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National culture and innovation diffusion. Exploratory insights from agent-based modeling

Benoît Desmarchelier [1], Eddy S. Fang *

Xi'An Jiaotong-Liverpool University, China

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ABSTRACT

The present paper sets to conduct a theoretical investigation on the role of national culture in shaping innovation diffusion patterns in different markets. We build a culturally grounded agent-based model to examine the question and introduce cultural heterogeneity to our simulations by merging two of Hofstede's dimensions of culture (individualism/collectivism and uncertainty avoidance) with Rogers' seminal work on innovation diffusion behavior. Our findings suggest that both dimensions of culture influence diffusion rates. The model also puts forward the importance of network topology as an enabling factor of national culture on diffusion processes.

1. Introduction

The diffusion of new technologies, products, practices, preferences and behaviors has long been at the center of attention among both academics and business managers (Tarde, 1890; Tarde, 1901; Bass, 1969; Cantono and Silverberg, 2009). Following Rogers' seminal work in the field (Rogers, 1962), it is now broadly acknowledged that innovation diffusion processes are dependent upon four main factors including: the characteristics of the innovation itself, the communication channels within the population of interest, the social system connecting agents, and a time factor.

Over the past years, the social aspect of innovation diffusion has caught increasing attention due to the fast changing social environment ensuing – especially – from the emergence of new communication technologies (Backstrom et al., 2012; Goel et al., 2012). A growing strand of the literature is hence now devoted to studying "social contagion" within processes of innovation diffusion, thereby covering a range of social factors such as network effects, competitive concerns, social-normative pressures or peers influence (Katz and Shapiro, 1985; Farrell and Saloner, 1986; Arthur, 1989; Van den Bulte and Stremmersch, 2004; Jansson, 2011; Watts and Dodds, 2007).

However, in the current context of increasing global market integration, it is quite surprising to note that only a handful of contributions have paid attention to group-level – or country-level – differences in terms of adoption of innovations (Peres et al., 2010). It has indeed been established that certain novel technologies follow distinct diffusion patterns in different countries, and this is especially apparent when comparing developed and developing economies, with the former recording slower diffusion rates (The World Bank, 2008). Reflecting on the influence of specific consumption habits on diffusion processes across countries, studies such as Iyengar et al. (2009) and Chircu and Mahajan (2009) contribute an explanation to this observed difference in diffusion rates by highlighting specific usage behaviors of innovations in telecommunications in developing countries, while Desiraju et al. (2004) observe similar patterns in a study on the adoption of novel pharmaceutical products in developed and developing countries.

Beyond divergences in usage behavior, cross-country diffusion studies have also engaged with the question of culture's influence. In this context, culture is commonly defined as "the collective programming of the mind that distinguishes the members of one group or category of people from another" (Hofstede et al., 2010 p.6). Hence, independent of the characteristics of specific products and how it fits the habits of various people, it is also advanced that social groups – composed of individuals with a shared culture – have different propensities to adopt or reject innovations (Takada and Jain, 1991; Tellefsen and Takada, 1999).

Yet, while these econometric studies were pivotal in emphasizing the role of national culture in shaping diffusion patterns, we argue that several important questions in this context have not yet been addressed due to data-related or methodological limitations. First, most studies mainly derive conclusions based on data from Europe and/or the United States — as illustrated above. Given the comparatively lower cultural distance within the selected group of (high-income) countries – on some, if not all, dimensions – the relevance of previous findings is likely to be limited. The inclusion of a broader range of

* Corresponding author at: Xi'an Jiaotong Liverpool University, 111, Ren'ai Road, Suzhou, Jiangsu Province, China. Tel.: +86 512 88180451.
E-mail addresses: Benoit.Desmarchelier@xjtlu.edu.cn (B. Desmarchelier), eddy.fang@liverpool.ac.uk (E.S. Fang).
[1] Tel.: +86 512 88167128.

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cultural groups, especially from emerging markets, may indeed introduce additional variance in the data, and thus contribute further insights and nuances to the previously identified relationships between cultural dimensions and aggregate patterns of innovation diffusion. Second, existing studies on the relationship between cultures and diffusion dynamics have traditionally taken a macro perspective towards diffusion phenomena by focusing on aggregate cross-country patterns of (successful) diffusion. This approach, while allowing to distinguish the respective role of individual cultural dimensions, only yields partial insights for specific cultural configurations. Indeed, given that culture is measured by mapping social groups onto six concurrent dimensions, isolating the influence of each of these dimensions does not allow any inference on the comparative rate of diffusion. Econometric findings in previous studies hence only yield partial explanations as to how the cultural traits of agents prompt innovations to diffuse faster in certain markets rather than others (see OECD, 2004) for a list of countries ranked by the pace of diffusion of technological innovations).

The present paper contributes to the topic of innovation diffusion and culture by building a culturally grounded agent-based model[2] (ABM hereafter) of innovation diffusion, which resonates with recent attempts to rely on 'cultural agents' in agent-based models to study various phenomena such as decision making (Roozmand et al., 2011), negotiations (Hofstede et al., 2012), or trade (Burgers et al., 2010). However, we apply this framework of analysis to the issue of innovation diffusion and thereby bring a novel perspective on the topic. We introduce group specific attributes to diffusion models based on two known dimensions of culture ("uncertainty avoidance" and "individualism/collectivism"). Using culture theory in agent-based modeling allows us to sidestep issues related to data availability in specific markets by simulating diffusion processes within a controlled set of cultural configurations. Moreover, given the attention ABM traditionally dedicates to modeling agents' behavior in the dissemination of information and adoption decisions, this paper also complements existing econometric studies on the topic by providing insights as to how culture matters to market adoption.

Our simulations show how culture matters for explaining differences in cross-border diffusion rates. More specifically, we find a positive influence of "uncertainty avoidance" and a negative one of "individualism". In addition, we also derive from our findings a relative ranking of countries in terms of their efficiency in the diffusion of innovations. Interestingly, our ranking follows closely empirical country-level data on diffusion performance.

This paper is structured as follows: Section 2 lays down the theoretical foundation of our model and discusses the rationale behind cultural agents and our ABM of innovation diffusion. Section 3 then continues with a formal presentation of the model, starting with the construction of social networks in which agents are embedded, and followed by a presentation of agents' attributes and rules. Simulation results are then exposed in Section 4. Section 5 concludes the paper with a discussion on the findings.

2. Integrating theories of culture and innovation diffusion

In the innovation diffusion literature, studies have to a large extent built on models of disease spreading, such as the so-called S-I-R framework — i.e. Susceptible-Infected-Recovered (see for instance May and Lloyd, 2001), and have often relied on automatic, contact-triggered, spreading mechanisms between agents. While such transmission method have been widely adapted to models of diffusion in the social sciences (Watts, 2002; Watts and Dodds, 2007; Delre et al., 2007), the role of agents as information processing entities might have been underestimated. Indeed, the decision to adopt an innovation must be dissociated from the reception of information about the innovation, and the former must be understood in light of a range of assessment heuristics.

Illustrating this point, Dwyer et al. (2005), building on Hofstede's multidimensional measurement of culture — i.e. individualism, uncertainty avoidance, masculinity, power distance, long-term orientation, and indulgence (Hofstede et al., 2010)[3] study the diffusion of seven technological innovations across thirteen European countries, and conclude that four out of five dimensions tested contribute shaping variations in cross-national diffusion rates in their sample of countries. More specifically, they find that individualism and long-term orientation have a negative impact on innovation diffusion while masculinity and power distance exhibit a positive one. Tellis et al. (2003), on the other hand, studying the diffusion of ten durable consumption products in sixteen European countries, find a partial impact of culture on diffusion take-off since only one out of the two dimensions tested was significant — uncertainty avoidance was found to be negatively correlated with take-off time. Van den Bulte and Stremmersch (2004), in an investigation covering 52 consumer durables and 28 countries (83% of which in Europe and the United States), also find that four of Hofstede's dimensions cause variations in product diffusion rates — i.e. low uncertainty avoidance, higher collectivism, power distance, and masculinity lead to faster diffusion rates.

An increasing number of contributions have emerged to highlight the need to take into account the complexity of agents' decision processes when modeling diffusion phenomena (Fu and Liao, 2012). It is within this broader framework that we call upon the emerging concept of "cultural agent", which recently came forward in the ABM literature (Mascarenhas et al., 2013; Bosse et al., 2014; Hofstede et al., 2012). Cultural agents are defined as "autonomous agents that are culturally influenced in the way they perceive and socially interact with others" (Mascarenhas et al., 2013 p. 325). Applied to the question of innovation diffusion, it entails that receiving information about an innovation is not a sufficient condition for adoption, but adoption heuristics in general, and group-level cultural characteristics in particular, must be taken into account.

In order to build our model, we follow Rogers' seminal work on innovation–decision (Rogers, 1962; Rogers, 1995) and introduce variance in adoption heuristics based on Hofstede's dimensions of culture (Hofstede et al., 2010). The theoretical model developed hereunder derives cultural heterogeneity among agents based on two dimensions: "uncertainty avoidance", and "individualism/collectivism". Another common dimension in diffusion studies, "power distance", is hence not used in this paper. Indeed, power distance appears to be related to the type of innovation in question. For instance, if we consider the case of a new product, which confers increased social status, the input of power distance will be more obvious. As we attempt to study innovations in general, this dimension is not considered in our model. On the other hand, further scrutiny on the use of this dimension in innovation models have been introduced by contributions such as Teboul et al. (1994) who suggest that it is the adoption of a novelty (in their case, technology) which creates power distance rather than the other way around.

[2] Agent-based modeling, when applied to economics, can be defined as "a computational approach that aims to explain economic systems by modeling them as societies of intelligent software agents" (Osinga et al., 2011).

[3] Power distance captures how social groups from a given culture "handle the fact that people are unequal" (Hofstede et al., 2010 p. 55). Cultures with high power distance tend to "treat people with a higher status in a privileged manner" (Mascarenhas et al., 2013 p. 326). A culture is said to be collectivist (or individualist) if it considers that the interests of the group (or individual) prevail on those of individual (or group). Masculinity is opposed to femininity, which, in the words of Hofstede, characterizes cultures that are respectively valorizing assertiveness, as opposed to modesty. Uncertainty avoidance captures the degree of tolerance of ambiguity. The lower a culture scores in terms of uncertainty avoidance, the more its members are tolerant towards ambiguous or unexpected situations. Long-term orientation, on the other hand, "stands for the fostering of virtues oriented towards future rewards — in particular, perseverance and thrift" (Hofstede et al., 2010 p. 239). Indulgence "stands for a tendency to allow relatively free gratification of basic and natural human desires related to enjoying life and having fun. On the opposite end, restraint, reflects the conviction that such gratification needs to be curbed and regulated by strict social norms." (Hofstede et al., 2010 p. 281).