Decision Support

Heuristic decision making in network linking

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ABSTRACT

Network formation among individuals constitutes an important part of many OR processes, but relatively little is known about how individuals make their linking decisions in networks. This article provides an investigation of heuristic effects in individual linking decisions for network formation in an incentivized lab-experimental setting. Our mixed logit analysis demonstrates that the inherent complexity of the network linking setting causes individuals' choices to be systematically less guided by payoff but more guided by simpler heuristic decision cues, and that this shift is systematically stronger for social payoff than for own payoff. Furthermore, we show that the specific complexity factors value transferability and social tradeoff aggravate the former effect. These heuristic effects have important research and policy implications in areas that involve network formation.

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1. Introduction

Network formation among individuals has important effects in many social, operational, and economic contexts, ranging from word-of-mouth communications among consumers (e.g., Iacobucci & Hopkins, 1992) and virtual communities (e.g., Wellman et al., 1996) to job opportunities (e.g., Granovetter, 1995) and mortality (e.g., Berkman & Syme, 1979). Therefore, the OR community has lately modeled such decentral network creation processes (e.g., Baron, Durieu, Haller, & Solal, 2006; Demaine, Hajiaghayi, Mahini, & Zadimoghaddam, 2012; Fabrikant, Luthra, Maneva, Papadimitriou, & Shenker, 2003; Harmsen - van Hout, Herings, & Dellaert, 2013; Hellmann & Staudigl, 2014; Janssen & Monsuur, 2012; Monsuur, 2007; Olaizola & Valenciano, 2014). The applications of these models vary from military and other communication networks to large-scale networking settings as the Internet and their approaches differ from non-cooperative and cooperative game theory to structural optimization mechanisms.

In the current paper, we comply with the recent call by Hämäläinen, Luoma, and Saarinen (2013) to explicitly consider behavioral phenomena within OR processes, as these processes are highly sensitive to behavioral effects. Accordingly, the abovementioned OR models on decentral network creation may result in opposite recommendations for optimal interventions. Although the approaches of these models vary in several respects, they all take optimizing individuals as a starting point, at most with some random deviation therefrom (e.g., Baron et al., 2006; Hellmann & Staudigl, 2014), whereas we investigate in how far real people systematically deviate from this assumption.

There exists a recent and increasing experimental literature on network formation. One stream in this literature is involved with testing integral game-theoretic models of network formation. They include variants of Bala and Goyal's (2000) noncooperative network formation model (e.g., Berninghaus, Ehrhart, & Ott, 2006; Callander & Plott, 2005), Jackson and Wolinsky's (1996) pairwise cooperative network formation model (e.g., Deck & Johnson, 2004), and fully cooperative network formation models like Jackson and van den Nouweland's (2005) (e.g., Charness & Jackson, 2007). This research identifies several conditions under which theoretically stable network structures are reproduced in the laboratory and addresses their efficiency. Another stream of experimental studies examines the role of network formation as endogenously emerging in other relevant settings of cooperative decision making (e.g., Brown, Falk, & Fehr, 2004; Corbae & Duffy, 2008; Di Cagno & Sciubba, 2010; Hauk & Nagel, 2001; Kirchsteiger, Niederle, & Potters, 2005). This research shows that cooperation decisions are considerably influenced when individuals are allowed to choose their partners versus when a fixed interaction structure is imposed. Furthermore, Falk and Kosfeld

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(2012), Goeree, Riedl, and Ule (2008), and van Dolder and Buskens (2014) found social motives in network formation.

From this experimental work it became clear that in extremely complex, dynamic and strategic situations, predictions of network formation models are not always accurate. An issue that has been largely ignored in this previous work though is that the complexity that individuals face in network formation may moderate their decisions already on a much more basic level. Also disregarding dynamics and strategic interaction, the network formation process is typically a complex decision setting, for individuals' utilities are not only dependent on multiple characteristics of the choice options, like in most consumer choices (e.g., Swait & Adamowicz, 2001), and even not only additionally on the number of other individuals choosing the same option, like with global network externalities (e.g., Katz & Shapiro, 1985). They depend on all individuals in the entire pattern of network links, differently by their exact positions (e.g., Sundararajan, 2008). Furthermore, this network complexity varies depending on whether the type of value that is exchanged through the network only affects direct neighbors or is rather transferable via indirect links (Harmsen - van Hout et al., 2013) and depending on whether decision makers care about the effects of their choices on other individuals (Fehr & Schmidt, 2003).

Such complexity may cause errors in their evaluation of different link formation options and hence in their choice process. Although previous research acknowledges the mere existence of errors (e.g., Charness & Jackson, 2007), these are simply modeled as random and the underlying process remains undisclosed. In fact, the complexity causing such errors is typically removed by providing experimental subjects with numerical payoff information in the network linking choice interfaces. The objective of the current paper is to investigate whether systematic heuristic shifts occur in individual decision making in network formation as a function of complexity in the network linking setting. Such complexity effects have been studied in several other choice contexts (e.g., Bonner, 1994; Dellaert, Donkers, & Soest, 2012; Sung, Johnson, & Dror, 2009; Timmermans, 1993).

For this purpose, we focus on a static, non-strategic network setting in which the decision maker can choose to create or delete one link or to do nothing. Such a situation constitutes the simplest network linking decision context, which allows us to study the effects of complexity under highly controlled conditions. To prevent possible confounding effects that do not originate from complexity of the network setting but from strategic interaction among individuals, we thus analyze individual one-period decisions, so decisions of others in the network are deliberately excluded.

A typical decision task as we study is as follows. The individual "you" in Fig. 1 is connected with several other individuals in a network and is facing the one-shot choice problem to change at most one link: her choice options are to delete one of her existing links, so with "a" or "d", to create a link with one individual that she is currently not directly connected to, so "b" or "c", or not to change anything. This results in a new network structure that generates value for "you" as well as for "a" through "d", whereas "a" through "d" do not make any changes to the network.
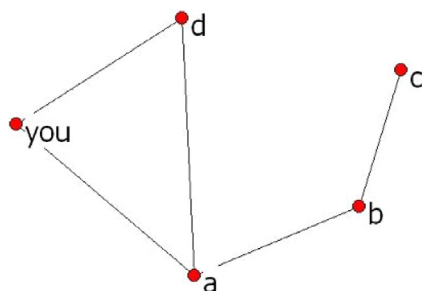
In this individual decision-making experiment we vary three complexity factors that are relevant in the context of network linking. The first factor is baseline opacity of choice consequences. We induce this by providing participants in some treatments with a comprehensive payoff table, which is an effective way to systematically reduce complexity. The second factor is transferability of value over the network. We induce this by having participants in some treatments derive value from direct neighbors only, which reflects a situation where social value is derived from communication, and having participants in other treatments derive value from direct as well as indirectly connected individuals, which reflects a situation where informational value is derived from communication. The third factor is social tradeoff between own payoff and others' payoff. We induce this by informing participants in some treatments that nobody else was affected by their choices, and informing participants in other treatments that the other participants in the room would be passively affected by their choices in a specific way.

These factors complicate the choices that individuals make about creating and maintaining links in the network. We examine whether these choices therefore become systematically less payoff-motivated but more guided by simpler heuristic decision cues, and furthermore whether this shift to heuristic cues is systematically stronger for the extent that individuals' choices are guided by social payoff, that is, the payoff generated for other individuals, than for the extent they are guided by own payoff.

In order to test our hypotheses, we confront participants in the lab with multiple linking choice situations similar to the one in Fig. 1. Their choices have a direct impact on their monetary rewards in the experiment, which differ with respect to the three abovementioned complexity factors (baseline payoff opacity, value transferability, social tradeoff), leading to different treatments. We perform a comprehensive parametric test of the hypotheses by estimating a mixed (i.e., random parameters) logit model (Hensher, Rose, & Greene, 2005; McFadden, 2001) incorporating several payoff and decision cue variables as well as their interactions with the complexity factors. This allows us to investigate the impact of complex network properties on individuals' decisions, while allowing for heterogeneity of the decision makers.

Using this approach, we identify two cues that are merely qualitatively related to payoff but appear to have a significant additive impact on linking decisions: whether the choice option implies a deviation from the status quo or not, and the number of direct neighbors of the (potential) linking partner involved in the choice option. The effects of these heuristic cues are different under the various complexity factors. Furthermore, we demonstrate that social preferences throughout strongly rely on a numerical overview of choice consequences (which is usually provided in the laboratory but missing in real life), since apparent pro-social decision behavior in treatments with such an overview disappears in identical treatments without.

In Section 2, we present our theoretical framework and hypotheses. Section 3 describes the experimental design and the approach used for the mixed logit estimation. The results of our experiment and hypotheses tests are reported in Section 4. At the end of this section, we perform several robustness checks, among which whether observed shifts in behavior may as well be captured by differences in randomness among complexity conditions. Section 5 concludes the paper with a discussion including implications for OR decentral network creation modeling.

2. Theoretical framework

The objective of this section is to present our hypotheses about heuristic effects in individual decisions of network formation and compare them to predictions on individual choice behavior underlying the previous experimental network formation literature.

Fig. 1. Example network formation setting.