	(0.013)	(0.013)
Bulgaria	−0.108	−0.034	−0.035								
	(0.080)	(0.080)	(0.080)								
Czech Republic	0.154***	0.149***	0.149***	Czech Republic	0.176***	0.197***	0.196***				
	(0.029)	(0.029)	(0.029)		(0.034)	(0.034)	(0.034)				
Denmark	0.250***	0.226***	0.225***					Denmark	0.102***	0.142***	0.142***
	(0.030)	(0.030)	(0.030)						(0.013)	(0.012)	(0.012)
Finland	0.179***	0.167***	0.167***								
	(0.035)	(0.035)	(0.035)								
France	0.051*	0.085***	0.085***	France	0.178***	0.230***	0.229***	France	−0.075***	−0.037***	−0.037***
	(0.029)	(0.029)	(0.029)		(0.035)	(0.034)	(0.034)		(0.014)	(0.013)	(0.013)
Germany	0.098***	0.076***	0.076***	Germany	0.153***	0.183***	0.182***	Germany	0.010	0.011	0.011
	(0.029)	(0.029)	(0.029)		(0.033)	(0.032)	(0.032)		(0.013)	(0.012)	(0.012)
Greece	−0.109	0.008	0.007								
	(0.080)	(0.080)	(0.080)								
Hungary	0.121***	0.049	0.048	Hungary	0.214***	0.261***	0.260***				
	(0.030)	(0.030)	(0.030)		(0.036)	(0.036)	(0.036)				
Ireland	0.082**	0.129***	0.129***								
	(0.040)	(0.040)	(0.040)								
Italy	0.158***	0.184***	0.183***	Italy	0.114***	0.107***	0.106***	Italy	−0.113***	−0.089***	−0.090***
	(0.029)	(0.029)	(0.029)		(0.036)	(0.035)	(0.035)		(0.015)	(0.014)	(0.014)
Netherlands	0.116***	0.103***	0.103***	Netherlands	0.171***	0.158***	0.156***	Netherlands	0.002	0.031**	0.031**
	(0.029)	(0.029)	(0.029)		(0.034)	(0.034)	(0.034)		(0.013)	(0.012)	(0.012)

(*continued on next page*)

Table A6. (*continued*)

Cameras	Online	Offline	Pred. offline	Portable MPs	Online	Offline	Pred. offline	Portable PCs	Online	Offline	Pred. offline
Poland	0.062**	0.082***	0.082***	Poland	0.052	0.080**	0.078**	Poland	−0.097***	−0.066***	−0.066***
	(0.030)	(0.030)	(0.030)		(0.037)	(0.037)	(0.037)		(0.014)	(0.013)	(0.013)
Portugal	0.158***	0.167***	0.167***	Portugal	0.095**	0.067	0.066				
	(0.032)	(0.032)	(0.032)		(0.046)	(0.045)	(0.045)				
Romania	0.191***	0.110***	0.110***	Romania	0.243***	0.174***	0.173***				
	(0.034)	(0.033)	(0.033)		(0.046)	(0.045)	(0.045)				
Slovakia	0.220***	0.191***	0.191***	Slovakia	0.213***	0.217***	0.215***	Slovakia	−0.103***	−0.075***	−0.076***
	(0.030)	(0.030)	(0.030)		(0.036)	(0.036)	(0.036)		(0.014)	(0.013)	(0.013)
Slovenia	0.263***	0.211***	0.211***	Slovenia	0.183***	0.170***	0.169***				
	(0.030)	(0.030)	(0.030)		(0.042)	(0.041)	(0.041)				
Spain	0.033	0.122***	0.122***	Spain	0.117***	0.160***	0.158***	Spain	−0.098***	−0.080***	−0.080***
	(0.032)	(0.031)	(0.031)		(0.044)	(0.043)	(0.043)		(0.014)	(0.013)	(0.013)
Sweden	0.180***	0.174***	0.174***								
	(0.031)	(0.031)	(0.031)								
Constant	3.670***	3.663***	3.663***	Constant	3.822***	3.931***	3.933***	Constant	7.173***	7.626***	7.622***
	(0.050)	(0.050)	(0.050)		(0.040)	(0.038)	(0.038)		(0.761)	(0.709)	(0.709)
Brand dummies	Yes			Brand dummies	Yes			Brand dummies	Yes		
Product dummies	No			Product dummies	No			Product dummies	Yes		
Observations	4,877	4,877	4,877	Observations	1,831	1,831	1,831	Observations	1,927	1,927	1,927
R-squared	0.582	0.589	0.589	R-squared	0.777	0.777	0.777	R-squared	0.880	0.896	0.896

Hedonic price regressions for the set of products which are sold both online and offline: (i) offline prices; (ii) online prices; (iii) predicted offline prices in the absence of the online channel. Standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Appendix B

Table B1, Fig B.1, Fig B.2, Fig B.3, Table B2

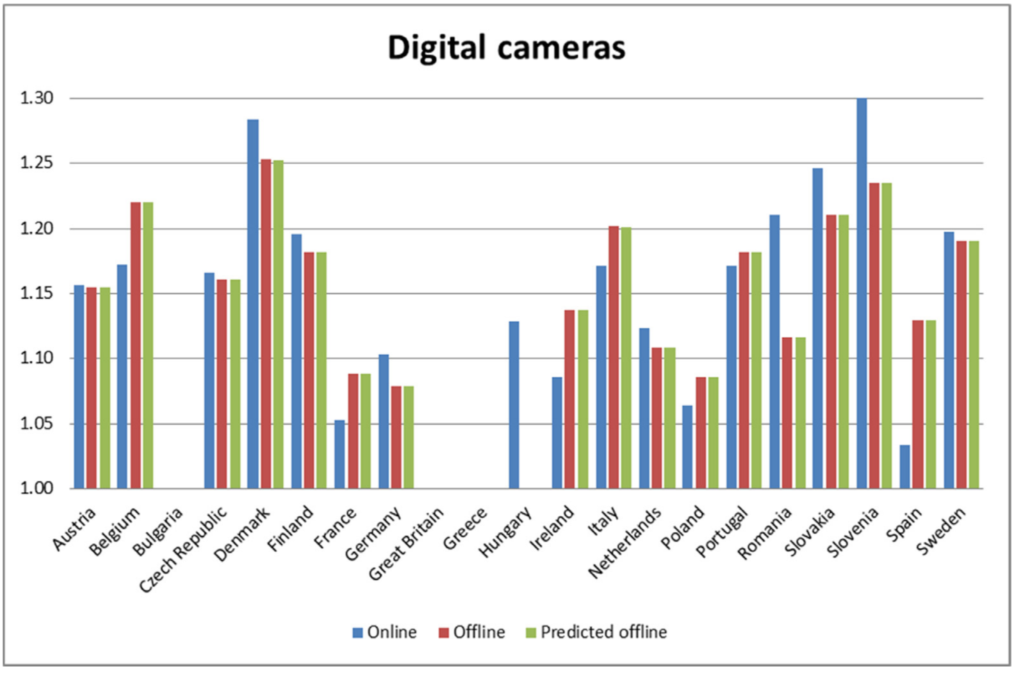

Fig. B1. Differences in average prices of digital cameras (in %). Differences in quality-adjusted prices across selected EU countries in 2008/2009 (in percentage relative to the UK) based on hedonic price regressions for digital cameras.

Table B1.
Diversion ratios.

	Digital cameras			Portable MPs			Portable PCs			Portable PCs (BLP)		
Country	Online share (%)	Total Sales change (%)	Diversion ratio (%)	Online share	Total sales change	Diversion ratio	Online share	Total sales change	Diversion ratio	Online share	Total Sales change	Diversion ratio
Austria	7.4	2.3	68.4	13.6%	3.8%	71.8%						
Belgium	3.6	1.3	64.0	2.7%	0.7%	73.4%	6.7%	2.4%	64.2%	6.7%	3.2%	52.8%
Bulgaria	0.0	0.0	58.4									
Czech Republic	9.2	3.7	60.0	14.9%	4.5%	69.7%						
Denmark	11.6	5.4	53.7				25.3%	7.5%	70.3%	25.3%	9.6%	62.2%
Finland	0.6	0.2	65.8									
France	9.4	3.3	64.6	15.2%	4.2%	72.3%	16.5%	6.0%	63.8%	16.5%	8.9%	45.8%
Germany	7.7	2.6	67.1	22.4%	6.3%	72.0%	28.8%	10.2%	64.5%	28.8%	14.2%	50.6%
Great Britain	12.7	5.3	58.6	27.9%	8.2%	70.6%	21.6%	8.4%	60.9%	21.6%	12.2%	43.7%
Greece	0.0	0.0	58.8									
Hungary	6.4	2.7	57.6	6.5%	2.0%	70.0%						
Ireland	6.1	2.5	58.9									
Italy	2.8	1.0	62.6	6.4%	1.8%	72.7%	5.3%	2.2%	58.7%	5.3%	3.2%	39.3%
Netherlands	5.5	1.7	68.9	14.2%	3.9%	72.7%	21.0%	7.6%	64.0%	21.0%	10.4%	50.4%
Poland	6.0	2.5	58.4	6.6%	1.9%	71.3%	12.9%	5.2%	59.8%	12.9%	7.8%	39.7%
Portugal	2.8	1.1	60.1	1.3%	0.4%	73.0%						
Romania	3.4	1.6	53.0	2.2%	0.6%	70.9%						
Slovakia	4.7	2.1	55.3	5.0%	1.4%	70.8%	28.1%	12.7%	54.8%	28.1%	19.9%	29.3%
Slovenia	7.2	3.0	58.4	6.1%	1.7%	71.6%						
Spain	2.2	0.8	63.2	7.3%	2.1%	71.5%	6.3%	2.6%	58.9%	6.3%	3.6%	42.5%
Sweden	7.7	2.5	67.7									
Total	6.7	2.4	63.5	17.6%	5.0%	71.5%	19.1%	7.0%	63.3%	19.1%	10.0%	47.6%

Online share: the share of online in total sales. Total sales change: change in total sales due to introduction of online channel. Diversion ratio: share of online sales which would go offline if there was no online distribution channel.

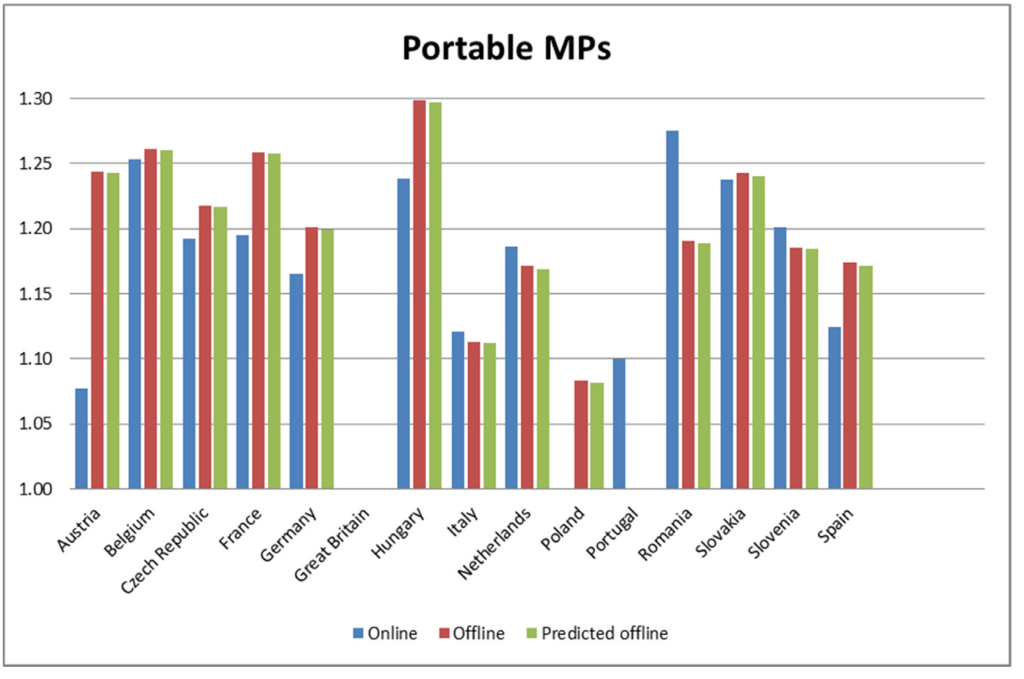

Fig. B2. Differences in average prices of portable media players (in %). Differences in quality-adjusted prices across selected EU countries in 2008/2009 (in percentage relative to the UK) based on hedonic price regressions for portable media players.

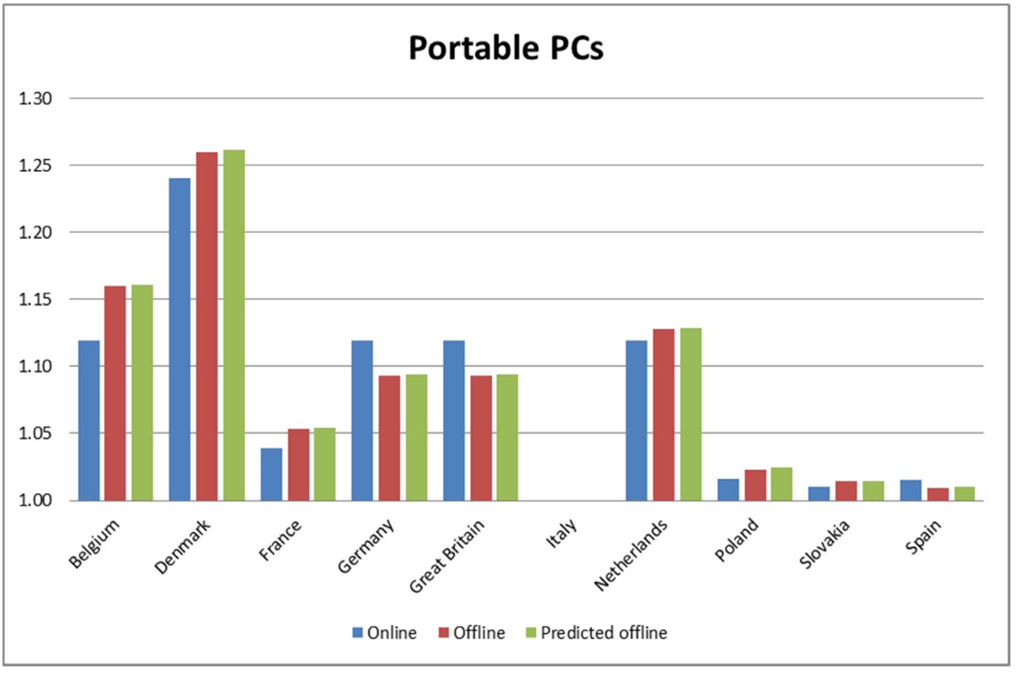

Fig. B3. Differences in average prices of portable computers (in %). Differences in quality-adjusted prices across selected EU countries in 2012 (in percentage relative to Italy) based on hedonic price regressions for portable computers.

Table B2.
Changes in consumer surplus and profits after removing the online channel.

	Digital cameras		Portable MPs		Portable PCs		Portable PCs (BLP)	
Country	CS	Profits	CS	Profits	CS	Profits	CS	Profits
Austria	−6,585	−1,639	−1,441	−179				
Belgium	−3,129	−885	−391	−130	−3,424	−1,190	−4,471	−1,563
Bulgaria	−7	−3						
Czech Republic	−5,980	−1,816	−649	−146				
Denmark	−1,952	−675			−12,236	−3,485	−15,415	−5,102
Finland	−280	−68						
France	−53,508	−13,773	−16,411	−5,181	−55,357	−20,138	−82,962	−30,840
Germany	−60,929	−16,108	−36,747	−18,564	−146,462	−51,019	−200,855	−72,135
Great Britain	−46,233	−14,874	−54,013	−31,895	−59,397	−23,062	−84,946	−31,924
Greece	−18	−10						
Hungary	−2,917	−908	−269	−58				
Ireland	−1,479	−469						
Italy	−11,446	−3,173	−4,999	−2,395	−7,575	−3,391	−11,141	−4,260
Netherlands	−9,738	−2,228	−3,962	−876	−19,151	−7,007	−26,243	−10,032
Poland	−11,676	−3,698	−1,221	−166	−16,100	−6,975	−24,042	−9,213
Portugal	−1,658	−511	−133	−45				
Romania	−1,265	−493	−40	−15				
Slovakia	−831	−270	−82	−20	−4,053	−1,859	−6,302	−2,531
Slovenia	−762	−268	−80	−7				
Spain	−7,213	−2,030	−3,176	−2,060	−7,621	−3,325	−10,735	−4,082
Sweden	−7,470	−2,017						
Total	−235,076	−65,915	−123,617	−61,737	−331,377	−121,451	−467,111	−171,681

The changes in consumer and producer surplus in thousand Euros after removing the online sales channel.

Appendix C

In this Appendix we provide expressions for the calculation of consumer surplus and the diversion ratios.

As mentioned in the text, consumer surplus is given by the well-known "log sum" formulas (see McFadden, 1978 or Anderson et al., 1992). For the two-level nested logit model, consumer surplus is (omitting the country subscript c):

$$CS = \frac{1}{\alpha}\ln\left(1 + \sum_{g=1}^{G}\exp(I_g)\right)$$

where

$$I_g \equiv (1-\sigma_2)\ln\sum_{h=1}^{H_g}\exp(I_{hg}/(1-\sigma_2))$$

$$I_{hg} \equiv (1-\sigma_1)\ln\sum_{h=1}^{J_{hg}}\exp(\delta_j/(1-\sigma_1))$$

and $g=1,...,G$ are the groups, and $h=1,...,H_g$ are the subgroups of group g, such that the total number of products is $\sum_{g=1}^{G}\sum_{h=1}^{H_g} J_{hg} = 1$.

For the random coefficient logit model, consumer surplus is the log sum formula of a logit, integrated over the idiosyncratic taste realizations:

$$CS = \int \frac{1}{\alpha}\ln\left(1 + \sum_{j=1}^{J}\exp(\delta_j + \mu_j(v))\right)dP_v(v)$$

where $\mu_j(v) = [x_j, -p_j]\sum v_i$ and v_i are standard normal variables for the idiosyncratic tastes for the product characteristics and price (following the notation in the text).

We compute consumer surplus both under the current observed price equilibrium $\mathbf{p}^0$ and under the counterfactual equilibrium $\mathbf{p}^1$ when all online products $j \in O$ are removed (where O denotes the set of online products). For example, for the random coefficients logit, the change in consumer surplus is:

$$\begin{aligned}CS^1(\mathbf{p}^1) - CS^0(\mathbf{p}^0) = &\int \frac{1}{\alpha}\ln\left(1 + \sum_{j=1, j\notin O}^{J}\exp(\delta_j(p_j^1) + \mu_j(p_j^1, v))\right)dP_v(v)\\ &- \int \frac{1}{\alpha}\ln\left(1 + \sum_{j=1}^{J}\exp(\delta_j(p_j^0) + \mu_j(p_j^0, v))\right)dP_v(v)\end{aligned}$$

and similar for the nested logit.

Diversion ratios are usually defined as the ratio of the cross-price over the own-demand derivatives resulting from small price changes. But one can also define them more generally as the result of other events, such the elimination of a product (or a very large price change). As discussed in the text, we defined the diversion ratio as the fraction of online sales that would go to the offline channel if the online distribution channel would be removed. Formally,

$$\text{D(online to offline if online removed)} = \frac{\sum_{j=1,j\notin O}^{J} q_j^1 - \sum_{j=1,j\notin O}^{J} q_j^0}{\sum_{j=1,j\in O}^{J} q_j^0}$$

where $q_j^0 = s_j^0 L$ and $q_j^1 = s_j^1 L$ are the current and counterfactual equilibrium sales quantities of product j.

Note that this is a special case of the more general expression of the diversion ratio, where not necessarily the entire online distribution channel would be removed:

$$\text{D(online to offline if online reduced)} = \frac{\sum_{j=1,j\notin O}^{J} q_j^1 - \sum_{j=1,j\notin O}^{J} q_j^0}{\sum_{j=1,j\in O}^{J} q_j^1 - \sum_{j=1,j\in O}^{J} q_j^0}$$

The special case of removing online entirely then obtains if $\sum_{j=1,j\in O}^{J} q_j^1 = 0$.

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