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Cultural dissimilarity: Boon or bane for technology diffusion?

Elena Beretta[a], Magda Fontana[b,*], Marco Guerzoni[b,c,d], Alexander Jordan[b]

[a] DAUIN, Politecnico di Torino, Turin, Italy
[b] DESPINA, Big Data Lab, Department of Economics and Statistics, University of Turin, Italy
[c] ICRIOS, Bocconi University, Milan, Italy
[d] BRICK, Collegio Carlo Alberto, Turin, Italy

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ABSTRACT

The paper provides a theoretical model of technology adoption based on the idea that the diffusion of information about a technology depends both on the social structure of the adopters and their degree of assortativity. We propose a framework that - while retaining the core assumptions of epidemic diffusion models - allows for explicit modelling of the social structure via social network and of agents cultural heterogeneity via agent-based simulation. Decision-making takes place in institutional contexts where individual features trigger differentiated imitative responses and societal organization acts as medium on which information flows. The model simulates the diffusion of fertilizers in five Ethiopian villages (Peasant Associations), which differ in both political and relational structures and farmers belong to numerous ethnic and religious groups. Starting from survey data we run a compositional understanding simulation with the aim of reproducing observed diffusion curves on the basis of unobserved individual interactions. By minimizing the divergence from model output and observed diffusion, the exercise of categorical calibration and time series fit identify a set of plausible parameters for each village. Results highlight the importance of cultural dissimilarities to understand the diffusion processes.

1. Introduction

The paper provides a model of technology adoption based on the idea that the diffusion of a technology is affected by non-economic factors such as the social structure in which the adopters are embedded and their degree of assortativity. Assortativity measures the fact that information acquired by ingroup is considered more reliable and thus affects adoption choices. The role of social and cultural factors in determining the rate of technology adoption has been largely acknowledged in literature since the seminal work by Katz (1961) and highlighted by recent studies such as Walsh et al. (forthcoming). Guerzoni and Jordan (2016) extensively discussed that the literature does not suggest a mechanism. However, this literature is a collection of very informative anecdotal evidence rather than an encompassing framework to explain how culture might impinge on the diffusion process. For instance, Wellin (1955) discussed the poor diffusion of health technology in Peru, Lee and Ungson (2008) the diffusion of ICT in Korea, Nardon and Aten (2008) the ethanol adoption in Brazil, Trompenaars and Hampden-Turner (1998) the diffusion of portable music players in Western societies, and Guerzoni and Jordan (2016) the diffusion of fertilisers in Ethiopia. This is not true for other factors in the vast literature on diffusion of innovation, in which very often clear mechanisms have been both surmised and tested. A detailed review of the literature, which is beyond the scope of this paper, is very well summarized by Meade and Islam (2006), who reviewed not only diffusion in economics but also in similar fields such as marketing and organizational studies. A second and well-aged review is by Lissoni and Metcalfe (1993) who, on the contrary are more focus on economics of innovation only. Finally, Geroski (2000)'s review focuses on the modelling techniques employed to describe the process of innovation diffusion.

Thus, we can identify a gap in the literature of diffusion, which has not managed so far to include in a theoretical framework, the otherwise well-documented impact of culture on diffusion. The paper proposes a framework that, while retaining the core assumptions of epidemic diffusion models, allows for explicit modelling of the social structure via social network and of agents cultural heterogeneity via agent-based simulation. The key assumption is that information acquired by an individual belonging to a different group is not considered reliable and in some cases it is even ignored. The degree of this effect depends on the homophily of the environment, that we measure with an assortativity parameter.

An ideal case study is the diffusion of chemical fertilisers in Ethiopian Peasant Associations, since chemical fertilisers are a superior

* Corresponding author at: Despina, Department of Economics and Statistics 'Cognetti de Martiis', Lungo Dora Siena 100A, Turin 10124, Italy.
E-mail address: magda.fontana@unito.it (M. Fontana).

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technology with very low costs of adoption and in the area we observe a very high degree of religious and ethnic differences. The accurate replication of the observed diffusion curves validates the model and corroborates the idea that including non-economic factors in the analysis of technology diffusion improves the explanatory power of models and widens the scope for policy intervention. The paper is organized as follows: Section 2 presents the theoretical frame to simulate diffusion within social networks. Section 3 presents the data selected from the Ethiopia Rural Household Survey (ERHS) and investigates the cultural composition of the rural networks. Section 4 describes the settings and specifications of the agent-based model and Section 5 analyses the general simulation diffusion patterns of the settings. Section 6 presents the best fitting simulation of each village. Finally, Section 7 closes the paper with a summary and some practical considerations.

2. Theoretical background

The analysis is grounded on Griliches (1957) epidemic diffusion model. Epidemic models historically date back to the investigation of smallpox dissemination by Bernoulli (Zhang et al., 2016). Among them, the susceptible-infected-recovered (SIR) model and the susceptible-infected-susceptible (SIS) model are the most prominent ones. Both models follow the set of assumption: At the beginning, individuals are characterised by being either susceptible or infected. In the next time step, a currently infected individual has the chance to infect a susceptible individual. Afterwards, if the infection was successful the susceptible individual turns its status to infected and the previously infected individual turns into recovered (SIR) or into susceptible (SIS). In the SIR model, recovered individuals cannot be infected again while individuals can be repeatedly infected in the SIS model (Shakarian et al., 2015; Zhang et al., 2016). Epidemic models fit well our theoretical and empirical scenario. On the theoretical side, epidemic models assume a population of potential adopters where innovation diffuses via information transmitted by individual contact and is mediated by some measure of individual proximity. In our research, we focus on the adoption of a superior technology that is not yet well known by potential adopters. Differently from traditional epidemic models however we model heterogeneous adopters. Heterogeneity impinges on the ability to trigger imitative behaviour, i.e. to spread the contagion. In addition, we expand the original epidemic model by introducing social networks as the medium on which the contagion of information takes place. In our setting, the probability of adoption depends on the cultural similarity of the agents sharing the information (Guerzoni and Jordan, 2016). Cultural similarity affects adoption in that agents can exhibit homophilic behaviour, i.e. they might tend to give a higher weight to the behaviour of and the information conveyed by similar others (McPherson et al., 2001; Rogers, 2003). On the empirical side, the data we use for the study regards relatively small communities where information can be easily assumed to be homogeneously available, potential adopters are geographically close, and the technology to be adopted is unique. Moreover, communities differ according to their cultural composition and to their social organization.

In social networks literature, the degree of homophily might be captured by the concept of assortativity. Its impact on the diffusion of innovation is taken into account mainly along two lines: similar individuals easily share information and agents external to a group are more likely to be the source of novel information, as in the case of bridging cliques (Granovetter, 1973; Rogers, 2003). In the model, assortativity defines sensitivity to difference. In making the adoption decision, agents can discriminate between information deriving from either similar or different individuals. Precisely, we assume that information acquired by a similar individual is considered more reliable. If there is no assortativity, the information from individual in a different group is ignored. Conceptually, we use assortativity in the sense of Newman (2002, 2003), although in the technical operationalization of the model it works differently. For Newman, assortativity is a property of the nodes which impact upon the probability of observing an edge among them. In our case, given a network, assortativity impacts on the likelihood that an existed edge is activated. The model is a more general version of Newman' approach, since if we draw the network of activated edge, we end up in the standard Newman definition. The idea of coupling epidemic models (Geroski, 2000) with social networks introduces a mechanism very much similar to Valente (1996) framework. However, in Valente the ego-network of an individual is evaluated in order to take the adoption decision, while in our model it is simply a way of information diffusion such as in epidemic models.

The diffusion of fertiliser in Ethiopian Peasant Association fits in the the proposed framework. Firstly, homophily plays a crucial role in Sub-Saharan Africa. Although Ethiopia remained largely untouched by the arbitrary redefinitions of borders that followed the end of the colonial era, the resistance to the restructuring of provinces and regional states as part of the ethno-regional federalism has shown that Ethiopia is still characterized by very cohesive differentiated cultural groups, which results in fragile national identities and in frequent local conflicts (Abbink, 2006). Secondly, cultural heterogeneity reverberates on social structures, i.e. villages exhibit social arrangements that vary considerably in their organization. Finally, the vast body of literature that deals with the diffusion of technology in agricultural contexts falls short in explaining the variance in adoption rate through the traditional socio-economic or geographical factors. The literature covers farm size (David, 1966; Dadi et al., 2004), tenure (Feder et al., 1985), risk & uncertainty (Havens and Rogers, 1961; Mansfield, 1961; Dercon and Christiaensen, 2011), distance to market (Sunding and Zilberman, 2001), constraints in supply, credit, labour (Croppenstedt et al., 2003; Dadi et al., 2004; Carlsson et al., 2005) as well as the role of neighbours and development agents (Rogers, 2003; Krishnan and Patnam, 2014).

3. Data selection

The data selection of five rural villages defined as Peasant Associations (PAs) draws from the Ethiopia Rural Household Survey (ERHS), which originally covers fifteen villages over the time span from 1994 to 2009. Focusing on five villages accounts for the necessity to observe the beginning of fertiliser diffusion at almost similar dates to study homogeneous diffusion processes. Ethiopian agriculture employs 85% of the country's available labour force but its factor productivity lags far behind in comparison to western societies (Diao et al., 2007; AGRA, 2014; CIA, 2015). In addition, Ethiopian soil quality has been worsening for decades and there is an urgent need to adopt innovative technologies and to develop resilience against reoccurring droughts and famines (UNDP Ethiopia, 2014). Chemical fertilisers such as DAP and Urea bear the potential to augment yields and have been historically promoted and made available by the current Ethiopian government and its predecessors (Kassa, 2003).

The focus is on five rural and remote villages without proper infrastructure (dirt roads, no electricity, no local markets and partially long distances, up to 20 km, to the next market). In these villages, access to agricultural technologies depends heavily on the efforts of the government and hence the set of available technology solutions to fight soil degradation is prescribed by the government that focuses its efforts to promote fertilisers. The five villages have been selected since they experienced the first adoption around to the same year (1994), when the survey has been launched and the cultural composition recorded. This choice have some benefits, since we do not face the problem of the first adopter, we know that the first adoption and the subsequent adoption path occur under similar conditions and, finally, we could identify the cultural composition of each village precisely at the time of adoption.

Fig. 1 depicts the fertiliser diffusion patterns for the five PAs. The left-hand side graph displays diffusion curves referring to the date of occurrence per calendar year. Among the villages the first adoption took place in 1992 and the last adoptions were recorded at the end of