Review of Income and Wealth
Series 49, Number 1, March 2003

USING SCANNER DATA TO ESTIMATE COUNTRY PRICE PARITIES: A HEDONIC REGRESSION APPROACH

BY SAEED HERAVI*

Cardiff Business School

ALAN HESTON

University of Pennsylvania

AND

MICK SILVER

Cardiff Business School

This paper uses scanner data from the bar-code readers of retailers to provide estimates of inter-country price parities at the level of the basic heading. The use of such data is appealing given its extensive coverage of transactions, information on weights, prices and characteristics of items at a highly detailed level. The study uses dummy variable hedonic and exact/superlative hedonic index number formulations applied to an inter-country context for both bilateral and multilateral comparisons. Unlike conventional methods, such methods are not confined to matched samples comparisons and thus make use of the entire sample. Their application extends to price survey data using checklists on characteristics. The application is to scanner data on about 1 million transactions for television sets over two months in three countries. It is, to the authors' knowledge, the first such use of scanner data and application of the above hedonic frameworks in this context.

1. INTRODUCTION

Scanner data from the bar-code readers of retailers benefits from an impressive coverage of transactions along with the availability of information on sales, prices and the quality features of models of products sold. Such data are available for a large range of products, though less so in developing countries, and have the potential to form the basis of much improved purchasing parity estimates. The methods outlined and applied in this paper using scanner data can also be applied to price surveys in which quality characteristics are collected via checklists along with prices—a proposal for the forthcoming International Comparisons Project (Zieschang, Armknecht, and Smith, 2001)—and thus also have some application to developing countries. This paper seeks to illustrate how such data can be used

Note: We acknowledge the support from GfK Marketing UK Ltd. for the provision of the data and Pat Barr in particular for his help. Support was also received by Alan Heston from the National Science Foundation (NSF) and by Mick Silver from the NSF/American Statistical Association and BLS. Helpful comments on an earlier draft were received from an anonymous reference, Robert Hill (University of New South Wales), Bart van Ark (University of Groningen) and other participants at a Joint World Bank-OECD Seminar on Purchasing Power Parities, 30 Jan–2 Feb, 2001, Washington D.C. The usual disclaimers apply.

*Correspondence to: Mick Silver, Cardiff Business School, Cardiff University, Colum Drive, Cardiff CF10 3EU, U.K. (Silver@cardiff.ac.uk).

for parity measures and in doing so, contrasts the results from different formulae. A key advantage of scanner data and the use of checklists is the availability of information on the characteristics of items sold. This allows use to be made of all the data, rather than a sample restricted over time to matched data, since differences in prices due to quality differences can be controlled for using a hedonic regression framework, rather than matching.

The plan of the paper is to provide in Section 2 some background on how parities are estimated in traditional purchasing power studies. In Section 3 the estimation of parities using hedonic regressions is discussed using a dummy variable method and superlative-exact *hedonic* indices, hereafter referred to as SEHI. In a recent, seminal paper Kokoski, Moulton, and Zieschang (1999) applied a similar framework to inter-area price comparisons within the U.S. Their data source was the tight, matched item specifications used by the U.S. Bureau of Labor Statistics for the compilation of their consumer price index (CPI). In this study we use a superlative/exact *hedonic*, but developed for use with scanner data to compare prices across countries where matching has limited application. A feature of scanner data is its almost comprehensive coverage of transactions. Methods have to be devised to ensure data are not lost by restricting the analysis to items that can be matched, and thus losing some of the benefit of the data.

Section 4 describes the data and variables for an application using scanner data from different types of outlets on models of television sets in France, the Netherlands and the U.K. to estimate price parities for television sets (TVs). The data set is rich in the coverage and scope of transactions as well as the extensive detail available on unit values, volumes (and thus weights) and characteristics for each individual model of TV sold. It thus permits us to examine alternative formulae and approaches to the estimation of such parities. While the study is limited to one consumer durable, such data are available for a wide range of products, the results here being illustrative of a proposed methodology for a rich data source. Section 5 provides the results and Section 6 concludes.

2. Background on Spatial Parities

2.1. *Traditional Methods*

Before discussing hedonic methods the usual ways in which parities have been generated at the basic heading level are briefly outlined (for details see Balk, 1996a, 1996b, 2001; Diewert, 1999; Hill, 1999; Rao, 2001). The binary case is important for at least two reasons. First, binary comparisons have been taken as the model for both two country comparisons as well as multilateral comparisons using the star system of linking a country to one or several nodes. The accepted method of binary comparisons has been to compute a geometric mean of the price ratios within a basic heading parity. Usually no weights are attached to the individual price ratios within a basic heading, but weights can be used in aggregation above the basic heading and Fisher's formula is typically applied. A second important reason to look at the binary case is that it has been used by the EU as a basis for developing multilateral estimates of basic heading parities. The EU practice is for countries to distinguish over a basket of several thousand specified goods and services between: (a) items regarded as *representative* (also formerly denoted as "*" (star) items); (b) other less important items that are *priced*; and (c) items *not priced* by a country. Between any pair of countries, only representative items for country A will enter into pp_{AB}, and for country B, only its representative items will enter into pp_{BA}. These become the inputs for the EKS estimation (Elteto and Koves, 1964; Szulc, 1964) that generate a transitive set of parities for all the countries at the basic heading level. Should country A and B not price items that are representative in the other country, their estimated pp_{AB} are based upon their indirect comparisons through third countries.

If each country prices each item within a basic heading and the geometric means of the ratios are calculated, these will be transitive across the countries. However, since not all prices will be available for all items within a basic heading, then a directly estimated pp_{AB} will not in general equal an indirect pp_{AB} derived from pp_{Aj}/pp_{Bj}, where j are further countries being compared. This requires the development of multilateral approaches. The two approaches most commonly used are the EKS method and the country product dummy (CPD) method (Summers, 1973). They both have the property that if each country prices all items, their estimated pp_{AB} will be the same and equal to that obtained in the binary case.

The EKS method permits transitivity to be attained by taking into account direct and indirect comparisons across countries. The CPD method is a basic hedonic regression model akin to those used for temporal studies. In (1) below for $j = 1, 2, \ldots, m$ countries, $i = 1, 2, \ldots n$ items in a basic heading, and p_{ij} the price of item i in country j, and ε_{ij} the error term, the prices are regressed against the two sets of dummy-variables. One set contains a dummy for each country, α_j, other than the numeraire country, and the second set a dummy for each item specification, z_i.

(1) $$\ln p_{ij} = \sum_{i=1}^{n} \beta_i z_i + \sum_{j=2}^{m} \alpha_j D_j + \varepsilon_{ij}$$

The transitive parities, α_j, are the logarithm of the estimated country parity for the heading relative to the numeraire country. The item coefficients, β_i, are the logarithms of the estimates of the average item price in the currency of the numeraire country. The CPD method in effect produces an estimated complete price matrix for a basic heading, and the country parities are the geometric means of the ratios of country prices to those estimated for the numeraire country.

2.2. *Scanner Data, Parities and Hedonic Regressions*

Scanner data benefit from having an extensive coverage of transactions over all items sold as opposed to a selection of varieties of selected representative items in a sample of outlets. The coverage extends to all transactions in the period as opposed to a survey date and takes transaction as opposed to display prices. For individual varieties or models within a basic heading, data are available on the unit value, volume and thus values for weighting at this lower level of aggregation. Data are also available on the characteristics of each variety or model allowing hedonic regressions to be estimated. The use of scanner data for the basic headings of CPIs has moved from the advocacy stage to the stage of serious research about costs and benefits.[1] The computational matching of prices across countries using scanner data is problematic. First, there is a problem with the coding. Scanner data have a code to describe each model of a good. The code can be extended to include the type of outlet in which it is sold, in order that a particular model of a good in a particular type of outlet is matched against its counterpart in successive periods. Since individual retailers often have unique codes for the same model, the matching is in practice closer than by "model and outlet type." A problem with such matching is missing observations. For scanner data they arise when there is no transaction in that outlet (type) in a period, possibly because the item is no longer being sold, or is on display but no one has bought it. This contrasts with the practice of price collectors who may record a display price whether or not the item has been sold. More important is the validity of the codes being used. In principle universal product codes should be used by manufacturers as part of their bar-codes. However, providers of scanner data acknowledge that the same model sold in a different country may be given a different code. Also new models with quite similar characteristics to the old models are given new codes.

3. Hedonic Parity Adjustments Using Scanner Data

Two methods are considered for measuring quality-adjusted price changes using scanner data: the dummy variable hedonic method and a superlative-exact hedonic index (SEHI) approach, whose application for comparisons over time has been considered by Silver and Heravi (2001, 2003).

3.1. *Dummy Variable Hedonic Method*

This is akin to the CPD method developed by Summers (1973) given by equation (1), except that it includes a detailed set of variables on the quality characteristics, including the makes, of the items. Thus price variation, in local currencies, within and between countries is explained by variation in the quality characteristics of each item as well as the country dummy variables to pick up the parities. The variation in quality across (and within) countries is not controlled for by the selection of a sample of items, so that "like" is compared with "like." It is controlled for in the regression equation by partialing out any quality differences. As such there is no need in principle to sample just (directly or indirectly) matching items, from the population of items. Since matching is not used, sampling can be from all available data, thus making the most of the rich coverage of scanner data. The theoretical basis for the method *within a country* has been derived by Rosen (1974) where a market in characteristic space is established (see also Triplett, 1987). Empirical studies and econometric issues are surveyed in Griliches (1990), Triplett (1990) and Gordon (1990); but see also Berndt, Griliches, and Rappaport (1995), Moulton, Lafleur, and Moses (1998), Hoffmann (1998) and Silver (1999). The hedonic regression is given by:

[1]Early studies include Silver (1995) and Saglio (1995), though see also Haan and Opperdoes (1997), Dalén (1998), and papers in Shapiro and Feenstra (2003).

(2) $$\ln p_{ij} = \beta_0 + \sum_{k=1}^{k_1} \beta_k z_{ik_j} + \sum_{k=k_{1+1}}^{K} \beta_k z_{ik_j} + \sum_{j=2}^{m} \alpha_j D_j + \varepsilon_{ij}$$

where j represents the m countries, and i, the individual items. However, in this case i refers to an item that has K characteristics. In the CPD equation (1) there was no intercept, and each β_i was an estimate of the price of the item. In (2), β_0 is the log of the price of the base item, in our application the simplest Sony 14″ TV set, in the currency of the base country, the U.K., sold in multiple outlets. The remaining β_ks simply modify that coefficient and α_j are the heading parity that would convert the price to, say, guilders (the data preceding EMU).

The β_ks have been broken into two groups, those for $k = 1, 2, \ldots k_1$, and those for $k = k_1 + 1, \ldots K$. The distinction being made here is between what we will term *core characteristics* of an item, in our case screen size, a feature that will be present for all i. The other group includes characteristics, like widescreen, which is a feature of less than 20 percent of the models. This division of the characteristics is not essential to the estimation but it is useful for thinking about the general problem of spatial parities, and we will return to this subsequently.

The dummy variable hedonic approach as conventionally used is not without problems. First, it implicitly treats each model as being of equal importance, when some models will have quite substantial sales, while for others sales will be minimal. Scanner data includes data on sales and a weighted least squares estimator may be employed (Ioannidis and Silver, 1999; Silver and Heravi, 2002), this being considered in the empirical section.

A second problem arises with the manner in which the dummy variable method takes account of changing coefficients over time, or in this context, across countries. It is the usual practice in temporal analysis that the coefficients are held constant. Dummy slope coefficients on each characteristic for each period would relax the constraint. Yet this renders the estimate of the parity adjustment, the coefficient on the dummy (country) intercept, dependent on the values of the performance characteristics (Kokoski *et al.*, 1999; Silver, 1999). In an international context the restriction amounts to assuming preferences and production technology for characteristics are constant across countries, at some constrained average level. These problems are dealt with in the SEHI formulation, the dummy variable hedonic method being a restricted version of the SEHI hedonic approach.

3.2. *Superlative-Exact Hedonic Indices (SEHI)*

We first consider bilateral comparisons and borrow the framework developed by Feenstra (1995), substituting spatial for temporal comparisons. Feenstra's framework was based on each item being separately aggregated with a quality adjustment for any remaining quality differences. However, with scanner data the inability to match items in different countries leads to an unacceptable loss of data. In the following exposition, and in the calculations below, this is modified and $i = 1 \ldots N$ are now item groups. These will initially be defined as screen sizes in the application below for television sets. The country A (base) and country B weighted quality-adjusted bounds for a COLI, when p_i

is linear in z_i, i.e. a linear specification of the hedonic equation, are given by (Feenstra, 1995)[2]:

$$\text{(3a)} \qquad \left[\frac{\sum_{i=1}^{N} x_{iB}\overline{p}_{iB}}{\sum_{i=1}^{N} x_{iB}\hat{p}_{iA}}\right] \leq \frac{E(p_B, z_B, U)}{E(p_A, z_A, U)} \leq \left[\frac{\sum_{i=1}^{N} x_{iA}\hat{p}_{iB}}{\sum_{i=1}^{N} x_{iA}\overline{p}_{A}}\right]$$

$$\text{(3b)} \qquad \begin{aligned} \hat{p}_{iB} &\equiv \overline{p}_{iB} - \sum \beta_{kB}(\overline{z}_{ikB} - \overline{z}_{ikA}) \\ \hat{p}_{iA} &\equiv \overline{p}_{iA} + \sum \beta_{kA}(\overline{z}_{ikB} - \overline{z}_{ikA}) \end{aligned}$$

where Laspeyres and Paasche are upper and lower bounds in (3a) on their respective "true" economic theoretic COLIs: x is quantity sold, $\overline{p}_{iB}$ and $\overline{p}_{iA}$ are sales weighted average prices for each item group (screen size) for country B and A respectively. In (3b) $\overline{z}$ is a vector of K characteristics with associated β_{kB} derived from linear hedonic regressions over all product varieties (models) for each characteristic K. Differences in the quality of models are picked up in (3b) via differences in their characteristics ($\overline{z}_{ikB} - \overline{z}_{ikA}$) which are multiplied by estimates of their associated β_{kB}. With sales data available, the vector z can be the sales-weighted average usage or mix of each characteristic in each country. Note that $\hat{p}_{iB}$ corrects the observed average prices $\overline{p}_{iB}$ for differences in the characteristics between the two countries, corresponding to the "explicit quality adjustment" described by Triplett (1990, p. 39).

In (3a), for example, the average prices in each country of TVs of different screen sizes are being compared and the comparison is weighted by the sales share of each screen size. However, the quality mix in each screen size may differ between countries and affect the price comparison. The adjustment in (3b) is for characteristics other than screen size in each item group. Thus, for example, if more sets in country B have widescreen, Nicam stereo, are made by Sony etc., the differences in these weighted averages are computed for each screen size—maybe for 25 inch sets the proportion with widescreens in country B is 0.3 compared with 0.2 in country A. These are the differences between countries in weighted averages of models with widescreen—the difference in ($\overline{z}_{ikB} - \overline{z}_{ikA}$) for k = widescreen. These differences for each characteristic have to be aggregated by an estimate of the relative importance (in a price determining sense) of each characteristic. They are multiplied by the estimated coefficients from a hedonic regression. Thus, for example, in the first equation in (3b) an hedonic regression is estimated using only country B's data to derive estimates of each of the βs for each characteristic. The product of these βs and weighted changes to z are then summed and subtracted from the average price to quality adjust it.

There are a number of advantages to the use of the SEHI approach. First, it utilizes the coefficients on the characteristics to adjust observed prices for quality differences, so that data are not lost in matching. Second, it incorporates a weighting system using data on the sales of each model and their characteristics, rather

[2]A formulation is also given for geometric means using a semi-logarithmic formulation for the hedonic regression.

than treating each model as equally important. This also has important implications for the extension of the analysis to a multilateral framework where relative sales in each country forms part of the weighting system. Third, it does not constrain the coefficients to be the same, as in the CPD and dummy variable methods, allowing separate Laspeyres and Paasche estimates based on the purchasing patterns and coefficients of each of the countries being compared. Fourth it makes efficient use of the data, the comparisons in (3a) being akin to strata in stratified sampling, controlling for between core variable variation, while within strata variation is controlled for by the regression in (3b). Finally, the approach has a direct correspondence to a constant utility index number formulation derived from economic theory by Fixler and Zieschang (1992), Feenstra (1995) and Diewert (2002) and applied to inter-area comparisons within the U.S. by Kokoski *et al.* (1999).

3.3. *The Multilateral Case*

Having developed a methodology for estimating superlative bilateral parities for a basic heading where weights are available, how do we move to the multilateral case? At least four approaches suggest themselves. The first, which would be easier on the reader, is to simply run a pooled hedonic regression across countries and use the country parities that emerge. The second would be to use a classic Gini-EKS approach, and the third would be the purposeful binary chain, a variation of Robert Hill's spanning tree approach (Hill, 1999). Finally, the fourth uses a transitive, superlative hedonic method, as undertaken by Kokoski *et al.* (1999) for matched inter-area U.S. data, but developed using the above framework for international comparisons with scanner as opposed to matched data.

From our perspective, which tries to use as much of the price information as possible, we would propose two ways to obtain a common set of binary price comparisons to implement the Gini/EKS and Hill's approach. Following our distinction between core and secondary characteristics, we would generate a set of cells for core characteristics, say makes, outlet types, and screen sizes. The first way is to generate price ratios for each cell as in (3a) above. This will be termed the country mix method.

The second way is to obtain a price for each cell for each country where the sales share was significant, using a mix of secondary characteristics common to all the countries. This will be termed the average mix method. The price would be estimated from a hedonic regression equation, weighted and pooled or not, that question being left to the empirical section. For countries without scanner data, but with some information on weights, prices could be directly collected. This set of cells or models could then be used to develop binary comparisons for each pair of countries. As noted we could construct a set of binary comparisons based upon (3a). The Fisher index could be used and transitivity imposed on the set of binary comparisons using Gini-EKS. This would be a way to combine the various binary comparisons.

A third approach is to use purposeful binaries along the lines of the spanning tree approach of Robert Hill (1999). In this approach, binary comparisons would be made between pairs of countries that would be likely to have similar mixes of secondary characteristics and similar weights in the various cells. In the Hill approach this would correspond to a path that would minimize the Paasche-Laspeyres spread implicit in (3a). It is not proposed that the Hill algorithim actually be carried out for each basic heading, but rather this consideration is used to generate a set of binaries linking all of the countries. In our three-country example, this is fairly easy to do, so we will illustrate it in the empirical section. The final approach follows Kokoski *et al.* (1999) whereby multilateral SEHI are compiled comparing country A in the above formulations with a reference supercountry, and then country B and C, each in turn with the reference country. The multilateral system is then derived from these binary comparisons. The principles are similar to the binary comparisons, whereby one of the countries in equation (3) is an amalgam of all countries, its average reference quality characteristic set, $\bar{z}$, being aggregated across all three countries. Estimates of the coefficients for each characteristic are taken from constrained weighted (by volume of transactions) least squares estimates of hedonic regressions using data from all countries.

4. An Empirical Study: Scanner Data

The empirical work utilizes scanner, bar-code data for television sets for June and July 1998 in three countries: the U.K., France and the Netherlands. Scanner data provides, for each item, information on price (unit value), sales (through aggregation of transactions), characteristics of the product (linked to the item or model number), retailer and time of purchase. The scanner data provide transaction prices for all transactions as opposed to a price collector collecting display prices for a sample of branded varieties on what are intended to be representative items taken from a sample of outlets for a single day in each month. As will be seen, the coverage of the scanner data for an item extends to millions of transactions each year. Supplementary data were also collected from outlets without bar-code readers. The relative merits of the practical use of such data for CPI compilation have been discussed in Silver (1995), Fenwick *et al.* (2002) and Richardson (2000).

The observations are for a model of the product for which there was a transaction in the country in a particular outlet-type. For example, an observation in the data set for June and July 1998 includes the unit value (£284.52), volume (3,686 transactions) and quality characteristics (including possession of Nicam stereo and fastext text retrieval facilities) of a (Panasonic TX21MD3 21 inch screen) television set sold in electrical multiples only in the U.K. For June and July 1998 there were 4,827 observations: 1,186 for the Netherlands, 2,146 for France and 1,495 for the U.K., representing over a million transactions over June and July 1998—about 0.2, 0.6 and 0.3 million transactions in each of the Netherlands, France and the U.K. respectively. Observations may be for the same model in different outlet-types; models were, on average sold in 1.37 different outlet types in the Netherlands, but more so for France at 1.97 and the U.K. at 2.2. The coefficients of variation for prices in the Netherlands, France and U.K. are 0.77, 0.80 and 0.93 respectively and such non-trivial price variation requires explanation in terms of their quality characteristics. The variable set is quite extensive and includes:

- *Price* is the unit value of a model in a month/outlet type across all transactions, i.e. sales value/sales volume (see Balk (1996) for the statistical properties of unit values).
- *Volume* is the sum of the transactions during the period. As will be shown below many of the models sold in any month have relatively low sales.
- *Vintage* is the year in which the first transaction of the model took place. New models can coexist with old models, both as a result of an inability to dump the old model before the launch of the new one and as an appreciation that different sub-markets exist for models of different vintages.
- The *characteristics* set includes: (i) manufacturer (make)—dummy variables for about 36 makes; (ii) size of screen; dummy variables for possession of: (iii) Nicam stereo; (iv) tube type—flat screen tube/Trinitron; (v) tuner—Pal, Pal/Secam, Pal/Secam/NTSC, Pal plus varieties; (vi) satellite; (vii) text retrieval system—fastext/TOP, teletext; (viii) Dolby system; (ix) wide screen; (x) S-VHS socket; (xi) digital.
- *Outlet-type*. The country and outlet classification are: NL Departmental and Catalogue; NL Electrical multiples; NL Photographers; Fr Departmental; Fr Electrical multiples; Fr Hypermarkets; Fr Specialist (independents); Fr Catalogue; UK Mass merchandisers (departmental); UK Electrical multiples; UK Renters and others n.e.c; UK Independents; UK Catalogue. These were combined into four groups for each country: multiples, mass merchandisers, catalogue and independents with NL Departmental and Catalogue being allocated to mass merchandisers.

The volume of transactions for models/outlet-types is highly negatively skewed with a relatively large number of models having low sales volumes. If models of TVs in an outlet type with sales of 30 or less in the two months were ignored, we would be left with only 45, 60 and 58 percent of observations for the Netherlands, France and U.K. respectively. Yet these remaining observations would account for 97, 99 and 98 percent of transactions in these respective countries. The top 71 or 5 percent of makes in an outlet-type in the U.K. by sales accounted for 126,229 or 41 percent of transactions.

The top three makes (out of over 30) dominate the market accounting for between a third and a half of the volume of sales. Some makes achieve relatively high sales with relatively few models, for example Philips and Sony in the U.K. sold a similar number of varieties, though Sony achieved very much higher sales. The desirability of different features of TVs varies between countries. For example, digital TV at this time was less important in France, while flat screen/Trinitron technology was taken up to a similar degree between countries. Purchases of wide screen TVs were more prevalent in Netherlands and larger screen sizes in France. The breakdown of outlet types was given above, the classifications varying across countries making comparisons less reliable. Multiples are the dominant outlet type for TV sales in the Netherlands while the U.K. market makes more use of catalogue sales.

5. An Empirical Study: Results

5.1. *The Dummy Variable Hedonic Method*

The OLS regression results are given in Model I of Table 1. The sample of 2,633 excludes models with country sales of less than 30 in any outlet type. Such models with limited sales may have unusual pricing policies. The $\bar{R}^2$ can be seen to be relatively high at 0.965 and the magnitude and signs are of the appropriate order and nature. For example, a widescreen TV has a price margin of (exp(0.300) – 1) ∗ 100 = 35 percent, or more properly, with the adjustment of half the standard error (Goldberger, 1968), i.e. (exp(0.300 + 0.00769) – 1) ∗ 100 = 36 percent. All quality features have a positive sign, with the exception of the provision of a satellite tuner, probably as a result of some multicollinearity. The dummy variables for makes were benchmarked on a Sony, which in Europe carries an up-market premium, most other makes having negative coefficients. Exceptions include Bang & Olufsen who serve a niche, relatively high-priced market. The outlet-types were benchmarked on multiples with, for example, purchases in independent outlets having an (exp(0.100073 + 0.5 (0.012407)) – 1) ∗ 100 = 11 percent price premium. The nature of the purchase experience is regarded as a quality characteristic of the transaction and thus expected service affects price. The country dummy variables are benchmarked on the U.K. with an estimate of parities at this basic heading for the Netherlands against the U.K. of (exp(0.738 + 0.5(0.023)) = 2.12 fl/£ and France against the U.K. of (exp(2.161 + 0.5(0.017)) = 8.76 fr/£. The models suffer from some heteroskedasticity, though heteroskedastic consistent standard errors were used for the tests following a procedure by White (1980).

The relatively crude classification of outlet-types into multiples, independents, mass merchandisers and catalogue is an attempt to provide a consistent categorization of the richer classification available as outlined above. Estimates in Model II of Table 1 use this finer classification benchmarked on U.K. multiples. The results for individual outlet-types in individual countries are estimates of how price comparisons differ across purchases in different outlet-types within and between countries. For example, in France the multiples are (1 – (2.292/2.341)) about 2 percent cheaper than department stores, while in the Netherlands multiples are (1 – (0.841/0.836)) 0.6 percent more expensive than their department stores. In the context of estimating heading parities, knowledge of outlets and their likely influence on price within a country is clearly important for making appropriate price comparisons.

Examination of Model III in Table 1 indicates very little difference between the results from OLS and WLS estimators. The estimates of the coefficients for parities for TVs in particular are very close at 0.719 and 2.132 for the Netherlands and France using WLS and 0.738 and 2.161 using OLS. After exponentiation and adjustment for the standard errors these translate to parity estimates of 2.11 and 2.09 for the Netherlands and 8.76 and 8.55 for France using OLS and WLS respectively. The econometric models using both of these estimators restricted the sample to volumes of transactions greater than 30 for an individual observation. However, when the whole sample was used for WLS, the coefficients were still very similar. Finally, the model was re-estimated having converted prices to their dollar equivalent using the average exchange rates for June and July (IMF, *International*

TABLE 1

REGRESSION RESULTS

Variable	Model I—OLS, n > 30, Country and Outlet Type		Model II—OLS, n > 30, Country and Outlet Type		Model III—WLS, n > 30, Country and Outlet Type	
	Estimated Coefficient	Standard Error	Estimated Coefficient	Standard Error	Estimated Coefficient	Standard Error
Characteristics						
Constant	6.532***	0.529	6.268***	0.512	5.968***	1.040
Flatscreen	0.143***	0.014	0.152***	0.014	0.196***	0.026
Teletext	0.119***	0.014	0.116***	0.013	0.124***	0.019
Fastext	0.177***	0.016	0.173***	0.015	0.208***	0.021
Digital	0.089***	0.008	0.086***	0.008	0.084***	0.013
Satellite	–0.176**	0.057	–0.186***	0.053	–0.242**	0.075
S-VHS	0.033**	0.012	0.033***	0.012	0.011	0.020
Widescreen	0.300***	0.015	0.300***	0.015	0.336***	0.023
Dolby	0.179***	0.017	0.187***	0.017	0.170***	0.023
Nicam stereo	0.111***	0.014	0.114***	0.014	0.116***	0.018
Screen size	–0.125***	0.025	–0.122***	0.024	–0.999	0.051
(screen size)^2	0.0060***	0.0011	0.0058***	0.0011	0.0046	0.0023
(screen size)^3	–0.00008***	0.000016	–0.00005***	0.000015	–0.000031	0.000033
Vintage	–0.009	0.005	–0.007	0.005	–0.005	0.009
Tuner (PAL1 omitted)						
PAL/SECAM	0.059***	0.015	0.060***	0.014	0.076**	0.026
PAL/SECAM/NTSC	0.072***	0.016	0.068***	0.016	0.059*	0.025
Makes (Sony omitted)						
Akai	–0.086*	0.030	–0.099***	0.029	–0.120*	0.051
Alba	–0.319	0.172	–0.346***	0.207	–0.174*	0.072
Amstrad	–0.148	0.082	–0.203	0.117	0.006	0.065
Beko	–0.317***	0.038	–0.345	0.030	–0.185**	0.063
Binari	–0.264***	0.017	–0.276***	0.017	–0.211***	0.028
Bang & Olufsen	1.346***	0.083	1.334***	0.086	1.303***	0.110
Blaupunkt	0.109***	0.019	0.090***	0.017	0.180***	0.038
Bush	–0.074	0.040	–0.123***	0.037	0.015	0.048
Crown	–0.279***	0.019	–0.228**	0.038	–0.212***	0.028
Daewoo	–0.122***	0.023	–0.127***	0.023	–0.903*	0.038
Decca	0.329*	0.160	0.337	0.219	0.288	0.178
Dual	–0.134	0.093	–0.096	0.093	–0.047	0.083
Ferguson	–0.202***	0.043	–0.189***	0.043	–0.222***	0.054
Goodman	–0.159**	0.053	–0.180***	0.077	–0.097	0.053
Grundig	0.096***	0.023	0.091***	0.023	0.091**	0.033
Hitachi	–0.782***	0.020	–0.077***	0.018	–0.019	0.028
JVC	–0.046	0.023	–0.051*	0.022	–0.016	0.030
LG	–0.141***	0.028	–0.151	0.029	–0.770	0.048
Loewe	0.512***	0.034	0.505***	0.035	0.534***	0.048
Mitsubishi	–0.148***	0.033	–0.131***	0.033	–0.063*	0.031
NEI	–0.306***	0.046	–0.286***	0.049	–0.240***	0.036
Nokia	0.012	0.043	–0.003	0.044	0.011	0.063
Nordmen	0.226*	0.110	0.220	0.120	0.276*	0.131
Orion	–0.293*	0.117	–0.257*	0.126	–0.182*	0.073
Panasonic	0.082***	0.018	0.073***	0.017	0.077**	0.026
Phillips	0.129***	0.016068	0.122***	0.015	0.175***	0.025
Pye	–0.061	0.040	–0.100***	0.036	0.031	0.039
Saba	–0.082*	0.032	–0.079***	0.032	–0.011	0.049
Samsung	–0.128***	0.039	–0.142***	0.035	–0.040	0.065
Sanyo	–0.098***	0.028	–0.117***	0.026	–0.041	0.035
Schneider	0.015	0.037	0.012	0.036	0.050	0.050
Sharp	–0.081***	0.021	–0.076***	0.021	–0.012	0.028
Tatung	0.002	0.032	–0.005	0.033	0.093*	0.046
Teletun	0.045	0.072	0.033	0.071	0.107	0.058
Thomson	0.053*	0.022	0.048***	0.021	0.147***	0.031
Toshiba	0.009	0.020	–0.001	0.020	0.049	0.027
Others	–0.259***	0.025	–0.229	0.024	–0.283***	0.041

TABLE 1 (*continued*)

Variable	Model I—OLS, n > 30, Country and Outlet Type		Model II—OLS, n > 30, Country and Outlet Type		Model III—WLS, n > 30, Country and Outlet Type	
	Estimated Coefficient	Standard Error	Estimated Coefficient	Standard Error	Estimated Coefficient	Standard Error
Country and outlet (UK multiples omitted)						
NL Department	–	–	0.836***	0.030	–	–
NL Multiple	–	–	0.841***	0.025	–	–
NL Photographer	–	–	0.786***	0.039	–	–
Fr Department	–	–	2.341***	0.032	–	–
Fr Multiple	–	–	2.292***	0.023	–	–
Fr Hypermarket	–	–	2.147***	0.024	–	–
Fr Specialist	–	–	2.387***	0.023	–	–
Fr Catalogue	–	–	2.257***	0.027	–	–
UK Merchandiser	–	–	0.129***	0.019	–	–
UK Renter	–	–	0.129***	0.032	–	–
UK Independent	–	–	0.182***	0.018	–	–
UK Catalogue	–	–	0.286***	0.020	–	–
Outlet type (multiples omitted)						
Mass merchandisers	–0.041***	0.012			–0.064**	0.023
Independents	0.100***	0.012			0.130***	0.018
Catalogues	0.112***	0.016			0.108***	0.023
Country (UK omitted)						
The Netherlands	0.738***	0.023			0.719***	0.034
France	2.161***	0.017			2.132***	0.027
Adjusted R^2	0.965		0.968		0.969	
Sum of squared residuals	125.545		116.637		99.658	
n	2633		2633		2633	
F statistic, zero coeffs.	1288		1196		927	

Standard errors are adjusted for heteroskedasticity.
***, **, *denote statistically significant at a 0.1, 1 and 5% level respectively for two-tailed tests.

Financial Statistics, December 1998, Washington D.C.). Again the model performed well in terms of $\overline{R}^2 = 0.90$, the coefficients yielding exchange rate adjusted parity estimates for the Netherlands and France respectively of –0.5181 and –0.1312 compared with the U.K.

The above framework is quite restrictive since it assumes the coefficients attached to each quality variable are constant across countries. By including interaction effects for each of France and the Netherlands benchmarked on the U.K., an unconstrained model in which coefficients can vary across countries can be estimated. An F-test for the constrained versus unconstrained model tests the null hypothesis that $\beta_k = \beta_{jk}$ for all $K = 1, \ldots K$ in (2), i.e. that the coefficients are the same across countries. Not all makes, though all characteristics were available in all countries, the unconstrained model having 128 variables, compared with 57 in the constrained model. The F-test statistic was 0.624, with a critical $F_{71,2505,0.05}$ = 1.297, thus rejecting the null hypothesis at a 5 percent level. Having rejected the null, it is of interest to identify which estimated coefficients are subject to inter-country variability. These are given in Table 2. The omitted, benchmark variables for the *t*-tests for these interaction terms are based on the U.K. For example, the test in Table 2 for the Blaupunkt make being that $(\beta_{FR,Blaupunt} - \beta_{UK,Blaupunt}) = 0$, and

TABLE 2

CONSTANCY OF COEFFICIENT ACROSS COUNTRIES

	$(\beta_{France} - \beta_{UK})$	Standard Error	$(\beta_{NL} - \beta_{UK})$	Standard Error
Makes (Sony omitted)				
Blaupunkt	–0.099*	0.043	–	–
Daewoo	0.222***	0.051	0.254***	0.048
Grundig	0.202**	0.074	0.207*	0.080
Mitsubishi	–0.183*	0.086	–	–
Nokia	–0.413***	0.111	–	–
Panasonic	0.106*	0.041	–	–
Philips	0.156***	0.039	0.154***	0.041
Telelun	–0.235**	0.078	–	–
Thomson	0.190*	0.092	–	–
Amstrad	–	–	0.450***	0.067
Hitachi	–	–	0.259***	0.059
JVC	–	–	0.135*	0.056
Tatung	–	–	0.130*	0.054
Characteristics				
Flat screen technology	0.097**	0.034	–	–
Digital	0.075**	0.023	0.055*	0.022
Satellite	–0.249**	0.080	–	–
S-VHS	0.059*	0.027	0.117***	0.038
Fastext	–	–	0.115**	0.038
PAL/SECAM	–	–	0.068*	0.033
PAL/SECAM/NTSC	–	–	0.132**	0.047
Vintage	–	–	–0.028*	0.012
Outlet (multiples omitted)				
Catalogue	–0.313***	0.029	–	–
Independents	–0.074**	0.024	–0.189***	0.037
Mass merchandisers	–0.245***	0.025	–0.125***	0.030

Standard errors are heteroskedastic consistent.
***, **, *denote statistically significant at 0.1, 1 and 5% level respectively for two-tailed tests.
Comparisons are only given when the differences are statistically significant at a 5% level or less.

similarly for other characteristics. The Philips brand, for example, is estimated to have a marginal value of about $(\exp(0.15 + 0.5\ (0.04) - 1) * 100 = 18.5$ percent above that of the U.K. for both the Netherlands and France and the estimated marginal values of digital facilities exceeds the U.K. in both countries. It should be noted that the 32 differences listed in Table 2 are only those coefficients where the differences are statistically significant, there being a further 96 bilateral comparisons where the differences were not statistically significant.

5.2. *Superlative-Exact Hedonic Indices*

In presenting our SEHI results an unconstrained equation has been used that employs 10 different screen size dummy variables, instead of treating size continuously as in the regression equations in Table 1. Table 3 shows how we build up the SEHI results. While this is clearly stated in the equations, Table 3 is also useful because it provides a more general framework for using hedonic equations to generate detailed heading parities. We believe the framework of Table 3 is general enough to include basic headings for services and non-durables, and flexible enough to accommodate price information from individual country

TABLE 3

ILLUSTRATION OF SEHI CALCULATION FOR 12 SCREEN SIZES

Size of Screen (inches)	FR Mean Price	FR-NL Adjust Price	FR-UK Adjust Price	FR Share Sales	NL Mean Price	NL-FR Adjust Price	NL Share Sales	UK Mean Price	UK-FR Adjust Price	UK Share Sales
1. <14	1,616	1,780	2,193	0.0111	533	498	0.0018	210	239	0.0111
2. 14	1,293	1,071	1,010	0.1097	395	401	0.094	152	156	0.1241
3. 15–19	2,440	1,961	1,743	0.0081	706	632	0.0115	270	244	0.0099
4. 20	1,388	1,230	1,378	0.0413	534	505	0.0473	219	219	0.0328
5. 21	2,299	1,972	2,256	0.1594	806	743	0.1311	296	260	0.1956
6. 24	5,797	5,074	6,012	0.0050	1,822	1,631	0.0471	554	467	0.0085
7. 25	4,229	3,204	3,736	0.0776	1,312	1,315	0.1596	447	409	0.1819
8. 26	3,965	4,478	4,498	0.3208	2,076	1,502	0.3426	631	507	0.2016
9. 29	5,988	4,996	5,522	0.1345	1,744	1,641	0.0794	643	562	0.1051
10. >29	10,667	11,913	11,075	0.1325	3,979	3,125	0.0855	1,398	1,202	0.1319

regressions or prices obtained otherwise with information on core and secondary characteristics.

Table 3 gives the simplest breakdown of core characteristics in (3a), namely by ten screen sizes. For each screen size the mean price in each country is provided in national currencies, without holding constant the other quality characteristics of the set. The average price of a 14-inch set for example is 1293 fr, 395 fl and £152, corresponding to ratios to the £ of 8.51 fr and 2.60 fl. The adjusted prices take account of the secondary characteristics that differ between the countries for the typical TV set in the cell. The FR-NL adjusted price of 1071 fr is obtained by applying the French coefficients to the average quality of 14-inch sets in the Netherlands. Similarly the FR-UK, NL-FR, and UK-FR adjusted prices apply the coefficients of the first country to the characteristics of the second, the NL-UK, and UK-NL being implicit in the others. The following illustrates the process for 14-inch sets:

	France/UK (fr/£)	*NL/UK (fl/£)*	*France/NL (fr/fl)*
Mean prices 14″	8.51 (1293/152)	2.60 (395/152)	3.27 (1293/395)
Fr adjusted	6.64 (1010/152)	n.a. (n.a.)	2.71 (1071/395)
UK adjusted	8.29 (1293/156)	3.06 (395/129)	n.a. (n.a.)
NL adjusted	n.a. (n.a.)	2.06 (313/152)	3.22 (1293/401)

There are two ways we can compare 14-inch screen sizes between France and the UK: adjusting France's average price and comparing it with the U.K. mean or adjusting the U.K.'s average price and comparing it to France's mean. In Table 3, we have country weights, sales shares, for each of the screen size groups, so these price ratios can be aggregated in the usual ways. To illustrate, in Table 4A, the weighted average of the FR/NL ratios is 2.9628, given as the first entry using NL weights—stylized as the base country here. In the next column the FR/NL ratio is 3.0128 using the current country.

The aggregation in the first core component of equation (3a) was according to ten screen sizes. The correction for quality differences within each of these categories across countries, as given by (3b), utilized makes, outlet types and all other characteristics. The core characteristic(s) should be selected on the grounds that the categories exist in both countries so there will be no missing cells. In addition the characterization should be salient in that it explains price variation and distinguishes between a good proportion of models, not being confined to a minority of models. All of these criteria are met by screen size (Lowe, 1999; Moulton *et al.*, 1998; Ioannidis and Silver, 1999). We extend the categories to include possession of other quality features, such as Nicam stereo and widescreen. The weighted aggregation is then for particular screen sizes, with or without Nicam stereo and flatscreens, substantially extending the aggregation in equations (3a) with little loss of data. Weighted arithmetic means, given by Laspeyres and Paasche in equations (3a) and (3b), and Fisher's index are used for aggregation.

Table 4 has six panels; the formulation in each panel is made up of different core characteristics. In the first three the aggregation starts with the ten screen sizes, adding to that, whether or not flat screened or not, and finally if it possesses Nicam stereo. The aggregation then changes to 20 brands, ten screen sizes and three types of outlets, a total of 600 cells. The left side of each panel of Table 4 has been discussed above. The right hand side contains two sets of information. The columns labeled "Obs del/used" and "Volume del/used" illustrate what happens as we increase the number of core cells. In panel 4A all the observations are used, representing the volume of transactions indicated. There are potentially 3,331 price ratios between France and the Netherlands, representing 832,401 transactions. In

TABLE 4A

Bilateral SEHI Results, by Sizes (10)

Bilateral Comparison	Base Country Weights (Laspeyres)	Current Country Weights (Paasche)	Fisher	Obs del/used	Volume del/used	EKS/ AEKS
France/NL	2.9628 (NL)	3.0128 (France)	2.9877	0/3331	0/832401	2.9251/ 2.9764
NL/UK	3.1410 (UK)	3.1587 (NL)	3.1499	0/2680	0/505728	2.7855/ 2.9833
France/UK	8.5034 (France)	8.8028 (UK)	8.6505	0/3641	0/943767	0.1227/ 0.1206

Countries in parentheses are used for the weights and the hedonic coefficients.

TABLE 4B

Bilateral SEHI Results, by Sizes and Flat Screen (10 ∗ 2)

	Arithmetic					
Bilateral Comparison	Base Country Weights (Laspeyres)	Current Country Weights (Paasche)	Fisher	Obs del/used	Volume del/used	EKS/ AEKS
France/NL	2.9589 (NL)	3.0159 (France)	2.9873	4/3327	172/832229	2.6558/ 2.8430
NL/UK	3.1740 (UK)	3.1620 (NL)	3.1680	51/2629	6360/499368	2.5828/ 2.9897
France/UK	8.4962 (France)	8.8028 (UK)	8.6505	54/3587	7722/936045	0.1312/ 0.1245

Countries in parentheses are used for the weights and the hedonic coefficients.

TABLE 4C

BILATERAL SEHI RESULTS, BY SIZES AND FLAT SCREEN AND NICAM

Bilateral Comparison	Arithmetic: Base Country Weights (Laspeyres)	Arithmetic: Current Country Weights (Paasche)	Fisher	Obs del/used	Volume del/used	EKS/ AEKS
France/NL	2.9089 (NL)	2.9635 (France)	2.9360	39/3400	6824/825162	2.6934/ 3.0584
NL/UK	3.1649 (NL)	3.1321 (UK)	3.1485	201/2464	25344/479969	2.8778/ 2.9157
France/UK	8.5106 (France)	8.8261 (UK)	8.6655	117/3524	15633/928134	0.1174/ 0.1224

Countries in parentheses are used for the weights and the hedonic coefficients.

TABLE 4D

BILATERAL SEHI RESULTS, BY BRANDS (20)

Bilateral Comparison	Arithmetic: Base Country Weights (Laspeyres)	Arithmetic: Current Country Weights (Paasche)	Fisher	Obs del/used	Volume del/used	EKS/ AEKS
France/NL	2.9222 (NL)	2.9600 (France)	2.9410	0/3332	0/832417	2.6773/ 2.8686
NL/UK	3.2097 (UK)	3.4380 (NL)	3.3219	0/2681	0/505744	2.6870/ 3.1442
France/UK	8.8652 (France)	8.8992 (UK)	8.8810	0/3641	0/943767	0.1390/ 0.1285

Countries in parentheses are used for the weights and the hedonic coefficients.

TABLE 4E

BILATERAL SEHI RESULTS, BY BRANDS AND SIZES (20 ∗ 10)

Bilateral Comparison	Arithmetic: Base Country Weights (Laspeyres)	Arithmetic: Current Country Weights (Paasche)	Fisher	Obs del/used	Volume del/used	EKS/ AEKS
France/NL	2.9790 (NL)	2.97967 (France)	2.9793	161/3170	34527/797874	2.8913/ 2.8425
NL/UK	3.1895 (UK)	3.4678 (NL)	3.3258	203/2477	30307/475421	2.8495/ 3.3379
France/UK	9.1575 (France)	8.8731 (UK)	9.017	185/3456	41343/902424	0.1224/ 0.1144

Countries in parentheses are used for the weights and the hedonic coefficients.

the first row of Table 4A it is indicated that it was possible to use all potential price ratios. When we moved to 4B we began to lose observations because there were empty cells. The cost of having a large number of cells is that we lose more and more observations, so by 4F, 610 out of 3,331—nearly 20 percent—of the observations cannot be used. If this technique were extended to a larger number of countries, the selection of core characteristics becomes more important.

TABLE 4F

BILATERAL SEHI RESULTS, BY BRANDS AND SIZES AND OUTLET-TYPES (20 ∗ 10 ∗ 3)

Bilateral Comparison	Arithmetic: Base Country Weights (Laspeyres)	Arithmetic: Current Country Weights (Paasche)	Fisher	Obs del/used	Volume del/used	EKS/ AEKS
France/NL	2.9919 (NL)	3.0364 (France)	3.0141	610/2721	120047/712354	3.0812/ 2.8982
NL/UK	3.1854 (UK)	3.3798 (NL)	3.2811	594/2086	90704/415024	2.8635/ 3.1449
France/UK	8.7951 (France)	8.8028 (UK)	8.7951	459/3182	85598/858169	0.1195/ 0.1159

Countries in parentheses are used for the weights and the hedonic coefficients.

TABLE 5

FISHER SEHI INDICES AGGREGATED BY DIFFERENT CORE VARIABLES*

	Fisher Screen Size	Screen Size/Flat Screen	Screen Size/Flat Screen/Nicam	Fisher Makes	Makes/ Screen Size	Makes/Screen Size/Outlet Types
France/UK	£8.65	8.65	8.67	8.88	9.02	8.80
France/NL	£2.99	2.99	2.94	2.94	2.98	3.01
NL/UK	£3.14	3.17	3.15	3.32	3.33	3.28

*For screen sizes ten non-overlapping groups were used, each of which had observations in each country.

Tables 5 and 6 summarize some of the results from Tables 2 and 4. Results from the hedonic dummy variable approach using OLS and WLS estimators are given in Table 6. The TV parities generated from the dummy variable hedonic equations in Table 1 are transitive. The parities are presented in two forms, as national currencies per £ and francs per guilder, and as a price level with the U.K. or Netherlands as 100. The price levels are the parities divided by the exchange rate expressed as a percentage of the base country. Table 6 also includes EKS parities that are transitive. However, the SEHI results in Table 6 are not transitive.

As described earlier, one way to produce multilateral parities from the SEHI results is to follow the procedure that Robert Hill has advocated. That is to use a minimal spanning tree that chooses a chain of binary comparisons which minimizes the Paasche-Laspeyes spread over all possible chains. With only three countries, the possible chains are few. In fact, there is little to choose between France and the U.K., but we believe France has a small claim to be the node to link the U.K. and the Netherlands. Thus the entry in the fourth column of Table 6 is the derived NL/UK fl/£ parity that is transitive with the FR/UK and FR/NL comparison. For comparing multilateral results, the first three columns are used for OLS and WLS hedonic regression estimates, being naturally transitive. The SEHI multilateral comparisons use the first two columns of Table 6, FR/UK and FR/NL and the fourth NL/UK node that is compiled to be transitive, as opposed to the initial third column estimate. Transitivity may also be achieved in this multilateral

TABLE 6

SUMMARY OF BINARY AND MULTILATERAL RESULTS

	FR/UK fr/£	FR/NL fr/fl	NL/UK fl/£	Node (NL/UK) fl/£	UK = 100 FR/UK	UK = 100 FR/NL	NL = 100 NL/UK
Hedonic regression estimates							
OLS estimator	8.76	4.15	2.11		87.9	145.6	60.3
WLS estimator	8.55	4.09	2.09		85.8	143.5	59.7
Fisher indices: screen size/flat screen/Nicam stereo							
SEHI	8.67	2.94	3.15	2.95	87.0	103.1	90.1
EKS	7.66	2.70	2.84		76.8	81.2	94.7
Multilateral: super-country reference	9.16	0.91	3.15		91.8	101.9	90.1
Fisher indices: make/screen size/outlet type							
SEHI	8.80	3.01	3.28	2.92	88.3	105.6	93.7
EKS	9.15	3.16	2.90		91.8	82.9	110.8
Multilateral: super-country reference	9.36	2.93	3.19		93.9	102.9	91.2
Average June/July exchange rates	9.97	2.85	3.50				

framework for SEHI using the super-country reference described above, results being presented for aggregation by size/flat screen/Nicam.

First, Table 5 shows that the selection of core characteristics for the Laspeyres, Paasche and Fisher aggregation is not of great importance. The estimates for NL/UK, aggregated in (3a) by size/flat screen/Nicam with little loss of data, compared with an aggregation by make/size/outlet-type with significant data loss, are 3.15 and 3.28 respectively. The correction for the other characteristics in (3b) seems to work—it makes up for what is not included in (3a).

Second, the results show the Laspeyres-Paasche spread to be very small. It has to be borne in mind that the expenditure weights applied are up-to-date actual data covering just about all transactions. They do not suffer from differences in weighting patterns that might arise from the manner in which the sample is selected or imprecision from sampling errors.

Third, Table 6 compares the OLS and WLS hedonic results and these are very similar. However, they differ quite substantially from their more sophisticated counterparts, the Fisher SEHI estimates. For example, for FR/NL the estimates using OLS regression and SEHI are 4.15 and about 3 respectively.

Fourth there is some difference in the estimates for FR/UK using multilateral Fisher estimates based on a super-country reference: 8.67 and 9.16 respectively for the size/flat screen/Nicam aggregation and 8.80 to 9.36 for the make/size/outlet aggregation. This difference is of the same order as those obtained for the differences for NL/UK when using a SEHI approach and a node for France using Hill's spanning tree to convert to a multilateral framework—for example, 3.15 for the SEHI and 2.95 for the multilateral formulation. Finally, while EKS and Fisher indices are of the same broad order of magnitude, some differences, for example for FR/UK, by size/flat screen/Nicam of 8.67 and 7.66 are notable.

The results are generally quite close. If such findings continue there may be a case for using more straightforward dummy hedonic estimates, which are transitive. They are also quite close to the currency exchange rates for all three countries concerned.

6. Conclusions

This paper has explored the use of scanner data and hedonic methods to estimate country parities. Prices of unmatched items were included in the sample since the hedonic regression controlled for quality variations. Fixler and Zieschang (1992), Feenstra (1995) and Diewert (2002) have developed frameworks for superlative hedonic comparisons and such frameworks were successfully adapted for use in this study. Scanner data have substantial benefits over matched data collected by price collectors. These include their coverage and the availability of weights, along with data on quality characteristics to account for quality differences across countries. There is, to the authors' knowledge, no application of the use of these hedonic techniques and such data for this purpose. The advantages of the data demand the development of appropriate techniques for its use.

A variant of Feenstra's (1995) approach was adapted to meet the special needs of scanner data for inter-country analysis. The importance of using core variables, which can be matched across countries, and thus not lose much information, was identified as was the closeness of Laspeyres and Paasche-type bounds for the preferred Fisher index. The extension to multilateral comparisons was also undertaken, as were comparisons of the EKS and Fisher results.

The results from the dummy variable hedonic tests of constancy of coefficients are also of interest. Statistical offices in one country may be tempted to use hedonic regression results from other countries to adjust for quality differences. Such tests show that coefficients can differ between close European countries. Scanner data of the sort discussed are available on a cross-country and pooled time series basis and a natural extension of the work is the integration of consumer price indices and international price indices.

Finally, the study here has focused on the use of scanner data. However, the principles and methods apply to any data source as long as characteristics on the item are collected along with the prices. It is emphasized, especially given the forthcoming International Comparison Programme, that methods based on matching run the risk in many product areas of excluding unmatched items. Silver and Heravi (2002) have shown for CPI analysis that such excluded prices are quite different from the matched prices, and their exclusion leads to significant bias. Zieschang *et al*. (2001) advised the use of checklists to collect quality characteristics on samples of prices. Such samples need not be matched since the hedonic frameworks outlined above, along with the data on quality characteristics from the checklist, allows the effect on prices of differences in quality to be controlled for.

References

Balk, B., "On the Use of Unit Value Indices as Consumer Subindices," in B. Balk (ed.), *Proceedings of the International Working Group on Price Indices*, Voorburg: Statistics Netherlands, 1996a.

———, "A Comparison of Ten Methods for Multilateral International Price and Volume Comparisons," *Journal of Official Statistics*, 12, 199–222, 1996b.

———, *Aggregation Methods in International Comparisons: What have we Learned?* Report Series, Research in Management, Erasmus Research Institute of Management, Erasmus University, Rotterdam, 2001.

Berndt, E. R., Z. Grilches, and N. J. Rappaport, "Econometric Estimates of Price Indices for Personal Computers in the 1990s," *Journal of Econometrics*, 68, 243–68, 1995.

Dalén, J., "Experiments with Swedish Scanner Data," *Proceedings of the Third Meeting of the International Working Group on Price Indices*, Research Paper no. 9806 (ed. B. Balk), pp. 163–8, Statistics Netherlands, 1998.

Diewert, W. Erwin, "Axiomatic and Economic Approaches to International Comparisons," in Heston and Lipsey (eds), *International and Inter-area Comparisons of Prices, Output and Productivity*, Committee on Research on Income and Wealth, NBER, University of Chicago Press, Chicago, 1999.

———, "Hedonic Regressions: A Consumer Theory Approach," in Mathew Shapiro and Rob Feenstra (eds), *Scanner Data and Price Indexes*, National Bureau of Economic Research, Studies in Income and Wealth, Vol. 61, University of Chicago Press, Chicago, 2002.

Elteto, O. and P. Koves, "On an Index Number Computation Problem in International Comparisons" (in Hungarian), *Statisztikai Szemle*, 42, 507–18, 1964.

Feenstra, R. C. "Exact Hedonic Price Indices," *Review of Economics and Statistics*, LXXVII, 634–54, 1995.

Fenwick, D., A. Ball, M. Silver, and P. Morgan, "Price Collection and Quality Assurance of Item Selection in the Retail Prices Index: How can Scanner Data Help," in M. Shapiro and R. Feenstra (eds), *Scanner Data and Price Indices*, National Bureau of Economic Research, Studies in Income and Wealth, Vol. 61, Chicago: University Press, 2002.

Fixler, D. and K. Zieschang, "Incorporating Ancillary Measures of Processes and Quality Change into a Superlative Productivity Index," *Journal of Productivity Analysis*, 2, 245–67, 1992.

Goldberger, A. A., "The Interpretation and Estimation of Cobb-Douglass Functions," *Econometrica*, 35, 3–4, 464–72, 1968.

Gordon, R. L., *The Measurement of Durable Goods Prices*, University of Chicago Press, Chicago, 1990.

Griliches, Z., "Hedonic Price Indices and the Measurement of Capital and Productivity: Some Historical Reflections," in E. R. Berndt and J. E. Triplett (eds), *Fifty Years of Economic Measurement: The Jubilee Conference of Research in Income and Wealth*, *Studies in Income and Wealth*, Vol. 54, NBER. University of Chicago Press, Chicago, 185–206, 1990.

Haan, J. de and E. Opperdoes, "Estimation of the Coffee Price Index Using Scanner Data: The Choice of the Micro Index." *Proceedings of the Third Meeting of the International Working Group on Price Indices*, Research Paper no. 9806, ed. B. Balk, Statistics Netherlands, 191–202, 1997.

Hill, R. J., "International Comparisons Using Spanning Trees," in Alan Heston and Robert E. Lipsey (eds), *International and Inter-area Comparisons of Prices*, *Output and Productivity*, Committee on Research on Income and Wealth, NBER, University of Chicago Press, Chicago, 109–22, 1999.

Hoffmann, J., "Problems of Inflation Measurement in Germany," *Economic Research Group of Deutsche Bundesbank*, Discussion Paper 1/98, Deutsche Bundesbank, Frankfurt, 1998.

Ioannidis C. and M. Silver, "Estimating Exact Hedonic Indexes: An Application to UK Television Sets," *Journal of Economics, Zeitschrift Für NationalÖkonomie*, 69, 1, 1999.

Kokoski, Mary F., Brent R. Moulton, and Kimberly D. Zieschang, "Inter-area Price Comparisons for Heterogeneous Goods and Several Levels of Commodity Aggregation," in Alan Heston and Robert E. Lipsey (eds), *International and Inter-area Comparisons of Prices, Output and Productivity*, Committee on Research on Income and Wealth, NBER, University of Chicago Press, Chicago, 1999.

Lowe, R., "The Use of the Regression Approach to Quality Change for Durables in Canada," paper presented at the Fifth Meeting of the International Working Group on Price Indices in Reykjavik, Iceland, August 26, 1999 (available on http://www4.statcan.ca/secure/english/ottawagroup/meet.htm).

Moulton, B., T. J. LaFleur, and K. E. Moses, "Research on Improved Quality Adjustments in the CPI: The Case Televisions," in W. Lane (ed.), *Proceedings of the Fourth Meeting of the International Working Group on Price Indices*, Bureau of Labor Statistics, Washington, D.C., 77–99, 1998.

Rao, D. S. Prasada, "Weighted EKS and Generalised CPD Methods for Aggregation at Basic Heading Level and Above Basic Heading Level," Paper presented at the Joint World Bank–OECD seminar on Purchasing Power Parities, Recent Advances in methods and applications, Washington, D.C., January 30–February 2, 2001.

Richardson, D., "Scanner Indices for the CPI," Conference on use of Scanner Data in CPI, NBER and Conference on Research in Income and Wealth, Washington, 15–16 Sept, 2000, in M. Shapiro and Rob Feenstra (eds), *Scanner Data and Price Indices*, National Bureau of Economic Research, Studies in Income and Wealth, Vol. 61, Chicago University Press, Chicago, 2000.

Rosen, S., "Hedonic Prices and Implicit Markets: Product Differentiation and Pure Competition," *Journal of Political Economy*, 82, 34–49, 1974.

Saglio, A., "Comparative Changes in Average Price and a Price Index: Two Case Studies," in L. M. Duchare (ed.), *Proceedings of the First Meeting of the International WorBing Group on Price Indices*, Statistics Canada, Ottawa, 1995.

Silver, M., "Elementary Aggregates, Micro-Indices and Scanner Data: Some Issues in the Compilation of Consumer Prices," *Review of Income and Wealth*, 41, 427–38, 1995.

———, "An Evaluation of the Use of Hedonic Regressions for Basic Components of Consumer Price Indices," *Review of Income and Wealth*, 45, 1, 41–56, 1999.

Silver, M. S. and S. Heravi, "Scanner Data and the Measurement of Inflation," *The Economic Journal*, 111, June, 384–405, 2001.

———, "The Measurement of Quality-Adjusted Price Changes," in Mathew Shapiro and R. Feenstra (eds), *Scanner Data and Price Indices*, National Bureau of Economic Research, Studies in Income and Wealth, Vol. 61, Chicago University Press, Chicago, 2003.

———, "Why the CPI Matched Models Method May Fail Us: Results from an Hedonic and Matched Experiment Using Scanner Data," Paper presented at a Symposium on Hedonic Methods in Price Statistics, Conference on Issues in Price Level Measurement, Statistische Bundesamt and Deutsche Bundesbank, Wiesbaden, Germany, June 2001. Published as *European Central Bank (ECB) Working Paper No. 144*, ECB, Frankfurt, 2002.

Summers, R., "International Comparisons with Incomplete Data," *The Review of Income and Wealth*, March, 1973.

Szulc, B., "Index Numbers of Multilateral Regional Comparisons" (in Polish), *Przeglad Statysticzny*, 3, 239–54, 1964.

Triplett, J. E., "Hedonic Functions and Hedonic Indices," in *The New Palgraves Dictionary of Economics*, 630–4, 1987.

———, "Hedonic Methods in a Statistical Agency Environments: An Intellectual Biopsy," in E. R. Berndt and J. E. Triplett (eds), *Fifty Years of Economic Measurement: The Jubilee Conference on Research in Income and Wealth, Studies in Income and Wealth*, Vol. 56, NBER. Chicago University of Chicago Press, 207–38, 1990.

White, H., "A Heteroskedasticity-Consistent Covariance Matrix and a Direct Test for Heteroskedasticity," *Econometrica*, 48, 721–46, 1980.

Zieschang, K. D., P. A. Armknecht, and D. Smith, "Integrating Inter-area and International Price Comparisons with Consumer Price Index Compilation," Joint World Bank-OECD Seminar on Purchasing Power Parities: Recent Advances in Methods and Applications, Washington D.C., January 30–February 2, 2001.