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On Measures of Gender Occupational Segregation: Statistical and Conceptual Considerations (a Response to Grusky and Levanon)

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In a recent article (2005), the authors proposed the first-order approximation (FOA) index for the measurement of gender occupational segregation across detailed occupational categories. The FOA index can remedy the two inherent limitations—sensitivity and singularity—associated with the ratio index and the association index, especially when applied to the measurement of micro-segregation. Grusky and Levanon (this issue), while acknowledging these limitations, view the FOA index as a misguided effort to remedy the shortcomings of the other indexes. When responding to Grusky and Levanon, the authors address two kinds of controversies. The first aims directly at the methodological reasoning put forward by Grusky and Levanon and centers on the statistical properties and statistical assumptions embodied in the various measures. The second revolves around different paradigmatic approaches to the study of occupational segregation and centers on different conceptual views of the gender segregation phenomenon.

Keywords: *FOA index; margin-free indices; occupational segregation*

More than a decade ago, Charles (1992) proposed the *ratio* index for estimating gender occupational segregation, and a few years later Charles and Grusky (1995:945; see also Grusky and Charles 1998) presented a modified version of the ratio index—the association index (A). The latter was hailed as a generic measure, the validity of which was not limited to broad occupational categories. In a recent article published in this journal (Jerby, Semyonov, and Lewin-Epstein 2005),

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we addressed two inherent limitations—sensitivity and singularity—of both of these measures (R and A), limitations that are especially pronounced when the indexes are computed for highly detailed occupational classifications. The alternative measure we proposed—the first-order approximation (FOA) index—offers a unified solution to the limitations of the indexes introduced by Charles and Grusky.

In response to our article, Grusky and Levanon (2006 [this issue]; GL hereafter) acknowledge limitations associated with the ratio index and the A index when faced with sparse data arrays. They then go on to critique the FOA index as a misguided effort to remedy the shortcomings of available measures and propose yet another measure—an index that, in their view, can surmount the limitations associated with previous indexes. We herewith respond to their critique and propositions and briefly point to ways in which the FOA index can be used in future research.

While acknowledging the contribution of our article to the scholarly literature aimed at measuring segregation across detailed occupational classifications, GL are also critical of the FOA index as a valid measure of occupational segregation. They are critical of FOA for three reasons: The main problems with the FOA index are its sensitivity to (a) cross-city differences in the overall size of the labor force, (b) the relative number of women in the labor force, and (c) the mix of occupations. They also treat a central aspect of our critique—singularity—as a ''nonproblem,'' and they neglect the ''sensitivity problem'' (which is not alleviated by the newly corrected A_M version).

The three problems highlighted by GL, as well as the ''nonproblem'' to the singularity issue, dictate the course of our response. Generally speaking, our response addresses two kinds of controversies. The first response is aimed directly at the methodological reasoning put forward by GL and centers on statistical properties and statistical assumptions embodied in the various measures. Our second response revolves around different paradigmatic approaches to the study of occupational segregation and centers on different conceptual points of view regarding the gender segregation phenomenon. We will argue that within our theoretical approach, the sensitivity of the FOA index to the ''relative number of women in the labor force and . . . the mix of occupations''

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(Grusky and Levanon 2006:569) is an advantage rather than a disadvantage.

EMPTY CELLS—STRUCTURAL OR SAMPLING ZEROS?

One of the major disagreements we have with GL is with regard to the existence of mono-gender occupations (i.e., cells empty of either men or women in an occupational category) and with regard to the complete absence of occupations from a specific labor market in sparse and incomplete data arrays. While we work under the premise that empty cells represent structural zeros, GL contend that empty cells are *all* and *always* sampling zeros. This is neither a technical nor a trivial disagreement but rather a fundamental issue that needs to be further discussed and clarified.

Let us start with a claim, commonly shared by sociologists, that "to capture the real essence of gender occupational segregation it is necessary to examine rather detailed categories" (Jerby et al. 2005:122). However, detailed occupational classification poses a problem for users of the ratio index since small occupations are more likely to be mono-gender occupations (e.g., Bielby and Baron 1986).

As originally proposed in our article (Jerby et al. 2005), the FOA index attempts to remedy two intrinsic deficiencies of the ratio (R) index: singularity for mono-gender occupations and sensitivity with regard to the inclusion of ultra-segregated occupations—deficiencies that are not overcome by shifting from the ratio index to the association index (A). Unfortunately, GL do not respond to the fundamentals of our critique. That is, they do not deal with the inherent shortcomings embodied in both the ratio index (R) and its variant A. Instead, they shift the discussion to statistical problems arising from relationships of samples to populations.

The ratio (R) and the association (A) indices, as initially proposed by Charles (1992) and Charles and Grusky (1995), are based on a nonlinear function that generates both singularity and sensitivity. The ln function prevents both indices from integrating mono-gender occupations (i.e., structural zeros) into the computation. This is a major shortcoming that our article addresses and one that the FOA rectifies. In response, GL argue that structural zeros actually do not

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exist,[1] and consequently the singularity argument is rendered irrelevant. In their view, empty cells are *all* sampling zeros. By defining that the problem is external to the indices themselves, they free the original R and A indices from the singularity critique. This approach is based on the idea that even a complete census is best regarded as "but one of the infinity of populations that will result by chance from the same underlying system of social and economic causes" (Deming and Stephan 1941:48), meaning that a so-called 100 percent sample is merely a sample from a larger "super-population." GL also argue that there is always an $N + 1$ trial that hypothetically can validate their argument that any empty cell is only a sample product.[2]

In accord with the hyperstatistical approach adopted by GL, mono-gender occupations represent sparse data arrays, and occupational selectivity reflects incomplete data arrays. This statistical approach is problematic since it contradicts the real essence of the segregation phenomenon—a phenomenon that is fully revealed only across detailed occupational categories. In other words, gender occupational segregation becomes more pronounced and more evident as the occupational classification becomes more detailed. Likewise, occupations tend to be more gender-typed as the analysis addresses more detailed occupational classifications (e.g., Bielby and Baron 1986). It is a fundamental feature of the phenomenon that we define as *micro-segregation* (Jerby et al. 2005).

The ratio index and its variant A do not have upper and lower bounds. The option of attributing the *highest* value on these two segregation scales to mono-gender occupations (as we are able to do with the FOA index) is not a viable solution since both attain infinity for mono-gender occupations. Hence, the *sampling zeros argument* advanced by GL is a convenient, albeit synthetic, solution that serves researchers who advocate the use of measures such as the ratio and the association indices. In effect, the claim that all the observed mono-gendered occupations are sampling products shifts the burden from the limitations of the measures to shortcomings of the data sets. The sampling zeros strategy leads to the "empirical borrowing" procedure[3] (Weeden 1998) and later to the development of A_M that is restricted, above all, by the lack of any finite extreme value of the (original) R and A scales. Note that adding a small arbitrary value to all empty cells is an artificial correction, while (+2) and (−2) are the

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real limit values that FOA produces for perfect segregation. By contrast, the ratio index and its variant A lack such parallel finite values (mono-gender occupations become "blind points" on their segregation scale).

IS FOA SENSITIVE TO THE SAMPLE SIZE?

In critiquing the FOA index, GL claim that they found it to be sensitive to "the overall size of labor force," an apparent drawback for a measure to be used for comparative purposes. However, we argue that this observation is a feature of the data and a result of sociological processes, rather than a property of the index. That is, the "sensitivity" of FOA to "the overall size of labor force" is a result of differences in segregation rates between large and small cities, as expected by sociological theory and as repeatedly shown by previous students of gender occupational segregation (Stephan and McMullin 1982; Abrahamson and Carter 1986; Abrahamson and Sigelman 1987). Indeed, GL also note that perfectly segregated occupations are more likely to appear in small cities than in large ones and that occupations with fewer incumbents are more likely to be perfectly segregated.

GL further argue, "Because the FOA index so harshly penalizes a perfectly segregated occupation, Smalltown ends up with a high FOA value" (Grusky and Levanon 2006:559). Actually, in comparison to the original A index (Charles and Grusky 1995), it is the latter measure that penalizes mono-gender occupations more severely. While FOA yields moderate values of ± 2 for perfectly segregated occupations, both A and R "explode" as they approach plus or minus infinity. It should be emphasized, therefore, that if GL were to "apply A . . . to the sample array after replacing, for all segregated occupations, the observed data with those expected under the model" (p. 565), then a proper comparison should be to also apply FOA to the *replaced* data. Table 1 of GL thus depicts, in a confusing way, a comparison of results obtained for FOA that are based on the original data and results obtained for A that are calculated on the basis of manipulated data.

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GL also claim that the higher likelihood of mono-gender occupations appearing in small units (e.g., occupations and towns) results from small units' sampling principles. In the example they present, the probability of observing a perfectly segregated occupation after 10 trials is relatively high ($\approx .35$). However, the population parameters in their example are "ultra-segregated" ($\theta_1 = .1$ and $\theta_2 = .9$). Therefore, observing a perfectly segregated occupation, in this case, is not a significant misrepresentation of the parameters. In addition, we argue that, when the population parameters are perfectly integrated ($\theta_1 = .5$ and $\theta_2 = .5$), the probability of observing a perfectly segregated occupation after the same number of trials (i.e., 10) falls substantially to $(.5)^{10} + (.5)^{10} = .00097$. Consequently, we can, quite confidently, regard empty cells as structural zeros—mono-gender occupations that represent the extremes of the segregation phenomenon on the index scale. It is also worth noting that, if the population parameters were perfectly segregated (i.e., $\theta_1 = 0$ and $\theta_2 = 1$ or $\theta_1 = 1$ and $\theta_2 = 0$) for a given occupation, then that specific occupation would show up as perfectly segregated *no matter how large or small the sample size.* However, GL cannot incorporate this possibility. Apparently, if they were to embrace this possibility, they would refute the basic premise underlying their estimation approach (i.e., a total absence of structural zeros—or mono-gender occupations—in the "population").

GL appear to agree that neither the ratio index (R) nor the association measure (A) are able to handle detailed data arrays and to arrive at accurate estimates of micro-segregation. Hence, when discussing the FOA index, GL propose yet another correction for both the ratio and the association indices, involving a rather complicated correction process (denoted A_M). A log-multiplicative model (Grusky and Levanon 2006, equation (2)) is proposed to control for occupational selective processes. They use data for metropolitan statistical areas (MSAs) in Iowa to illustrate the properties and virtues of A_M. Notwithstanding the virtues of A_M, GL find that "the relationship between FOA and A_M is nearly linear." It is worth noting that despite the fact that "the PUMS data from Iowa include many small cities" and "its segregation arrays are unusually sparse and incomplete" (Grusky and Levanon 2006:568), the relationship between FOA and A_M is nearly linear. Apparently, the two indices yield similar estimations of gender segregation. However, the computation of FOA is much more parsimonious. In

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practice, then, we are left with a rather simple dilemma whether to prefer the parsimonious FOA (which treats empty cells as structural zeros) or the complex estimation procedure (performed by A_M) that eventually yields *nearly the same results* to the FOA measure.

A DIFFERENT CONCEPTUAL APPROACH

In deciding upon a measurement procedure, it is essential to clarify and define the relations between the theoretical concept and its empirical measures. Several scholars of segregation have explicitly addressed the problematic aspects surrounding the specific relations between theoretical concepts and measurements of gender occupational segregation. Weeden (1998), for example, highlights this issue when writing that "there is some ambiguity about what should be included in the concept and measurement of sex segregation" (p. 477). She refers also to James and Taeuber (1985), who stated that "segregation analysts have not adequately justified their measures on conceptual grounds." Siltanen, Jarman, and Blackburn (1995) went even further to suggest that "in the matter of substantive definitions researchers have been too willing to let 'segregation' be defined by the properties of available measures" (p. 97). Since the critique put forward by GL reflects in part disagreement on what segregation indexes should measure, we would like to take this opportunity to suggest, as well, that segregation indices are merely an operational definition of the segregation phenomenon. As such, they serve as measures of the theoretical concept—gender segregation. Indeed, when adopting a specific measure and when making statistical assumptions about the measure, we actually define the scope and focus of the phenomenon we study.

AN ALTERNATIVE VIEW

We embrace a different conceptual approach in the measurement of gender occupational segregation from that taken by GL. Our disagreement with GL is not only a methodological matter but also a

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paradigmatic matter. Basically, we conceptualize segregation as a phenomenon that is defined by its margins (i.e., the attributes of the margins are endogenous to the segregation phenomenon). Consequently, the measure we prefer for gender occupational segregation is *sensitive* to the occupational structure and to the gender composition of the labor force and therefore also to the overall size of the labor force. Indeed, we regard these components as integral dimensions of the phenomenon, and as such, they are components that can be identified and further studied.

In their "Cautionary Tale of Three Cities," Grusky and Levanon (2006) provide theoretical reasoning as to why the margins (supply of women and composition of jobs) can affect rates of segregation across different hypothetical cities (i.e., traditional, small, and post-industrial). We agree that a margin-free (MF) index is a valid measure for students of segregation who are interested in capturing segregation through the prism of occupational categories. We prefer, however (following the same theoretical logic introduced by GL), to arrive at an index whose margins are, in effect, not exogenous but endogenous to the index (but whose endogenous components are identifiable). Such an index and its components offer a complementary perspective and additional directions for comparative research in the area of gender occupational segregation.

From a statistical point of view, MF measures have many appealing advantages. The MF paradigmatic concept reflects an ongoing effort to purify the net association of gender by occupations from the margins' effects (the log-multiplicative model suggested by GL in equation (2) to control for occupations' selective processes is inherent to this effort). However, the view that a margin-free criterion is the "ultimate" and "only" framework with which to evaluate the validity of occupational gender segregation indices is problematic and rather limiting. The MF paradigmatic conceptualization (and particularly the *occupational invariance* imperative[4]), to which the ratio (R) and A indices fully conform, adopts an approach that forces scholars to view segregation through the occupational prism. In other words, researchers who implement the MF paradigm explicitly (and at times implicitly) view occupations as ontological entities. Accordingly, occupational gender segregation is defined as a pure association between gender and occupation, and therefore, the basic occupational

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segregation table includes nothing more than a $I \times 2$ contingency table (where I represents the number of occupational categories) (Bridges 2003:548).

The ratio index, developed within this framework (Charles 1992), ignores the number of workers in occupational categories since it treats occupations as the fundamental entities. Consequently, all occupations contribute equally to the summary measure—regardless of their relative size (i.e., the number of employees included in the occupational category). This procedure, in effect, inflates the impact of small units and deflates the impact of large occupational categories. As a result, the index is blind to the number (or the proportion) of individuals subjected to occupational segregation. It follows that, if the researcher is interested in the distribution of workers across occupations, the ratio index as a proxy of segregation may misrepresent the phenomenon and thus may distort conclusions.

In our view, it is essential to provide a complementary perspective for the study of gender occupational segregation that captures the presence and the distribution of individuals across occupations. Weighting occupations by their relative size shifts the focus of the index from occupations to *the population subjected to segregation.* Elsewhere (work in progress by Jerby, Semyonov, and Lewin-Epstein[5]), we propose a weighting procedure that, while negating the MF concept, also embraces somewhat a different approach to the study of occupational segregation. We briefly allude to this procedure later in the article.[6]

DEPENDENCE ON THE GENDER MARGIN

The paradigmatic demand for "compositional invariance" regards the *variation* in gender composition[7] across social systems (i.e., local labor markets, time) as irrelevant for the segregation phenomenon. Accordingly, a totally integrated occupation is one in which the male's and female's representation is identical to their share in the entire labor force. When taking this perspective, GL raise the following question (and answer): "Is it appropriate to conclude, as users of the FOA index would, that Traditional City is more segregated than other cities? Absolutely not. It is simply that women in Traditional

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City are less likely to enter the labor force" (Grusky and Levanon 2006:557).[8]

We, however, take a different view on the subject. We view gender composition of the labor force as endogenous to the segregation phenomenon. The gender composition reflects the impact of exclusion-inclusion mechanisms that prevent or enable members of a distinct group (e.g., women) from joining the economically active labor force. Therefore, we conceptualize segregation as a two-dimensional phenomenon or as a result of a selection process with a double barrier: The first is entrance barriers to the labor market, and the second is social barriers to occupations. In other words, we view gender segregation as simultaneously influenced by the ability of women to, first, join the economically active labor force and, second, to become fully integrated into the various segments of the labor market (i.e., occupations). Under this premise, we propose to conceptualize gender segregation as a two-dimensional phenomenon.

Following this logic, we propose a two-dimensional index (derived from the FOA index) that we denote ISR (index for segregation regime).[9] The ISR permits a more accurate and better understanding of gender occupational segregation by displaying the two distinct components of the segregation regimes and is expressed in the following notation:

$$\mathrm{ISR} = \sum_{i=1}^{I} A_i |r_i - \overline{R}| = \sum_{i=1}^{I} \frac{n_i}{N} \left| \frac{f_i - m_i}{n_i/2} - \frac{F - M}{N/2} \right|,$$

where i indexes the occupation-specific identification; f_i and m_i are the numbers of women and men, respectively, in the ith occupation; n_i is the total number of employees in the i^{th} occupation ($n_i = f_i + m_i$), and N is the total number of employees in the labor market. F and M are the total numbers of women and men in the entire market.

The ISR is composed of two components: Each one represents a distinct dimension of the segregation phenomenon. The first dimension pertains to the gender composition of the labor force corresponding to what we defined as the "entrance barriers to the labor market." The second captures the extent of heterogeneity around the mean corresponding to the "market barriers to occupations." When ISR is presented in a two-dimensional vector form, as a decomposition of the

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scalar index, it provides greater insight and enables more meaningful comparisons of gender segregation across markets and across time.

CONCLUSIONS

During the past decades, the study of gender occupational segregation has progressed rapidly in terms of theory, methodology, and empirical research. The work by GL and by us (Jerby et al. 2005) should be viewed as two attempts to advance the methodological knowledge in the field of gender segregation. Our recent exchange (of punches) on the pages of this journal should be viewed as an amicable disagreement about the best ways gender occupational segregation should be measured. However, while we share the same goal—advancement of methodological knowledge in the study of gender segregation—we disagree on both the virtues and assumptions of the measures, and we disagree about the conceptual approach one need adopt when studying gender occupational segregation.

GL view the absence of either men or women from an occupational category as statistical zeros (resulting from sampling procedure), while we entertain the possibility of structural zeros and true mono-gender occupations (occupations that represent the extremes of the segregation phenomenon's scale). We advocate a measure that not only resolves the singularity and the sensitivity problems but is also unstandardized and has upper and lower bounds. Furthermore, we offer the use of a two-dimensional index that simultaneously pertains to the barriers faced by women in attaining both equal participation in the economically active labor force and equal distribution in the occupational structure.

GL advocate the use of a margin-free measure that treats occupations as the units of the analysis while we arrive at a weighted measure that captures the segregation regime that is experienced by individuals in the labor market. The dilemma of whether an individual or an occupation-centered conceptualization of segregation is to be preferred is a theoretical rather than a methodological consideration. In this respect, the margin-free coercive concept should be reconsidered to enable comparative analyses to address both equally important aspects of individuals and occupations.[10]

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Accordingly, A_M and ISR/Ip indices (as well as D and Ds) should not be viewed as substitutes. They may coexist as complementary tools in the sociological "toolbox" for comparative analyses of gender segregation. These indices address different dimensions or aspect of the complex segregation phenomena. Each index can be regarded as a different "filter" through which researchers can observe and capture different aspects or different dimensions of this complex phenomenon. Researchers should be aware of the specific attributes of the measures and how these measures correspond to their conceptual framework. It is our hope that the measure we offer here and the debate that it has generated will motivate further research and discussion in what was prematurely viewed as "an open-and-shut case" of measuring gender occupational segregation.

NOTES

1. To sharpen the problematic aspects of this logic: An occupation would be recognized as structurally perfectly segregated only under extreme conditions that obviously can never be satisfied. However, in essence, from a sociological point of view, perfect segregation does exist when either men or women are denied access to certain occupations due to cultural norms and constraints that do prevail in many traditional soci-eties such as Muslim ones where women and men are secluded to specific occupations (e.g., Semyonov, Lewin-Epstein, and Brahm 1999).

2. As Grusky and Levanon (2006; GL) present it, "The question at hand, then, is whether an occupation that shows up as perfectly segregated after 10 hires is likely, when an 11th position opens up, to continue being perfectly segregated" (p. 558). In the same vein, they argue, "Smalltown's employers did not have an adequate chance, as do employers in large cities, to demonstrate that they are open to hiring both genders" (p. 559).

3. The borrowing procedure violates the crucial assumption that *specific* local structural attributes differentially shape segregation patterns (especially for the phenomenon extremes) and reduces the variance. Weeden (1998:478), for example, acknowledges this limitation.

4. The *occupational invariance* imperative requires segregation indexes to be invariant to changes in the relative size of occupations, *if the gender composition remains constant.*

5. See also Jerby (2002).

6. From this point of view, our approach is built on the logic embodied in the interpretation of the index of dissimilarity. Indeed, when attributing equal weight to occupations, employees are differentially weighted, and when attributing equal weight to individuals, occupations are differentially weighted. Since either of these approaches could be appropriate, depending on the interest of the researcher, we would like to further elaborate on the advantages embodied in the approach we propose and to point toward new directions for future research on the subject.

7. The gender composition of the labor force is highly correlated with females' labor participation rate, and therefore, these variables are in fact interchangeable.

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8. This idea represents an extreme approach of voluntary action. Accordingly, employers (as well as the societal norms) are predominantly gender blind/indifferent to gender (or as GL would argue, employers just need the adequate [statistical] chance to demonstrate that they are open to hiring both genders). Therefore, it is implicit by their arguments that women who are not included in the labor force have a clear preference to be unemployed.

9. In fact, the index for segregation regime (ISR) is a different representation of the known Ip (Karmel and MacLachlan 1988).

10. The ratio index, as well as the size-standardized dissimilarity index, refers to occupations as the fundamental unit of analysis, whereas the dissimilarity index and the proposed ISR (= 4 Ip) refer to the individuals as the fundamental entity.

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