Research Policy 45 (2016) 724–745

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

Gains from others' losses: Technology trajectories and the global division of firms

Chia-Hsuan Yang [a], Rebecca Nugent [b], Erica R.H. Fuchs [a,*]

[a] Department of Engineering and Public Policy, Carnegie Mellon University, Pittsburgh, PA, USA
[b] Department of Statistics, Carnegie Mellon University, Pittsburgh, PA, USA

ARTICLE INFO

Article history:
Received 12 August 2014
Received in revised form
15 December 2015
Accepted 19 December 2015
Available online 18 January 2016

Keywords:
Offshoring
Innovation
Human capital
Product life cycle
Manufacturing
Location of knowledge

ABSTRACT

This paper offers new insights into the role of firms versus individuals in driving technology directions, and the extent to which human capital may be lost during industrial shifts. We explore in particular whether (1) firms who move manufacturing offshore slow U.S.-based R&D activities in an emerging technology and (2) the inventors originally within these offshoring firms, leave, and continue innovating in the emerging technology at different institutions. We focus on the 28 leading U.S. optoelectronic component manufactures for telecommunications and the inventors who patent at these firms. In the case of U.S. optoelectronic component manufacturers for telecommunications, offshoring is associated with a decrease in innovation in the emerging technology, but an increase in all other types of patenting. The majority of inventors depart to firms outside the industry and stop work in the emerging technology. However, an important minority of emerging technology inventors at the offshoring firms go to a single onshore firm in the same industry (which gains from others' losses and subsequently dominates this space). Our results suggest a strong role for firms and firm strategy in driving innovation directions, and the corresponding opportunities faced by individuals.

1. Introduction

In the technology strategy literature there exists a tension regarding the respective roles of firms versus individuals in driving technology directions and the extent to which each holds the knowledge stocks for driving those directions (e.g. Abernathy and Clark, 1985; Christensen, 1997). On the one hand, research on industry evolution and technology trajectories has pointed out the importance of firm strategy in identifying technology trajectories and driving innovation. On the other hand, research on the creation and transfer of knowledge has viewed the individual as the source of knowledge capital, emphasizing the role of scientist and engineer mobility in disseminating knowledge (e.g. Almeida and Kogut, 1999), and the lengths to which inventors will go to persist in their research directions (e.g. Furman).

These tensions on the interaction between firm and individual strategies in driving technology directions play themselves out in the debates on offshoring. Here, research has suggested that if firms move manufacturing overseas to developing nations, these firms may lose incentives to produce the most advanced technologies (Fuchs and Kirchain, 2010) and supporting industrial commons (suppliers, human capital in the form of labor markets, and knowledge flows) and R&D may soon follow (Pisano and Shih, 2009).

Leveraging a case of extensive offshoring by U.S. optoelectronic component manufacturers for telecommunications, this research seeks to contribute to these larger debates. We first seek to understand whether, driven by the different offshore production economics found in (Fuchs and Kirchain, 2010), firms that move manufacturing offshore slow U.S.-based R&D activities in the emerging technology. We then explore the implications of the firm's offshoring decisions for inventor innovation trajectories (and thus the human capital originally built within those firms). In particular, we seek to understand whether inventors originally employed at these firms continue innovating in the emerging technology at different institutions.

This paper leverages an extensive new dataset on the optoelectronics industry to unpack the relationship between offshoring of manufacturing to low-wage countries and innovation directions back in the United States. We focus our study on the 28 leading U.S. optoelectronic component manufacturers for telecommunications and the inventors who patent at these firms. Leveraging seven different sources of industry data, we hand-construct a dataset of all

* Corresponding author. Tel.: +1 412 268 1877; fax: +1 412 268 3757.
E-mail address: erhf@andrew.cmu.edu (E.R.H. Fuchs).

http://dx.doi.org/10.1016/j.respol.2015.12.005
0048-7333/

U.S.—owned optoelectronic component manufactures for telecommunications. We then triangulate hand-classified USPTO patents, SEC filings, phone-collected firm survey data, inventor resumes, and select interviews with key inventors.

We find that the *majority* of individuals change research directions in association with their choice of institutions (in this case, to which firms, they go). Meanwhile, the firms and their associated strategies (both in offshoring and in hiring) dominate our story on innovation. Specifically, we find that offshoring is associated with a decrease in firm innovation in the emerging technology. The majority of inventors depart to firms outside the industry and stop work in the emerging technology. However, an important minority of inventors from across the offshoring firms move to a single onshore firm in the same industry, which "gains from others' losses"[1] and subsequently dominates emerging technology innovation in the industry. Interestingly, the inventors that go to the firm that stays onshore and dominates in the emerging technology largely are not those with existing knowledge capital therein. The constraint is not fear of non-compete enforcement or patent litigation, rather inventors who were leaders in the emerging technology prior to offshoring choose for a variety of reasons to not pursue jobs at the onshore firm.

These results contribute to current debates on the benefits of domestic manufacturing and the relationship between manufacturing and innovation. We find that what *type* of manufacturing facility is moved overseas to a developing nation is critical to determining *whether* – as traditional economics would suggest – offshoring of manufacturing to a developing nation is associated with increased activities in higher-value activities by the offshoring firms back in the home country; or – as knowledge-based theories and recent work from engineering would suggest – offshoring of manufacturing to a developing country is associated with reduced innovation. In contrast to classical economic trade theories, while offshoring is associated in some firms with increased innovation in other areas, in no case do we find offshoring associated with increased innovation in the industry's emerging technology. These results also differ from Vernon's seminal product cycle theory (Vernon, 1966) in two important and fundamental ways: First, the offshoring firms move manufacturing overseas much earlier in their product cycle than would be suggested by Vernon. Second, and most importantly, our results suggest that firms may be changing their innovation *directions* as a consequence of these earlier choices to move overseas. Specifically, in having the opportunity to move manufacturing overseas earlier in their product cycle, the firms may shift earlier from product to process innovation, slowing or stopping advance of the emerging technology by firms themselves and/or pushing those activities out to other industries, institutions or nations.

Our results also contribute to theory on the location of knowledge and the drivers of technology trajectories. While recent research has found that inventors will go to great lengths to persist in their research directions, despite institutional changes or other outside forces, in our case, we find that the *majority* of individuals change research directions away from the emerging technology after changing firms. Meanwhile, firms and their strategies (both in offshoring and in hiring) dominate our story on innovation directions. These results suggest a strong role for firms and firm strategy both in driving innovation directions, and in constraining the corresponding opportunities faced by individuals.

2. The intersection of offshoring with theories on industry evolution, individual mobility, and technology change

2.1. Theories on industry evolution and technology trajectories

The technology strategy literature emphasizes the role of the firm in identifying technology trajectories and driving innovation (Abernathy and Clark, 1985; Christensen, 1997; Henderson and Clark, 1990). According to product life cycle theories, many technologies start in a period of uncertainty about user preferences and technological means of satisfying them, during which there is significant firm entry and product innovation. Once a dominant design emerges, the focus of firm efforts switches from product to process innovation[2], and there is a shake-out in the number of producers (Abernathy and Utterback, 1978; Agarwal and Gort, 1996; Anderson and Tushman, 1990; Mueller and Tilton, 1969; Tushman and Rosenkopf, 1992). Eventually, returns to investment in the prevailing technology fall as possibilities within the dominant paradigm are exhausted, setting the stage for a move to another generation of technology and a repetition of the cycle (Dosi, 1982; Foster, 1986; Gardiner, 1986; Sahal, 1985). This framework is not universally applicable. In some industries significant process improvements occur well before the emergence of a dominant design (Klepper and Simons, 2005). Alternative mechanisms have been identified as being explanatory drivers of entry, exit, and innovation over the product life cycle including differences in firm innovative capability (Klepper, 1996, 2002; Sosa, 2009), prior firm experience (Klepper, 2002; Sosa, 2009, 2011, 2013), firm size (Agarwal and Audretsch, 1999; Klepper, 1996), the timing of firm entry (Bayus and Agarwal, 2007), the experience of firm founders (Agarwal et al., 2004; Klepper and Simons, 2000), the innovation environment (Sarkar et al., 2006), and the evolution of markets (Agarwal and Gort, 1996; Klepper and Thompson, 2006). A technology's "limits" can also exceed those predicted (Christensen, 1993; Henderson et al., 1995; Utterback and Kim, 1985). This extended life can be determined not only by the structure of the dominant design and the laws of physics, but also by the needs and preferences of the technology's users, the capabilities of a technology's components, the evolution of key complementary technologies, and by increased innovation in the incumbent technology in response to the threat of a technological discontinuity (Foster, 1986; Henderson et al., 1995; Mowery and Rosenberg, 1979; Utterback, 1996).

2.2. Theories on human capital and knowledge flows

In contrast to the above literature, which focuses on the role of firms in technology evolution, a significant literature has also pointed to individuals as "active agents in the creation and spatial diffusion of knowledge" (Almeida and Kogut, 1999). This literature suggests that a firm's tacit knowledge is embedded in human capital (Berman et al., 2002; Hitt et al., 2001; Lepak and Snell, 1999; Szulanski, 1996), and that routines and resources transfer from old to new organizations through personnel migration (Aldrich and Pfeffer, 1976; Anton and Yao, 1995; Franco and Filson, 2006; Palomeras and Melero, 2010; Pfeffer and Leblebici, 1973; Rosenkopf and Almeida, 2003). Hiring firms can tap into the expertise of a worker's prior employer (Corredoira and Rosenkopf, 2010; Singh and Agrawal, 2011; Song et al., 2003) and employees from other firms also bring social capital in the form of external contacts from the time they were still in their prior workplace (Carnahan and

[1] Here, the onshore firm achieves a double gain: First, the onshore firm is able to hire researchers from its former competitors. Second, the reduction of innovation by the competitors that move offshore increases the competitive position of the companies who stay onshore and pursue the emerging technology.

[2] In a survey of 600 durable goods firms across 20 countries, Ettlie (1997) finds R&D intensity and total quality management (e.g. process improvement) to be inversely correlated.