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The embeddedness of organizational performance: Multiple Membership Multiple Classification Models for the analysis of multilevel networks

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ABSTRACT

We present a Multiple Membership Multiple Classification (MMMC) model for analysing variation in the performance of organizational sub-units embedded in a multilevel network. The model postulates that the performance of organizational sub-units varies across network levels defined in terms of: (i) direct relations between organizational sub-units; (ii) relations between organizations containing the sub-units, and (iii) cross-level relations between sub-units and organizations. We demonstrate the empirical merits of the model in an analysis of inter-hospital patient mobility within a regional community of health care organizations. In the empirical case study we develop, organizational sub-units are departments of emergency medicine (EDs) located within hospitals (organizations). Networks within and across levels are delineated in terms of patient transfer relations between EDs (lower-level, emergency transfers), hospitals (higher-level, elective transfers), and between EDs and hospitals (cross-level, non-emergency transfers). Our main analytical objective is to examine the association of these interdependent and partially nested levels of action with variation in waiting time among EDs – one of the most commonly adopted and accepted measures of ED performance. We find evidence that variation in ED waiting time is associated with various components of the multilevel network in which the EDs are embedded. Before allowing for various characteristics of EDs and the hospitals in which they are located, we find, for the null models, that most of the network variation is at the hospital level. After adding these characteristics to the model, we find that hospital capacity and ED uncertainty are significantly associated with ED waiting time. We also find that the overall variation in ED waiting time is reduced to less than a half of its estimated value from the null models, and that a greater share of the residual network variation for these models is at the ED level and cross level, rather than the hospital level. This suggests that the covariates explain some of the network variation, and shift the relative share of residual variation away from hospital networks. We discuss further extensions to the model for more general analyses of multilevel network dependencies in variables of interest for the lower level nodes of these social structures.

1. Introduction

Interest in the analysis of multilevel networks has been growing rapidly in recent years (Snijders et al., 2013; Wang et al., 2013). Despite such interest, the general view persists that: "This area of network modelling remains thoroughly underdeveloped." (Snijders, 2011: 137). This seems to be particularly the case in the study of formal organizations, whose nested hierarchical structure makes the analysis of multilevel networks unavoidable (Lomi et al., 2014). Nevertheless, the multiple levels spanned by networks within and between organizations are typically considered independent and analyzed separately as independent levels of action (Borgatti and Foster, 2003; Kilduff and Tsai, 2003). As Moliterno and Mahony (2011: 444) concluded in their extensive review of the literature: "[W]hile some recent network scholarship has begun considering multiple levels of analysis, the majority of scholarship in this area has examined single- and within-level network structures and relationships."

For this reason, extant studies of organizational networks are generally unable to deliver on their central promise to provide a bridge across multiple structural levels of action (Contractor et al., 2006). This is particularly the case in the study of

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interorganizational relations, where the nodes are individual organizations, characterized by an internal structure with multiple hierarchical levels (DiMaggio, 1986). In this paper, we present a new model for the analysis of multilevel networks – a Multiple Membership Multiple Classification (MMMC) model – which addresses this problem directly. A MMMC model was recently applied to the analysis of (single level) social network and group dependencies (Tranmer et al., 2014). We present here, for the first time, an extension of this model for the analysis of multilevel networks. To establish the empirical value of the MMMC model in this context, we present an illustrative application to the empirical analysis of interorganizational relations – a natural multilevel setting (DiMaggio, 1986; Laumann et al., 1978).

Our work extends existing research in at least two ways. Firstly, like studies based on Hierarchical Linear Models (HLMs), our study spans multiple levels of analysis. Unlike HLMs, however, the model we propose takes explicitly into account dependencies induced by network ties within and between structural levels through multiple affiliations. In this way, our study contributes to research in this area by extending available statistical models for multilevel systems to the analysis of multilevel social networks. Secondly, like recent studies based on Multilevel Exponential Random Graph Models (MERGMs), we are analysing multilevel network data (Wang et al., 2013). However, unlike MERGMs, whose target of inference is multilevel network structure as defined by ties within and across levels, the focus of the MMMC model is on variation in *outcomes* associated with attributes of the lower-level nodes across and between the levels of a multilevel network. More specifically, the MMMC model focuses on the way in which multilevel network dependencies are associated to variations in a *behavioural dependent variable* defined for nodes at the lowest level, rather than on the presence or absence of ties among such nodes. Also, unlike MERGMs, the models we propose are not restricted to binary networks, but are applicable to a broader range of weighted networks.

MMMC models have only recently been applied to network data (Tranmer et al., 2014). To our knowledge, however, they have not been applied to multilevel networks. Here, we specify the MMMC for a multilevel network and illustrate its application to data that we have collected on Emergency Department (ED) waiting times – a generally accepted measure of ED operational performance (Horwitz et al., 2010; Lambe et al., 2003). The network we examine is multilevel because it implicates multiple interdependent levels of action. The first level is defined in terms of transfers of emergency patients between EDs (lower-level nodes). The second level is defined in terms of elective patient transfer between hospitals (higher-level nodes) containing the ED units. Finally, the third level involves transfer of non-emergency patients between EDs and hospitals (cross-level relations). The empirical example illustrates in practice how the MMMC that we have developed may be adopted to address recent calls to develop multilevel approaches to the analysis of intra and interorganizational networks (Baker and Faulkner, 2002; Brass et al., 2004). The multilevel data structure that we will be analysing in the empirical part of the paper is described, schematically, in Fig. 1.

Our analysis focuses on variations in ED waiting times. Waiting times are an important measure of how well EDs respond to patient needs, and are commonly used as an indicator of the timeliness, efficiency, safety and patient-centeredness of emergency care (Horwitz et al., 2010). The illustrative example we present as an application of the MMMC model for multilevel networks is almost ideal for at least two reasons: (i) detailed information on the various forms of patient transfers is publicly available, and (ii) the attention paid by health authorities in assessing health care outcomes makes the data particularly reliable.

We organize the article as follows. In Section 2, we outline the motivation for developing statistical models for multilevel network dependencies. In Section 3, we review methods and models for single level networks, including network autocorrelation models, and multilevel approaches via the Multiple Membership (MM) Model. We outline their conceptual similarities and differences. In Section 4, we introduce the MMMC model for the analysis of multilevel networks, explaining how it is an extension of the single level network MM model. We explain how the parameter estimates from the MMMC model provide information about multilevel network dependencies in a lower level nodal dependent variable. In Section 5, we describe the research design of our example, and the approach that we adopt for the estimation and evaluation of the model. In Section 6 we present the results of the analysis, and discuss their possible interpretation and implications. We conclude the article with a reflection on the limitations, general usefulness, and applicability of MMMC models to more general studies of multilevel network dependencies.

2. The multilevel structure of interorganisational networks

The recent interest in models for multilevel networks is driven in part by advances in statistical modelling (Wang et al., 2013) and in part by the rediscovery of the classic theoretical insight that social networks connect multiple levels of action (Boorman and White, 1976; White et al., 1976). Statistical models to investigate how structural levels of action may be (de)coupled have only recently become available.

Interorganizational communities provide an almost ideal setting for exploring the joint implications of these parallel trends. This is the case because organizations may be represented as network nodes with an internal structure characterized by multiple levels of action (Simon, 1996). This determines a recognized need for the development of rigorous approaches to the analysis of multilevel networks generated by interorganizational relations (Aguinis et al., 2011; Mathieu and Chen, 2011; Oh et al., 2006; Rousseau, 1985, 2011)

In his work on the interorganizational field of US Resident theatres, DiMaggio sets the stage for the development of models for multilevel networks that we present in this paper (1986: 363):

> "The insight that organizations consist of individuals and subunits with quite different agendas and objectives is exceptionally difficult to capture in an interorganizational framework, where the smallest units of analysis are organizational nodes in networks. Indeed, network imagery militates towards treating and talking about organizations as if they were unitary actors with constant and uncontested objective functions."

We explain how this "exceptional" difficulty may be addressed by considering organizations as the macro level in a multilevel network for which the internal structure of "organizational nodes" represents the micro level. This allows us to represent in one model the way in which organizational behaviour is affected by: (i) network relations between organizations; (ii) networks of relations between sub-units contained within organizations, and finally (iii) networks connecting units to organizations across-levels.

3. Models for cross-sectional network dependencies

Here, we review existing approaches for analysing single level and multilevel networks, focusing on the cross-sectional case. We identify the targets of inference for such analyses. We especially focus on models for network dependence. We explain the similarities and differences of these approaches, starting with the single-level network, before considering multilevel networks.

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