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Letter to the Editors

The Measurement of Occupational Gender Segregation

Occupational gender segregation remains a serious area of enquiry for social scientists. Blackburn *et al.* (1995) examined problems in its measurement by comparing the properties of marginal matching (MM) and the sex ratio and dissimilarity indices. In this comment it is argued that their paper has three serious shortcomings.

Measurement criteria

Occupational gender segregation exists when women and men are differently distributed across occupations from what is consistent with their overall shares of employment, irrespective of the nature of job allocation (Jonung (1984), p. 45).

Blackburn *et al.* (1995) confined their discussion of criteria by which to judge indices of segregation to composition and occupations invariance. Their attempt to devise a single summary statistic of overall gender segregation with these properties inhibits the detailed analysis of employment data by gender (see Charles (1992) and Charles and Grusky (1995)).

Watts (1992), pages 476–477, argued that a gross index of gender segregation should satisfy the criteria of organization equivalence, size invariance and gender symmetry, where gender symmetry refers to the invariance of an index when female employment or share data are replaced by corresponding male numbers and vice versa (see also James and Taeuber (1985)).

The requirements of composition and occupations invariance and the strong form of the principle of transfers are unnecessarily restrictive in judging the adequacy of a single value index. If temporal changes in a gross index exhibiting the above three properties can be decomposed to yield a composition effect which is compatible with composition and occupations invariance and the principle of transfers in its weak form, such an index should be used in studies, complemented by other carefully constructed descriptive statistics. (The weak principle of transfers requires that segregation declines when say a female worker moves from a female-dominated occupation to a male-dominated occupation and is replaced by a male worker from this latter occupation, *ceteris paribus*.)

Critique of marginal matching

Despite papers by Blackburn *et al.* (1993, 1994, 1995) and Rubery and Fagan (1995), no proof has been provided to demonstrate that MM is characterized by composition and occupations invariance.

Under the MM procedure, occupations are ordered according to declining female share of employment, so that the most female-dominated occupation appears first. The occupations are divided into 'female' and 'male'. The number of females and males in each group can be summed, thereby creating a 2×2 segregation table as shown below (see Blackburn *et al.* (1995), p. 326):

$$\begin{pmatrix} F_{\mathrm{f}} & M_{\mathrm{f}} \\ F_{\mathrm{m}} & M_{\mathrm{m}} \end{pmatrix} \tag{1}$$

where the subscript denotes the type of occupation; for example M_{f} represents the number of males in the female occupations.

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Symmetry is imposed on this matrix by imposing the cutting (dividing) point between the two groups of occupations such that the number of males in the female occupations equals the number of females in the male occupations, i.e. $M_f = F_m$.

Several summary statistics used in the sociology literature now coincide under this classification of occupations, including ϕ and τ, and the amended dissimilarity and standardized sex ratio indices. The association statistic for MM can be written

$$\mathrm{MM} = F_f/F - M_f/M. \tag{2}$$

Under MM the cutting point between the two groups of occupations is varied to match the changing gender composition of employment over time, so that the corresponding 2×2 segregation table remains symmetric. This typically entails the occupation on the margin being split between the two rows of the segregation table.

Blackburn *et al.* (1993), p. 349, asserted that only under MM can the 'unwanted artifactual effects of this changing composition of the labour force (employment?) be nullified' (see also Blackburn *et al.* (1995), p. 327, and Rubery and Fagan (1995), p. 239). Thus it must be presumed that the gross measure of segregation based on this arrangement of the employment data has the properties of composition invariance and gendered occupations invariance. No numerical or algebraic proof is presented to support this claim.

This measure of segregation changes when say there is an equal percentage increase in the number of female employees in all occupations. The 2×2 segregation table is no longer symmetric, since the number of females in male occupations has increased but the number of males in female occupations has remained unchanged. The new segregation table, before MM, is

$$\begin{pmatrix} (1+\alpha)F_f & M_f \\ (1+\alpha)F_m & M_m \end{pmatrix} \tag{3}$$

where 100α denotes the percentage increase in female employment. MM requires that some of the employees in the male occupations with the highest female share of employment be switched to the female occupations to restore symmetry.

The new segregation table under MM can be represented as

$$\begin{pmatrix} \hat{F}_f & \hat{M}_f \\ \hat{F}_m & \hat{M}_m \end{pmatrix}. \tag{4}$$

If the claims about the properties of MM are correct, then the value of the association statistic is unchanged because of composition invariance, so that

$$\widehat{\mathrm{MM}} = \hat{F}_f/\hat{F} - \hat{M}_f/M = \mathrm{MM} = F_f/F - M_f/M = Z \tag{5}$$

where Z denotes the initial value of the association statistic and

$$\hat{F}_f + \hat{F}_m = (1+\alpha)F, \tag{6}$$

$$\hat{M}_f + \hat{M}_m = M, \tag{7}$$

$$\hat{M}_f = \hat{F}_m. \tag{8}$$

Equations (5)–(8) yields solutions for the new elements of the segregation table, namely

$$\hat{M}_f = \hat{F}_m = \hat{F}M(1 - Z)/\hat{T}, \tag{9}$$

$$\hat{M}_m = M - \hat{M}_f = M(M + \hat{F}Z)/\hat{T}, \tag{10}$$

$$\hat{F}_f = (\hat{F}/\hat{T})\{MZ + F(1 + \alpha)\} \tag{11}$$

where $\hat{T}$ is the new level of total employment.

It can be readily shown, by setting α to 0, that, under MM, the level of female employment in the female occupations, F_f, before the expansion of female employment, can be written

$$F_f = F(MZ + F)/T. \tag{12}$$

The change in female employment in female occupations, after matching the marginals, is

$$\hat{F}_f - (1 + a)F_f = \alpha(1 + \alpha)(1 - Z)F^2M/T\hat{T}. \tag{13}$$

Similarly it can be shown that the corresponding change in male employment in female occupations is

$$\hat{M}_f - M_f = \alpha(1 - Z)FM^2/T\hat{T}. \tag{14}$$

Then the required ratio of female to male employment in the marginal occupation(s) which is transferred in part or in total to the female occupations is given by

$$\{\hat{F}_f - (1 + a)F_f\}/(\hat{M}_f - M_f) = (1 + \alpha)F/M. \tag{15}$$

Hence composition invariance is possible under MM, but only if the overall gender composition of the marginal occupations corresponds to the new overall gender composition of all occupations. Although, for any gender distribution of employment by occupation, there is a unique cutting point, it imposes no constraints on the gender composition of the marginal occupations. Therefore the adoption of MM does not guarantee composition invariance. Watts (1994) has provided an algebraic demonstration of the absence of gendered occupations invariance.

Finally this approach is intuitively unappealing because disaggregated employment data by gender and occupation are suppressed by the construction of the 2×2 table. This is confirmed by the examination of the empirical work in Blackburn *et al.* (1995), pages 327–329. Only limited insights can be gained from the movement over time of a single index. From the perspective of policy formulation, it is important to be able to establish which groups of occupations are integrating and those which are subject to a high and constant level of segregation. The policy maker can then attempt to establish whether there are any impediments to occupational integration in the latter occupations, or whether the observed pattern of segregation is the outcome of relatively free choice, i.e. differences in the gender distributions of work skills and experience.

Recent developments

Siltanen (1990a, b) and Watts (1990) have documented the shortcomings of the sex ratio index. Watts (1992) and Blackburn *et al.* (1993) concur that the dissimilarity index ID fails to exhibit gendered occupations invariance and Watts (1992) has outlined the problems associated with the decomposition of the ID index adopted by researchers, including Organisation for Economic Co-operation and Development (1985) and Rubery (1988). Thus discussion of these indices in a contemporary review is inappropriate, particularly when there have been further developments in index measurement, which are now summarized.

Watts (1992, 1994) demonstrated that the Karmel and Maclachlan index exhibits the desired properties for an index of gender segregation which are outlined above, thereby enabling the isolation of a pure (margin-free) composition effect (see Karmel and Maclachlan (1988)). Also the index can be broken down to identify the contribution to the absolute level and the rate of change of overall segregation of particular groups of occupations through the calculation of index values and composition effects by occupational group (Watts, 1992, 1994), despite the fact that, like the index of dissimilarity and the MM approach, the gross value of the Karmel–Maclachlan index is computed by reference to a 2×2 segregation table. (For example, in Australian, British and US studies, Watts and Rich (1992, 1993) and Watts (1995) have calculated the contribution of four occupational groups, namely professional and managerial, clerical, service and sales, skilled blue-collar occupations and unskilled blue-collar, to the overall pattern of segregation. In contrast with the symmetric segregation table based on MM, the 2×2 segregation table associated with the computation of the gross values of the ID and Karmel–Maclachlan indices is founded on the notion of male and female dominance.)

In cross-national studies of segregation Charles (1992) and Charles and Grusky (1995) adopted log-multiplicative specifications to identify gender-specific, occupation-specific and national factors. By contrast, researchers, including Butler (1987), Hutchens (1991), Silber (1989) and Deutsch *et al.* (1994), advocate the use of different versions of the Gini coefficient because they believe that the Gini measure of income inequality is equally applicable to the measurement of gender segregation (see also Lampard (1994)).

Finally Hakim (1992, 1993a, b, 1994) has introduced a 'new approach' to the measurement of segregation, via a tripartite classification of occupations into female and male dominated and mixed. Jacobs (1995) used this classification in a time series study of mobility.

Conclusion

Blackburn *et al.* (1995) adopted a very narrow perspective about the issues surrounding the measurement of gender segregation and recent developments in measurement. Further their claims about the properties of MM remain unsubstantiated.

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Authors' Response

We are pleased to see that Watts agrees with us to a large extent, although this might not be immediately apparent to the reader. It will be helpful if we indicate where the major areas of agreement are and where his interpretation of our work is mistaken.

He writes favourably of the Gini coefficient which we also think is useful (especially after we established it is a special case of Somers's *D*). He neglects to mention our demonstration that, contrary to his claim, segregation behaves differently from money (Blackburn *et al.*, 1994a). Also, as we have pointed out before, there is a problem that as an occupation's male:female ratio becomes more extreme its contribution to the coefficient increases

geometrically. Since in his favoured Karmel–Maclachlan index KM (formerly known as IP) the increase is linear, as in marginal matching (MM), he presumably would accept our evaluation of the Gini coefficient for this purpose.

Watts agrees with us (Blackburn *et al.* (1995), p. 324) that a segregation measure should have gender symmetry, and that it should meet James and Taeuber's (1985) criteria of organization equivalence and size invariance together with the weak form of the principle of transfers (Blackburn *et al.*, 1993; Siltanen *et al.*, 1995). As these last three are not particularly problematic we simply gave an appropriate reference (Blackburn *et al.* (1995), p. 325).

He accepts our demonstration that most segregation indices can be expressed as statistics of association in a 2×2 segregation table. He even acknowledges that this is so for KM, though he does not go on to acknowledge that KM is simply a weighted version of ID, which he rejects. $\mathrm{KM} = \mathrm{ID}(2n_{1.}n_{2.}/n_{..}^2)$, which has a value which ranges from $\frac{1}{2}\mathrm{ID}$ to $\alpha\mathrm{ID}$, where $\alpha \to 0$, depending on the values of $n_{1.}$ and $n_{2.}$.

It is true that we have not discussed the use of log-linear models for segregation analysis. However, such analysis is, of course, based on the odds ratio, which we show is not suitable for segregation research (Blackburn *et al.* (1995), pages 325–326).

He provides a lengthy proof that MM does not conform to *his* definition of composition invariance, and he makes a similar claim for gendered occupations invariance. However, this is quite irrelevant as he uses a different definition of invariance from ours. This might be a misunderstanding with regard to composition invariance, as he uses the same definition as James and Taeuber (1985), but there can be no such excuse with respect to gendered occupations invariance since we introduced this criterion. In any case this is a curious criticism since KM, which he advocates, does not have these properties in his sense or ours, and he claims that this is unimportant.

He is wrong to believe that a summary statistic 'inhibits' and 'suppresses' analysis or gives 'only limited insights'. Like a median or standard deviation, MM gives important information. In this case it has enabled us to show that previous beliefs about trends in segregation were mistaken. Of course it cannot alone provide a complete analysis, which is why we have elsewhere devoted a chapter (Siltanen *et al.* (1995), chapter 2) to outlining nine complementary analyses. Perhaps Watts has not understood that we have followed the convention of treating these as 'concentration' measures, as distinct from 'segregation' measures such as KM and MM.

One of these analyses entails grouping occupations as male, mixed or female, a strategy also advocated by Hakim (1993). Watts indicates approval of Hakim's strategy, but does not mention that we have also recommended this approach to concentration (not segregation as Watts says).

We have previously pointed out that his notion of decomposing a segregation measure (like other related approaches) is unsound (Blackburn *et al.*, 1994b).

Finally, he berates us for adopting (on sound editorial advice) a specific focus, rather than trying to cram everything into one paper. However, the references indicate that we have other publications where interested readers can pursue some issues further. Watts's complaint is also that we discuss the sex ratio SR, which we had previously shown to be defective, and ID, which he had also shown to be flawed. As we point out in Blackburn *et al.* (1995), these are the most widely used measures of segregation; whether we like it or not they are better known than MM, which we advocate, or KM, which he favours. However, whereas KM was introduced about 30 years ago and subsequently rejected (Jones, 1992), MM was introduced into segregation analysis only in 1990 (Blackburn *et al.*, 1993) and has already been taken up in research for the United Nations, the International Labour Office and the European Community (United Nations, 1995; Siltanen *et al.*, 1995; Rubery and Fagan, 1995).

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