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The ecological fallacy: How to spot one and tips on how to use one to your advantage

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ABSTRACT

The ecological fallacy is a common and little understood error in the interpretation of statistical data wherein inferences about individuals are based on the aggregate of the group from which they belong. This opinion piece overviews the importance of avoiding the error and illustrates the ease with which mistakes in inference can be made by examining some papers appearing in recent conferences and journals, and by demonstrating with artificial data representing Hofstede's cultural dimensions. It concludes with an appeal for caution when considering the combination of aggregate data with our surveys of individuals.

CHINESE ABSTRACT

生态谬误是统计数据解读中一种常见且很少人了解的错误，人们会误从个人所属集团的汇总中推论出个人数据。本评论概述了避免该错误的重要性，并通过近期会议期刊上的论文和霍夫斯泰德教授文化方面的人工数据说明推论错误的经常出现。本文最后呼吁在综合考虑聚合数据与个人调查时，一定要认真谨慎。

1. Introduction

A fallacy is an error of logic usually based on mistaken assumptions. The ecological fallacy is an error of deduction that involves deriving conclusions about individuals solely on the basis of an analysis of group data (O'Dowd, 2003).

This paper is prompted by some conference papers and journal articles over the years where presenters accepted the ecological fallacy. The ecological fallacy also is something one sees often in published literature, especially in attempts to include Hofstede's cultural dimensions in a cross-national study (Hofstede, 2001; 2014). The paper seeks to explain what it is to become victim to the ecological fallacy, the consequences of making the error, and finally, by inference, some techniques for presenting otherwise useless results that will often snow the naïve reviewer or audience.

1.1. History of the term, ecological fallacy

The term "Ecological Fallacy" was coined by Robinson in 1950, following Thorndike (1939), when he highlighted the correlation between % illiterate and % African-American in the US. Across the "Nine Census Regions" r = 0.95, across the 50 States r = 0.77, and at the Individual level r = 0.20 (Robinson, 1950). How could it be that at the aggregate level the correlation was very high yet at the individual level the correlation was almost irrelevant? This is an important issue when government policy and grant money hinge on the decision. More recently we have seen statistics which show that those US states with the lowest levels of college graduates are most likely to vote Republican (Gelman et al., 2008; Morford, 2004), yet the wealthy (and presumably well-educated) are regarded as the Republican base. It turns out that the wealthiest citizens within each state are indeed the greater supporters of the GOP. Between the states there is a negative relationship between wealth and conservatism; within the states it is a positive relationship (Gelman et al., 2008).

In 19th century Europe, Durkheim pointed out that suicide rates were higher in countries that were more heavily Protestant (Durkheim, 1897). The logical inference for many readers was that the social conditions under Protestantism promoted suicide. This "Common Interpretation" of Weber's Protestant Work Ethic (Weber, 1905) argues that industrial capitalism is facilitated by Protestantism rather than Catholicism, and occurred in predominantly Protestant countries earlier as a result. An examination of Durkheim's aggregate data seems to support such a conclusion. More recently, however, Delacroix and Nielsen (2001) show that measures of Industrial Capitalism have little relationship to Protestantism within countries, and even less at the regional level (when such measures are available). They suggest that the "common interpretation"

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is a result of anecdote and mere observation of 20th century prosperity.

From the 1970s, economic commentators argued that Individualist economies, defined by Hofstede's cultural dimensions, such as the US and Western European countries, outperformed Collectivist economies, such as China and Korea. The logical inference was that Collectivism holds Asian countries back economically (Landes, 1999). Then by the 2000s similar commentators argued that Collectivism was responsible for the growth of the Tiger Economies (Zurndorfer, 2004). They couldn't both be right. So in the late 2000s the argument was modified somewhat to posit that Collectivism drives efficiency while Individualism drives innovation (Gorodnichenko and Roland, 2010, 2012). So this new argument is that we should see the Tiger Economies perform well on production but relatively poorly on new patents and design. No doubt, the story will have to change again as writers try to account for the number of patents from Indian, Chinese, Japanese and Korean technology companies, which now equal or exceed European and US producers on most measures (Adams et al., 2013; WIPR, 2014). Fortunately, researchers are now taking multi-disciplinary perspectives on the issue, incorporating biology, geography, history and culture to account for economic development (Spolaore and Wacziarg, 2013).

The following section briefly examines some papers presented at recent international conferences and in peer-reviewed journals that demonstrate the ecological fallacy commonly presented in the business disciplines.

2. The mistake of using country as an indicator of individuals' cultural values

Papers presented to recent conferences and in journals serve as convenient examples of the ease and readiness with which we make the ecological fallacy.

Malai (2007) made an extensive study that investigated, amongst other issues, the cultural impact on Perceived Customer Value. More than 600 international travellers from six countries were surveyed using an instrument presented in four languages on Customer Loyalty, Perceived Service Quality and Perceived Brand-Name Value. The culture construct, Individualism, simply used Hofstede's score for the six countries of the survey respondents. In other words, instead of asking a series of questions designed to measure each respondent's level on the Individualism–Collectivism scale, it was assumed that all subjects from the same country had exactly the same score. The subsequent analysis thus involved regression of national averages against respondent-level scores from a different data set. It is not surprising then that the best result in the study was about 7% explained variance. This is a terrible waste – After about 40 questions had been asked of so many respondents, it would be a small marginal cost to add, say, five more questions to gain a short-form measure of Individualism/Collectivism and other cultural dimensions (Cozma, 2011).

Licht et al. (2011) measured tobacco purchase behaviour of smokers in four countries to compare the extent of price minimisation and tax avoidance behaviour. Straightforward univariate and bivariate analyses were useful and contributed most to the paper, but it was too tempting to include a multivariate logistic regression model to assess the likelihood of using each price/tax avoidance behaviour. In this model, country was used as a main-effects causal indicator of individual behaviour, which had the effect of statistically washing out more useful information about socio-economic influences. It would have been more informative to create a separate model for each country, thus regarding country as an environmental and economic constraint or moderator on each model.

Volkema (2004) compared the negotiation preferences of consumers in nine countries. Without taking any actual measures of the Hofstede dimensions, it was concluded that these cultural measures directly affected negotiation styles when average Hofstede cultural dimensions were substituted for each country. In this case, simple bivariate correlations severely overstated all relationships. A more detailed statistical analysis in the same journal, but different context, demonstrated that such simple naïve substitution of cultural dimensions for country can overstate the relationship between cultural dimensions and dependent variables by 74% (Beugelsdijk et al., 2014).

The intention here is not to single out papers or authors for vilification: These are examples of papers one can see in well-regarded conferences and journals in all of the business disciplines each year. Brewer and Venaik (2014) offer several other examples from organisational behaviour, management, international business, and accounting. One can sympathise with the temptation to simplify a study and take advantage of the contributions of others: *"This person is of this background. Experience, or a noted authority, says that on average such people have these attributes. Therefore I shall infer that this person has those same attributes."* It's convenient, saves time, and generally helps us deal with the world. Unfortunately, similar logic says that women are bad drivers, Muslims are terrorists, French are arrogant, and Americans are rich and stupid. Except for the ones that we've actually met.

Occasionally there is little way around risking the ecological fallacy. For example, national census data are often merged with customer data to describe the demographics of market segments. The finest level of measurement currently available from the Australian census data is at the "Statistical Area Level 1" (SA1) (ABS, 2011) which is the aggregation of 400 persons on average. Census data from Australia's 54,000 SA1's often are combined with industry data, or customers' address data in order to gain a broader understanding of a customer base – see for example, RDA Research (Dommett, 2014). The underlying assumptions are that people who reside in the same area live similar lives and that what is true for the Statistical Area is also true for the individual. Neither assumption holds up completely, of course, but often it can be taken as a "rough approximation" of the characteristics of group members. Moreover, it can be more useful than not making the approximation at all. Census-based analysis will have even finer granularity when Mesh Blocks become the basic unit of geographical measurement from 2016. Mesh Blocks will aggregate data from an average of just 65 people. To the extent that such analysis works it is because each Statistical Area is small, increasing the likelihood of homogeneity in the aggregated data observation. When the aggregation level is large and heterogeneous then we're setting ourselves up for trouble. With a large and heterogeneous aggregated data set then, at best, the researcher will see very poor goodness-of-fit measures; at worst the data will lead to completely misleading inferences.

2.1. An example of fallacious ecological inference

Fig. 1 illustrates average scores for ten different countries on two Hofstede Dimensions, Masculinity/Femininity (M/F) and Individualism/Collectivism (I/C). It is clear that the mean scores are positively correlated: $r = 0.90$ ($\alpha < 0.05$). The logical, but incorrect, inference is that M/F and I/C are positively correlated across all members of this sample.

We might expect then that a person with a high I/C score would also have a high M/F score. Interestingly, a correlation of these two variables across all respondents in this data set shows a zero correlation coefficient, as illustrated in Fig. 2.

This counterintuitive result becomes even more surprising when we discover that within each country the correlations are actually negative! Overall, the correlation between M/F and I/C within countries on average is –0.91, as illustrated in Fig. 3. In contrast to the inference drawn from the mean country data illustrated in Fig. 1 we see in Fig. 3 that those respondents who have the higher I/C scores