# Occupational Gender Segregation: Index Measurement and Log Linear Models

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ABSTRACT

Empirical studies of gender segregation by occupation must be founded on rigorous measurement procedures. There appears to be a consensus that any indexes which are employed in the analysis of time series or international cross section employment data must be either margin free or decomposable to yield a margin free component. On the other hand, Charles and Grusky (1995) advocate the use of multiplicative log models, from which a margin free odds ratio can be derived. In this paper the construction and interpretation of the Dissimilarity and Karmel/Maclachlan indexes are contrasted with the multiplicative modelling of gender segregation and the associated log index.

Keywords: **GENDER SEGREGATION, SEGREGATION INDEXES, LOG LINEAR MODELS.**

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## Introduction

Occupational gender segregation remains a serious area of inquiry for social scientists (see the special issues of the *Review of Radical Political Economics*, September 1993 and *the Journal of Econometrics*, March 1994, and recent studies by King 1992; Charles 1992; Charles and Grusky 1995; Nermo 1996; Watts and Rich 1991; 1992a,b, 1993 and Watts 1995a).

The pre-eminence since 1955 of the Index of Dissimilarity in the study of occupational and residential segregation has been challenged in recent years. Watts (1992) advocates the use of the Karmel and Maclachlan (IP) index (Karmel and Maclachlan, 1988). By contrast, Charles (1992) and Charles and Grusky (1995) adopt a structural approach in their cross country studies, in which their index of segregation is based on a log multiplicative model.[i]

There appears to be agreement amongst researchers that, along with other properties, a measure of segregation should be margin free to enable rigorous cross section and time series comparisons.

In this paper, it is argued that the IP index has a number of desirable properties, which make it a more appropriate index for use in studies of gender segregation by occupation than either the Index of Dissimilarity or Charles and Grusky's log (CG) index. Second, despite the emergence of model based approaches, index measurement remains an integral component of national, and to

a lesser extent, cross national studies of gender segregation. The use of an appropriate index to measure quantitative changes in segregation over time informs and provides focus for complementary forms of analysis, including case studies, other descriptive statistics and possibly econometric analysis.[ii]

The desirable properties of an index of gender segregation are explored in the next section. The properties of the Dissimilarity, IP and CG indexes are examined in the following section. The potential for decomposing these indexes to reveal the contributions of different groups of occupations to the overall level and change in the pattern of segregation is also considered. The econometric modelling of gender segregation is subjected to scrutiny, with reference to the work of Charles and Grusky (1995). By way of illustration, index magnitudes are calculated based on UK employment data by employment and gender for the period 1979-92. Concluding comments are in the final section.

## The Measurement of Occupational Gender Segregation

The type of empirical investigation of gender occupational segregation being undertaken will influence the methodology which should be adopted. Most empirical studies take the form of a time series analyses of an individual country (see Beller 1985, Karmel and Maclachlan 1988, King, 1992, OECD. 1985, Rubery 1988, Watts and Rich 1991; 1992a,b, 1993; Watts 1995a) but cross country studies have been undertaken (see Charles 1992, Charles and Grusky 1995, and Jacobs and Lim 1992). Index measurement has characterized the time series

studies and the combination of regression analysis and index computation in the work of Charles and Grusky and Jacobs and Lim.

Occupational gender segregation is said to exist when women and men are differently distributed across occupations than is consistent with their overall shares of employment, irrespective of the nature of job allocation (Jonung, 1984, p.45). An index of gender segregation can be viewed as measuring the extent to which men and women are unevenly distributed across occupations (see Massey and Denton, 1988). Explicit in the calculation of an index is the specification of a counterfactual, integrated distribution of employment by occupation and gender.

Denote the employment distribution by gender and occupation by the n*2 matrix N where

$$N = \begin{bmatrix} F_1 & M_1 \\ F_2 & M_2 \\ \cdots & \cdots \\ F_n & M_n \end{bmatrix}$$

and $F_j$ ($M_j$) denotes the number of females (males) in occupation j (j =1,...,n). Denote an index of segregation as S(N).

A gross index of occupational gender segregation should satisfy the four criteria of Organization Equivalence, Size Invariance, Gender Symmetry and the Principle of Transfers in its weak form (Watts 1992, pp. 476-77).

If an index is unaffected either by the combination of two occupations which have an identical pattern of segregation or by the division of a single group of occupations into units with identical segregation patterns, then it exhibits Organization Equivalence. Size Invariance refers to the invariance of the index when the populations are changed proportionately, so that $S(\lambda N)=S(N)$ where $\lambda$ is a positive scalar.

The magnitude of a Gender Symmetric index is unaffected by say replacing female employment or share data by corresponding male numbers and vice versa in the index definition (see Siltanen 1990, p.12). Otherwise there are two values for the index and movements in the values may be contradictory (Karmel and Maclachlan, 1988, p.188).

The strong Principle of Transfers requires that segregation declines when say a female worker moves from a female dominated occupation[iii] to a less female dominated occupation and is replaced by a male worker from the latter occupation, *ceteris paribus*, so that the occupational structure and overall gender composition of employment are unchanged (Watts 1992, Siltanen 1990, pp.8-9).

The Principle of Transfers in its weak form requires that the transfer of a female employee from a female dominated occupation to a male dominated one and her replacement by a male employee from the male dominated occupation leads to a decline in the index, because both occupations have become less gender

dominated. The weak form of the Principle of Transfers is satisfied by many linear indexes, including the Dissimilarity Index and the IP Index.

The evaluation of different indexes, based solely on these four criteria, is inadequate, if it is desired to track trends in the pattern of occupational gender segregation in a time series analysis, because, over time, the overall gender shares of employment change, which are generally accompanied by a change in the distribution of employment across occupations. Likewise, simple cross country comparisons of gender segregation would be biased by differences in the overall gender shares of employment and shares of employment by occupation.

Accordingly many economists and sociologists argue that the gross index of gender segregation employed in empirical studies should be margin free, so that changes in its magnitude over time are independent of the interrelated changes in the overall gender shares of employment and the occupational structure (see, for example, Blackburn et al 1993,1995 and Charles, 1995). This requires that the gross index itself is characterized by both Composition Invariance and Occupations Invariance. Composition Invariance refers to the invariance of the index, following uniform, percentage changes in the number of males and females in each

occupation reflecting the overall, but typically unequal, percentage changes in male and female employment, so that

(2)

where $\Lambda$ denotes a diagonal matrix, whose elements $\lambda_i > 0$ (i = 1,2).

Occupations Invariance requires that the measure of segregation be invariant to changes in the relative size of occupations, if the gender composition of these occupations remains constant. Consider the n*n diagonal matrix, $\Gamma$, whose jth diagonal element is written $\gamma_j > 0$, (j = 1,2,….n) then the condition of Occupation Invariance can be written as

$$S(\Gamma N) = S(N) \qquad (3)$$

An alternative view is that temporal changes in the chosen gross index of segregation, which satisfies the first four criteria described above, should be decomposed to reveal a margin free component (Composition Effect).[iv] Advocates of index decomposition include Blau and Hendricks (1979), Jonung (1984), Beller (1985), OECD (1985), Rubery (1988) and Watts (1992). Composition and Occupations Invariance, in addition to the other four criteria, are very demanding requirements for a gross index of gender segregation, so that the adoption of a decomposition procedure warrants serious consideration.

Finally, rigorous comparisons of index magnitudes in both time series or cross section studies require compatible occupational definitions and hence equal numbers of occupations. This problem is acute both in time series studies which must confront the emergence of new occupations, as well as in cross-country studies in which the need for compatible occupational definitions generally confine studies to a limited number of aggregated occupations. A consistent

classification of occupations can be achieved, albeit with difficulty, either by the exclusion of some occupations or through combining them with compatible ones.[v]

## Indexes of Gender Segregation

### Index of Dissimilarity

Despite the emergence of new methods of analysis, the Index of Dissimilarity remains an important form of measurement, particularly in the United States, (see, for example, Albelda 1986, p.405; Jacobs 1993; King 1992, p.31; Cherry and Mobilia 1994).

The Index of Dissimilarity can be written as

$$ID = (1/2)\sum_j \left|(F_j / F) - (M_j / M)\right| \qquad (4)$$

where $F_j$, $M_j$ denote the number of female and male employees in the jth occupation and F,M are total female and male employment, respectively. The Index satisfies four criteria, namely Organization Equivalence, Size Invariance, Gender Symmetry and the Principle of Transfers in its weak form.

White (1985, p.202) claims that the index, when applied to residential segregation, 'is easily interpreted as the percentage of one group which would have to change residences in order to produce an even distribution' (see also, Albelda 1986, p.405; Massey and Denton 1988, p.284; King 1992, p.31; Rubery and Fagan 1995, p.239, Charles and Grusky 1995, p.933; Nermo 1996, p.322). Cortese, Frank and Cohen (1976, pp.634-35) demonstrate that the ID index

represents the share of either group that must be removed, *without replacement*, to achieve zero segregation. All excess (fe)males in (fe)male dominated occupations are culled, so that the distribution of employment associated with gender integration, explicit in the ID measure, differs in its occupational structure from the actual employment distribution. Hence the ID index is inappropriate to measure trends in gender segregation (see also Watts 1992).

The ID index fails to exhibit Occupations Invariance, but exhibits Composition Invariance. The standardized ID Index is Occupations Invariant, but is not Composition Invariant (Charles and Grusky, 1995, p.935).

The Index of Dissimilarity has been decomposed to counter the absence of Occupations Invariance (see Blau and Hendricks 1979, Beller, 1985, p.238, OECD 1985, p.68, Rubery, 1988, p.13), but Watts (1992, pp.481-482) argues that these approaches are flawed.

The recent innovations with respect to the analysis of gender segregation can be seen as a response to these problems. Two solutions to the problems of index definition can be identified in the literature, namely (i) the construction of a margin free index; and (ii) the development of a procedure to decompose a ‘satisfactory' index of segregation.

Charles' Structural Index

In a cross-national study Charles and Grusky (1995) adopt log-multiplicative specifications to identify gender specific, occupation specific and national factors. The logarithmic CG index is utilized which takes the form

$$CG = \exp\left\{(1/n)\sum_{j=1}^{n}[\ln(F_j/M_j) - \{(1/n)\sum_{j=1}^{n}\ln(F_j/M_j)\}]^2\right\}^{1/2} \quad (5)$$

The index is gender symmetric but the (geometric) mean female to male ratio is highly sensitive to the degree of occupational disaggregation, because the approach entails the standardizing of the occupations to equal size. Consider dividing an occupation into m equal sized occupations (m>1) with the same gender composition, then each of these m (equal) female to male ratios would have equal weight as the gender ratios of the other n-1 occupations in the mean ratio computation, in addition to increasing the number of occupations in the calculation by m-1, thereby biasing the computation. Hence this index does not exhibit Organization Equivalence. It does exhibit Occupations Invariance, due to the standardisation of the occupations, and also Composition Invariance.

All index computations are sensitive to the extent of occupational disaggregation, since the aggregation of occupations tends to hide outlying gender ratios (aggregation bias). In a time series study with compatible occupation definitions, the logarithmic index tends to exhibit significant fluctuations, due to the sensitivity of its magnitude to the gender ratio. Indeed, if an occupation is completely segregated with zero (fe)male employees, the logarithm of the gender ratio is not defined, which makes inter-temporal comparisons of index magnitudes

difficult, unless these occupations are either combined with others or removed from the calculations.

On the other hand, in cross-national studies this problem is less acute, because the number of occupations under study is usually small, due to the difficulties of reconciling the different classifications across countries. The variance of employment, even across the major occupations, is significant, however, (see Charles and Grusky, 1995, Table A1, p.964). Also, the suppression of cross-national differences in the disaggregated occupational structure leads to little insight being gained about differences in the pattern of gender segregation.

Charles and Grusky (1995) analyse 6 major occupations in their cross country study but are able to examine compatible data for 45 occupations for Japan and the USA. The minimal disaggregation of occupations is justified for all countries by showing that, for these two countries, disaggregation makes little difference to the results. This test provides no guidance as to whether the limited disaggregation makes any difference for other countries in their study for which detailed, compatible occupational data are not available.

The Karmel and MacLachlan Index

Karmel and Maclachlan (1988, p.188) define their index as

$$IP = (1/T)\sum_{j=1}^{n}\left|Fj - a(Mj + Fj)\right| \qquad (6)$$

where T, a, are total employment and the female share of total employment and $F_j$, $M_j$ are as defined. The number of females in occupation j under occupational integration would be $a(M_j + F_j)$. Thus the index denotes the total level of employment that would have to relocate with replacement to achieve zero segregation by gender, but maintaining the occupational structure and the overall gender shares of employment. Underpinning the index calculation is a counterfactual distribution of employment with an integrated structure of employment and the same overall gender and occupational shares. The index has a simple interpretation, in contrast to the Index of Dissimilarity. An oblique reference is made to the IP index by Duncan and Duncan (1955, p.211).

The IP index exhibits Organization Equivalence, Size Invariance and Gender Symmetry. The IP computation is also linear and again based on the distinction between female and male dominated occupations, so that the weak Principle of Transfers holds. The IP and ID indexes are simply related:

$$IP = 2a(1-a)ID \tag{7}$$

The index is neither Composition Invariant, nor Occupations Invariant.[vi] Karmel and MacLachlan (1988, pp.190-191) show how a temporal change in their index can be decomposed into Composition and Mix Effects where the latter can divided into Occupation, Gender and Interaction Effects (see Appendix). Caution must be exercised in drawing inferences from the Occupation and Gender Effects, however, due to the presence of the Interaction Effect.

The Composition Effect, which is based on the difference between the IP index magnitudes of the transformed period one distribution of employment and the period two distribution, picks up the impact of the change in the gender composition of individual occupations and excludes the impact of the change in the occupational structure and the related change in the overall gender shares between the two periods (Watts 1993, p.317). Thus, the Composition Effect is both Composition and Occupations Invariant, and hence margin free. It is expressed as a percentage of the average index values thereby revealing the rate of change of the index magnitude.[vii]

The IP index and its decomposition are less well suited to cross national studies. If researchers can construct a coherent and reasonably detailed classification of occupations, common to all countries, some insights can be gained by cross-section comparisons of countries through the calculation of pairwise IP Composition Effects. By definition, these rankings are independent of the differences in the overall gender shares of employment and the associated occupational structures, but are not necessarily transitive across countries, so it may not be possible to establish a unique and consistent ordering of countries at a point in time.[viii]

## Segregation within Occupational Groups

The Karmel and Maclachlan approach can been extended to analyze groups of occupations within the overall structure of employment (see studies by

Watts and Rich, 1992a, 1993 and Watts, 1995a). These calculations are straightforward using the KM Index, since it can be written as a weighted sum of the normalised contributions of the individual Occupational Groups (OGs):

$$IP = (1/T)\sum_{j=1}^{n}\left|F_j - a(F_j + M_j)\right| = \sum_{I}(T_{OI}/T)\sum_{i\varepsilon I}\left|F_i - a(F_i + M_i)\right| / T_{OI} \qquad (8)$$

where $T_i$, $T_{0I}$ denote total employment in the ith occupation and Ith Occupational Group, respectively.

Further, Composition Effects can be calculated for each OG, which measure the speed of change in segregation within each OG in the context of the overall gender shares and occupational structure of employment (Watts and Rich, 1992a, 1993; Watts, 1995a). This decomposition enables the identification of the source of change in the overall pattern of segregation[ix] and provides some insights to assist in policy prescription. By distinguishing between more and less prestigious and highly paid groups of occupations, the approach overcomes to some degree the criticism of Fossett, Galle and Kelly (1986, p.423) that the Dissimilarity Index (and other indexes of segregation) measure 'nominal differentiation not inequality'.

## Econometric Models

The small number of annual observations under a consistent occupational classification often rules out the use of time series (single country) econometric analysis, due to insufficient degrees of freedom. On the other hand, index computation can be viewed as measurement without theory, so that explanations

of the patterns of change identified by index measurement tend to be speculative. Through bootstrapping or jacknifing techniques, however, confidence intervals can be established for many indexes of segregation to establish the statistical significance of changes over time (cf. OECD, 1985, p.64).

Also the correct calculation of summary statistics across Occupational Groups yields more detailed insights into the source of the overall pattern of change, if not the cause. Further, it should be noted that in calculating these summary statistics across Occupational Groups and in aggregate, the integrity of the data across the individual occupations is not undermined through aggregation, prior to numerical analysis, in contrast to standard econometric time series modelling (e.g. Rubery 1988).

Charles and Grusky (1995) adopt a log-multiplicative model to identify the dominant segregation profiles in a cross-country study of gender segregation.[x] In an earlier paper, Charles (1992) incorporates scalable contextual variables.

The advantage of this approach is that it enables the identification of the causal factors influencing the pattern of gender segregation across countries, through the examination of their statistical significance. In contrast to time series studies, however, this approach is essentially static. Gender segregation is a dynamic process, so that an important dimension is neglected.

Occupational Segregation in Britain 1979-92

British employment data from the Labour Force Survey defined under the revised Warwick Occupational Categories are used to illustrate the properties of the different indexes of segregation. British employment reached a local minimum in 1983 and a local peak in 1990, so the complete sample period, 1979-92 is divided into 3 sub-periods, 1979-83, 1983-90, 1990-92, to reflect the stages of the business cycle.

In Table 1 the index magnitudes, which are based on 76 occupations, are shown for the years, 1979, 1983, 1990 and 1992. The magnitude of the CG index is divided by 10 to make it comparable to the other indexes. With the exception of the CG measure over the 1979-83 recession, the indexes show similar trends.

**Table 1 Index Magnitudes for the ID, IP & CG Indexes for Total U.K. Employment by Gender 1979-92**

| **Year** | **1979** | **1983** | **1990** | **1992** |
|---|---|---|---|---|
| **ID** | 0.657 | 0.648 | 0.599 | 0.580 |
| **IP** | 0.313 | 0.313 | 0.295 | 0.287 |
| **CG** | 0.910 | 0.982 | 0.539 | 0.519 |

Source: UK Labour Force Survey

The similarity of the trends of most of the indexes does not provide a justification for being indifferent about the choice of index used. Other studies, including Karmel and Maclachlan (1988), have shown that indexes can exhibit inconsistent trends.

In Table 2 changes in the IP indexes are subjected to decomposition to establish the Composition Effects. The Composition Effects for the CG Index for the four sub-periods, are calculated as the percentage growth rates of the index magnitudes.[xi]

The average value of the CG index is used as the base of the calculation. The Composition Effect for the upturn, 1983-90, reveals the volatility of the Charles index under a detailed occupational disaggregation.

**Table 2 IP Index Decomposition for Total Employment by Gender 1979-92**

| | INDEX VALUES | | INDEX DECOMPOSITION (%) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $IP_1$ | $IP_2$ | TCH | COMP | MIX | GEN | OCC | G/O |
| **1979-1983** | 0.313 | 0.313 | 0.06 | -0.89 | 0.95 | 0.03 | 1.51 | -0.59 |
| **1983-1990** | 0.313 | 0.295 | -6.08 | -6.14 | 0.06 | -0.87 | 1.69 | -0.76 |
| **1990-1992** | 0.295 | 0.287 | -2.72 | -2.17 | -0.55 | -0.83 | 0.60 | -0.32 |
| **1979-1992** | 0.313 | 0.287 | -8.74 | -9.25 | 0.51 | -1.71 | 3.80 | -1.58 |
| | $CG_1$ | $CG_2$ | | COMP | | | | |
| **1979-1983** | 0.910 | 0.982 | | 7.61 | | | | |
| **1983-1990** | 0.982 | 0.539 | | -58.25 | | | | |
| **1990-1992** | 0.539 | 0.519 | | -3.78 | | | | |
| **1979-1992** | 0.910 | 0.519 | | -54.72 | | | | |

Notes: $IP_1$, $IP_2$ denote the initial and final values of the Karmel and Maclachlan index.
$CG_1$, $CG_2$ denote the initial and final values of the Charles and Grusky index
TCH denotes Total % change in the index magnitude;
COMP denotes (%) Composition Effect;
MIX is the (%) Mix Effect, which is subdivided into the Occupation (OCC), Gender (GEN) and Gender/Occupation (G/O) Effect.
Source: see Table 1.

Movements in the IP index disaggregated into the 4 Occupational Groups are reported in Table 3. The Clerical, Service and Sales (CS) Occupational Group is the most segregated, followed by the Skilled Blue Collar (SK), the Unskilled

(US) and Professional and Managerial (PM) (see Watts and Rich, 1992b for a definition of these Occupational Groups). In 1992, for example, 33.3% of the Clerical, Service and Sales workforce needed to be relocated to achieve a structure of employment across these occupations, consistent with the gender shares of overall employment, as compared with only 19.6% of the Professional and Managerial group.

**Table 3 IP Index Magnitudes and Composition Effects by Occupational Group**

| | PM (28) | | CS (21) | | SK (10) | | US (17) | |
|---|---|---|---|---|---|---|---|---|
| | Share | $IP_I$ | Share | $IP_I$ | Share | $IP_I$ | Share | $IP_I$ |
| **1979** | 0.239 | 0.226 | 0.305 | 0.358 | 0.193 | 0.344 | 0.262 | 0.317 |
| **1983** | 0.283 | 0.222 | 0.309 | 0.359 | 0.175 | 0.364 | 0.233 | 0.326 |
| **1990** | 0.321 | 0.196 | 0.320 | 0.344 | 0.154 | 0.377 | 0.205 | 0.311 |
| **1992** | 0.344 | 0.196 | 0.331 | 0.333 | 0.139 | 0.377 | 0.186 | 0.306 |
| **Composition Effects** | | | | | | | | |
| **1979-1983** | -4.88 | | 1.01 | | 1.69 | | -2.72 | |
| **1983-1990** | -11.37 | | -4.07 | | -2.93 | | -7.48 | |
| **1990-1992** | -2.03 | | -3.00 | | -1.19 | | -1.66 | |
| **1979-1992** | -18.74 | | -6.08 | | -2.54 | | -11.26 | |

Source: see Table 1.
Notes: The bracketed numbers in the column headings denote the numbers of occupations in each group.

Over the period 1979-92 occupations in the Professional and Managerial OG showed the fastest rate of decline in net segregation, as measured by the Composition Effect, followed by the Unskilled occupations. On the other hand, the occupations which were highly segregated in 1979, namely Clerical, Service and Sales and Skilled Blue Collar, integrated most slowly over the period. Net segregation only declined in the Professional and Managerial and Unskilled

occupations during the first downturn. By contrast, over the upswing of 1983-89, integration occurred across all four groups with the greatest reductions again in Professional and Managerial and Unskilled occupations. The recent recession, 1990-92 was qualitatively different with modest declines in segregation across all the OGs. Further discussion of these results is beyond the scope of this paper.[xii]

## Conclusion

The study of gender segregation remains an important area of academic research. The gender composition of employment by occupation and its evolution over time is the outcome of the complex interplay of economic, social, political and institutional forces, but these cannot be understood and articulated if there is not a coherent means of organizing and reporting the available evidence.

Correctly calculated summary statistics can be a concise means of presenting the dominant trends. Most researchers agree that simple comparisons of index magnitudes either over time or across countries can be misleading, unless either the index is margin free or can be decomposed to identify a margin free element. A number of index measures used in recent studies, including the Index of Dissimilarity, and the CG index, do not possess the appropriate characteristics for measuring the change in the extent of segregation. The CG index is non-linear and gives greater weight to higher segregated occupations, which is not necessarily a desirable feature. Adoption of a particular measure cannot be

justified by the observation that the particular dataset under examination yields similar trends, based on this and other measures.

The Karmel and Maclachlan index has some desirable characteristics for a measure of segregation and has a simple interpretation. The decomposition procedure enables the computation of long term trends in horizontal segregation in the form of (margin free) Composition Effects, differentiated by Occupational Group, without sacrificing the integrity of the data through aggregation.[xiii]

The rigorous measurement of the extent of and change in the pattern of gender segregation is essential, if inferences are to be drawn for policy prescription. The speed of entry of women into atypical occupations is of interest to a number of authors (e.g. Reskin and Roos 1990; Figart and Mutari, 1993). While it is possible to derive confidence intervals for the index through jacknifing and other techniques, index measurement does not identify the causal factors which explain the pattern of change over time.

Log linear models, in particular, are not suited to time series analysis. Also problems arise when time series econometric techniques are applied, due to the large number of occupations under consideration and the lack of degrees of freedom, due to the limited data based on a consistent occupational classification.

The log multiplicative models advocated by Charles and Grusky (1995) can be utilized in cross country studies and assist in identifying dominant

segregation profiles, but the approach is static. Contextual factors can be introduced into the analysis and tested for statistical significance.

A comprehensive cross national study of segregation would embrace both the documentation of trends across countries through index measurement and the use of log-multiplicative models to identify the dominant segregation profiles and significant contextual factors.

The study of gender segregation should not be confined to complex numerical techniques however. Where appropriate, reference should be made to longitudinal surveys, case studies and simple descriptive statistics, but all must be used with care in order to understand these processes and to explore other dimensions of segregation. For example, it is easy for dominant trends to be hidden in a detailed occupation by occupation study, drawing on descriptive statistics.

## Appendix

To decompose changes in their index, Karmel and Maclachlan (1988, pp. 190-91) define two new indexes, which are based on the IP index, namely:

$$IP_A = (1/T_2)\sum_{j=1}^{n}\left|F_{j1} - \bar{a}(F_{j1} + M_{j1})\right|(T_{j2}/T_{j1}) \qquad \text{(A1)}$$

where

$$\bar{a} = \sum_{j=1}^{n} F_{j1}(T_{j2}/T_{j1})T_2 \quad \text{and}$$

$$IP_B = (1/T_2)\sum_{j=1}^{n}\left|(1-a_2)(F_2/F_1)F_{j1} - a_2(M_2/M_1)M_{j1}\right| \qquad \text{(A2)}$$

The index $IP_A$ is obtained by proportionately increasing the number of males and females in each occupation by the percentage increase in the employment level in that occupation from period one to period two. The resulting female share of total employment is denoted by $\bar{a}$. The initial gender composition of each occupation is retained but the share of total employment by occupation is adjusted to that prevailing in period two. The percentage (forward) Occupation Effect is written as $100*(IP_A - IP_1)/(IP_1 + IP_2)/2$.

The index $IP_B$ is calculated by adjusting the numbers of females (males) in each occupation by the increase in total female (male) employment. Thus the overall gender composition of employment corresponds to that of period two. The percentage (forward) Gender Effect is written as $100*(IP_B - IP_1)/((IP_1 + IP_2)/2)$.

A third distribution of employment by gender across occupations is generated by successive transformations of the original distribution by the occupation and gender calculations detailed above. On the first and subsequent odd iterations the levels of female and male employment in each occupation are uniformly adjusted to bring total employment in each occupation equal to that prevailing in period two. On the even iterations the total levels of male and female employment are brought into line with those corresponding to period two by the uniform adjustment of male and female employment in each occupation. The numerical adjustments continue until the gender and occupational structure of the

transformed (period one) gender distribution of employment across occupations converges over consecutive iterations, that is the proportional error is less than 0.025% - with respect to either the gender totals after the occupational transformation or the occupational totals after the gender transformation. Thus the transformed structure of employment has the same occupational shares of total employment and overall gender shares as the period two distribution, but differs in its gender shares of employment across individual occupations. This procedure was devised by Deming and Stephan (1940). Karmel and MacLachlan (1988, p.194) provide an example.

Denoting the index associated with this transformed distribution as $IP_C$, the forward percentage Mix Effect is $100*(IP_C - IP_1)/((IP_1 + IP_2)/2)$. The forward residual Interaction Effect is $((IP_C - IP_1)-(IP_A - IP_1)-(IP_B - IP_1))/((IP_1 + IP_2)/2)$. The percentage forward Composition Effect is $100*(IP_2 - IP_C)/((IP_1 + IP_2)/2)$.

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## Endnotes

[i] Butler (1987), Hutchens (1991), Silber (1989) and Deutsch, Fluckiger and Silber (1994), advocate the use of the Gini coefficient, but, unlike the IP index, it cannot be decomposed to reveal the contribution of different groups of occupations to the overall level and rate of change of segregation. See James and Taeuber (1985) for a discussion of its properties.

Blackburn, Jarman and Siltanen (1993); Blackburn, Siltanen and Jarman (1995), Blackburn, Jarman and Siltanen (1997) advocate the use of the Marginal Matching technique, but see Watts (1994, 1995c, 1997).

[ii] Vertical segregation is not addressed in the paper. Additional issues of measurement are raised. Typically economy wide employment data are based on a classification of occupations by skill rather than hierarchy, so that the exploration of vertical segregation is more suited to case studies.

[iii] An occupation is said to (fe)male dominated if it has a higher (fe)male share of employment than the overall (fe)male share of employment.

[iv] The Composition Effect would be zero, if either the gender composition of each occupation remained unchanged, but the relative size of occupations changed, or the number of females and/or males changed uniformly across occupations.

[v] Massey and Denton (1988) identify five dimensions of residential segregation, namely evenness, exposure, concentration, centralization and clustering. The exposure measure has no obvious relevance to occupational segregation, unless intra-firm employment data are available. The last three measures appear

irrelevant to occupational segregation, because they embrace a spatial dimension, but a number of writers use a socioeconomic or prestige scale as a means of calculating the social distance between male and female employment distributions (see Charles and Grusky 1995, pp. 956-60 and references therein).

[vi] For example, the upper bound of the index is $2MF/T^2$, which is twice the product of the overall male and female shares of employment. This characteristic has been a source of criticism (Jones, 1992, Blackburn et al, 1993, p.355), that is only valid if a satisfactory margin free index can be defined and/or the proposed decomposition procedure for this index is invalid.

[vii] The IP index can also be applied in an innovative manner to determine the contributions of full-time and part-time employment to the overall pattern and rate of change of segregation by total employment (Watts and Rich, 1991,1992b).

[viii] In an incomplete study of gender segregation in the Armed Forces, it was found that, following pairwise comparisons, there was a transitive ordering across the four branches of the services across 38 common occupations, but the ordering was not transitive for groups of occupations.

[ix] For example, Blau (1989) resorts to descriptive statistics, rather than utilise a decomposition procedure, to explain why the rate of integration slowed in the 1980's in the USA, as measured by changes in a normalised Dissimilarity Index.

[x] The particular year used for each country must be chosen carefully, so that all countries are in the same phase of their respective business cycles, because in time series studies the overall level of gender segregation has been shown to be

sensitive to the state of the business cycle (Watts and Rich 1992a, 1993, Watts 1995a).

[xi] The growth formula used was
$CE_{CG} = 100 * (CG_2 - CG_1) / ((CG_2 + CG_1) / 2)$

[xii] A more detailed analysis of the pattern of change in gender segregation in the U.K. over the period 1979-89 can be found in Watts and Rich (1993).

[xiii] A multi-dimensional version of the IP index can be utilized to explore trends in occupational segregation by gender and race (Silber, 1992, Watts, 1995b, 1997b).