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Satya R. Chakravarty* and Sumita Chakravarty**

On Employment Segregation by Sex

Introduction

EARNING differences between men and women exist in almost all countries of the world. The most important reason behind this is that women tend to be concentrated in a subset of occupations which are usually low paid.

The increasing consciousness about the earning inequality between men and women have motivated economists to pay some attention to the problem of employment segregation by sex. This interest in employment segregation has naturally raised the question of how to measure such a segregation. The first attempt along this line has been made by Duncan and Duncan (1955). The Duncan-Duncan index can be interpreted as the proportion of male (female) workers required to be shifted between occupation categories such that the distribution of the proportions of male workers is same as that of the proportions of female workers. Although Duncan and Duncan's measure remains the most popular, several alternatives and variations have been suggested in the literature (see, for example, Moir and Selby Smith (1979), Lewis (1982), Butler (1987), Karmel and Maclachlan (1988), Silber (1989, 1992), Hutchens (1991), Chakravarty and Silber (1994) and Kakwani (1994)).

The purpose of this paper is two-fold. Firstly, we characterize the well-known Duncan-Duncan index using economically interesting axioms. Such an axiomatization enables us to understand the most popular measure of segregation from a deeper perspective. Next, we employ the Duncan-Duncan measure to analyze employment segregation by sex in India during the years 1981 and 1991.

The paper is organized as follows. In Section 2 we present the characterization results. The empirical analysis is reported in Section 3. Finally, Section 4 concludes.

An Axiomatization of the Duncan-Duncan Index

Suppose in an economy there are n mutually exclusive sectors. For concreteness we analyze sectoral segregation of male-female employment. The formal analysis applies

* Indian Statistical Institute, Calcutta 700 035.
** 83/2 B.T. Road, Calcutta 700 090.

equally well to any other characteristic that partitions the set of employees, e.g., occupation, age group, industry, level of education. The number of male and female employees in sector i are given respectively by M_i and F_i. Let $M = \sum_{i=1}^{n} M_i$ and $F = \sum_{i=1}^{n} F_i$. That is, M and F are the total number of male and female employees in the economy. Suppose $f_i (= F_i/F)$ and $m_i (= M_i/M)$ stand respectively for the proportions of female and male employees in sector i, $i = 1, 2, \ldots n$.

We begin our analysis with the construction of a local segregation index, that is, the segregation index for an arbitrary sector i. These local indices will form the basis of our overall or global index. An index of employment segregation for any arbitrary sector i is a function g that associates a non-negative value L_i to the vector (f_i, m_i). That is, $L_i = g(f_i, m_i)$ represents the level of segregation in sector i.

We now suggest some postulates for g. The first postulate is Reflexivity: $g(f_i, m_i) = 0$ if and only if $m_i = f_i$.

Reflexivity means that if the proportions of male and female workers in sector i are the same, then there is no segregation in this sector. Further, the converse is also true. Since one way of looking at segregation is to consider the difference between the proportions of male and female workers in different sectors, we will certainly want L_i to be equal to zero if these two proportions are the same in sector i.

The next property is impartiality. This property demands that the amount of segregation that exists in an occupation i when one compares its proportion of female employees with the proportions of male employees should be the same if one were to compare the proportions of male and female employees. More precisely.

Impartiality: $g(m_i, f_i) = g(f_i, m_i)$.

Sometimes the proportions of male and female workers in a sector may change by an equal amount. Such a change may take place through a redistribution of workers among sectors or through a change in the total labour force. For instance, suppose that there are 3 sectors and the proportions of employees in these sectors are $f_1 = .5$, $m_1 = .3$; $f_2 = .2$, $m_2 = .3$ and $f_3 = .3$, $m_3 = .4$. Now consider a redistribution of workers between sectors 1 and 2 such that the new proportions of workers become $f_1 = .4$, $m_1 = .2$; $f_2 = .3$, $m_2 = .4$ and $f_3 = .3$, $m_3 = .4$. That is, the redistribution decreases (increases) the proportions of male and female employees in sector 1(2) by the same amount .1. Since we are essentially interested in the difference between the proportions of male and female workers in different sectors it is reasonable to argue that the redistribution did not change the local segregation in sectors 1 and 2. A local segregation index that satisfies this condition of invariance with respect to changes in its two arguments is called translation invariant. More precisely, g is translation invariant if $g(f_i, m_i) = g(f_i + c, m_i + c)$ for all fractions c such that the sum of the transformed proportions of male (female) employees becomes unity. We state this formally as

Translation Invariance: g is a translation invariant function.

Proposition 1. *The only local segregation index L_i that satisfies reflexivity, impartiality and translation invariance is given by $h(|f_i - m_i|)$ where the non-negative function h satisfies the condition that $h(0) = 0$.*

Proof. By definition $L_i = g(f_i, m_i)$. *Let us assume that* $f_i > m_i$. Then by translation invariance,

$$\begin{aligned} L_i &= g(f_i - m_i, 0) \\ &= h(f_i - m_i) \text{ (say)} \end{aligned} \tag{1}$$

Next, let $f_i < m_i$. Now, in view of impartiality $g(f_i, m_i) = g(m_i, f_i)$. Then by translation invariance again ·

$$\begin{aligned} L_i &= g(m_i - f_i, 0) \\ &= h(m_i - f_i) \end{aligned} \tag{2}$$

From (1) and (2) we have ·

$$L_i = h(|f_i - m_i|). \tag{3}$$

Non-negativity of g requires non-negativity of h. Finally, reflexivity requires that $h(0) = 0$. This establishes the necessity part. The sufficiency is easy to check. □

In the remainder of this section we assume, for simplicity, that h is the identity mapping, that is, $h(z) = z$. thus, L_i becomes $|f_i - m_i|$. Let us now turn to the derivation of the overall segregation index. We assume that the overall index is a real valued function of local indices. In many branches of economics there is a convention of defining a global index as a function of local indices. For instance, in welfare economics a social welfare function is defined as a real valued function of individual utility functions. Thus, an overall segregation measure is given by $I(L_1, \ldots, L_n)$ where $L_i = |f_i - m_i|$ and the n-coordinated function I is real valued.

We now state some axioms for a global index I. The first axiom is symmetry. According to symmetry I remains invariant under any permutation of its arguments. That is, I is insensitive to the order in which L_i's are written. Thus, in measuring overall segregation only local segregation levels matter. All over characteristics, for instance, the names of the sectors, are irrelevant.

Symmetry: I remains invariant under any permutation of $L_1, \ldots, L_n$.

If the distribution of the proportions of female workers in different sectors is same as that of the proportion of male workers, then there exists absolutely no sectoral segregation by sex. This is the case of minimum or zero segregation. In contrast, a segregation index should take on the maximum value when males and females are in separate occupations (see also Kakwani, 1994). This seems intuitively reasonable because it says that the female (male) workers are completely concerntrated in a subset of occupations. That is, the male and female workers are completely segregated. We formalize this idea as

Complete Segregation: If $f_i\,(m_i) > 0$ implies $m_i\,(f_i) = 0$ for all i, then $I = 1$.

Now, to characterize the Duncan-Duncan index we consider the following form of global segregation.

DEFINITION. The overall measure of segregation G is a positive weighted sum of local segregation indices. More precisely,

$$G = \sum_{i=1}^{n} a_i L_i \tag{4}$$

where the weights a_i's are positive.

The measure G given by (4) is analogous to the generalized utilitarian form of social welfare function. According to the generalized utilitarian form social welfare is taken as a positive weighted sum of individual utility functions. If the weights are the same, the generalized utilitarian rule becomes the well-known utilitarian form.

We now have

PROPOSITION 2. *The only overall segregation index of the form* (4) *that satisfies symmetry and complete segregation postulates is the Duncan-Duncan index*

$$G = \frac{1}{2} \sum_{i=1}^{n} | f_i - m_i | \tag{5}$$

Proof. G in (4) remains invariant under permutation of L_i's if a_i's are the same, that is, for some $a > 0$, $a_i = a$, where $i = 1, 2, \ldots, n$. Consequently, G becomes

$$G = a \sum_{i=1}^{n} | f_i - m_i |. \tag{6}$$

Consider the case of complete segregation. Assume without loss of generality that female workers are concentrated in first k occupations and the male workers are concentrated in remaining $(n-k)$ occupations. That is, $\sum_{i=1}^{k} f_i = \sum_{i=1}^{n} m_i = 1$. G in (6) satisfying this condition becomes $2a$. But by hypothesis in this case $G = 1$, which gives $a = 1/2$. Putting this value of a in (6) we get the desired form of G. This establishes' the necessity part. The sufficiency is easy.

In addition to the above stated properties, G in (5) satisfies another interesting property suggested by Kakwani (1994). It decreases under a small shift of the female (male) labour force from a female (male) dominated sector to a male (female) dominated sector. (A sector i is called female dominated if $f_i > m_i$.) Since the Duncan-Duncan index is bounded above by 1, we can regard its complement from 1 that is, $(1 - \sum_{i=1}^{n} | f_i - m_i | /2)$ as a measure of integration between female and male employees. An increase in the value of the segregation index is equivalent to a reduction in integration.

Suppose that the total number of n sectors have been subdivided into k major sectors. There are n_i minor sectors in major sector i, $\sum_{i=1}^{k} n_i = n$. Let f_{ij} (m_{ij}) be the proportion of female

(male) workers in the minor sector *j* that belongs to major sector *i*. Clearly,

$$\sum_{i=1}^{k} \sum_{j=1}^{n_i} f_{ij} = \sum_{i=1}^{k} \sum_{j=1}^{n_i} m_{ij} = 1.$$

Then the Duncan-Duncan measure can be written as

$$G = \frac{1}{2} \sum_{i=1}^{k} \sum_{j=1}^{n_i} | f_{ij} - m_{ij} |. \quad (7)$$

Now, let $f_{i.}(m_{i.})$ be the proportion of female (male) workers in major sector *i*. Note that

$f_{i.} = \sum_{j=1}^{n_i} f_{ij}$ and $m_{i} = \sum_{j=1}^{n_i} m_{ij}$. Then the between-major sector measure of segregation is

$$G_b = \frac{1}{2} \sum_{i=1}^{k} | f_{i.} - m_{i.} |. \quad (8)$$

One can check that $G > G_b$. We can in fact regard $G - G_b$ as a measure of within-major sector segregation.

Employment Segregation in India

In this section we estimate trends in employment segregation by sex in India. The required data on male and female employment have been obtained from the tables published in Census of India for the years 1981 and 1991, The data were classified by state, place of residence (rural or urban) and industrial category.

We have divided the 30 states and union teritories into six regions stated below

South West	AndhraPradesh; Tamil Nadu; Karnataka; Kerala; Lakshadweep; Pondicherry.
Central	Gujarat; Rajasthan; Goa; Daman and Diu; Dadra and Nagar Haveli. Maharashtra;
North East	Madhya Pradesh. Uttar Pradesh; Himachal Pradesh; Delhi; Punjab; Haryana;
North East	Chandigarh. Bihar; West Bengal; Orissa; Andaman and Nicobar Islands. Tripura;
	Manipur;Nagaland; Meghalaya; Arunachal Pradesh; Sikkim; Mizoram.

The 9 industrial categories have also been subdivided into three following major sectors.

Primary	Cultivators; Agricultural Labourers; Livestock, Forestry, fishing, hunting and
Secondary :	plantations, orchards and allied activities; Mining and quarrying. Manufacturing,
Tertiary :	Processing, Servicing and Repairs; Constructions. Trade and Commerce;
	Transport, Storage and Communications; other services.

In columns land 3 of Table 1 we present the estimates of the total segregation index for 1981 and 1991 using employment data classified according to alternative criteria. In columns 2 and 4 of the table the between-group indices (for subdivisions of states into regions and industrial categories into major sectors) are presented. Certain interesting conclusions emerge from the table. While for the data classified according to place of residence and state there is minor increase in segregation (in both cases the increase is less than 10%), for industrial classification segregation decreases by 12%. Thus, trend in segregation is sensitive to the method of classification of data. The reason behind the opposite trend might be the following. The local segregation in some industries has gone down but such industries probably are not in the states for which local segregation increased significantly. Consequently, the overall statewise segregation outweighed the negative impact of the overall industrial segregation.[1] Next, for statewise classification, in both the years only about 1% of the total segregation could be accounted for by the within-group component. In contrast; for industrial classification this figure turns out to be 42% in 1981 and 30% in 1991. Here also we note the decreasing trend in segregation for industrial classification.

TABLE 1: MALE-FEMALE EMPLOYMENT SEGREGATION IN INDIA IN 1981 AND 1991 BY PLACE OF RESIDENCE, STATE AND INDUSTRIAL CATEGORY

Classification criterion	*1981*		*1991*	
	overall index G	*between group index G_b*	*overall index G*	*between group index G_b*
Place of Residence	.1100	—	.1190	—
State	.2645	.2603	.2836	.2808
Industrial Category	.2662	.1537	.2341	.1764

Conclusions

We have specified a set of economically attractive conditions that will exactly identify the Duncan-Duncan index of employment segregation in a sepecific framework. Using Indian data it was observed that the trend in segregation, as depicted by this index, is sensitive to the criterion of classification of the data.

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1. Micro level (e.g., industry and statewise) investigations may identify the real factors behind this.