Firm Organization in the Digital Age: IT Use and Vertical Transactions in U.S. Manufacturing*

Chris Forman
Cornell University

Kristina McElheran
University of Toronto

April 30, 2018

Abstract

We investigate whether manufacturing plants change the degree to which they outsource downstream value-chain activities in the wake of advances in information technology (IT). Using U.S. Census Bureau data for over 5,500 establishments over ten years, we observe whether production is destined for further transformation within the same firm or is sold to external value chain partners. We also directly observe how plants are using general-purpose IT for different types of coordination. Exploiting the technology shock of the commercial internet in the mid-1990s, we compare pre-internet transaction patterns to post-internet ones at a given plant as a function of changes in IT use. Controlling for time-varying plant and firm characteristics – including changes in the ownership of establishments throughout the firm - our results show that externally-focused coordination over the internet was associated with a significant increase in market-based exchange. Moreover, this comes at the expense of internal vertical transfers and is consistent with a causal relationship between IT use and firm re-organization over time. To the extent that firm boundaries depend on the volume and locus of economic activity – and not just the number of units a firm owns – this has profound implications for the organization and size of firms in the digital age.

JEL Codes: L220 (Firm Organization and Market Structure), L6 (Manufacturing), O330 (Technological Change)

Keywords: information technology, supply chain, vertical integration, internet, complementarities

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* Chris Forman: Dyson School of Management, Warren Hall, Ithaca NY 14853. Kristina McElheran, University of Toronto, 105 St. George Street, Toronto ON, M5S 3E6. With particularly thanks to Francine LaFontaine for help with framing, we also thank Chad Syverson, Theresa Fort, Avi Goldfarb, Shane Greenstein, Manpreet Hora and seminar participants at Harvard Business School, Carnegie Mellon University, New York University, the University of Calgary, the University of Maryland, the University of Texas at Dallas, the NBER Summer Institute, the RDC Annual Conference, the NBER Productivity Lunch, the Workshop on Information Systems and Economics (WISE), the MIT Organizational Economics Lunch, the Center for Economic Studies, and the Smith Innovation and Entrepreneurship Conference for helpful feedback. Research assistance was provided by Jin Woo Chang and Wang Jin. We are indebted to T. Lynn Riggs, Jim Davis, and other members of the Center for Economic Studies for their support. Any opinions and conclusions expressed herein are those of the author(s) and do not necessarily represent the views of the U.S. Census Bureau. All results have been reviewed to ensure that no confidential information is disclosed. All errors remain our own.

1. Introduction

The impact of recent breakthroughs in information technology (IT) can be seen everywhere today – even in the productivity data.[1] Yet, if we are to fully understand the influence of this technological change in the economy, we must consider not only how it impacts the efficiency of existing production, but also how production itself may be fundamentally redesigned. In fact, this is often the most important channel by which new technologies come to shape economic outcomes. The steam engine and electrification transformed the nature of production and work in the 19th and 20th centuries, but only after massive relocation and reorganization (Rosenberg and Trajtenberg 2004), Jovanovic and Rousseau 2005). Digital technologies are widely expected to spark a similar upheaval in the 21st (Malone and Rockart 1991, Milgrom and Roberts 1992, Brynjolfsson and Saunders 2010, Brynjolfsson and McAfee 2014), though systematic evidence remains sparse relative to speculation.

One important stream of research has argued that IT may alter the organization of production by shifting the coordination costs that influence firm boundary decisions (e.g., Malone et al. 1987, Clemons et al. 1993, Hitt 1999). In particular, if IT reduces the costs associated with external market exchange, then firms might participate in fewer steps of the value chain, becoming less vertically integrated and potentially smaller, on average (Brynjolfsson, Malone, Gurbaxani, and Kambil 1994) over time.

Yet digital technologies may also affect the costs of coordinating *within* firms. If IT reduces the costs of managing internal transactions, then we would expect a rise in larger, vertically integrated firms – with very different economic implications (Afuah 2003; Brews and Tucci 2004). Ultimately, the relationship between observed organizational choices and IT use depends on the net impact of these competing forces, making it difficult to disentangle the precise mechanisms at work.

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[1] Nobel-prize winning economist Robert Solow famously quipped that "You can see the computer age everywhere but in the productivity statistics." Conventional wisdom now considers this "paradox" to have been resolved with better measurement (Brynjolfsson and Yang 1996) and methods for accounting for firms' complementary intangible investments (Brynjolfsson and Hitt 2000, Dedrick et al. 2003, Melville et al. 2004). Recent studies of the productivity impact of IT include Bloom et al. (2010) and Tambe and Hitt (2011); a useful recent review is provided by Cardona et al. (2013).

Another challenge is that prior work on IT and firm organization has largely focused on the ownership of productive assets.[2] However, the activities (Wernerfelt 1984) and associated transactions (Coase 1937) firms undertake may differ in important ways from ownership structure – and, we argue, may be just as important for how we think about firm organization and boundaries in the wake of technological change. In this paper, we provide novel evidence on how the volume and locus of vertical transactions in the U.S. manufacturing sector shifted, regardless of asset ownership, in conjunction with specific applications of information technology.

In particular, we make headway by taking advantage of U.S. Census Bureau micro data that precisely distinguish external versus internal coordination over IT networks. We link this to largely untapped Census data on downstream transactions as well as other production details for a large representative sample of manufacturing plants. Using the Economic Censuses in 1992 and 2002, we compare transactions patterns within the same plant before and after the diffusion of the commercial internet. This allows us to control for time-invariant drivers of firm activity choices and is highly representative of the sector as a whole.

Studying firm organization at the level of transaction patterns is an important contribution of this paper. Much of the more-recent research on firm boundaries focuses on what determines the ownership of productive assets (e.g., Grossman and Hart 1986; Hart and Moore 1990; Acemoglu et al 2004). Yet, core work in transaction cost economics (TCE) argues that key dimensions of the phenomenon are best understood at the level of the transaction (Coase 1937; Masten 1984; Williamson 1991; Oxley 1997). Building on this line of argument, we provide novel evidence that firms meaningfully shift the volume and locus of their activities in ways not captured by measures of ownership structure.

This matters because it conforms to a poorly-understood empirical fact: contrary to most theoretical models, firms very often both "make" *and* "buy." Only 14% of the value produced by the

[2] Large-scale multi-industry empirical studies of IT and firm boundaries have typically measured vertical integration according to joint ownership of production units assigned to industries that are more or less vertically integrated according to input-output tables (Dewan, Michael, and Min 1998; Hitt 1999; Ray, Wu, and Konana 2009).

plants in our large representative sample stayed within the firm boundary for further processing in 1992, falling to 12% in 2002.[3] A large percentage that owned vertically-related production units according to the Bureau of Economic Analysis' input-output tables reported no internal vertical transfers whatsoever. Moreover, the forces that determine the locus of the marginal transaction when either make or buy is an option are *precisely the ones that are sensitive to the impact of IT*. Thus, our measures not only illuminate an important empirical phenomenon but also tie it very specifically to the economics of digital transformation.

To conduct our analysis, we take as our dependent variable the value of plant shipments transferred to other plants within the same firm for further assembly, fabrication, or manufacture, normalized by the plant's total sales, i.e., the percentage of within-firm transfers (WFT). To our knowledge, this represents the first opportunity to directly observe the governance of downstream vertical transactions within firms across multiple industries and over time.[4]

We exploit the rapid decline in information processing and communications costs during our sample period – in particular, those enabled by the widespread commercialization of the internet in the mid-1990s – to explore how the resulting new IT uses changed how firms optimally organized their activities. **Controlling for both fixed and time-varying drivers of how much downstream vertical activity takes place within the firm, we find that a one-standard-deviation increase in IT used for external coordination is associated with a roughly 8% decrease in the percentage of within-firm transfers.** We further demonstrate that the organizational response to the adoption of external IT is not just an artifact of short-term growth at the focal plant (i.e., growth in the denominator of our ratio), but is also accompanied by a reduction in internal vertical transfers. It holds after firms have had sufficient time

[3] This low percentage of vertical transfers within co-owned value chains is corroborated using different measures (also collected by the U.S. Census Bureau) by Atalay, Hortacus, and Syverson (2013). Parmigiani (2007) also investigates "make *and* buy" and advocates for more research into this "concurrent sourcing" practice.

[4] Atalay, Hortacsu, and Syverson (2013) conduct a multi-industry study of vertical transfers using Census micro data. However, commodity flow transfers are not directly observed, but rather inferred based on the location of shipments from the establishments in question to postal codes where the parent firm owns another unit. For examples that use direct data within specific industries, see the studies surveyed in Lafontaine and Slade (2007).

to adjust across a number of margins, and thus is unlikely to be a transient trend. IT for internal coordination has no effect on the intensity of vertical transfers during the period we study.

While our initial results treat IT adoption as an exogenous factor that influences economic outcomes, we examine the implications of this assumption through a series of additional analyses.[5] In addition to controlling for a range of other plant, firm, and local factors that are believed to shape vertical activity decisions, we show that the timing of organizational changes is consistent with the diffusion of the commercial Internet. Third, we instrument for external IT adoption using variables that will shift the costs of IT adoption. Our first instrument uses an engineering estimate of the local costs of delivering telecommunications services. Our second two instruments follow recent literature (e.g., Forman, Goldfarb, and Greenstein 2008, 2012; Augereau, Greenstein, and Rysman 2006) by using the IT investment behavior of geographically linked establishments within the same firm and of their competitors as instruments. Our conclusions remain largely unchanged.

While our interpretation is, for the most part, causal, we emphasize that strict casual identification is not necessary for our insights to matter for key economic outcomes. For instance, if some unobserved factor is promoting both external IT adoption and less vertical integration of activities, then our results remain informative about the magnitude of the complementarity that exists between these two decisions – and the long-term trends we should expect in the economy if past diffusion patterns persist.

The contribution of these findings centers on providing novel evidence to long-standing questions concerning the impact of IT on organizational structure (e.g., Malone, Yates, and Benjamin 1987; Gurbaxani and Whang 1991; Hitt 1999). A leading hypothesis has been that generic IT capital spending will be associated with a greater decline in external costs of monitoring than internal ones (e.g., Malone, Yates, and Benjamin 1987), generating the prediction that an increase in general IT capital spending should be associated with smaller (less integrated) firms.

[5] This empirical approach has been followed by a range of papers that study the implications of IT adoption decisions on organizational outcomes, including Athey and Stern (2002), Bloom et al. (2009), Forman, Goldfarb, and Greenstein (2012), and Aral, Brynjolfsson, and Wu (2012).

Large-scale multi-industry empirical studies have sought to test this hypothesis either by measuring the extent of vertical integration using average firm size within industries (Brynjolfsson, Malone, Gurbaxani, and Kambil 1994; Hu and Saunders 2012; Im et al. 2013) or by measuring the extent of firm participation in industries that are more or less vertically integrated according to input-output tables (Dewan, Michael, and Min 1998; Hitt 1999; Ray, Wu, and Konana 2009). These studies provide important insights into the scope of firm asset ownership and industry participation, however they are limited in the information they provide on how different margins of IT use have affected firm activities, and all rely on changes in asset ownership to some degree.

Understanding what drives the decision to organize economic activity according to the rules of organizations versus those of the market has been deemed "one of the most important issues in economics" (Lafontaine and Slade, 2007, p. 629) and represents a core research question in the strategic management literature (e.g., Argyres and Zenger 2012, *inter alia*). Important streams of work in both fields have looked at the relationship between advances in IT and organizational design (e.g., Baker and Hubbard 2003; Afuah 2003; Brews and Tucci 2004;)

****TABLES AND RESULTS DISCUSSION PENDING CENSUS DISCLOSURE REVIEW********