

# **Measuring Occupational Segregation and its Dimensions of Inequality and Difference**

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## **Measuring Occupational Segregation and its Dimensions of Inequality and Difference<sup>1</sup>**

The segregation of populations is an important feature of all societies<sup>2</sup>. The two main bases of segregation, at least as recognised in the industrially developed countries, are ethnicity and gender. Ethnic segregation is frequently measured in relation to residential location. That is, the ethnic segregation is concerned with the extent to which the various ethnic minorities are concentrated in particular areas. Also, ethnic segregation is found in employment, where different ethnic groups tend to work in separate occupations. Gender segregation is also concerned with the tendency to work in different occupations, in this case the separation involving women and men. However, gender segregation is not concerned with residential areas. Here the focus is on gender segregation, though it should be appreciated that much of the discussion is also relevant to ethnic segregation.

The purpose of this paper is to review the current state of knowledge on the measurement of segregation. Over the years many authors have contributed to a valuable body of useful research, with various developments in measurement. However, developments have not been fully integrated, and there has not been agreement on the most appropriate methodological approaches. Furthermore, the treatment of inequality has generally been inadequate. Accordingly the present account draws together the important methodological developments in the analysis of segregation, thereby providing a sound basis for further research.

The first point to note is that gender segregation is inherently symmetrical (Siltanen et al. 1995). In so far as women are separated from men, so are men separated from women in the employment structure under consideration<sup>3</sup>. Similarly the segregation of any two ethnic groups is symmetrical, whether it be in employment or residence.<sup>4</sup> Sometimes segregation has been used as a broad concept to include concentration (eg. Lewis, 1985; Walby, 1997; Anker, 1998). However, concentration is really a distinct concept which measures the proportion of women (or men) in a particular occupation or group of occupations, and is not gender symmetrical. Segregation may be seen as the net result of all the measures of concentration in the relevant occupations. That is, gender segregation is the resultant of the concentrations of women and men in all occupations of the labour force under consideration. The distinction between segregation and concentration appears now to be usually accepted

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<sup>2</sup> Segregation is often used to indicate total separation (the sheep from the goats, etc). However, the technical term, as used here, refers to a variable ranging from zero to total separation (from 0 to 1, or sometimes 0 to 100%).

<sup>3</sup> Sometimes the term segregation has been applied to a hypothetical situation where all occupations have the same number of workers (eg. Charles and Grusky, 2004). However, the present discussion concerns the employment of men and women in real labour markets.

<sup>4</sup> Here we are concerned with segregation of two groups. To explore the separation of several groups at once requires a different methodology.

## The Dimensions of Segregation

While there has been extensive research on segregation, there has been relatively little consideration of the *dimensions* of segregation. Yet an adequate understanding of the nature and significance of segregation requires the measurement of its component dimensions. The vertical dimension measures the *inequality* entailed in the segregation, while the horizontal dimension, being orthogonal to the vertical, measures difference without inequality. The resultant of these two dimensions is segregation as generally understood, which is also known as overall segregation to distinguish it from vertical segregation and horizontal segregation (Blackburn et al, 2000).

While it has become quite usual to refer to 'vertical' segregation, effective measurement has been less common and it is still unusual to treat it as a component dimension of what Blackburn et al have termed 'overall' segregation. Semyonov and Jones (1999: 242) use a sound measure of occupational inequality but don't treat it as an aspect of segregation. They argue 'occupational segregation and occupational inequality should be viewed as two distinct concepts'. More generally inequality is seen as integral to segregation, but even when it is measured directly it is typically not done in a way compatible with overall segregation. For instance, Emerek (2006) uses reasonable but totally different measures for vertical and overall segregation, so there is no way to compare them.

The term 'horizontal' segregation has been used less frequently. In so far as it has been used, it has usually been to refer to overall segregation, with the confusing consequence that the 'horizontal' has a vertical component. Only in the approach discussed here has the term been used in the usual mathematical and common sense way, for a dimension orthogonal to the vertical dimension.

For occupational segregation, whether ethnic or gender, the vertical dimension measures the desirability of the occupations. This is most usefully done with pay or a social stratification measure such as CAMSIS (Blackwell and Guinea-Martin, 2005; Blackburn et al, 2001). For residential segregation the areas included in the analysis have also to be ranked by some measure of desirability. This has not been attempted, but provided occupational data are available, measures of mean pay and stratification can be calculated for the economically active. Other possible measures for the relevant ethnic groups in each area are unemployment levels and mean life-style attainment scores<sup>5</sup>, or some variant of this based on available data. The point is that suitable measures for the purpose can be devised

The horizontal dimension is not measured directly. It is deduced from the values of Overall and Vertical segregation, following Pythagoras, i.e.  $O^2 = V^2 + H^2$  (where O, V and H represent overall, vertical and horizontal segregation respectively). The horizontal dimension is dependent on the vertical dimension; it represents the extent of difference in the absence of the sort of inequality measured by the vertical dimension.

The following discussion is in terms of the measurement of occupational gender segregation.

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<sup>5</sup> A measure exists composed of the type of tenure of the house, whether centrally heated, the density of people per room and the number of cars available to the household (Blackburn et al 1997: 255). The measure is based on the data available in the 1991 British Census.

This is the area where relevant work on the dimensions of segregation has been done. However, the logic can equally be applied to ethnic segregation (Blackwell, 2003).

### Measures of Segregation

There are several measures that have been used in the most influential studies of gender segregation. The different formulae for these segregation measures are related, and they may be simplified, as shown below. This enables us to see just how they are related to each other. It then becomes apparent which measures are most useful. It has also been demonstrated that the Gini coefficient is a limiting case of the correlation measure Somers' D (Blackburn et al, 1994)). This provides the necessary basis for consistent measurement of overall segregation and its vertical and horizontal dimensions.

Firstly it is necessary to set out the notation to be employed throughout. This notation is preferred to the orthodox statistical notation (as used in Blackburn et al 1995) because it is more descriptive and easier to follow for most non-statistician readers. I also set out the abbreviations for the segregation measures.

F = Number of women in the labour force

M = Number of men in the labour force

N = Total number of workers, men and women, in the labour force (F + M)

$F_i$  = Number of women in occupation i, a single occupation (i ranges from 1 to n, where n is the total number of occupations)

$M_i$  = Number of men in occupation i.

$N_i$  = Number of workers in occupation i

G = Gini coefficient for segregation for numerous occupations

MM = Marginal Matching measure

ID = Index of dissimilarity

SR = Sex Ratio

SR\* = Standardised Sex Ratio

WE = WE (Women in Employment) Index

IP = IP Index (also known as the Karmel-Maclachlan Index)

Most of the segregation measures can be expressed in terms of relations in the *Basic Segregation Table*. The table was introduced as early as 1993 by Blackburn et al (1993)<sup>6</sup>, who have used it regularly since then, but most writers still stick to the old, clumsy formulae. The table makes it much simpler to compare the nature of the various measures and appreciate their limitations.

In this table 'Female' occupations are defined as those with a higher proportion of women workers than the proportion in the labour force;  $F_i/N_i$  is greater than  $F/N$ . Similarly 'Male' occupations have a higher proportion of men than does the labour force;  $M_i/N_i$  is more than  $M/N$ . If occupations are ordered by the proportion of women (or men) workers, the cutting point (dividing occupations into 'male' and 'female') is where  $F_i/N_i = F/N$ .  $F_f$  then denotes the sum of 'female'  $F_i$ , where  $F_i/N_i > F/N$ , and thus the sum of all women in the 'female'

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<sup>6</sup> It was actually introduced in the working paper Blackburn et al (1990), but the journal article was not published till 1993.

**The Basic Segregation Table  
Women and Men in 'Female' and 'Male' Occupations**

	Women	Men	
<b>'Female' Occupations</b>	<b>F<sub>f</sub></b>	<b>M<sub>f</sub></b>	<b>N<sub>f</sub></b>
<b>'Male' Occupations</b>	<b>F<sub>m</sub></b>	<b>M<sub>m</sub></b>	<b>N<sub>m</sub></b>
	<b>F</b>	<b>M</b>	<b>N</b>

Note: M<sub>f</sub> denotes the number of men in 'female' occupations, etc.

occupations. Similarly M<sub>m</sub> is the sum of men in 'male' occupations, with corresponding values for F<sub>m</sub> and M<sub>f</sub>. N<sub>f</sub> and N<sub>m</sub> are then the totals of workers in 'female' and 'male' occupations. These values (F<sub>f</sub>, F<sub>m</sub>, M<sub>m</sub> and M<sub>f</sub>) vary over time and 'female' occupations can change to 'male' or, more usually, 'male' occupations can become 'female'.

In general, analyses of segregation have not considered a division into 'female' and 'male' occupations, and consequently have not considered the cutting point. Nevertheless, every index that distinguishes occupations by gender entails a cutting point implicitly. All the most popular measures are those that can be defined in term of the Basic Segregation Table, with an implicit cutting point at the proportion of the labour force who are women (F<sub>i</sub>/N<sub>i</sub> = F/N). This approach is understandable, though it has the disadvantage that the number of women in a labour force, and so the cutting point, varies with demography and many other things. There are, in fact, any number of possible cutting points. Without reflection 50:50 might seem the equality division, and this has been suggested but not used (Hakim 1979). The problem with using 50:50 as a dividing point is that no labour forces are composed of 50% men and 50% women, so it is an unrealistic measuring point. A more useful cutting point is suggested below when we come to the discussion of Marginal Matching.

To demonstrate how the various segregation measures are related to the Basic Segregation Table we start with the traditional complicated formulae and show the mathematical transformation. Other names have sometimes been used for the measures, but the ones used here are the most usual.

*Index of Dissimilarity (ID)*

This index, introduced by Duncan and Duncan (1955), is the most widely used measure of segregation and is particularly dominant in American literature. It has, in fact, reached a level of popular acceptance where it is often presented as *the* way to measure segregation, as though it were completely unproblematic. The index is defined as:

$$ID = \frac{1}{2} \sum |F_i/F - M_i/M|$$

where the modulus | | indicates the positive value of the difference enclosed. The mathematical expression using  $\sum$  and the modulus appears compact but conceals a far less compact reality. The formula has a separate term for every occupation, which gives well over 300 terms in many data sets.

However, the occupations (i) may be divided into 'female' occupations (j) - occupations where

$F_j/N_j > F/N$ , and 'male' occupations (k).

Thus  $\sum F_j = F_f$  and  $\sum M_k = M_m$ .

In 'female' occupations  $F_j/F > N_j/N > M_j/M$

Therefore  $F_j/F - M_j/M > 0$

Similarly  $M_k/M - F_k/F > 0$

$$\begin{aligned} \text{Thus ID} &= \frac{1}{2} \sum |F_i/F - M_i/M| \\ &= \frac{1}{2} \{ \sum (F_j/F - M_j/M) + \sum (M_k/M - F_k/F) \} \\ &= \frac{1}{2} \{ (F_f/F - M_f/M) + (M_m/M - F_m/F) \} \\ &= F_f/F - M_f/M \quad (= M_m/M - F_m/F) \\ &= D_c \end{aligned}$$

the *difference of proportions between columns* of the Basic Segregation Table (c indicating columns for women and men in the table).

#### *The WE Index*

This index was introduced by the OECD in European analysis (OECD 1980; 1985). It is called WE after the OECD's *Women in Employment* report (1980). Gorard (2000) uses  $\frac{1}{2}$ WE, which he calls the Segregation Index. WE may be measured by the formula:

$$WE = \sum |F_i/F - N_i/N|$$

Again the formula has potentially a huge number of terms. With similar algebraic manipulations to those used for ID, grouping occupations as 'male' or 'female' we obtain:

$$\begin{aligned} WE &= 2(F_f/F - N_f/N) \\ &= \frac{2[(F + M)F_f - F(M_f + F_f)]}{FN} \\ &= \frac{2M}{N} \left[ \frac{MF_f - FM_f}{FM} \right] \\ &= \frac{2M}{N} \left[ \frac{F_f}{F} - \frac{M_f}{M} \right] \\ &= \text{ID} \times 2M/N \end{aligned}$$

This measure is not symmetrical between women and men. As it is based on female dominated occupations we may think of it as the female version. The corresponding male version is

$$\text{ID} \times 2F/N,$$

and the mean of the two versions is ID.

The weighting term ( $2F/N$  or  $2M/N$ ) has nothing to do with segregation. It varies independently of segregation and is a distorting term which affects the whole range of values (including the upper limit). Thus it is better omitted, leaving ID.

*The Sex Ratio (SR)*

SR was used by Hakim in one of the first gender segregation analyses of the British labour force. Hakim (1981: 523) described this measure as ‘the difference between the level of over-representation [of women] in typically female jobs and the level of under-representation in typically male jobs’. Thus SR may be thought of as the ratio given by the observed proportion of workers who are of women in female occupation ( $F_f/N_f$ ) divided by the expected proportion of women in these occupations if there were no segregation ( $F/N$ ) less the equivalent ratios (observed:expected) of women in male occupations. Thus, put formally

$$\begin{aligned} SR &= \frac{F_f/N_f - F_m/N_m}{F/N - F/N} \\ &= N/F(F_f/N_f - F_m/N_m) \\ &= N/F \times D_r \end{aligned}$$

Where  $D_r$  is the difference of proportion between rows of the Basic Segregation Table ( $r$  indicating the rows of men and women in ‘male’ and ‘female’ occupations).

Again we see this is a ‘female’ version, with a corresponding ‘male’ version

$$SR_m = N/M \times D_r.$$

Here, however, the mean is not  $D_r$  but  $N^2/2MF$

As with WE, the weighting terms are a distortion which is better omitted.

*Standardised Sex Ratio SR\**

The Sex Ratio may be standardised to measure segregation without the inappropriate weighting, and so to occupy a range from 0 to 1 (Blackburn et al, 1995). The standardised form is

$$SR^* = D_r$$

Thus we have established that ID and  $SR^*$  are the two differences of proportions in the Basic Segregation Table.

*The IP Index*

This index, introduced by Karmel-Maclachlan (1988), also has a multi-term formula which we can simplify<sup>7</sup>. The usual formula is

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<sup>7</sup> IP may be expressed as  $IP = 2\alpha/N$ , where  $\alpha$  is the difference between observed and expected values in the table (expected being the values if there were no relationship). Unlike the other measures this appears to be independent of the marginal totals. However, this is an

$$\begin{aligned}
IP &= \frac{1}{N} \sum \left| M_i - \frac{M}{N} (M_i + F_i) \right| \\
&= \frac{1}{N} \sum \left| M_i \frac{F}{N} - \frac{M}{N} F_i \right| \\
&= \frac{MF}{N^2} \sum \left| \frac{M_i}{M} - \frac{F_i}{F} \right| \\
&= \frac{2MF}{N^2} \times ID
\end{aligned}$$

Similarly

$$IP = \frac{2 N_m N_f}{N^2} \times SR^*$$

It is interesting to note that the weighting of ID in the formula for IP is the inverse of the weighting of the mean of female and male values of SR, illustrating their fundamental difference.

Once again we see there is an undesirable, distorting weighting which is better omitted, leaving ID or SR\*.

#### *Marginal Matching Measure (MM)*

Marginal Matching was originally introduced to measure inequality in education (Blackburn and Marsh 1991). Subsequently it was realised that the inequality relationship between class background and type of school could be conceived as a form of segregation, and the Marginal Matching procedure was introduced to overcome the weaknesses of other segregation measures (Siltanen et al 1995).

It uses a modified Segregation Table. This is the same as the Table shown above, apart from the new definition of male and female occupations, giving different values for  $N_m$  and  $N_f$  and their components  $M_m$ ,  $F_m$ ,  $M_f$  and  $F_f$ . On the axis of occupations ordered by  $F_i/N_i$  we select a new cutting point. Instead of dividing occupations at the cutting point where  $F_i/N_i = F/N$ , the cutting point is chosen to provide matched distributions in the two sets of marginals of the segregation table. This is where 'female' occupations are those employing the highest proportions of women which together contain the same number of workers as there are women in employment, while 'male' occupations are those occupations which together contain the same number of workers as there men in employment.

Thus  $N_f = F$  and  $N_m = M$ , and it follows that  $F_m = M_f$

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illusion as the possible size and the significance of  $\alpha$  depend on the expected values, and so on the marginal totals.



In this symmetrical segregation table several statistics of association now coincide<sup>8</sup>, and are known as MM.

$MM = D_c = D_r = \phi^2 = \eta = \text{Tau}_b$ . Also the Gini is MM, as shown in Figure 1 below.

If and only if the table is symmetrical, i.e. with matched marginals, does  $\text{Tau}_b$  meet the requirements for a completely satisfactory, undistorted correlation coefficient. It can therefore be interpreted as measuring the extent to which the two variables vary together, i.e. the extent to which female occupations are actually staffed by women and male occupations by men. The essential point is that the interpretation is the same for all tables as the numbers of men and women vary.

Variations in the sex composition of the labour force are found from country to country and occur over time. These variations affect the marginals of the segregation table for all the segregation measures. The important difference with MM is that we keep the marginals matched. Changes in the relation between the two sets of marginal totals introduce undesirable changes in the relationships within the table which define the segregation measures. By keeping constant the relationship between the two sets of marginal totals, the matching of the marginals avoids varying marginal effects of changing marginals on measured segregation.

Now we have consistency in the measurement of segregation. On the negative side, the creation of the table to calculate MM is a relatively cumbersome procedure. Furthermore, as with the other measures we have considered, MM is only suitable for measuring overall segregation. Measures of vertical segregation cannot be dichotomised without a serious loss of information. Therefore, when we break segregation down into vertical and horizontal components we need to use the Gini coefficient for the full range of occupations.

### *Gini Coefficient (G)*

The measures based on the Segregation Table (Basic or Modified) are all dichotomous, grouping occupations into 'female' and 'male' categories. In contrast the Gini Coefficient treats all occupations separately (Silber, 1989, 1992, Lampard, 1994). The occupations are ordered by the proportions of men and women workers, as for the other measures, but there is no grouping into two categories of 'Male' or 'Female' occupations; all the information on the separate occupations is retained.

There are several formulae for the Gini Coefficient, all of which appear complicated but we can derive a simpler form. In the formula presented here,  $t$  is used to denote an occupation included in the cumulative total.

$$G = \sum_{i=2}^n \left\{ \sum_{t=1}^{i-1} F_{t/F} \sum_{t=1}^i M_{t/M} - \sum_{t=1}^i F_{t/F} \sum_{t=1}^{i-1} M_{t/M} \right\}$$

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<sup>8</sup> These values of  $D_c$  and  $D_r$  should not be confused with ID and SR\* as they are based on a different table.

$$\begin{aligned}
&= \left[1/F_M\right] \sum_{i=2}^n \left\{ \sum_1^{i-1} F_t \sum_1^{i-1} (M_t + M_i) - \left( \sum_1^{i-1} F_t + F_i \right) \sum_1^{i-1} M_t \right\} \\
&= \left[1/F_M\right] \sum_{i=2}^n \left\{ M_i \sum_1^{i-1} F_t - F_i \sum_1^{i-1} M_t \right\}
\end{aligned}$$

This may seem complicated but can be looked at in terms of ordering pairs of men and women by the ‘femaleness’/‘maleness’ of their occupations. Such ordering of pairs is a common tactic in measuring association (see, for example, Anderson and Zelditch, 1968). We follow the usual convention that P represents all pairs ‘consistently’ ordered and Q represents ‘inconsistent’ pairs. In this case, P includes all pairs of a man and a woman where the occupation of the woman has a higher proportion of workers who are women than does the man’s occupation (i.e. the ordering is consistent with segregation); Q includes pairs where the reverse holds. Then

$$G = \frac{P - Q}{FM}$$

This is **Somers’ D** where the ‘independent’ variable has only two values (here male and female)<sup>9</sup>. Thus we see that *G is also a statistic of association.*

When the occupations are grouped into the two categories of the Basic Segregation Table Somers’ D becomes a difference of proportions; and similarly for the grouping of the modified table. Thus we have

$$G = D_c = ID \text{ and also } G = MM.$$

These forms of the Gini Coefficient are the most suitable for segregation analysis. When we measure the vertical and horizontal dimensions of segregation we need to use every occupation; otherwise there would be a serious loss of information on the two dimensions. Therefore we use the full Gini coefficient for overall segregation. However, when we are only interested in overall segregation the dichotomous measures are suitable, and potentially somewhat better (Blackburn et al, 1994). The two variables, gender and gendered occupations, are internal to the relationship (unlike vertical variables such as pay) and so there is no loss of information in grouping occupations as male or female. Variations in the level of segregation are seen in variations on the diagonal of the table.

### Measuring the Dimensions

The study of overall segregation is important and worthwhile. However, for a full understanding of segregation, and what it entails, we need to consider its orthogonal dimensions of inequality and difference without inequality. Yet, as noted above, this has

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<sup>9</sup> Lieberman’s (1976) Index of Net Difference is the same as Somers’ D, and so the Gini Coefficient.

rarely been done<sup>10</sup>.

If we want to identify the inequality and difference entailed in segregation we need to be able to measure the vertical and horizontal dimensions. In order to do so it is necessary to use measures compatible with the measure of overall segregation. Dichotomous measures such as ID and MM are not suitable for the overall measure as their use would entail the loss of most of the inequality information on the corresponding vertical measure. The only measure we are considering which can be split into vertical and horizontal components is G, the Gini coefficient. Since this is an instance of Somers' D, we use Somers' D to measure the vertical dimension, thus achieving measurement consistent with overall segregation. The difference between overall segregation, O, and vertical segregation, V, lies in the ordering of occupations. When Somers' D is the Gini coefficient the ordering of occupations maximises D; that is, the ordering of occupations is in terms of the ratio of the non-occupation variable - the gender ratio. The ordering is from the highest to the lowest proportion of women (or vice-versa). For the vertical dimension the data are the same but the ordering of occupations is now in terms of the vertical measure - which most usefully is pay or the stratification measure CAMSIS. For instance occupations are ordered from the lowest paying to the highest paying (or vice-versa). As indicated above, the horizontal measure is then deduced, using  $H^2 = O^2 - V^2$ .

### **Conditions for a suitable measure**

In order for a segregation measure to be entirely satisfactory there are a number of conditions which should be satisfied<sup>11</sup>. These may be applied to select among the measures that have been described. Since the dimensions are components of overall segregation their suitability depends on the overall measure and need not be considered separately.

1. *Gender symmetry*, It is logically the case that men and women are equally segregated from each other. This requirement of symmetry is met by ID, MM and the Gini coefficient (G). It is also met by the standardised SR\* and by IP, but not by other indexes involving weighting by the marginal totals of the Basic Segregation Table, i.e. WE and SR, for which we have seen there are female and male versions.

2. *Constant upper limit* The value of the upper limit, representing total segregation, should be fixed. The value of this limit is set at 1, or sometimes scaled to 100. Again ID, MM, SR\* and G meet this condition. However, as we have seen, IP, WE and SR have variable upper limits depending on weightings based on the marginal totals. Such variability is not confined to the upper limit; the variable weighting actually affects the whole range of potential values, making meaningful comparison of values impossible, which is clearly unsatisfactory. They are weighted versions of ID. The weightings could equally well be applied to MM, but there is no apparent gain in doing so.

3. *Constant lower limit* All the measures considered meet this criterion. Since it is

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<sup>10</sup> Exceptions include Blackburn and Jarman (1997, 2004, 2006), Blackburn et al (2001), Brooks et al (2003).

<sup>11</sup> For extensive discussion of such criteria see James and Taeuber (1985), Siltanen et al (1995). The present brief discussion updates these accounts.

meaningless to think of negative amounts of separation, the lowest possible segregation value has always been taken to be zero, representing no segregation. In practice, if only due to random factors, even the most egalitarian and gender-blind country may be expected to have some degree of segregation. This led Cortese, Falk and Cohen (1976a and b) to advocate measurement from an 'expected' value. (They were writing about ethnic segregation but the reasoning is the same for gender.) While there is good logic in this point, the matter is not entirely straight-forward, as Taeuber and Taeuber (1976) pointed out. In fact the zero point is essential for measuring vertical segregation, as shown below, so it is necessary to stick with the usual convention of zero.

*4. Size invariance* The total number of workers should not affect the measured level of segregation. It is the relative sizes of values in a segregation table that matter, not the absolute sizes. This is essential for comparing populations, such as in different countries, or different samples of a population. All the indexes meet this criterion.

*5. Occupational equivalence* If two or more occupations have the same gender composition (proportions of women and men) it does not affect the measure of segregation whether these occupations are treated separately or combined in one. This is met by all our measures. In practice the subdivisions of an occupational category very rarely have the same gender composition and this variation does affect measurement; the more a broad occupational category is sub-divided, the higher the measured segregation. It is because of this pattern of increase with the number of occupations that standardisation on 200 categories was introduced, on the assumption of random variation in the gender composition of the subdivided categories (See below).

*6. Sex composition invariance* This requires that the level of measured segregation is not directly affected by the overall gender composition of the labour force. What is important for segregation is the extent of separation of women and men, not their numbers. The requirement is that the ratio of F/M should not affect the measure of segregation. It is immediately clear that WE, SR and IP do not meet the criterion, as they have weightings  $2M/N$ ,  $N/F$  and  $2MF/N^2$  respectively. Any change in F or M will necessarily affect SR\* so again the criterion is not met. For G, if all occupations change proportionately, and for ID and MM this becomes if there are proportionate changes in the two categories of male and female occupations (columns multiplied by constants), the values are unaltered. In reality it is most unlikely that changes in the relative numbers of men and women will not affect segregation. However, the possibility of no change has generally been regarded as sufficient to ensure that any changes observed are real.

*7. Gendered Occupations invariance* Here we are concerned with changes in the numbers of workers in occupations. For measures based on a segregation table it concerns the relative numbers in male and female occupations,  $N_f/N_m$ , while for G it concerns all occupations. While changes in occupational sizes are likely to be accompanied by changes in segregation, it is important that changes in the size of occupations should not have additional effects the measurement of segregation.. Such occupational changes alter ID and G in ways which do not necessarily represent changes in segregation, with the many occupational categories of G making non-segregation effects more likely. SR\* is only unchanged if the categories of male and female occupations are unchanged, which is not necessarily the case. For MM the segregation table is always symmetrical so that changes in the gender composition of the labour force, or in the distribution between female and male occupations does not change the

relation between the two sets of marginal totals - the segregation table remains symmetrical. On the other hand WE, SR and IP are distorted by changing proportions of women and men (marginal totals F and M) as these vary with the changes in numbers in female and/or male occupations.

All measures of segregation are attempting to measure the same thing yet all give different values, and so give different estimates of the degree of segregation. It is important to appreciate that there can be no 'true' measure of segregation. All measures define the variable they measure. Thus there is a sense in which all the various measures are correct, each measuring and defining its own concept. Yet, this is inconsistent with the fact that all aim to be measuring the same thing, namely segregation as we have defined it. That is, the aim is to measure the extent to which women and men are occupationally separated in the labour force under consideration. The various measures which include weightings from the marginal totals cannot be seen as consistent with this aim; they are measuring something else. On the other hand, the Gini coefficient and its two 2 x 2 versions, ID and MM, are consistent with the definition of segregation. In their different ways they are measures of segregation, and if used consistently they tend to tell the same story about gendered employment.

ID is the most widely used measure of overall segregation, and is a quite good measure, so it is always worth using it for comparability with other research. MM may be technically superior but is less easy to calculate and has been used less extensively, and is also worth using when the concern is overall segregation.. Comparing the two gives an indication of how far they are measuring the same thing, giving confidence in the findings. What matters is not whether they give the same value but consistency in the way they vary. When we need to measure the component dimensions of segregation (inequality and difference) we have to use the Gini coefficient, G, which is also a good measure which tends to vary with MM and ID.

### **The Lorenz Curve**

It is useful to visualise the main segregation measures graphically, and this can be done with a Lorenz curve. The Lorenz curve is well known in economics where it is used to display the Gini coefficient by plotting income or wealth against persons. It plots the proportion of the population's total income which accrues to increasing proportions of the population. However it can usefully be adapted for segregation analysis, where it has been termed the segregation curve (James and Taueber, 1985). Here the axes are rather different, being the proportions of the male and female members of the labour force, from 0 to 100%. The curves, which represent concentration, enclose areas corresponding to segregation, as measured by the Gini coefficient. Occupations are ordered from the most female to the most male ( $F_i/M_i$  decreasing). The curve plotted is not a presentation of these values directly but of the cumulative proportion of women plotted against the cumulative proportion of men as we move through the occupations in order. Starting from the left, the curve is very shallow as the occupations employ many women and few men; the curve gets steadily steeper as the proportion of men in the occupations increases, and finally rises very steeply as the male-dominated occupations are included. Since in a 2 x 2 table the Gini coefficient is simply the difference of proportions, with just two occupational categories, both ID and MM can be represented on a Lorenz curve.

Figure 1

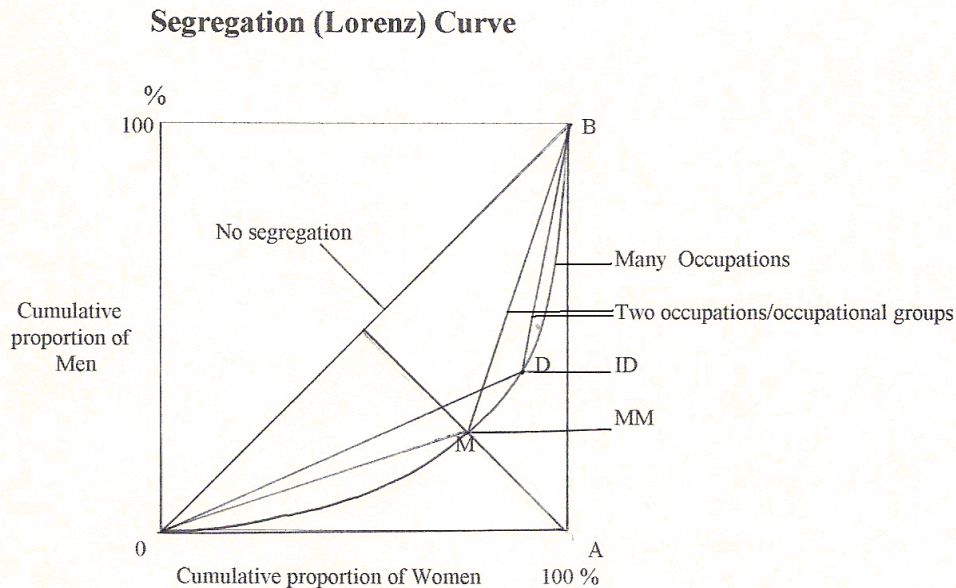


Figure 1 illustrates the three measures, together with zero and total segregation. The diagonal OB represents zero segregation<sup>12</sup> and the triangle OAB, suitably scaled to give a value of 1, represents total segregation. The area between OB and the curve OADB, measured as a proportion of total segregation triangle OAB, corresponds to the Gini coefficient for many occupations. For a smooth curve the number of occupations tends to infinity, and so a pure curve is not possible for segregation or any other purpose. Nevertheless, for many occupations the curve provides an approximation<sup>13</sup>. The two triangles OMB and ODB are shown representing the same number of occupations grouped into just 2 occupational categories in each case. The plotted point (M or D) represents the more female category ( $F_f$ ,  $M_f$ ) while, the plots being cumulative, the more male category is at the 100% point. The triangle OMB as a proportion of triangle OAB corresponds to MM. AM is the diagonal perpendicular to OB, so that M is equidistant from OA and AB, as  $M_f = F_m$ . Similarly ID is represented by triangle ODB divided by triangle OAB. The position of D is the point where the enclosed triangle has maximum area as the dividing point between male and female occupations provides the largest possible difference of proportions in a segregation table.

We may note that the area under the curve OADB is greater than the area of either triangle. Points M and D lie on the curve because the actual number of occupations is the same for all three measures. However, the grouping of occupations into two categories (male and female)

<sup>12</sup> Strictly the ordering of occupations to create the axes is not possible with no segregation, but any ordering would suffice. The diagonal is the limiting position of the curve as segregation tends to zero.

<sup>13</sup> The number of occupations must be less than or equal to the number of workers. If occupations equalled workers there would be total segregation (triangle OAB) while more occupations is impossible. In practice 200 or more occupations gives a good approximation to the curve.

reduces the values of the Gini when it is MM or ID. While the number of occupations determines the curve, it does so by defining points on the curve (one less than the total occupations plus O and B). With many occupations their joining up almost coincides with the curve, and the area they enclose - the Gini - is approximately that enclosed by the curve. However, any grouping of occupations reduces the enclosed area, as we see in the extreme of grouping into 2 categories, for MM and ID.

The curve OMBD varies with the number of occupational categories, such that the area between the diagonal and the curve increases as the number of occupations increases. This illustrates the fact that the value of the Gini coefficient increases with the number of occupational categories. and illustrates the reason for standardising segregation measures for the number of occupations. The same logic applies for standardising MM, while the fact that the area of triangle OMB is less than the area enclosed by the curve means that a different formula is required.

### **Standardising measures**

Having selected the useful measures, we need to standardise them. Standardisation has not normally been undertaken, though Anker (1998) introduced an alternative formula. In fact, standardisation is necessary, as we have noted, because all measures of segregation increase with the number of occupational categories. It was decided to standardise on 200 categories because it is within the range of available data sets and it is at a level where further increases in the number of occupations have a small and declining effect. While not strictly relevant to standardisation, it is large enough for possible measurement errors to be small. That is to say, the way the occupations are grouped into categories has little effect on the observed measure. For small numbers of categories there can be considerable variance depending on the particular grouping. For most purposes we may regard 20 as the appropriate minimum, though this is a far smaller number than is really desirable. Where there is no alternative it is possible to just 20 or even fewer categories, but with very cautious limits on interpretation. Where there are a large number of categories (150+) we may regard measures as approximately correct, and deviations, with fewer categories, from the standardised value with many categories, are seen as error.

Firstly we estimated the standardisation equation for MM<sup>14</sup>, which can be directly adapted for ID. Subsequently we used the same procedure to estimate the standardisation of G. Then we estimated standardisations for the vertical and horizontal dimensions.

#### *Standardising MM*

To standardise MM (Jarman et al, 1999; Blackburn et al, 1998), we estimated an equation to relate the 'expected' value of MM to the number of occupations, using a wide range of national data sets. Of course the actual 'observed' value of MM for each country differed from the estimated 'expected' value for the number of occupations in the data set for that country. For each country the observed to expected ratio was calculated. Then this ratio was applied to the estimated value for 200 occupations. This gave a set of comparable estimates of segregation level for a notional set of 200 occupations in each country.

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<sup>14</sup> A detailed discussion of the estimation process for standardising MM may be found in Jarman et al (1999: Appendix).

Our initial estimating equation was

$$MM_{nE} = 1 - \frac{1}{1 + \alpha(\log_{10}(n+y)/(1+y))^{\beta}}$$

where n is the number of occupations and  $\alpha$ ,  $\beta$  and y are the three parameters that are possible in the estimation equation<sup>15</sup>. E indicates the expected value, according to the estimated equation, for the particular number of occupations n (or 200).

However, it turned out that the estimate of y was approximately 0 in all the equations providing a good fit. Therefore it was dropped it from our estimating procedure, leaving the simpler equation.

$$MM_{nE} = 1 - \frac{1}{1 + \alpha(\log_{10}n)^{\beta}} \quad \alpha > 0, \beta > 0$$

We estimated the optimal values are  $\alpha = 0.60$  and  $\beta = 0.93$ .

Thus the final equation arrived at was

$$MM_{nE} = 1 - \frac{1}{1 + 0.6(\log_{10}n)^{0.93}}$$

Standardising on 200 occupations, we have for country 'i' with 'n' occupations

$$MM_{200i} = MM_{200E} \times MM_{ni}/MM_{nE}$$

and we have  $MM_{200E} = 0.56567$

#### *Standardising Gini*

Similar procedures were followed to standardise the Gini coefficient. Again a wide range of national data sets of varying sizes was used. Thus we obtained the formula<sup>16</sup>

$$G_{nE} = 1 - \frac{1}{1 + 1.7(\log_{10}n)^{0.93}}$$

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<sup>15</sup> We should note that this meets three basic criteria:  $MM_E = 0$  when  $n = 1$ ;  $MM_E$  increases as n increases; and  $MM_E \rightarrow 1$  as  $n \rightarrow \infty$ . The third criterion here is not precisely what is required, but the difference is negligible.

<sup>16</sup>Earlier standardisations for Canada and UK were estimated on limited data. The formula given here is more soundly based and so is to be preferred. The result is not greatly different but is more precise.



Then

$$G_{200i} = G_{200E} \times G_{ni} / G_{nE}$$

### *Standardising the Vertical and Horizontal Dimensions*

Once we have standardised the measure of overall segregation (G), we need to standardise the component dimensions. Since there is no reason why standardisation should change the ratio of vertical to horizontal components, V/H, the ratios of V and H to Overall segregation remain the same. Thus

$$V_{200i} = V_{ni} \times G_{200E} / G_{nE} \quad \text{and} \quad H_{200i} = H_{ni} \times G_{200E} / G_{nE}$$

Thus we have consistent measurement of segregation and its two dimensions, regardless of the number of occupations in the data set.

### **Conclusion**

Gender Segregation is a significant aspect of contemporary societies. It's measurement, however, is not entirely straightforward, and there have been various attempts to optimise measurement. Taking the example of occupational gender segregation, I have attempted to set out the basic considerations and to demonstrate adequate approaches.

The value of good measurement is not merely greater accuracy, as it can significantly advance our understanding. Three particular results from measuring the dimensions of segregation are worth mentioning, as they are not otherwise apparent (Blackburn and Jarman, 2006; Blackburn et al, 2009). Firstly we may note that overall segregation is not the measure of gender inequality it has generally been assumed to be, In fact vertical segregation, the actual measure of inequality, is inversely related to overall segregation; the higher the overall level, the higher the horizontal component while the vertical component tends to be lower. Secondly, inequality is not even a major aspect of segregation; the horizontal dimension of difference without inequality tends to be substantially larger than the vertical dimension. Thirdly, when the vertical component is measured by a stratification measure such as CAMSIS the result is almost invariably negative, at least in the industrialised countries, indicating advantage to women. Knowledge depends on sound methodology.

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