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Diffusion of web technologies and practices: A longitudinal study

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ABSTRACT

Our research objective was to undertake a longitudinally study of how technologies and practices used in web development diffuse over time and whether the diffusion patterns are affected by the regions or the industries in which they take place. The diffusion of web technologies is of interest as, they are highly visible and accessible across the globe and industries by their very nature, which makes it possible to potential adopters to trial them and experience first-hand their relative advantage, compatibility and complexity. Three different cases were chosen, in order to test our hypotheses based on the Diffusion of Innovations Theory. A system was built to collect data using the Wayback Machine. The data collected covered a period of 13 years. Our findings suggest that web innovations may diffuse differently when compared to each other, but also when regions and sectors are considered. Beyond testing the ecological validity of Diffusion of Innovations Theory in web-related technologies, our findings have practical implications which can inform the diffusion of technologies and standards.

1. Introduction

The World Wide Web (or web for short) has become a major part of our daily lives, with millions of users finding their way to web sites using their browsers. By the end of 2014 the number of Internet users globally was expected to reach almost 3 billion (up from about 1 billion in 2005), with penetration standing at 40% globally (but with only 32% in developing countries vs. the 78% in developed ones) (International Telecommunication Union, 2014). In the early days, developers often felt obliged to indicate that their web sites were still under construction by posting road construction signs on their pages. Over time this practice became less popular as developers realised that web sites are never finalised and that they are continuously evolving. New web standards and technologies, web browser capabilities, design trends, different types of devices and the ever improving Internet infrastructure fuelled web site change as stakeholders aspired to follow relevant innovations and remain competitive. Comparing a web site with a version dating only a few years ago can often highlight how much web developing practices have advanced over time. Understanding web site change and the underlying diffusion of web technologies is important both theoretically and practically. On one hand, it is of interest to study how innovations are propagated on a regional, but also global stage, while on the other the impact that the Internet has had on all aspects of our lives renders any insights of great practical importance for future developments.

Although considerable commentary exists on the paths of Internet development, there is little longitudinal research into patterns of web site change (Waite and Harrison, 2007, (p.180)) Web site change can be studied from two key vantage points. The first one is a micro approach revolving around the web site itself (e.g. (Koehler, 2002; Fetterly et al., 2004)). The alternative macro approach is to examine changes in a group of web sites, focusing on specific communities of practice,

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e.g. geographical or based on specific industries, or even on the web itself as a whole, by examining the underlying technologies. The second approach is more suited for studying diffusion patterns, especially methodologically, due to the very nature of the technologies of interest, which makes it possible to collect the required data programmatically. Based on the above, this paper's research objective is to study how technologies and practices used in web developing diffuse over time and whether the diffusion patterns are affected by the regions or the industries in which they take place. In doing so we firstly contribute to the literature by considering the diffusion of web technologies themselves, as opposed to the diffusion of the Internet and its penetration (Forman et al., 2005a; Liu, M.-c. and G. San, 2006; Wolcott et al., 2001; Kiiski and Pohjola, 2002) or the adoption of the technologies, typically with a focus on the application, at the organisational level (Chen, 2003; Raymond, 2001; Al-Qirim, 2007). Instead of just treating the Internet or the web as unified general purpose technologies (Bresnahan and Trajtenbergb, 1995) our study aims to close the gap between these two bodies of literature by examining the underlying technologies that give rise to our Internet and web experiences. Secondly, given that web technologies are by their very nature visible across the globe (Malecki, 2002; Gaspar and Glaeser, 1998; Tranos and Nijkamp, 2013; Brakman and Marrewijk, 2008) and different industries (Rogers, 2003), one could expect that potential adopters can trial them and experience first-hand their relative advantage, compatibility and complexity. In turn, one may have expected that the diffusion of web-development technologies would proceed in a similar manner. However, in practice this is not what our evidence suggests, as we found variations in the diffusion process. Of course, diffusion does not take place in a vacuum, but within market systems of different attributes and characteristics. Still, the differences observed for rather basic web development blocks that revolved around web standards offer valuable insights in terms of the fit of the models tested and potential managerial implications when it comes to launching new web-based technologies or even to how standards propagate across the web. Thirdly, methodologically, our contribution stems from using the Wayback Machine to collect and analyse data programmatically over a period of 13 years.

The paper will continue by presenting the relevant literature, before proceeding to discuss the methodology adopted. It will then present the results of the analysis and discuss these in the context of the research objectives set and the existing academic literature. The paper will conclude by outlining ways of extending this work and future research avenues.

2. Literature review

Innovation has been defined as "*the generation, development, and adaptation of novel ideas on the part of the firm*" (Damanpour, 1991), which, from an IT perspective, may refer to a new practice or operational idea (Lind and Zmud, 1991; Annukka, 2008). As ICT can affect firm productivity (Caldeira and Ward, 2003; Oliveira and Martins, 2011), not surprisingly there are many studies that have examined ICT innovation adoption, with various theories being tested (Oliveira and Martins, 2011; Rui, n.a). Theories may consider different units of analysis, typically the user, the firm or the market/innovation (Alshamaileh et al., 2013). As the focus of our work is the organisational diffusion of web technologies as expressed by their web site adopting and implementing such technologies, we turn our focus to the firm-level, grounding our work on Roger's Diffusion of Innovation Theory (DOI) (Rogers, 2003). In the sections following we present the main tenets of DOI and formulate hypotheses revolving around them to perform longitudinal tests.

2.1. Patterns of technology diffusion

Rogers (Rogers, 2003, (p.5)) defined diffusion as "*the process by which an innovation is communicated through certain channels over time among members of a social system*". In the context of DOI, an innovation is "*an idea, practice or object that is perceived as, but not necessarily, new by the individual or any other unit of adoption*" (Rogers, 2003, (p.12)) Innovations are not adopted by all in the same way. Innovativeness, i.e. the degree to which an individual is relatively earlier than other members of the social system in adopting an innovation, can segment the social system into 5 adopted categories, namely innovators, early adopters, early majority, late majority and laggards. When the number of individuals adopting an innovation is plotted on a cumulative frequency basis over time, for a successful innovation that spreads across almost all of the potential adopters in a social system, the resulting distribution is an S-shaped curve. The exact shape and location of each S-curve is innovation-specific and system-specific, describing the diffusion of a particular new idea among the member units of a specific system (Rogers, 2003, (p.275)). For instance, the seminal work of Ryan and Gross (Ryan and Gross, 1943), which focused on the diffusion of hybrid seed corn among farmers in two communities in Iowa, demonstrated that the diffusion of corn follows an S-shaped curve with a small number of adopters at the beginning of the curve and then a gradual increase of adopters over time. Various media, information and communications technologies have been found to diffuse in a similar manner (Norris, 2001; Brancheau and Wetherbe, 1990; Gurbaxani, 1990). More specifically, when it comes to web technologies, Chen (Chen, 2003) analysed the adoption of e-business standards such as XML and web services. He found that both XML and web services follow an S-shaped diffusion pattern. Teng et al. (Teng et al., 2002a) assessed 20 different information technologies and their diffusion patterns with respect to models that were subject to internal and external influence. They found evidence that models of diffusion due to imitation, such as the logistic S-curve, perform better than other more elaborate models. The S-shape is found in the literature to be appropriate for a variety of alternative assumptions about adoption mechanisms, e.g., Hall and Khan (Hall and Khan, 2003) argue that both the adopter heterogeneity and the learning/epidemic model lead to S-curves in innovation diffusion. Geroski (Geroski, 2000) also observes that both different theoretical models of technology diffusion and empirical studies lead to the conclusion that diffusion follows an S-shaped pattern.

For our study we selected the internal influence model (partly due to the longitudinal nature of the study and the methodology adopted, as discussed later in the paper), as represented by the logistic curve, which is based on the assumption that diffusion occurs only through contacts among members of the social system, proposing that: