The Analysis of Occupational Gender Segregation Over Time and Place: Considerations of Measurement and Some New Evidence

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Abstract: Despite the importance of occupational segregation as an area of investigation concerned with understanding women's employment status, pay levels, and promotional prospects during the last 20 years, there has been relatively little attention paid to the problems of trying to measure segregation levels in quantitative data. This paper argues that there are serious measurement problems which it illustrates by showing that two of the principal indices, the widely-used Index of Dissimilarity and the OECD's WE Index are highly flawed and produce unreliable results. It demonstrates the importance of these deficiencies using cross-national data from 9 countries for the period 1970-1982. The paper introduces a new way of analysing the form of these indices in the Basic Segregation Table, which is a 2×2 table of gendered occupations by sex. The paper suggests a new approach to measuring occupational segregation which provides more consistent and valid results. This is called Marginal Matching. The paper ends with an analysis of occupational gender segregation in England and Wales from 1951 to 1981. It concludes that, in contrast to research claims to date, the trend in segregation over this period is one of overall stability.

THE ANALYSIS OF OCCUPATIONAL GENDER SEGREGATION OVER TIME AND PLACE: CONSIDERATIONS OF MEASUREMENT AND SOME NEW EVIDENCE

Robert M. Blackburn, Jennifer Jarman and Janet Siltanen

Occupation gender segregation appears to be an exceptionally hardy perennial. Its persistence has been identified as a major factor in women's continued inferior earnings and status in employment. As such, segregation has been studied extensively. In these studies, two questions are foremost: to what degree is segregation a barrier to gender equality, and how effective are employment equity policies in dismantling this barrier? These questions implicitly call for analyses of gender segregation over different periods of time and across different geopolitical areas.

The value of historical and comparative analysis in elaborating social processes structuring gender inequalities is well established (Roos 1985;

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Skocpol 1977; Treiman and Roos 1983). Yet, in the case of occupational gender segregation, not much progress has been made. There are relatively few studies of occupational segregation which compare across countries. There are many more investigations which examine trends in occupational segregation within one country. However, often these are fraught with disagreements over the presence and direction of change. For example, there are varying reports about the presence and direction of change in the critical decade of the 1970s in the United States and Britain, when each country experienced some forward movement on equal opportunities provisions. Using the Index of Dissimilarity on US data sets, England (1981:228) reports 'negligible change', Jacobs (1989: 171) describes the movement in occupational gender segregation over the decade as a 'gradual decline', and Beller (1984:23) finds that it 'diminished significantly'. Using the Sex Ratio Index on UK data, Hakim (1981) concludes that the Equal Opportunities provisions of the 1970s *accelerated* an already existing trend toward decreasing segregation levels, whereas Siltanen (1990a) suggests that, allowing for flaws in the index, it is more likely that the legislation temporarily *reversed* a trend in the previous decade of increasing segregation.

Frequently, researchers point to problems with the inconsistency of occupational classification schemes over time, and questions of the aggregation and weighting of occupations, as the main concerns in comparative and historical analysis (Crompton and Sanderson 1990; England 1981; Jacobs 1989). While these are important concerns, our interest in this paper is to direct attention to the significance of segregation measures themselves in distorting the picture of gender inequality over time and place. Concerns about the quality of existing measures have started to appear in the literature (Siltanen 1990a, 1990b; Tzannatos 1990; Watts 1990, 1992). In this paper we widen the terms of the debate, by indicating that the solution to the problem of inadequate measures is not a matter of developing the 'ideal' index. No matter how one modifies existing measures, basic problems in making comparisons remain. Our solution is both neat and novel: it involves arranging the data in a suitable manner so that a simple statistic of association will give a dependable measure of the degree of gender segregation.

The paper has three main purposes. First, we show the seriousness of the measurement problem by looking at the difficulties in interpretation encountered in an influential attempt to measure changes in occupational and industrial gender segregation in a number of OECD countries. In that research an index developed by the OECD was used in conjunction with the Index of Dissimilarity – widely regarded as *the* segregation measure. Although both indices (like all segregation indices) are supposed to measure the same phenomenon, we show that they often contradict one another. We go on to explain that this is due to the forms of the

measures, and that both of them are flawed. This not only undermines all work based on these two major indices but raises doubts about other segregation indices. This has serious consequences for the understanding of employment processes, as well as for policy development and assessments of its effects. Furthermore, it undermines the basis on which occupations may be chosen for qualitative study (see Reskin and Roos 1990).

Our second purpose is to offer an alternative to existing procedures for measuring gender segregation in employment. This alternative is called Marginal Matching. In setting out the need for a new measurement approach, and in introducing the application of marginal matching to the study of gender segregation,[1] we also introduce criteria for assessing the adequacy of measurement procedures.

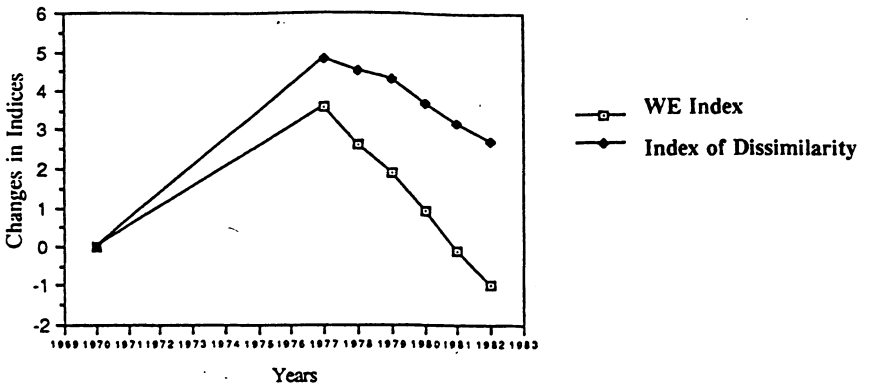
The third purpose is to present new evidence of the trend in occupational gender segregation in England and Wales. Using Census data from 1951 to 1981, we compare the trends suggested by the previous main measures of occupational gender segregation. We show that, although they all purport to measure the same thing, they give different pictures of the pattern of change over this period. Using the marginal matching procedure, we suggest that the actual trend is one of overall stability in the degree of gender segregation.

Inconsistencies in the Measurement of Segregation

There are two basic questions that we should like to have answered in the analysis of gender segregation in employment: does one place have a higher or lower level of segregation when compared to another place, and how have levels of segregation changed over time? Existing measurement procedures cannot provide valid answers to these two fundamental questions. To illustrate the problems, and underline the importance of a solution, we will use the OECD (1985) publication *The Integration of Women into the Economy* as a starting point. It is a unique document as it provides cross-national and historical data on occupational segregation. It looks at nine countries between 1970 and 1982. More than this, it is one of the few analyses of occupational segregation to use two segregation measures on the same data: the Index of Dissimilarity and the WE Index. The OECD adopted this strategy to counter methodological limitations of its own WE Index (Garnsey and Tarling 1982), and it is clear that the two indices are intended to measure the same concept of segregation. However, as an examination of the resulting patterns of segregation shows, this strategy has produced more confusion than clarification.

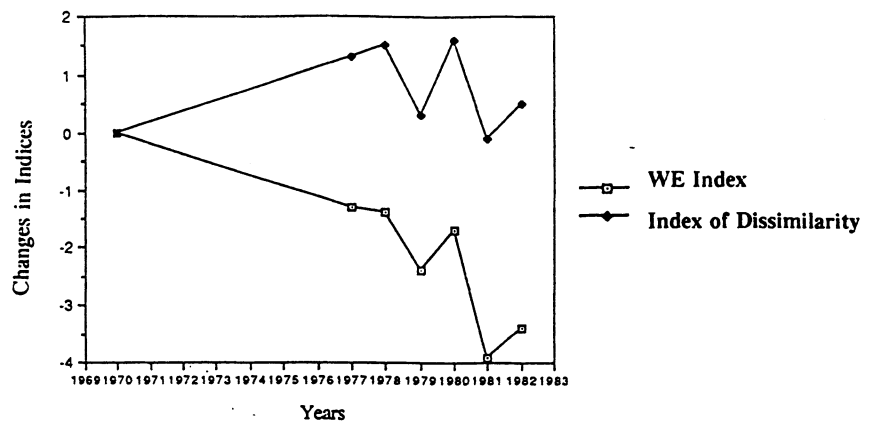
Later on we shall discuss in detail the form of the two indices used in the OECD paper, but here we wish to point out two striking problems of this

Figure 1 Changes in Occupational Segregation, as Measured by the WE Index and the Index of Dissimilarity, USA, 1970–1982



This graph is based on the values of the indices computed by the OECD (shown in Appendix). The 1970 value has been subtracted from each of the values in order to zero the graph, and thus show the patterns of change more clearly.

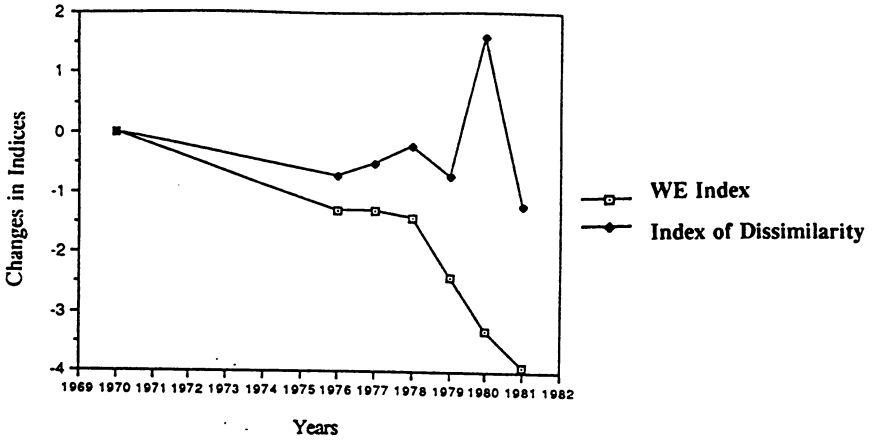
Figure 2 Changes in Occupational Segregation, as Measured by the WE Index and the Index of Dissimilarity, Australia, 1970–1982



See note to Figure 1 on source and construction.

analysis. The first problem is that the two indices show different trends in segregation within countries. Looking at the two indices for occupations (Appendix Part A, Tables 1 and 2), we see that there are a number of cases where the direction of change indicated by the Index of Dissimilarity is not the same as that indicated by the WE Index.[2] This is illustrated by the patterns of change in the USA and Australia (Figures 1 and 2). At first

Figure 3 Changes in Industrial Segregation, as Measured by the WE Index and the Index of Dissimilarity, Canada, 1970–1981



See note to Figure 1 on source and construction.

sight, Figure 1 seems to show the two indices following similar patterns of change in the USA, but there is a crucial difference. Using the WE Index, the trend in occupational segregation between 1970 and 1982 is a *decline* from 47.5 to 46.5; using the Index of Dissimilarity over the same period, the trend appears to be an *increase* from 37.9 to 40.6. In the case of Australia (Figure 2), the WE Index shows occupational segregation *declining* from 64.1 to 60.7 over the same time period in which the Index of Dissimilarity shows a slight *rise* from 47.4 to 47.9.

Even when the indices are in agreement as to the overall direction of change, they often indicate different rates of increase or decrease, and there are inconsistencies over shorter periods. In Norway, for example, the WE Index declines as the Index of Dissimilarity rises from 1970 to 1977 and again from 1978 to 1982. Thus, while both indices show an overall decline in segregation, the rate is galactic according to the WE index (moving from 71.1 to 55.8) and glacial according to the Index of Dissimilarity (moving from 49.1 to 48.3) (Appendix Part A).

In the industrial data, similarly inconsistent trend figures can be observed. In Canada for instance, as Figure 3 shows, the two indices diverged slightly from 1970 to 1976 and then quite rapidly, so that by 1980 the WE Index suggests segregation *decreased* from 40.3 to 37.0, whereas according to the Index of Dissimilarity segregation *increased* from 31.7 to 33.3.

The second problem with the OECD analysis is that the two indices produce different orderings of countries when they are ranked by the level of segregation. According to the WE Index, the country with the

Figure 4 Occupational Rankings, 1982

WE Index		*Index of Dissimilarity*	
	Most Segregated		
Australia	60.7	Norway	48.3
Norway	55.8	Australia	47.9
USA	46.5	Sweden	41.1
Canada	44.6	USA	40.6
Germany	44.2	Canada	37.9
Sweden	44.2	Germany	35.9
Japan	27.5	Japan	22.5
	Least Segregated		

greatest occupational segregation in 1982 was Australia followed by Norway, the USA and Canada (see Figure 4). According to the Index of Dissimilarity, a different pattern emerges: the most highly segregated country is Norway, followed by Australia, Sweden, and the USA. Sometimes the two indices produce the same rankings: for example, in 1970 both indices give the same ranking for all 7 countries for which there is data. However, the consistency of 1970 is not repeated and the overall pattern indicates serious difficulties in making comparisons among countries.

In the industrial rankings, the two indices again produce different patterns. Thus the WE Index for 1980 lists Belgium as being the most highly segregated, followed by Norway, Sweden and Australia. Using the Index of Dissimilarity the most segregated country appears to be Sweden, followed by Norway, Belgium and the UK. Other years show similar levels of inconsistency.

The OECD article is a striking demonstration of the issue of inconsistency with respect to two segregation indices. At a minimum we would expect satisfactory measures to provide consistent comparisons across place and over time. The kinds of inconsistencies in the OECD analysis illustrate that indices, intended to measure the same thing, are responding to different aspects of change or difference in labour force distributions. Obviously, one cannot compensate for the deficiencies of one index simply by supplementing its use with another. Each casts doubt on the accuracy of the other, and there is no obvious way to interpret them in combination. Also, it is clear that the insufficient identification of measurement issues has meant that a more useful procedure has not been developed and data patterns have not been accurately identified. The choice of a suitable measurement procedure is crucial (*pace* Hakim 1992).

An Acceptable Measurement Strategy

For an acceptable measurement strategy it is necessary to understand the ways in which indices respond to labour market variations, and how or whether these impinge on the measurement of segregation. There are three general questions that need to be addressed.

In the first place there is the conceptual question of the substance of segregation - what we *want* to be measured as opposed to what indices measure. We follow the usual practice of conceptualising segregation as the tendency for women and men to be separated in different occupations or industries (Fox and Fox 1987; Brosnan 1987; Tzannatos 1990). However, we recommend more attention to the meaning of segregation. If women are separate from men then, equally, men are separate from women. Thus segregation entails both men and women in a symmetrical relationship, and can be measured as the extent of their separation from one another in the employment structure.[3] It is useful to think of this as the relationship between the sex of the workers and the gendering of occupations. It is a feature of a country's employment structure, or some socially meaningful section of it, such as full-time employment or part-time employment.

Secondly, we have to consider the question of how we want a measure to behave when the object of the exercise is to trace change over time or make comparisons across countries. A number of criteria for satisfactory measurement have been identified, but we need only deal here with the important ones for our comparative purposes. These criteria require that a measure should not vary because of the effects of factors other than segregation. In particular, changes in the occupational or industrial structure or the sex composition of the labour force should not in themselves affect *measures* of segregation, except insofar as they do affect segregation itself. In other words, we want segregation indices to measure segregation alone, without distortion from any other component.

Thirdly, there is the question of the mathematical form of the measure; which elements are to be included and how they are related to each other. This then determines the degree to which a measure meets the criteria and provides a valid representation of segregation.[4]

Understanding Differences Between Indices

To understand the inconsistencies discussed previously, we need to look at the form of the indices. In particular, we want to know how these indices are influenced by factors other than the levels of gender segregation. To do this it will be helpful to introduce the Basic Segregation Table, an innovation which we think greatly simplifies the assessment of

Figure 5 The Basic Segregation Table: Women and Men in 'Female' and 'Male' Occupations

	Women	Men	
'Female' Occupations	F_f	M_f	N_f
'Male' Occupations	F_m	M_m	N_m
	F	M	N

Where
N is the total labour force
N_f is the total number of workers in 'female' occupations
F is the number of women in the labour force
F_f is the number of women in 'female' occupations, and so on.
Full notation is presented in the Appendix Part B.

occupational segregation measures (Blackburn, Siltanen and Jarman 1990). This is a 2×2 cross-tabulation of gendered occupations (female jobs and male jobs) by the sex of incumbents (women and men workers), as shown in Figure 5.

Since segregation has been conceptualised as the relationship between the sex of the workers and employment in gendered occupations, we can see that segregation is the relationship in the Basic Segregation Table. In other words, segregation is the degree of association between the two variables – gendered occupations and sex. The stronger this relationship, the higher the level of segregation, and the weaker this relationship, the lower the level of segregation.

The definition of 'male' and 'female' occupations is an important component of the concept of segregation. In our discussion we shall refer to two definitions. For illustrative purposes we shall first use the most common definition. It has been used, for example, for the WE index and the Index of Dissimilarity. 'Female' occupations are those where the female proportion of workers is greater than the female proportion of workers in the labour force as a whole, and 'Male' occupations are those where the male proportion is greater than the male proportion in the whole labour force. In this sense, female occupations may be regarded as those where women are over-represented and similarly male occupations are those in which men are over-represented. It is important to recognise, however, that there is no essential definition of 'male' and 'female' occupations. The concepts are sociological ones and we should be careful not to reify them in the analysis of segregation. Later on we shall propose an alternative definition that is more suited to comparative analysis.

In the discussion that follows we shall have occasion to present the

mathematical forms of the indices. The notation used is set out in full at the beginning of Part B of the Appendix. Although we shall refer to the conventional formulae for the indices, we show that they can be expressed more usefully in terms of statistics of association related to a 2×2 table. The advantage of setting out the form of indices in this way is that in the table we have a concise overview of the essential information used in their construction. It greatly simplifies the Index of Dissimilarity. Instead of a summation over all individual occupations (i), with the formula

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

which is mathematically adequate but intuitively hard to grasp, it is now the difference of proportions between columns in this table, i.e. the proportion of all women workers who are in female occupations less the proportion of all male workers who are in female occupations. In mathematical form,

$$ID = F_f/F - M_f/M.$$

(See Appendix Part B for proof.) As we shall see, the table also simplifies analysis of the form of the WE Index and of its relation to the Index of Dissimilarity.

Form and Problems of the WE Index

The WE Index was introduced in the OECD report *Women and Employment* (1980). It has been defined as the weighted sum of deviations from unity of the proportion of women in each occupation divided by the proportion of women in the labour force. It is simpler to think of it as the sum of the differences between the observed and expected proportions of women in each occupation, all differences being measured positively. This may be written

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

As it stands the WE Index has two basic flaws as a measure of segregation. In the first place, it is not symmetrical for men and women and so there are two versions, a male index and a female index, with each having different values (see Appendix Part B). For example, the OECD gives an industrial segregation value for WE of 54.0 for Norway in 1981; this is the female version and the male version would give a value of 22.6. The OECD only uses the female version but there is no logical justification for choosing one version over the other when measuring gender segregation. Quite different patterns in the differences among countries are obtained depending on whether the male or female version of WE is

used. Thus according to the male index in 1981 the most segregated country (for industry) was Sweden followed in order by Finland, the UK and Canada, yet with the female index these countries are ranked third, eighth, fourth and sixth respectively.[5] For simplicity, unless otherwise indicated, we shall follow the OECD practice of using WE to refer to the female version.

The second basic flaw of the WE Index is that one cannot compare the levels of the index in different situations (countries or time periods) because the maximum value depends on the labour force composition in each situation. Therefore the range is not standard in the situations being compared so the value of the index is not standard either. In fact the maximum value is twice the male proportion of the labour force which, for industrial data, in Finland would give a maximum of 1.05 for 1981, while in Belgium the maximum would be 1.36. Obviously, indices for these countries cannot be compared.[6]

Standardising for either of these shortcomings converts the WE Index into the Index of Dissimilarity (See Appendix Part B). In fact, we can express the WE Index in the form

$$WE = 2M/N \times ID.$$

The WE Index is simply the Index of Dissimilarity multiplied by twice the proportion of the labour force who are men.[7]

Having established the link between the two indices, let us re-examine the divergent patterns in the OECD report. Since the WE Index is the Index of Dissimilarity multiplied by a function of the sex composition of the labour force, the divergences between the two indices that we saw earlier, are due entirely to the patterns of change in the relative male/female breakdown of the labour force. For example, the 7% *increase* from 1970 to 1982 in the Index of Dissimilarity in the United States (from 37.9 to 40.6) was outweighed by a *decrease* of 9% in the male share of the labour force (from 63% to 57%),[8] producing a *decline* in the WE Index. The use of both indices does not clarify patterns of segregation because the WE Index is merely a distorted version of the Index of Dissimilarity.

Form and Problems of the Index of Dissimilarity

This might lead one to think that the Index of Dissimilarity can be taken as the appropriate measure, and certainly it is the most frequently used index of segregation. Much of the discussion about the limitations in applying the Index of Dissimilarity to the study of occupational segregation has focused on problems of the consistency of occupational schemes over time, and questions about weighting and standardisation of

occupations (for example, England 1981; Jacobs 1989). However, even if all criticisms of classification schemes are taken into account, there remains the question of whether the segregation measure itself produces meaningful results. An examination of its form indicates that the Index of Dissimilarity does not succeed in this respect.

Before we proceed, it is useful to remind ourselves of what we are trying to measure. As discussed earlier, segregation has been conceptualised as the relationship between gendered occupations (male and female) and sex (men and women). Thus the highest level of segregation occurs when 'male' occupations are entirely filled by men and no women, and 'female' occupations are filled entirely by women and only women. At all lower levels of segregation the 'male' and 'female' occupations contain a mixture of men and women, and the actual level is the extent to which the men are concentrated in the 'male' occupations and the women are in the 'female' ones. When there is no segregation gendered occupations cannot be identified, because in all occupations the female proportion is the same as the female proportion of the total labour force (F/N). Since we cannot identify gendered occupations, there is clearly no relationship between them and sex.

While there are factors – such as the overall male and female proportions of the labour force – which are influential in determining the relationship between these two variables, they are not the same as segregation and should not have independent effects on its measurement. It is important to have a measure of segregation which measures this relationship between gendered occupations and sex *and this alone,* without noise from external factors. This is a basic principle which runs through the following analysis.

A number of criteria have been identified that a measure of segregation should satisfy with respect to the adequacy of its mathematical form (see James and Taeuber 1985; Duncan and Duncan 1955; Blackburn, Siltanen and Jarman 1990). It is important to bear in mind that these mathematical discussions have very real consequences for the results of data analysis. As our purpose is to explain the deficiencies of the Index of Dissimilarity we shall confine our discussion to the two criteria that the Index fails to satisfy. The first one, Sex Composition Invariance, specifies that the measure of segregation, that is the relationship between gendered occupations and sex, should not be directly influenced by the ratio of women to men in the total labour force. The second criterion is one we have developed ourselves, and have dubbed Gendered Occupations Invariance, which requires that the measure should not be directly influenced by the relative numbers of workers in 'female' and 'male' occupations.[9]

To understand the nature of these criteria, and why they are not met by the Index of Dissimilarity, it will be useful to return to the Basic

Segregation Table. Once we recognise that segregation is the relationship in the table, it is evident that this relationship should be independent of *both* sets of marginal totals. We can then see that the requirement of Sex Composition Invariance, that the index should not be directly affected by the total numbers of men and women in the labour force, means that the way segregation is measured should be independent of the column marginals[10] of the table (F and M). Similarly Gendered Occupations Invariance means that the measurement should not be distorted by effects from the occupational marginals (N_f and N_m). In other words the two sets of marginal totals should only affect the measure indirectly, through their influence on segregation itself.

To see why the Index of Dissimilarity meets neither of these criteria we must recall that the Index is the difference of proportions between columns in the Basic Segregation Table, i.e. the proportion of all women workers who are in female occupations less the proportion of all male workers who are in female occupations $[F_f/F - M_f/M]$. There are, of course, several other statistics of association which might be used to measure the relationship in the table (such as the difference of row proportions, Yule's Q or the (log) odds ratio). To appreciate that there are distorting effects on the Index from the marginal totals it is important to recognise that all these statistics are affected differently by changes in the marginal totals. Each is intended to measure the same relationship, which in this case is the level of segregation. Clearly, for any single set of changes in the marginals there can only be one resultant change in segregation, yet each of these statistical measures responds differently, each suggesting a different degree and possibly a different direction of change in segregation. All are misleading, and all are subject to the same sort of criticisms that apply to the Index of Dissimilarity.[11]

Since the Index is the difference of column proportions, we can see immediately that it does not have Gendered Occupations Invariance, for as the occupational marginals change so does this difference of proportions, regardless of what changes, if any, there are in the degree of segregation (that is, in the relationship within the table). So, for example, if the number of workers in 'female' occupations increases while segregation remains unchanged, the index value changes automatically giving a false impression of real change in segregation. This point is simply the well-known property of a difference of proportions.[12]

There are two ways in which changes may come about in the occupational marginals, that is in the totals of workers in 'female' and 'male' occupations. Variations in the occupational structure will affect the numbers in these two categories. Also, changes in the gender composition of the labour force will alter the definitions of 'male' and 'female' occupations themselves, and therefore the relative sizes of the occupational marginals. Thus changes in occupational structure or the sex

composition of the labour force can induce variations in the Index of Dissimilarity unrelated to the level of segregation.

For these reasons alone we can see that not only Gendered Occupations Invariance but also Sex Composition Invariance (independence from the gender composition of the labour force) does not hold. However, it has been argued that the Index does meet the requirements of Sex Composition Invariance and it will be useful to see the basis for the claim and why we reject it. James and Taeuber (1985: 16) argue that the Index of Dissimilarity is independent of the gender composition of the labour force for the technical reason that multiplying the columns of the table by a constant does not change the index figure.[13] This type of property of a statistic measuring a relationship in a table has been called 'marginal independence', and there is a popular fallacy that it ensures the statistic is unaffected by changes in the marginal totals. However, this 'marginal independence' would only be relevant in the exceptional circumstances where a change in the number of female workers would entail increases of women in both female and male occupations in exactly the same proportions, and similarly for any change in male employment. Thus if the number of women in the total labour force increased by one million, this increase would be shared between male and female occupations in precisely the same ratio as the ratio which previously existed. Such circumstances are so implausible that independence in this respect is virtually meaningless, and is certainly not an adequate definition of Sex Composition Invariance.[14]

We see, therefore, that changes in the *measured* level of segregation, according to the Index of Dissimilarity, may be brought about by changes in employment patterns which, by definition, are not changes in segregation as such.[15] In other words, the index does not target segregation patterns precisely enough. In summary, the Index of Dissimilarity has such significant problems as a measure of the degree of gender segregation over time and across countries as to undermine any confidence in its results.[16]

A Fresh Approach: Marginal Matching

We have seen that the inconsistencies noted in the trends and rankings established by the WE Index and the Index of Dissimilarity can be attributed to the way in which the forms of the two indices are related, and how measurement is distorted by factors other than segregation. Understanding why different indices yield different results in comparative analysis is an important contribution to interpreting data patterns. Nevertheless, a more productive state of affairs would be one where we had confidence that our measure of segregation was producing valid

results. We have suggested that among the relevant criteria for a measure of segregation, two are especially significant for comparative study: Sex Composition Invariance and Gendered Occupations Invariance. To meet these criteria a new approach is required. The basis of this approach involves matching the marginals of the Basic Segregation Table.

Examining the Basic Segregation Table enabled us to see that measures of segregation are measures of association. Thus we can draw on a different sociological tradition where inequality is seen as a relationship measured by statistics of association.[17] This also fits the understanding of segregation that we have advocated: segregation is a symmetrical relationship. We have shown that the Index of Dissimilarity is one measure of association, and seen that it lacks Sex Composition Invariance and Gendered Occupations Invariance. For similar reasons, no other measure of association can guarantee Sex Composition and Gendered Occupations Invariance. In other words, there is no strictly statistical solution to the problems we have raised, but there is a solution, and it involves adjusting marginal distributions.

We have argued that existing measures of segregation fluctuate with changes in the sex and occupational composition of employment, that is with changes in the marginal totals of the Basic Segregation Table. Our approach eliminates these distortions by organising the data so that the measurement of the segregation relationship is comparable for all situations. We *control* the effects of the marginals rather than just allowing them to fluctuate and inappropriately influence the measurement of segregation levels. This involves using a different definition of gendered occupations from that associated with WE and ID. 'Male' and 'female' occupations are defined so that in the Basic Segregation Table the occupa- tional marginals have the same proportional distribution as the sex marginals.

To do this, occupations must first be ordered by the ratio of female to male incumbents ($F_i : M_i$). This provides a female-male dimension representing the gendering of occupations. On this dimension we must choose a suitable cutting point to distinguish 'female' occupations and 'male' occupations, for the purpose of establishing the segregation relationship. All indices require such a choice of cutting point, though previously (for example, for the Index of Dissimilarity) this has not been made explicit. The choice of the cutting point is crucial: here it is chosen to provide matched distributions in the marginals. This means that 'female' occupations are defined as those with the highest ratios of women to men which together contain the same number of workers as there are women in the labour force (we may think of this as moving along from the 'female' extreme of the dimension until the cumulative number of workers equals the total number of women). The remaining occupations fit the corresponding definition of 'male' occupations. In the

Basic Segregation Table, N_f now equals F and N_m equals M. Thus, the table is symmetrical. Whatever happens to the numbers of women and men in the labour force, the classification of occupations is adjusted to preserve this symmetry.

This gives us the basis of a measurement procedure which can produce valid results. For every country, or at every time point, the marginals are matched, giving a symmetrical table. This symmetry permits satisfactory measurement of the relationship in the data, for the relativities of the marginals are now consistent, and it ensures consistent interpretation for an appropriate statistic of association. Several statistics of association now coincide, including the two differences of proportions, phi and tau_B, and we refer to this set of statistics as MM. For measuring the strength of the segregation relationship we suggest that the most appropriate statistic is MM. This is the product-moment correlation coefficient, which measures the explained variance. Put less technically, MM may be interpreted as a measure of the extent to which gender and gendered occupations vary together – how far female occupations are staffed by women and male occupations by men. This is precisely what is needed for the measurement of segregation, but only with matched marginals is the correlation measurement completely satisfactory.[18]

We may regard the matching process as defining gendered occupations on the basis of the potential maximum segregation. The 'female' category is defined so that it could contain all the women workers and only women, while 'male' occupations would contain all the men and only men – total segregation, and a perfect relationship. No relationship means no segregation.

As with the Index of Dissimilarity and the WE Index, when the gender composition of the labour force varies, so too does the definition of 'female' and 'male' occupations, but now the change is intentional, for this is how Sex Composition Invariance and Gendered Occupations Invariance are ensured. For comparability, it is not the identification of particular occupations as 'male' or 'female' that matters but the *relationship* between the two variables of the table, that is, the relationship of segregation. Only by varying the dividing point between 'female' and 'male' occupations to 'match' the changing gender composition of the labour force can the unwanted, artefactual effects of this changing composition be nullified. At the same time, the deliberate varying of the occupational categories similarly avoids artefactual effects from changing occupations or industries.

Rather than thinking of segregation as a quantity, which might be measured as so many 'segometers', it should be understood in terms of the strength of relationship. The stronger the relationship, the greater the degree of segregation. The advantage of the approach is not that it gives a 'true' measure of segregation, whatever that might mean, but that it

gives measures which are comparable across situations. It may not be the answer to all problems in this area but we believe it is a powerful tool, allowing analyses of changes which were not previously possible. The approach can, of course, be used to look at segregation in sections of the labour market as well as the overall level.[19]

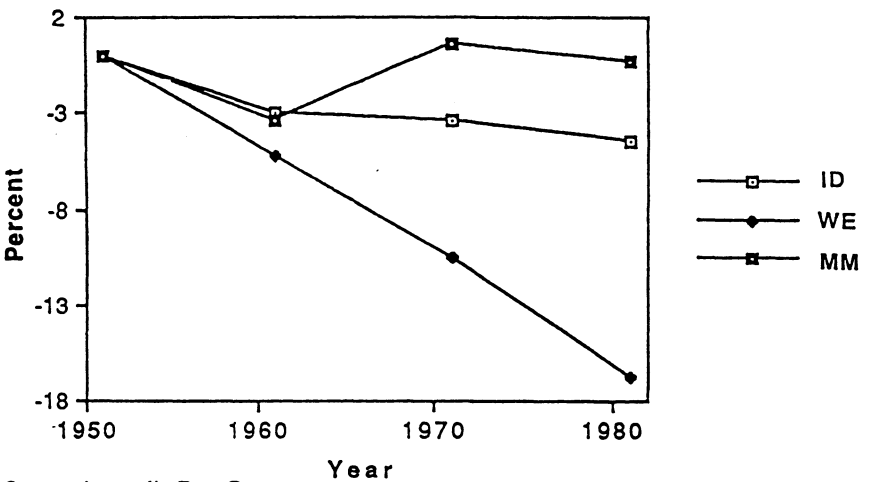
Segregation Trends in England and Wales

To complete our discussion we present an analysis of trends in gender segregation in England and Wales. The data are taken from the Census Reports for 1951 to 1981. Because of the familiar problem of different occupational classification schemes being used for each Census, some caution is appropriate in the interpretation of trends. However, since the same data are used for all the measures, they ought, if sound, to show the same trends.

In Figure 6 we show changes in the two indices we have been considering, the WE index and the ID index, together with changes in the recommended measure, MM. In order to compare the patterns of change as clearly as possible, for each measure we have graphed the percentage changes from the 1951 value.

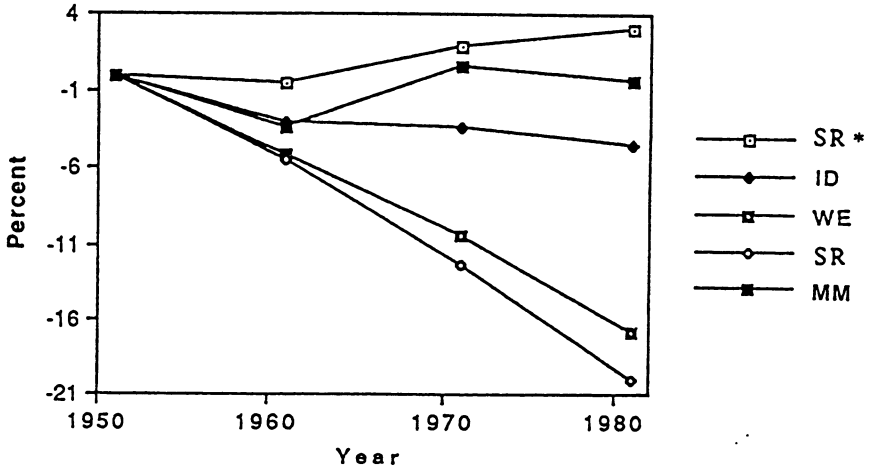
It is immediately apparent that the three measures tell very different stories. The one valid measure, MM, indicates that, despite some short-term fluctuations, the level of occupational gender segregation in

Figure 6 Percentage Changes in ID, WE and MM, England and Wales, 1951–1981



Source: Appendix Part C.

Figure 7 Percentage Changes in all Measures, England and Wales, 1951–1981



Source: Appendix Part C.

England and Wales remained virtually the same in 1981 as it was in 1951. This is an important finding.

The two indices used by the OECD paint a much more optimistic picture. The Index of Dissimilarity appears to show a decline of about 5% while the WE Index suggests a dramatic drop in segregation of roughly 17%. These results give an indication of the inaccuracy introduced by using these flawed measures. It is unlikely that they are any more accurate for other countries, and it is possible that their use in the OECD analysis has given an unduly optimistic view of developments around the world.[20]

The previous attempt to measure changes in the degree of occupational gender segregation in England and Wales is that by Hakim (1981) using the Sex Ratio (SR). Hakim's results have been widely accepted, and although the Sex Ratio has been extensively criticised in recent years (for instance Siltanen 1990a; Tzannatos 1990), until now there has been no attempt to put a more accurate trend pattern in their place. Elsewhere we have shown that the Sex Ratio and its standardised form SR* are related to the Basic Segregation Table and have similar deficiencies to those of ID and WE (Blackburn, Siltanen and Jarman 1990). We refer to SR* as the standardised form because it is constrained to a range from 0 to 1, and is the difference of row proportions in the Basic Segregation Table (it will be recalled that ID is the difference of column proportions in the table). SR is SR* divided by the female proportion of the total labour force.

As may be seen from Figure 7, the Sex Ratio is the least accurate of all the attempts to measure gender segregation in England and Wales. It suggest a decline of over 20%, which would be a quite amazing achievement if it had actually happened. The main reason for this excessively optimistic picture is the growth of female employment, to which the Sex Ratio is very sensitive. In contrast, the standardised version of this index is the only measure that appears to show an increase in segregation. We must stress that all these measures purport to measure the same thing and all are calculated on the same data. The discrepancies are entirely due to deficiencies in the indices. The previously accepted account of changes in occupational gender segregation in England and Wales has been highly misleading. Contrary to the optimistic picture of a dramatic decline, our analysis shows that the net change in segregation from 1951 to 1981 was negligible.[21] This is an interesting and important finding which calls for further investigation, in view of the numerous changes in relation to gender and work which did take place in that period.

Conclusion

This paper has taken as its starting point the problem that different occupational segregation indices reveal different trends and different rankings for the same data. This is obviously a highly unsatisfactory situation. We have considered two important indices, the Index of Dissimilarity, which is the most widely used measure of segregation, and the OECD's WE Index, developed for one of the few international comparisons over time. Substantial inconsistencies between the two indices were traced in occupational and industrial data involving time trends and country comparisons.

We examined the two indices in order to explore possible reasons for the inconsistent trends and rankings, and in so doing we have shown that there is a mathematical relationship between them: the WE Index is a weighted form of the Index of Dissimilarity, varying with the male share of the labour force. We went on to show that the Index of Dissimilarity is seriously flawed and thus its extensive use gives misleading results. This is disturbing because its limitations are not generally recognized and many occupational gender segregation (and 'racial' segregation) results are, consequently, in doubt. Elsewhere, we have shown that some or all of the weaknesses of these two indices are shared by other available occupational segregation indices (Blackburn, Siltanen and Jarman 1990).

The paper's main contribution is the introduction of a new approach to measuring occupational segregation which provides more consistent results. It defines gendered occupations (or industries) in such a way as

to match the marginals of the Basic Segregation Table (the number of workers in female occupations is the same as the number of women in employment, etc.). In these circumstances several statistics of association coincide and are known as MM; the use of MM allows consistent measurement in all cases. We should emphasise that the construction of MM is a procedure that can be used at different levels of analysis in the investigation of gender segregation. It is as applicable to industries as it is to occupations, and can be used to examine the degree of separation of women and men within significant areas of occupational and industrial structures. Furthermore, with a suitable stratification scale, MM can be used to measure 'vertical' gender segregation.

The values of MM were calculated for four years of census data for England and Wales. These values were compared with those for the two indices we have examined, ID and WE, showing clearly the deficiencies of those indices. Furthermore, previous doubts about the Sex Ratio were confirmed; it too gives a misleading picture of a decline in gender segregation which never took place.

The implications of this paper are obvious—the trends which have been measured with the WE Index or the Index of Dissimilarity should be remeasured using a less problematic measurement technique now that one is available. We have already seen how they, and the Sex Ratio, give a misleading picture of trends in England and Wales, and this result needs to be incorporated in a fuller comparative analysis. The need to do so is urgent given the importance of the policy and research agendas which have been, and are currently being, formulated on the basis of our understanding of trends and comparisons in occupational gender segregation.

Acknowledgements

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Notes

1. For examples of the application of marginal matching to areas other than occupational gender segregation see Blackburn and Marsh (1991), Marsh and Blackburn (1992).
2. The values cited here are the values of the indices computed by the OECD. Figures quoted in the text are those presented by the OECD, which are actually the index values × 100.

3. Some writers have referred to the 'concentration' of women in one or a few occupations as 'segregation'. We suggest that it is useful to distinguish between discussions of the proportions of men and women in a single occupation (or group of occupations) and an analysis of the separation of men and women in the labour force. Thus we use 'concentration' to refer to the tendency for one occupation, or a specific set of occupations, to be staffed by one sex, and 'segregation' for the extent to which men and women are employed in different occupations (see Siltanen, Jarman and Blackburn 1992).
4. For a fuller discussion of measurement strategy and the criteria defining an appropriate segregation measure, see Blackburn, Siltanen and Jarman (1990), and James and Taeuber (1985).
5. For female index values, see Appendix Part A, Table 3. Male index values are calculated as twice the Index of Dissimilarity, less the Female WE (Appendix B).
6. These values are calculated using the equation $WE = 2M/N \times ID$ (presented below and proved in the Appendix Part B) and the values for WE and ID presented by the OECD (see Appendix Part A, Tables 3 and 4). Since the maximum of ID is 1, the maximum of WE is 2M/N, which is $WE \div ID$.
7. While recognising the problem of a variable maximum, the OECD mistakenly assert that it is 'inversely related to the rate of female participation' (43). The participation rate of women may be expected to have an effect on the index but it is the relative male and female shares of the labour force which determine the maximum.
8. The male share of the labour force is calculated from the values of ID and WE presented by the OECD (see Appendix Part A) using the formula $2M/N = WE/ID$.
9. The most important discussion of criteria is by James and Taeuber (1985) who present four. Here we consider one of their criteria, but to make its reference clearer we have changed the name from Composition Invariance to Sex Composition Invariance. Similar reasoning applied to the naming of the new criterion. See Blackburn, Siltanen and Jarman (1990), and Siltanen (1990a) for a fuller discussion of the relevance of James and Taeuber's criteria for the measurement of occupational segregation.
10. For those unfamiliar with the use of the term 'marginals', it refers to column and row totals of a table. Thus in Figure 5 the gender marginals are the column totals, F and M, and the occupational marginals are the row totals N_f and N_m.
11. There are a number of statistics of association, each of which comprises the cross-product $(F_fM_m - F_mM_f)$ divided by its own standardising factor to produce a potential range from 0 to 1 (for the Index of Dissimilarity, since it is the difference of column proportions, the factor is FM). It is these factors which are affected differently by changes in the pattern of marginals totals. See Blackburn and Marsh (1991); Blackburn, Siltanen and Jarman (1990).
12. A further consideration is that even if changes in the occupational categories are such as to leave the difference of proportions unchanged, they will affect the sex composition of the labour force, possibly leading to redefinition of male and female categories with further marginal change.
13. Since their work predates our introduction of the basic segregation table, they express the point rather differently but the logic is exactly the same.
14. For a more extended discussion see Blackburn and Marsh (1991) and Blackburn, Siltanen and Jarman (1990).

15. Decomposing change in the segregation index into different components (Blau and Hendricks 1979) does not resolve this problem.
16. Limitations of ID have been noted previously in the literature (Tzannatos 1990; Watts 1992) but proffered solutions are not convincing. For example, the solution used by Watts (1992) is a weighted version of ID called IP. One disadvantage of IP is that its maximum is $2MF/N^2$, which varies with the ratio of F to M and has its greatest value when F = M. Indeed, for all levels of segregation, the weighting factor tends to increase measured segregation the closer F is to M. In other words IP has a variable range and is not sex composition invariant.
17. The use of statistics of association is a well established traditional approach. It might, nevertheless, be thought that as we have been able to introduce a contingency table we should follow the more usual current practice and adopt a structural modelling approach. However, we are concerned with the strength of relationship which calls for a measure of association, and in any case, the existing indices are variants of statistics of association. Contingency table analysis is primarily concerned with fitting models to the data, and the sophisticated developments relate more to multidimensional tables; where a statistic of association (interaction parameter) is used it is normally the log odds ratio. The traditional statistic Q is directly equivalent to the log odds (they are different standardisations of the odds ratio) and has the same problems as ID.
18. The difference of proportions in the table is now the same as MM, but it is no longer the Index of Dissimilarity since matching the marginals has changed the definitions of gendered occupations.
19. See Siltanen, Jarman and Blackburn (1993) for information on using marginal matching.
20. We are aware that in speaking of optimism we are introducing our own values, but we believe they are widely shared and it is important that people should not be misled into believing in progress which does not exist.
21. Rubery *et al.*, using MM, have found similar stability in the 1980s.

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APPENDIX

A. Indices of segregation (WE and ID) as calculated and presented by OECD

Table 1 Occupational Data, WE Index

	1970	1976	1977	1978	1979	1980	1981	1982
Australia	0.641		0.628	0.627	0.617	0.624	0.602	0.607
Canada	0.534			0.499	0.495	0.469	0.467	0.446
Germany	0.418			0.440		0.441		0.442
Japan	0.306		0.289	0.284	0.286	0.286	0.275	0.275
New Zealand	0.597	0.561					0.701	
Norway	0.711		0.693	0.568	0.544	0.549	0.558	0.558
Sweden			0.502	0.474	0.467	0.466	0.457	0.442
USA	0.475		0.511	0.501	0.494	0.484	0.474	0.465

Table 2 Occupational Data, Index of Dissimilarity

	1970	1976	1977	1978	1979	1980	1981	1982
Australia	0.474		0.487	0.489	0.477	0.490	0.473	0.479
Canada	0.408			0.406	0.404	0.392	0.393	0.379
Germany	0.326			0.353		0.355		0.359
Japan	0.251		0.233	0.230	0.233	0.233	0.224	0.225
New Zealand	0.425	0.413					0.486	
Norway	0.491		0.553	0.474	0.460	0.468	0.478	0.483
Sweden			0.441	0.425	0.422	0.424	0.422	0.411
USA	0.379		0.427	0.424	0.422	0.416	0.411	0.406

Table 3 Industrial Data, WE Index

	1970	1976	1977	1978	1979	1980	1981
Australia	0.451	0.429	0.423	0.410	0.421	0.419	0.395
Belgium	0.449	0.449	0.456	0.455	0.452	0.457	0.479
Canada	0.403	0.390	0.390	0.389	0.379	0.370	0.364
Finland	0.338	0.324	0.342	0.342	0.346	0.351	0.362
Germany	0.352	0.356	0.353	0.350	0.352	0.350	0.363
Japan	0.223	0.235	0.234	0.231	0.232	0.227	0.220
Norway	0.551	0.467	0.469	0.472	0.452	0.451	0.540
Sweden	0.504	0.450	0.447	0.443	0.426	0.425	0.426
UK	0.390	0.408	0.403	0.404	0.406	0.409	0.412

Table 4 Industrial Data, Index of Dissimilarity

	1970	1976	1977	1978	1979	1980	1981
Australia	0.333	0.330	0.328	0.320	0.326	0.329	0.310
Belgium	0.344	0.343	0.349	0.351	0.350	0.356	0.352
Canada	0.317	0.310	0.312	0.315	0.310	0.333	0.305
Finland	0.306	0.305	0.325	0.325	0.329	0.333	0.346
Germany	0.278	0.286	0.285	0.282	0.285	0.283	0.287
Japan	0.184	0.188	0.189	0.188	0.189	0.185	0.180
Norway	0.399	0.382	0.387	0.393	0.381	0.383	0.383
Sweden	0.416	0.394	0.396	0.388	0.385	0.386	0.394
UK	0.306	0.335	0.333	0.335	0.338	0.341	0.345

B. Mathematical proofs relating to ID and WE

Notation

The notation used here is that presented with the Basic Segregation Table (Figure 5).
Thus

N is the total labour force
N_f is the total number of workers in 'female' occupations
N_m is the total number of workers in 'male' occupations
F is the number of women in the labour force
M is the number of men in the labour force
F_f is the number of women in 'female' occupations
M_f is the number of men in 'female' occupations
F_m is the number of women in 'male' occupations
M_m is the number of men in 'male' occupations

What the table does not define is the numbers of people in individual occupations. If the 'female' occupational category comprises the set of occupations (j), and occupations (k) make up the 'male' category, we may define F_j, M_j and N_j as respectively the number of women, number of men, and total number of workers in occupation (j); with similar definitions for occupation (k).

Thus

$$F_f = \sum F_j,\ M_f = \sum M_j,\ N_f = \sum N_j,\ F_m = \sum F_k,\ M_m = \sum M_k, \text{ and } N_m = \sum N_k.$$

Where occupations are referred to *without being specified as 'male' or 'female'* we follow the usual convention of using (i). Thus the set of occupations (i) comprises the two sets of occupations (j) and (k). Then M_i is the number of men in occupation (i), and so on, and $\sum M_i = \sum M_j + \sum M_k$, etc.

Proof 1.

ID *expressed in the simpler form, as a difference of proportions*
The Index of Dissimilarity is defined as:

$$ID = \tfrac{1}{2}\sum \mid F_i/F - M_i/M \mid$$

(where $\mid \quad \mid$ indicates the positive value of the difference enclosed).

However, the occupations (i) may be divided into 'female' occupations (j) and 'male' occupations (k). In 'female' occupations $F_j/F > N_j/N > M_j/M$
Therefore $F_j/F - M_j/M > 0$
Similarly $M_k/M - F_k/F > 0$
Thus $ID = \tfrac{1}{2}\sum \mid F_i/F - M_i/M \mid$

$$\begin{aligned} &= \tfrac{1}{2}\{\sum(F_j/F - M_j/M) + \sum(M_k/M - F_k/F)\} \\ &= \tfrac{1}{2}\{(F_f/F - M_f/M) + (M_m/M - F_m/F)\} \\ &= F_f/F - M_f/M \\ &= D_c \end{aligned}$$

which is the difference of proportions between columns of the Basic Segregation Table (Figure 5).

Proof 2.

The WE *Index: standardisation, male and female versions, and the relation to* ID
The *WE* Index is defined as

$$WE = \tfrac{1}{2} \mid F_i/F - N_i/N \mid$$

With similar algebraic manipulations to those used for *ID* we obtain,

$$WE = 2(F_f/F - N_f/N)$$

The maximum occurs when there is complete segregation, so that

$F_f = F$ and
$M_f = 0$, giving $N_f = F$

Therefore

$$\begin{aligned} WE_{max} &= 2(F/F - F/N) = 2(1 - F/N) \\ &= 2M/N. \end{aligned}$$

If we standardise *WE*, as *WE**, by dividing by 2M/N, so that it has a maximum of 1, we get

$$WE^* = WE \div (2M/N)$$

We may write $WE^{\star} = 2\left(\frac{F_f}{F} - \frac{N_f}{N}\right)\left(\frac{2M}{N}\right)$

$$= \frac{N}{M}\left(\frac{F_f}{F} - \frac{N_f}{N}\right)$$

$$= \frac{(F+M)F_f - F(M_f+N_f)}{FM}$$

$$= \frac{MF_f - FM_f}{FM}$$

$$= \frac{F_f}{F} - \frac{M_f}{M}$$

$$= D_c$$

$$= ID$$

and $WE = 2M/N \times WE^{\star} = 2M/N \times ID$

For calculating the male proportion of the labour force from the OECD Index values we may rewrite the equation

$$2M/N = WE/ID$$

We may note that WE is not symmetrical with respect to men and women. In fact the form used by the OECD, which we have been considering, is actually the female version. We may call it WE_f to distinguish it from the male version WE_m, where

$$WE_m = \sum | M_i/M - N_i/N |$$
$$= 2(F_f/F - N_f/N)$$
$$= 2F/N \times ID$$

(following reasoning equivalent to that presented above)

Thus

$$WE_f + WE_m = 2(F+M)/N \times ID$$
$$= 2ID$$
$$\tfrac{1}{2}(WE_f + WE_m) = ID = WE^{\star}$$

and to calculate WE_m we may write

$$WE_m = 2ID - WE_f$$

Also we see that the relation between WE_f and WE_m may be expressed

$$WE_f/WE_m = M/F$$

C. Segregation Measures for England and Wales Census Data, 1951–1981

	1951	1961	1971	1981
MM	0.6332	0.6120	0.6372	0.6309
ID	0.6753	0.6551	0.6528	0.6454
WE	0.9340	0.8854	0.8369	0.7776
SR	1.9634	1.8574	1.7203	1.5702
SR*	0.6055	0.6022	0.6173	0.6244