NBER Digitization Post-Doctoral Fellowship Application

Frank Nagle
Harvard Business School

Technological progress and increased digitization have led to a drastic decrease in information costs, which in turn has led to a weakening of firm boundaries. This phenomenon is having a significant impact on the innovation and production processes of firms. My research seeks to theoretically understand and empirically quantify how digitization is changing firm boundaries and altering our existing notions of how firms function. Firms no longer create value by solely relying on internally developed resources. Instead, they are increasingly engaging with external communities, frequently referred to as the crowd, for important aspects of the value creation process. My current and ongoing research aims to shine light on this process by examining the implications of the non-pecuniary nature of many crowdsourced digital goods and by exploring the motivations of contributors to crowdsourcing. As a Digitization Post-Doctoral Fellow at the NBER, I will be able to update and submit the research from my dissertation, continue progressing on early stage projects, and contribute to the research community at the NBER.

Dissertation Research

My dissertation, entitled "**The Digital Commons: Tragedy or Opportunity? The Effect of Crowdsourced Digital Goods on Innovation and Economic Growth**" is comprised of four papers that examine the impact of crowdsourcing on firms' innovative and productive processes. In paper 1 (joint w/ Shane Greenstein), we examine how "digital dark matter", digitized goods that are non-pecuniary and effectively limitless inputs into production, causes measurement issues at a macro-level. By scanning 1% of the 1.5 billion IP addresses in the United States, we find that one such good, the Apache web server, accounts for a productivity mismeasurement of between $2 billion and $12 billion. This paper was the lead article in a recent issue of *Research Policy*. In paper 2 (joint w/ Elizabeth Altman and Michael Tushman) we present a conceptual argument for why technological progress and reductions in information costs are leading organizations to increasingly engage with external digital communities. We find that this external engagement changes the way firms innovate and alters many of the classic theories of the firm. This will be published in the forthcoming Oxford University Press Handbook of Creativity, Innovation and

Entrepreneurship.

In paper 3 (my job market paper), I explore the phenomenon at the firm level by empirically measuring the impact of firm usage of crowdsourced digital goods (CDGs) on productivity. I use data on firm usage of open source software, a widely used CDG, to understand how such free goods impact firm productivity. I address the endogeneity issues inherent in productivity studies by using inverse probability weighting, an instrumental variable approach, and data on firm management quality from the World Management Survey to add support for a causal interpretation. I estimate that across firms, a 1% increase in the amount of non-pecuniary OSS used by a firm leads to a .073% increase in productivity. This translates to a $1.38 million increase in production output for the average firm in my sample. This paper is targeted for *Management Science*, and will be submitted shortly after I graduate. Finally, in paper 4, I empirically investigate how contributing to a CDG can enhance the absorptive capacity of the firm. By directly contributing to the creation of these goods, firms can increase their ability to extract productive value from them. If selected for the NBER Digitization Post-Doctoral Fellowship, one of my first research activities will be to finalize this paper and submit it. Together, the four papers of my dissertation help shed light on an increasingly prevalent phenomenon that is changing how firms innovate and produce and is altering existing theories of the firm.

Ongoing Research

After finalizing the projects from my dissertation, I would use the majority of my time as an NBER Post-Doctoral Fellow to advance earlier stage projects I am currently working on. The first of these projects (joint w/ Chris Riedl) attempts to dig deeper into why individuals contribute to CDGs. Specifically, we examine the impact of disagreement amongst previously posted product reviews on the ratings and volume of future reviews. Because online reviews are typically non-normally distributed, we first develop a new method for measuring disagreement in such settings. Using data on nearly 300,000 movie reviews, we find that disagreement leads to a higher propensity to post a future review, but that these reviews tend to have a lower rating. Finally, we show that our measure has more explanatory power than the traditional measure of disagreement, standard deviation. This paper was selected for the Best Paper Proceedings of the 2014 Academy of Management Conference.

The importance of technology in increasing the firm's interactions with its ecosystem is also a theme in my ongoing work. With Kristina McElheran and Steve Kahl, I explore

how the technology adoption choices of a firm's supply chain partners influence the firm's technology decisions. We combine detailed data on firm-level adoption of Enterprise Resource Planning (ERP) software with data on public firms' customers and suppliers. Our preliminary results show that the firms who have a major customer that adopts ERP are more likely to adopt ERP than those that do not, suggesting an important external factor in the decision to adopt technology.

I am also exploring how newly emerging digital currencies are altering firm behaviors due to a reduction in transaction costs. In ongoing work (joint w/ Michael Kummer), I explore how an established e-commerce retailer reacts to the entry of a competitor that only accepts digital currency by lowering prices on goods that are offered on both platforms.

In addition to these ongoing projects, I am currently working with the Kauffman Foundation to collect data on how start-up firms use CDGs. The potential impact of CDGs on such firms is quite large as they are more credit-constrained than large incumbent firms, and are therefore more likely to benefit from the non-pecuniary nature of such goods.

Contribution to the NBER Community

As a regular participant in the NBER Productivity Lunches and the NBER Summer Institute, I am aware of how strong the NBER community can be. As the NBER Digitization Post-Doctoral Fellow, I could continue to add to this great community. By continuing my participation in NBER activities, as well as deepening my involvement with the Digitization Working group's activities, I believe my expertise could help enhance the importance of the group within the NBER and the greater academic community.