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Open standards, vertical disintegration and entrepreneurial opportunities: How vertically-specialized firms entered the U.S. semiconductor industry

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ABSTRACT

This paper shows how the emergence of open standards has created large numbers of entrepreneurial opportunities in the semiconductor industry by enabling vertical specialization. Integrating data on firms and technology evolution, we find a gradual increase in the percentage of firms represented by newly-founded "*de novo*" entrepreneurial startups, instead of "*de alio*" ones, as open standards emerged in semiconductor products and processes over the life of the industry. This standardization reduced transaction costs and fostered specialization, thus facilitating the entry of vertically-specialized new ventures. Vise versa, the rise of such new ventures further pushed the adoption of open standards, and the vertical disintegration of the industry. Our theory on how standardization creates opportunities for new ventures and our analysis of the semiconductor industry contribute to the technology entrepreneurship literature, as well as the industry architecture literature that has primarily focused on the impact of standardization on the disintegration of vertically-integrated incumbents.

1. Introduction

The manner and extent by which entrepreneurial opportunities emerge and evolve for new entrants in an industry have been of interest to economic and management scholars for many years (Schumpeter, 1934; Kirzner, 1973; Spencer et al., 2008). Technological discontinuities, in particular, have been considered a major source of opportunities for new entrants because some discontinuities destroy the core competencies of incumbents (Tushman and Anderson, 1986; Anderson and Tushman, 1990; Walsh et al., 2005; Christensen, 1997). These opportunities temporarily exist until a large reduction, i.e., a shakeout, in the total number of firms occurs through acquisitions, mergers, and exits (Gort and Klepper, 1982; Klepper and Grady, 1990; Agarwal and Gort, 1996; Klepper, 1997; Klepper & Simons, 1997). This shakeout could be driven by economies of scale (Klepper, 1997) or the emergence of a dominant design (Utterback, 1994; Suarez and Utterback, 1995).

This paper empirically analyzes an alternative pathway by which technological change creates opportunities for entrepreneurial startups in the wind of value chain disintegration (Stigler, 1951; Williamson, 1981). One way to represent this pathway is with the framework of industry architecture. Industry architecture is "an abstract description of the economic agents within an economic system" (Jacobides, Knudsen and Augier, 2006 pp. 1203), and can represent the degree of vertical disintegration in an industry – "the emergence of new intermediate markets that divide a previously integrated production process between two sets of specialized firms" (Jacobidies, 2005 pp. 465). One main driver of disintegration is the reduction in transaction cost (Williamson, 1981; Langlois, 2007; Baldwin, 2008) from for example the emergence of open standards (Farrell and Saloner, 1985; Shapiro and Varian, 1999). As a result, the ease and value of specialization is increased, and thus drives vertically-integrated firms to disintegrate (Langlois, 1992; 2003, 2007; Klepper, 1997; Baldwin and Clark, 2000; Arora et al., 2001; Steinmueller, 1987; Baldwin, 2008).

In spite of this wide agreement that vertical disintegration are somehow related to entrepreneurial opportunities, however, the specific connection has not been explicitly recognized nor empirically examined in the entrepreneurship literature (Baron and Shane, 2007; Bygrave and Zacharakis, 2010; Shane, 2010) or in the industry architecture literature. In particular, the industry architecture literature primarily focuses on incumbents, the appropriate degrees of vertical

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integration of firms for specific types of products, and how the emergence of vertical disintegration impacts on integrated incumbents in the semiconductor (Monteverde, 1995; Macher, 2006) and other industries (Sorensen, 2003). New ventures, however, are not investigated in this context within existing empirical studies. Whether, how specifically, and to what extent entrepreneurial opportunities and new ventures may emerge in the wind of vertical disintegration remains a research question.

Through an analysis of the U.S. semiconductor industry, this paper addresses the relationships between the emergence of open standards, vertical disintegration and the emergence of entrepreneurial opportunities for new entrants. This industry was chosen as an object of analysis because there has been a large amount of technological changes and a large number of new entrants particularly in the U.S. (Walsh et al., 2005) in a clear historical process of vertical disintegration in the industry's history (Tassey, 1990). For the U.S., the number of new entrants is in the thousands (Braun and MacDonald; 1982; Borrus, 1987; Saxenian, 1994; Angel, 1994) and new firms continue to emerge (Jones, 2006; Clark, 2006).

This paper shows that the emergence of open standards has created large numbers of entrepreneurial opportunities in the semiconductor industry, perhaps more than have other forms of technology change. As open standards gradually emerged between design and manufacturing within the semiconductor industry and between the semiconductor and systems industries in the form of "standard modules," the success of specialized entrepreneurial startups gradually increased. Open standards reduced the costs of having work done by multiple agents and the barriers to entry for entrepreneurial startups with resources constraints. New ventures had a greater incentive than did incumbents to embrace open standards and vertical specialization because of their resource and capacity constraints and greater need for return on investment. In turn, the overall vertical disintegration of the semiconductor industry can be partly attributed to the rise of vertically-specialized new ventures and their push for open standards.

Our theory and empirical analysis contribute to the technology entrepreneurship literature that has primarily focused on technological discontinuities as a major source of opportunities for new entrants to an industry, as well as the industry architecture literature that has focused on the impact of standardization on the disintegration of vertically-integrated incumbents.

2. Literature review

A predominant viewpoint in the technology entrepreneurship literature is that technological discontinuities temporarily create opportunities for new entrants because some discontinuities and their associated technological changes destroy (as opposed to enhance) the core competencies of incumbents (Prahalad and Hamel, 1990; Tushman and Anderson, 1986; Anderson and Tushman, 1990; Walsh et al., 2005; Christensen, 1997). These opportunities temporarily exist until a shakeout in the total number of firms occurs (Gort and Klepper, 1982; Klepper and Grady, 1990; Agarwal and Gort, 1996; Klepper, 1997; Klepper and Simons, 1997) where economies of scale in R&D and other activities is a major driver of these shakeouts (Klepper, 1997). On the other hand, the emergence of vertical disintegration might enable entry after a shakeout occurs because it reduces economies of scale. For example, the emergence of independent suppliers of process equipment, which is one example of vertical disintegration, reduced the economies of scale in R&D for product manufactures and thus enabled the entry of new product manufacturers after a shakeout in them had occurred (Klepper, 1997).

Other scholars have focused on other forms of vertical disintegration such as those between modules in a physical system (Langlois, 1992; Langlois and Robertson, 1992; Baldwin and Clark, 2000; Christensen et al., 2002; Langlois, 2003, 2007). Scholars explain the emergence of this vertical disintegration in terms of a growing market (Stigler, 1951), changes in transaction costs (Williamson, 1981; Baldwin, 2008) and capabilities (Teece and Pisano, 2007), and an interaction between them (Jacobides, 2005; Jacobides and Winter, 2005). All of these factors (and the ones in subsequent paragraphs) are subsumed under the term "industry architecture" because this framework has been successfully used to describe the evolution of many industries, including mortgage banking (Jacobides, 2005; Jacobides and Winter, 2005), construction (Cacciatori and Jacobides, 2005), apparel (Jacobides and Billinger, 2006), and mobile Internet (Tee and Gawer, 2009).

The emergence of open modular designs and/or interface standards may facilitate vertical disintegration through reducing the transaction costs associated with different firms supplying different modules (Ulrich, 1995; Sanchez and Mahoney, 1996; Baldwin and Clark, 2000) and also reducing the scope of integrative capabilities (Jacobides, 2005; Jacobides and Winter, 2005) or combinative capabilities (Kogut and Zander, 1992; Van den Bosch et al., 1999) for individual firms, and complementary assets (Mitchell, 1989, 1991; Tripsas, 1997). When these modular designs reduce the necessity of knowledge-based integrative or combinative capabilities and complementary assets to the extent that modular organizations (Hoetker, 2006), user innovations (von Hippel, 2005) or "transaction-free" zones (Baldwin, 2008) can emerge, they also drive the integrated firms to vertically disintegrate and enable the entry of vertically-specialized firms (Klepper, 1997). The vertically-specialized organizational form, which provides better economies of scale in R&D for modular innovation and in production by supplying to multiple customers, can emerge either as new ventures or through spinoffs of incumbents. However, whether the resulting vertically-specialized firms are more likely to be new venture startups than the spinoffs of incumbents remains a question, and is the primary focus of our analysis of the semiconductor industry in Section 5.

Open modular designs and open interface standards in turn often emerge as a result of the changes in technology, legal, regulatory, and firm decisions in the life cycle of an industry. Modular designs are those in which the interfaces that determine how the functional components or "modules" in a product or process design will interact are specified in for example, design rules, to enable the substitution of component variations within the design (Ulrich, 1995; Sanchez and Mahoney, 1996; Baldwin and Clark, 2000). The term "standard" or "interface standard" (Farrell and Saloner, 1985; Shapiro and Varian, 1999) is often used to define the way in which these different modules interact, particularly when products from different firms are compatible with the same interfaces. Although the terms modular design and standard interface are typically used in reference to clearly delineated and stable physical modules whose standard interfaces are determined by top-down processes (Farrell and Saloner, 1985; Langlois, 1992; Langlois and Robertson, 1992; Sanchez and Mahoney, 1996; Shapiro and Varian, 1999; Baldwin and Clark, 2000), transaction-free modular designs can also emerge between different functions (Brusoni and Prencipe, 2001, 2006; Cacciatori and Jacobides, 2005; Jacobides, 2005; Jacobides and Billinger, 2006) where the transaction-free boundaries for both different functions and modules can evolve over time. Such transaction-free interfaces (Baldwin, 2008) may emerge in bottom-up processes (von Hippel, 2005; Jacobides, 2005; Jacobides and Winter, 2005) that make it difficult for incumbents to notice such changes and respond.

However, while standardization makes the vertically-specialized organizational form a viable option, it does not necessarily destroy the differentiated value of integrative or combinative