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Sharing the proceeds from a hierarchical venture ☆

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ABSTRACT

We consider the problem of distributing the proceeds generated from a joint venture in which the participating agents are hierarchically organized. We introduce and characterize a family of allocation rules where revenue 'bubbles up' in the hierarchy. The family is flexible enough to accommodate the *no-transfer* rule (where no revenue bubbles up) and the *full-transfer* rule (where all the revenues bubble up to the top of the hierarchy). Intermediate rules within the family are reminiscent of popular incentive mechanisms for social mobilization or multi-level marketing.

1. Introduction

Agents often organize themselves into hierarchies when involved in joint ventures (e.g., Mookherjee, 2006). There exist numerous reasons to explain this fact. The hierarchical form, in which workers deal with the routine problems and managers deal with the exceptions, arises as an optimal way to structure the organization of knowledge (e.g., Garicano, 2000). Ownership or power structures generate natural hierarchies with related chains of command and responsibility (e.g., Ichniowski and Shaw, 2003). It is also argued that workplace structures that are rich in sequentiality are desirable from the point of view of incentives (e.g., Winter, 2010). Furthermore, hierarchies yield stable cooperation structures when it comes to allocating resources (e.g., Demange, 2004). Hierarchies may also relate to crowdsourcing and social mobilization systems

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(e.g., Pickard et al., 2011), as well as multi-level marketing (e.g., Emek et al., 2011), task solving systems such as Amazon Mechanical Turk (e.g., Rand, 2012), or financial systems such as BitCoin (Babaioff et al., 2012).

In this paper, we are concerned with the problem of sharing the collective proceeds generated from hierarchical ventures. To analyze this problem, we consider a stylized model in which a group of agents are involved in a joint venture. The group is structured in layers, each reflecting a different degree of responsibility, command, or even seniority. Thus, an agent located at a given layer is in command of (or, at least, held accountable for) all agents located at any lower layer. In such a hierarchy, agents are characterized by their degree of responsibility (location in the hierarchy), and the individual revenue they produce for the joint venture. Based on that information, the issue is how to allocate the overall produced revenue among the agents. Our stylized model is flexible enough to accommodate various forms of organizations that are frequent in different professional sectors. Instances are law firms (e.g., Galanter and Palay, 1990), physicians' practices (e.g., Kletke et al., 1996) as well as renowned architectural practices (e.g., Winch and Schneider, 1993).

Two focal, and somewhat polar, allocation rules can be considered for the setting described above. On the one hand, the *no-transfer rule*, in which each agent keeps her revenue (thus, ignoring the hierarchy). On the other hand, the *full-transfer rule*, in which the agent at the top of the hierarchy gets all the proceeds (thus, ignoring individual contributions). A compromise between these two polar rules, in which certain upward transfers are allowed, can be formalized, and we do so in this paper. The resulting family of *geometric rules* is close in spirit to the *MIT strategy* (e.g., Pickard et al., 2011), the winning strategy for the so-called DARPA Network Challenge.[1] It is also reminiscent of multi-level marketing strategies (e.g., Emek et al., 2011) in which individuals are compensated not only for the sales they generate, but also for the sales of those they recruited.[2] These strategies can be seen as specific *geometric (incentive tree) mechanisms* (e.g., Lv and Moscibroda, 2013) that are usually considered in the computer science literature.[3] An *incentive tree* models the participation of people in crowdsourcing or human tasking systems. An incentive tree mechanism is an algorithm that determines how much each individual participant shall receive based on all the participants' contributions, as well as the structure of the solicitation tree. In geometric incentive tree mechanisms, a certain fraction α 'bubbles up' from one agent to the immediate superior, a fraction α^2 bubbles up to the immediate superior of the immediate superior, and so forth. In our case, a geometric rule states that the lowest-ranked agent gets a share λ of her revenue, her immediate superior gets a share λ of her revenue, and of any remaining 'surplus' from the lowest-ranked agent, etc. Thus, there is an obvious connection between the geometric rules we consider here and geometric incentive tree mechanisms. It is worth emphasizing, nevertheless, that the latter are typically not budget balanced and, thus, cannot be considered as sharing rules.

We provide normative foundations for the family of geometric rules described above. In the benchmark case of linear hierarchies, we show that the family is characterized by four simple and intuitive axioms (Lowest Rank Consistency, Highest Rank Revenue Independence, Highest Rank Splitting Neutrality, and Scale Invariance). If we add an additional axiom, referring to two-agent problems in which the highest-ranked agent is not productive, the intermediate geometric rule for which $\lambda = 0.5$ is singled out within the family. If, instead, axioms modeling order preservation (with respect to either individual revenues, or hierarchy positions) are added, the two polar rules are obtained.

The member of the family arising when $\lambda = 0.5$, which translates to our context the MIT strategy mentioned above, is also singled out as an optimal rule, when we enrich our framework to deal with endogenous hierarchies. More precisely, suppose the aim is to maximize the expected revenues of the agent at the top of the hierarchy (the highest-ranked agent), when the process to get subordinates is probabilistic and based on the upward transfers the rules allow. The highest-ranked agent, while selecting a geometric rule, would face a tradeoff: high upward transfers vs. weak incentives for subordinates to join the hierarchy voluntarily. We show that the optimal rule to deal with such a tradeoff is precisely the intermediate geometric rule for which $\lambda = 0.5$. This occurs, not only when (possible) subordinates are *myopic*, but also when they are *farsighted* and take into account their ability to hire further subordinates themselves.

Our contribution is also related to the sizable literature on fair division in networks. This literature mostly organizes itself into two strands.

On the one hand, the strand in which the networks give rise to cooperative games and where the structure of the network is exploited in order to define fair allocation among agents connected in the graph. The canonical case is that of cost sharing within a rooted tree, which can be traced back to Claus and Kleitman (1973) and Bird (1976). For fixed trees, the so-called Bird rule, which can be seen as a counterpart to the no-transfer rule, and the so-called serial rules, which convey a different form of transfers to the ones described above, are prominent. This is, for instance, the case in the problem of sharing a polluted river (e.g., Ni and Wang, 2007; Dong et al., 2012) which is reminiscent of the problem considered here (with the modification of considering negative revenues, and thus interpreting them as costs). Another specific (and well-known) instance of this strand of the literature is the so-called *airport problem* (e.g., Littlechild and Owen, 1973), in which the runway cost has to be shared among different types of airplanes with a linear graph representing the runway. The rules (and some of the axioms) highlighted in our work will also be reminiscent of some of the rules considered

[1] This is a social network mobilization experiment, conducted by the Defense Advanced Research Projects Agency, to identify distributed mobilization strategies and demonstrate how quickly a challenging geolocation problem could be solved by crowdsourcing (DARPA Network Challenge, 2010).

[2] Famous cases include companies such as Avon Products, Inc., or Herbalife International.

[3] Computer scientists have been concerned with mechanisms that are immune to *sybil attacks* in which a reputation system is subverted by forging identities in peer-to-peer networks (e.g., Drucker and Fleischer, 2012). This is actually a type of manipulation to which the mechanism arising from the *MIT strategy* is susceptible.