The Diffusion of Internet-based Distance Education Technology among U.S. Associate Colleges

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Abstract

This paper analyzes the diffusion of internet-based distance education technology (NETDE) among the U.S. associate colleges. The study finds that an institution with experience in using an earlier generation distance education technology is more likely to adopt NETDE than an institution without such an experience. The finding supports the view of Cohen and Levinthal (1990) that an organization's "absorptive Capability" plays a significant role in its innovative activities. Institution size also facilitates the adoption of NETDE. We relate this size effect to market power because the size effect is partly caused by customer switching costs present in the NETDE market. Finally, we find that, among public institutions, the presence of close competitors motivates an institution to adopt NETDE earlier.

Keywords: Innovation Adoption, Internet-based Distance Education, Distance Learning, Organizational Knowledge, Switching Cost.

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1 INTRODUCTION

Since Griliches (1957), the diffusion of technological innovation has been recognized as an important topic in the study of technological change. Many empirical studies have examined the roles of many firm-level and industry-level factors, especially firm size, plant size, market concentration and rival precedence, in technology adoption (Davies, 1979; Oster, 1982; Karshenas and Stoneman, 1993; Gourlay and Pentecost, 2002). In addition to these factors, the role of knowledge in innovation has received considerable attention. For example, some recent studies (Colombo and Mosconi, 1995; Gourlay and Pentecost, 2002) find that a firm's knowledge base has significant effect on its innovation adoption decisions. The idea of knowledge base is close to Cohen and Levinthal (1989, 1990)'s concept of "absorptive capability." They write:

> Thus, prior related knowledge confers an ability to recognize the value of new information, assimilate it, and apply it to commercial ends. These abilities collectively constitute what we call a firm's "absorptive capacity." (Cohen and Levinthal, 1990)

To adopt an innovation, a firm needs to acquire new knowledge that it did not previously possess. If the new knowledge is similar to the knowledge base a firm already has, then it is easier for the firm to assess and acquire the new knowledge which is necessary for the adoption of the innovation, increasing the probability of adoption. In contrast, if a firm has a small knowledge base, one would expect a lower probability of adoption. One of the objectives of this paper is to provide further evidence on the role of "absorptive capability" in technology adoption.

We analyzed the adoption of internet-based distance education technology (hereafter NETDE) by American associate colleges. Associate colleges in the U.S. typically offer two-year courses covering general education or specific occupational education and award associate degrees and certificates, although they may also award baccalaureate degrees in rare cases. NETDE is a distance education technology that delivers instructions to off-campus students through the internet. Colleges differ in terms of their experiences with earlier generations of distance education technology, which in-

clude one-way audio, two-way audio, one-way video, two way-interactive video, etc. We use such experiences to measure a college's "absorptive capability" in its adoption of NETDE because these experiences enhance an institution's knowledge base for NETDE adoption.

The paper also studies the roles that a number of additional factors play in technology diffusion. First, we analyze the roles of organization size and market power in technology adoption. With only a few exceptions, most empirical studies find a positive and significant effect of size on technology adoption (Hannan and McDowell, 1987; Colombo and Mosconi, 1995; Gourlay and Pentecost, 2002). In contrast, the effect of market power is far from conclusive (Hanna and McDowell, 1984a, 1984b, 1987; Levin, Levin, and Meisel, 1987; Romeo, 1975; Karshenas and Stoneman, 1993). In this study, we provide new empirical results. Furthermore, we suggest that there exists an implicit linkage between the size effect and the market power effect. In particular, if it is costly for buyers to switch to new producers, then a large producer in the old product market obtains more market power in a related new product market in the sense that more buyers are "stuck with" its products (Klemperer, 1987). With more "secured" customers, a large producer tends to adopt an innovation earlier. Based on this reasoning, we argue that the positive effect of firm size on innovation adoption provides an indirect supportive evidence to Schumpeter's conjecture that market power facilitates innovation (Schumpeter, 1942).[1]

Second, we investigate the role of market demand on technology diffusion. Schmookler (1966) and Mansfield (1968) both suggest that large market demand motivates innovative activities. This study attempts to provide more empirical evidence on this issue (Levin, Levin and Meisel 1985, 1987; Oster, 1982). Third, we use a variety of measures to test the effect of market competition on the diffusion of NETDE. Finally, our study contributes to the literature of innovation diffusion among higher education institutions (Link and Scott, 2003) and contributes to this literature by incorporating education quality into our analysis.

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[1]However, in his earlier work (Schumpeter, 1934), Schumpeter suggests that competition promotes innovation. In the current study, when we discuss Schumpeter's hypothesis, we refer to the view expressed in his later work.

The paper proceeds as follows. In Section 2, we briefly introduce the history of Internet-based distance education. In Section 3, we develop a theoretical model to study the optimal timing of NETDE adoption and develop hypotheses based on this model. In Section 4, Cox and Weibull survival models are specified to test the hypotheses. Section 5 reports estimation results and and discussions, and Section 6 concludes the paper.

2 THE NETDE TECHNOLOGY

The technology that uses networks to connect computers and to permit communication among them first emerged in 1969 in the United States. The earliest network was called ARPAnet. Over time, the size of the networks expanded and the network communication technology experienced gradual, and sometimes significant, improvements. In 1983, TCP (Transfer Control Protocol) and IP (Internet Protocol) were adopted by international network standard organizations to replace the early version of Network Control Protocol (NCP). The new protocols were faster, easier to use, and less expensive to implement than NCP. From then on, all networks that use TCP/IP have collectively become known as the Internet. The standardization of TCP/IP boosted the number of internet sites and users exponentially. In 1991, the World Wide Web (WWW) technology was introduced. WWW is a system of internet servers that supports specially formatted documents. The documents are formatted in a markup language called HTML (HyperText Markup Language) that supports links to other documents, as well as graph, audio, and video files. This makes it possible to jump from one document to another simply by clicking on hyperlinks and facilitates communication through the Internet.

The instructional technologies used by the U.S. associate colleges include traditional classroom teaching and a variety of distance education technologies. The latter include traditional technologies such as one-way audio, two-way audio, one-way video, two-way interactive video, and others. The Internet-based distance education technology emerged in the early 1980s. The earliest application of the Internet in distance education in our sample occurred in 1983. Coincidentally, 1983 is the

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year TCP/IP was officially adopted and the Internet received its official name.

For colleges and universities, a primary benefit of NETDE is to expand their accessibility to potential learners. NETDE provides great flexibility in the time and location of learning. Many potential students who would otherwise be unable to receive higher education are able to do so with NETDE. The adoption of NETDE might also enable colleges and universities to expand their instructional capacity without much investment in new buildings. For students, the benefits of NETDE primarily include time flexibility and reductions in travel cost (Ozdemir and Abrevaya, 2007; Ozdemir et al., 2007). Time flexibility is especially valuable for many working students because NETDE allows them to avoid some opportunity costs of on-campus learning, primarily the salaries earned from current jobs.

Past research that investigates the cost implications of NETDE instruction provides inconclusive results. A study conducted at the University of Illinois finds that unit costs dropped on all nine courses when NETDE delivery substituted for classroom instruction. However, Arizona Learning System, a state-wide distance education consortium, finds that the cost per course enrollment of NETDE is higher than that of traditional classroom instruction (Rumble, 2001, p. 84). Bates (2000) argues that the unit cost of NETDE relative to classroom instruction varies by class size and the amount of special purpose materials used in NETDE. Due to some measurement problems present in these studies, we are not sure to what degree these costs represent the economic cost. For example, are the buildings on campus considered to be sunk or not? If they are sunk, then the economic cost of using them is zero. In the two calculations cited by Rumble (2001), buildings are treated as non-sunk. One conclusion we might draw is that from the institutions' perspective, education delivered through NETDE does not seem to have a substantial cost advantage over traditional classroom instruction. Compared to other distance education technologies, NETDE may even be significantly more costly (Rumble, 2001, p. 85).

Regarding the quality of NETDE instruction, some studies show that there is no significant difference in learning outcomes between traditional classroom learning and NETDE learning (Phelps,

Wells, Ashworth and Hahn, 1991; Finkelstein, 2000, p. 21; Allen and Seaman, 2004). In our estimation, we examine the effect of education quality on the adoption of NETDE.

3 THE THEORY AND HYPOTHESES

Institutions are of three types: public not-for-profit, private not-for-profit, and private for-profit. Each of these institutions provides differentiated NETDE products. The market demand that an institution faces is

$$p = a - bq, \tag{1}$$

where p is market price per unit of NETDE enrollment, q represents the quantity of NETDE enrollment, a and b are coefficients.

To adopt NETDE, each institution must spend amount $F(t)$ on capital equipment, where $F(t)$ is decreasing (due to technological progress in capital goods production) and concave (due to the limited potential of improvements in technology) over time. Further, the investment is assumed to be sunk. The variable costs in offering NETDE primarily are made up of the cost of instruction. For simplicity, we assume the marginal cost of NETDE is constant and denote it by c. In Figure 1, line 1 (L1) represents market demand, line 2 (L2) represents marginal cost, and line 3 (L3) represents marginal revenue. Not-for-profit institutions (public or private) aim to maximize social welfare. Thus, these institutions set their output q at the level where marginal cost c equals the market price. Hence, we have

$$c = a - bq. \tag{2}$$

Through (2), the optimal output q_s^* is given by (3)

$$q_s^* = (a - c)/b. \tag{3}$$

Figure 1: Optimal Output: For-profit and Not-for-profit Institutions

Social welfare at time t is represented by triangle ABC whose area is given by $(a-c)^2/2b$. The total social welfare of NETDE adoption is

$$w = \int_t^\infty \frac{(a-c)^2}{2b} d\tau - F(t). \tag{4}$$

To simplify the analysis, the discount factor is assumed to be 0. The institution's objective is to choose time t to maximize (4). The first order condition is

$$G = \frac{\partial w}{\partial t^*} = -\frac{(a-c)^2}{2b} - F'(t^*) = 0. \tag{5}$$

According to (5), we obtain

$$\frac{\partial G}{\partial t^*} = -F''(t^*) \le 0. \tag{6}$$

$$\frac{\partial G}{\partial a} = -(a-c)/b \le 0. \tag{7}$$

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$$\frac{\partial G}{\partial b} = (a - c)^2 / 2b^2 \geq 0. \tag{8}$$

$$\frac{\partial G}{\partial c} = (a - c)/b \geq 0. \tag{9}$$

According to the total derivative theorem, we further have

$$\frac{\partial t^*}{\partial a} = -\frac{\partial G/\partial a}{\partial G/\partial t^*} \leq 0 \tag{10}$$

$$\frac{\partial t^*}{\partial b} = -\frac{\partial G/\partial b}{\partial G/\partial t^*} \geq 0 \tag{11}$$

$$\frac{\partial t^*}{\partial c} = -\frac{\partial G/\partial c}{\partial G/\partial t^*} \geq 0 \tag{12}$$

Instead of social welfare, for-profit institutions aim to maximize profit (represented by the area BDEF in Figure 1). For a monopoly institution facing a linear demand, the optimal output and current profit at time t are given by (13) and (14) below, respectively.

$$q_p^* = (a - c)/2b. \tag{13}$$

$$\pi(t) = (a - c)^2 / 4b. \tag{14}$$

Following a similar procedure outlined for not-for-profit institutions above, the first order condition for a for-profit institution is

$$G = (a - c)^2 / 4b - F'(t^*) = 0. \tag{15}$$

Comparing the two first order conditions (5) and (15), the optimal adoption date of the for-profit institutions should be later than that of not-for-profit institutions because $(a - c)^2 / 4b$ is less than $(a - c)^2 / 2b$ and $F(t^*)$ is concave in t^*. Hence, we have our first hypothesis.

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Hypothesis 1. For-profit institutions should adopt NETDE later than not-for-profit institutions, other things equal.

The directions of the impacts of coefficients a, b, and c on t^* are the same for both a for-profit and not-for-profit institutions, as given by (10), (11), and (12). Using the results above, we next examine the effects of different factors on the adoption time of NETDE.

3.1 The effect of absorptive capability

Despite its different technology, NETDE is similar to earlier distance education technologies in its ability to deliver instruction to off-campus students. Because of this similarity, the knowledge accumulated by a college in its experience with earlier generations of distance education technology contributes to its "absorptive capability" in the adoption of NETDE. Thus, we expect an institution with such an experience to have a lower marginal cost in delivering instruction online than an institution without such an experience. By (12), lower marginal cost implies earlier adoption time. Hence we have the following hypothesis.

Hypothesis 2. Institutions with experience in using earlier generations of distance education technology should adopt NETDE earlier than institutions without such an experience.

As discussed in Section 5, we asked associate colleges if they delivered distance education in the past using one-way audio, two-way audio, one-way video, or other technologies. If the answer is "yes," the variable Ade is set to 1; Ade equals 0 otherwise.[2]

3.2 The effect of institutional size

Economists' interest in the relation between firm size and innovativeness started as early as Schumpeter who expressed different views on the issue at different stages of his research (Schumpeter,

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[2]Theoretically, the intensity of the utilization of alternative distance education technologies before the adoption of NETDE could be a better measure of "absorptive capability." Unfortunately, historical data on the enrollment in these courses are unavailable. Some surveyed institutions reported their enrollments in alternative distance education courses in academic year 2004-2005. However, this enrollment figure is endogenous because the adoption of NETDE can impact the enrollments in alternative distance education courses. As a result, the intensity of utilization of alternative distance education technology is not incorporated into the statistical model discussed in section 4. Distance education office is another good measure of "absorptive capability." However, most institutions established distance education office after NETDE was adopted. To keep more observations in the estimation, we choose to exclude distance education office from the model.

1934; 1942). Though most studies find a positive effect of firm size on innovative activities, Oster (1982) finds a negative correlation between firm size and the likelihood of technology adoption.

In the adoption of NETDE, large institutions have some advantages. First, an institution with a large enrollment in traditional classroom instruction is more likely to face larger market demand for NETDE education. For associate colleges, classroom instruction primarily attracts students from local community, and hence traditionally an institution's size is largely determined by the population in the area it serves. If potential NETDE students face considerable cost in collecting and assessing information of NETDE courses on the market, and an institution has some advantage in spreading its course information to local residents (due to, for example, more local social networking and a larger local alumni body), then a large institution is likely to face large market demand for its NETDE education. In turn, this large demand tends to promote the adoption of NETDE. Similarly, if there is a minimum efficient scale in the utilization of NETDE, a large institution is more likely to quickly adopt NETDE and reach this scale. Using a as a proxy for the size of the market, (10) suggests that the size of an institution positively affects NETDE adoption.

On the other hand, size has its drawbacks as well. The emergence of an innovation may destroy the rent of existing assets, and thus a big producer is likely to lose more than a small producer due to its larger stock of current capital goods. This is one of the reasons why monopoly power tends to retard innovation (Reinganum, 1989, p. 868). However, this factor seems unlikely to have a substantial effect in the diffusion of NETDE. Since many resources used in classroom instruction may also be used in NETDE instruction, the rent of existing assets does not change much. For example, an experienced classroom instructor can learn to deliver instruction through NETDE after proper training.

Christensen (1997) discusses the concept of "innovator's dilemma," where leading firms with an earlier generation of technology may very likely miss the opportunity to exploit a disruptive innovation. Two factors make an innovation disruptive. First, the innovation is potentially dominant in the future market but is only marginal in the current market. Second, the strategic management

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techniques of current leading firms blind them from recognizing the importance of adopting the innovation. In our context, NETDE is an important innovation, but it need not marginalize classroom education. Also, the management techniques of classroom education seem unlikely to prevent the administration of a college from recognizing the advantages of NETDE. We therefore maintain that NETDE is not a disruptive innovation in the sense of Christensen (1997).

In summary, we expect that size-related advantages of NETDE adoption outweigh its size-related inertia, and hence size has a positive effect on the adoption of NETDE.

Hypothesis 3. The size of an institution should have a positive effect on NETDE adoption.

3.3   The effect of market size

The larger the size of the market, the larger the demand for the product of a producer, and thus the easier it is to recoup the investment in technology that improves that product. In higher education, especially within the context of associate colleges, states and local communities represent the markets for students. Thus, the size of a state market is closely related to the population of that state.[3] We therefore use the state population between ages 18 and 65 as a measure of demand for NETDE, and expect a large state population to facilitate adoption.

Hypothesis 4a. State population has a positive effect on the probability of NETDE adoption, other things equal.

The benefits of NETDE may also be related to state population density. Lower population density implies a longer travel time, on average, to access classroom instruction (Ozdemir et al. 2007). Since NETDE stands to reduce travel costs, the demand for NETDE should be larger in states with lower population densities.[4] For reasons similar to those discussed for Hypothesis 4a, we state the following hypothesis.

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[3]Note that state population may not be a good proxy for market demand for a small number of institutions that primarily compete in a local market rather than the whole state. To mitigate this weakness, we also use population density to proxy market demand in hypothesis 4b below.

[4]The geographic distribution of residents can be highly uneven. In extreme cases, a state may have a significant proportion of its residents located in one or two big cities (such as Nevada and Arizona). However, since even in such states a substantial proportion of residents are dispersed in rural areas, state population density can serve as a proper measure of mean travel costs.

Hypothesis 4b. State population density has a negative effect on the probability of NETDE adoption, other things equal.

The hypotheses presented here are to some extent related to a stream of literature that examines the effect of location on the adoption of information and communication technologies (ICT) (Forman and Goldfarb, 2005). One school of thought in this stream argues that the gross benefits of ICT adoption will decrease with the size of an adopter's location, other things equal (Cairncross, 1997; Forman et al., 2005), whereas another school of thought maintains that the benefits will increase with the size of location (Gaspar and Glaeser, 1998). The underlying rationale for these arguments deals with the relative cost and availability of data communication technologies as well as complementary products and services (such as a skilled labor market) in rural and urban areas. Past empirical research provide evidence supporting both views. In our context, the main benefit of NETDE is eliminating the need to travel for education. We therefore side with the former school of thought discussed above and expect a higher level of NETDE adoption in states with lower population densities, all else equal.

3.4 The effect of market competition

We test the Schumpeter hypothesis that monopoly power promotes innovativeness (Schumpeter, 1942). In our setting, taking a as given, intensified competition implies a larger b. That is, given price p, the quantity demanded decreases when competition intensifies. We know from (11) that b has a negative effect on the propensity to adopt NETDE. A variety of approaches are used to measure the degree of market competition. If a U.S. state is a proper education market for in-state public institutions (Appendix 1 discusses the boundaries of markets), we use the number of public institutions and Herfindahl index of a state market to measure the degree of market competition. If institutions primarily compete in local markets, we use the distance between an institution and its nearest competitor and the number of institutions within 50 miles of its location to measure the degree of market competition that the institution faces. The next hypothesis states the expected

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relationship between market competition and NETDE adoption.

Hypothesis 5. The larger the number of public institutions in a state, the lower the propensity to adopt NETDE. The larger the Herfindahl index in a state, the higher the propensity to adopt NETDE. The larger the number of institutions within 50 miles of an institution's location, the lower the propensity to adopt NETDE. The longer the distance from the nearest competitor, the higher the propensity to adopt.

3.5 Controlling for education quality

Besides the factors discussed above, we also examine the effect of education quality on the adoption of NETDE. We use an institution's graduation rate in 1993 as a measure of its education quality and treat it as an institutional characteristic. Since NETDE had had little impact on college teaching by 1993, our selection of graduation rate in year 1993 avoids simultaneity concerns.

4 THE STATISTICAL MODEL

A hazard model is employed to test the hypotheses discussed above. Time is divided into $M + 1$ intervals, $[0, a_1), [a_1, a_2), \cdots, [a_{M-1}, a_M)$, $[a_M, \infty)$, where a_m is a known constant for every m, and each interval is equal to one year. Let T denote the length of time between the time when NETDE first emerges and the time when an institution adopts NETDE. Let $F(t) = P(T \leq t)$, $t \geq 0$ denote the cumulative distribution function of T. For a positive value h, let $P(t \leq T \leq t + h | T \geq t)$ denote the probability of adopting NETDE in the interval $[t, t + h)$, under the condition that the institution has not adopted NETDE by time t.

A hazard function for t is defined as

$$\lambda(t) = \lim_{h \to 0} \frac{P(t \leq T \leq t + h | T \geq t)}{h}, \tag{16}$$

where $\lambda(t)$ is the instantaneous rate of adoption per unit of time, conditional on the institution having not adopted NETDE by time t.

Observations concluding their spells in the last interval $[a_M, \infty)$ are censored at time a_M. Define

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$x_1, x_2, \cdots, x_M$ as the covariates of an observation in each of the intervals, respectively. The covariates are time-varying (but constant within each interval).

Before estimation, we need to specify the hazard function. Here we use the piecewise-constant proportional hazard function because of its flexibility. For observation i, in each interval $m = 1, 2, \cdots, M$, the hazard function is

$$\lambda(s; x_{i,m}, \theta) = \exp(x_{i,m}\beta)\lambda_m. \tag{17}$$

We first use the Cox method to estimate the model primarily because of its merit of flexibility (with no restriction on the shape of the baseline hazard). The number of total observations in the sample is denoted by n. Define the cumulative number of adopters before the mth interval as n_{m-1}. The conditional probability that observation i adopts NETDE in interval $[a_{m-1}, a_m)$, given that any of the $n - n_{m-1}$ observations could have adopted NETDE in the interval, is given by

$$\frac{\exp(x_{i,m}\beta)\lambda_m}{\sum\limits_{j=n-n_{m-1}+1}^{n} \exp(x_{j,m}\beta)\lambda_m} = \frac{\exp(x_{i,m}\beta)}{\sum\limits_{j=n-n_{m-1}+1}^{n} \exp(x_{j,m}\beta)}. \tag{18}$$

The likelihood is obtained by summing up the partial likelihood of all observations. Hence the log-likelihood function is

$$L(\beta) = \sum_{i}^{n} \left\{ x_{i,m}\beta - \ln\left[\sum_{j=n-n_{m-1}+1}^{n} \exp(x_{j,m}\beta)\right] \right\}. \tag{19}$$

We also estimate a Weibull model [5] to investigate the issue of time dependence in diffusion. The hazard function is specified as

$$\lambda(s; x_{i,m}, \theta) = \exp(x_{i,m}\beta)\alpha\gamma\ t^{\alpha}. \tag{20}$$

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[5]The estimation of Weibull model is technically complicated when covariates are time dependent. To make the estimation procedure simple, we replace time-varying *Ade* and *Size* by time invariant variables *Adelength* and *Sizeave*. The definitions of *Adelength* and *Sizeave* are provided in Table 1.

5   DATA AND ESTIMATION

5.1   Data description

The data used in the estimation are obtained from the Integrated Postsecondary Education Data System (IPEDS) maintained by the U.S. Department of Education, the U.S. Census Bureau [6] and a survey conducted by the authors. The survey was conducted in May, June and July of 2005. In the survey, we asked institutions about the year of adoption of NETDE, the year of adoption of an earlier generation of distance education technology,[7] the enrollment of NETDE students and the number of NETDE courses offered. 1,361 surveys were sent out through emails to the persons in charge of academic affairs, or distance education, or instructional technology in each of the associate colleges. 353 responses were received, resulting in a response rate close to 26%. Figure 2 is plotted using the adoption dates provided by 309 of the responding institutions. Similar to several other previous empirical studies, the diffusion curve here is S-shaped. NETDE diffused at a relatively slow pace between 1983 and 1996 and at a high rate between 1997 and 2001. The diffusion process slowed down after 2001. Eighty-two percent of the institutions in our sample had adopted the innovation by the end of 2004-2005 academic year.

We also check whether the diffusion of NETDE exhibited a geographical pattern. For example, we want to know whether colleges near an IT hub such as Silicon Valley tended to adopt the innovation early, or whether the diffusion process started from one area and then spread out to the surrounding regions. After examining the adoption dates and home states of the adopters, we do not find an obvious geographical pattern in the diffusion process. The adoptions occurred largely at an even rate across geographical regions.

After removing some observations due to missing data, the sample size reduced to 285. The sample includes 246 public institutions, 20 private for-profit institutions and 19 private not-for-profit institutions. The 285 institutions in the sample are from 46 states. The academic year 1982-1983 is

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[6]See http://quickfacts.census.gov/qfd/states/00000.html for details.

[7]These technologies include one-way audio, two-way audio, one-way video, two-way video, and some others.

Figure 2: The Diffusion Path of NETDE Technology

chosen as the baseline year to measure the duration of an event because the earliest adoption in our sample occurred in 1983-1984 academic year. The latest adoption occurred in academic year 2004-2005. The censoring date is the end of summer semester in 2005 when the survey was conducted. As a result, 46 observations in the sample are right censored.

Table 1 shows the definition of variables and their descriptive statistics.

5.2 Estimation and discussion

We use software package SAS to estimate the Cox model (19) and Weibull model (20). The results are presented in Table 2, and in Table 3 which presents the results for public institutions only.

We first discuss Cox estimations. The coefficient of *Nonprofit* is significant in the Cox estimation in Table 2. The hazard ratio indicates that a not-for-profit institution is 180% more likely to adopt NETDE than a for-profit-institution, a result consistent with Hypothesis 1.[8]

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[8]A caution is that variable *Nonprofit* may capture some effect of government subsidy(Most public institutions receive subsidies for distance education from government.) Subsidy results in lower marginal (private instead of social) cost of instruction for an institution, hence promotes NETDE adoption. However, as supervisor and fund provider, government should have the authority to approve or stop an education program in a public institution, and we assume government's decision to be based on social cost concerns. As a result, the effect of lower private marginal cost due to subsidy on NETDE adoption may not be large. Based on the discussions, we interpret the statistical evidence as supportive to Hypothesis 1.

Table 1: Descriptive Statistics

Variable	Definition	Mean	SD	Max	Min
Ade	Time-varying covariate 1, if an institution provided alternative distance education before or in the period; 0, otherwise.	na	na	na	na
Adelength	The length of Ade experience between the adoption year and 2004	10.11	10.6	49	0
Coll	The number of public associate institutions in a state.	50	37.2	138	2
Density	The population density (residents per square mile) of the home state of an institution.	220.8	221.0	1134.4	5.1
Dn	(in 10 miles)Distance to the nearest institution.	2.94	3.24	15.06	0
Grate	The ratio of associate degree awarded to 12 month unduplicated headcount	0.22	0.15	0.93	0.001
Herf	Herfindahl Index for the public institutions in a state market.	890.7	1040.9	10000	124.7
Nonprofit	The legal status of an institution; 1 for not-for-profit institutions; 0, otherwise.	0.93	0.26	1	0
Num50	The number of institutions within 50 miles of the institution.	6.7	8.3	35	0
Pop	The population (with age greater than 18 and less than 65) of a state in 2000 (in millions).	7.21	6.25	22.0	0.3
Size	(in thousands)Time-varying covariate; The size of an institution in each year before it adopts NETDE or is cencored.	na	na	na	na
Sizeave	(in thousands)The average size of an institution in the period between 1983 and 2005.	4.87	5.24	34.95	0.10
Year	The year when an institution adopted NETDE.	1998.44	2.92	2004	1983

Table 2: The Determinants of The Adoption of NETDE: All Schools

Variable	Cox Estimation	Hazard Ratio	Weibull Estimation	Hazard Ratio
Ade	1.07(0.15) ****	2.93		
Adelenghth			0.038(0.006) ****	1.04
Density	-3.99E-4(3.42E-4)	1.00	- 0.0004(0.0003)	0.99
Dn	-2.78E-3(2.32-3)	0.99	-0.0027(0.0023)	0.99
Grate	-0.92(0.65)	0.40	-1.65(0.63)***	0.19
Nonprofit	1.03(0.49) **	2.80	1.36(0.48)***	3.89
Num50	0.006(0.01)	0.99	-0.019(0.01)*	0.98
Pop	-0.004(0.011)	0.99	-0.0035(0.011)	0.99
Sizeave			0.048(0.016)***	1.05
Size	0.046(0.015) ***	1.05		
α			6.44(0.34)**	
Log likelihood	-1218.09		11.16	
N	285		285	

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

Table 3: The Determinants of The Adoption of NETDE: Public Schools

Variable	Cox Estimation	Hazard Ratio	Weibull Estimation	Hazard Ratio
Ade	0.90(0.15) ****	2.45		
Adelenghth			0.033(0.0063)****	1.03
Coll	-0.0057(0.0073)	0.99	-0.0046(0.0075)	0.99
Density	-4.7E-4(3.59E-4)	1.00	-0.00057 (0.00036)	0.99
Dn	-0.045(0.024)*	0.96	-0.005(0.0023)**	0.99
Grate	-0.28(0.79)	0.76	-0.43 (0.79)	0.65
Herf	2.79E-5(8.67E-5)	1.00	1.25E-5(8.87E-5)	1.00
Num50	-0.0034(0.01)	0.99	0.016(0.011)	0.98
Pop	0.03(0.043)	1.03	0.027(0.045)	1.03
Size	0.03(0.017)**	1.034		
Sizeav			0.034(0.017)**	1.03
α			6.64(0.35)**	
Log likelihood	- 1110.4		39.61	
N	246		246	

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

The Cox estimation in Table 2 shows that the coefficient of the variable *Ade* (in the second column) is significant. The likelihood ratio [9] is 2.93 which indicates that within an interval an institution having experiences with earlier generations of technology has about 193% more probability to adopt NETDE than an institution not having the experience. We obtain similar results for variable *Ade* when including only public institutions in the analysis (See Table 3, column 2). These results are consistent with our theoretical prediction in Hypothesis 2 that an institution's "absorptive capability" (measured by its experiences with prior technologies) facilitates its adoption of NETDE. This result also supports the existence of rank effect in innovation diffusion (Karshenas and Stoneman,1993). Some empirical studies find a significant effect of technology complementarities on technology adoption (see, for example, Hwang and Weil, 1997, p. 30). The idea is that if technology A and B are complementary in production, then a firm using technology A has a greater incentive to adopt B than a firm without technology A. However, if the two technologies require similar organizational knowledge in their application, then the correlation between the use of technology A and B can not be solely attributed to the effect of technology complementarities, because it could also be the case that the use of technology A accumulates certain organizational capabilities which facilitate the adoption of technology B. In this situation, the control for the effect of organizational capability may be necessary to detect the effects of technological complementarities.

The Cox estimation in Table 2 suggests a positive and highly significant coefficient for *Size*, which is consistent with Hypothesis 3. This result is also in line with the results of many other studies. A common explanation for this finding is that large institutions usually have more internal resources (e.g., capital funds) under control. In the case of NETDE, internal resources may not be the primary reason for a size advantage because the required amount of capital investment is not large (Rumble, 2001). Instead, we suggest that friction in buyer searching activities may be important in explaining the size effect. Because NETDE courses offered by different institutions are differentiated, it can be quite costly for students to search for and assess information on NETDE

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[9]The hazard ratio is the ratio between the hazard rate after a one unit increase in the covariate and the hazard rate before the change.

courses. Consequently, students may be inclined to take NETDE course from the most familiar institution or which they trust most. This suggests that large institutions are more likely to face large demand for NETDE education than smaller institutions because they are more broadly known (e.g., due to their larger alumni body), supporting an earlier adoption by these institutions. The hazard ratio for *Size* indicates that an increase of 1,000 in size is associated with an increase in the probability of adoption in an interval by about 5%. The mean of *Size* is around 5,000. Thus, on average, a 20% increase in size results in a 5% increase in the probability of adoption in an interval. Comparing to the percentage change in the size of an institution, the change in the probability of adoption does not seem to be large. Since the diffusion process took about two decades, the effect of size on the cumulative hazard rate is more significant. Cox estimation provides similar results when including only public institutions in the analysis.

This effect of institution size is to some degree related to the Schumpeter's discussion of monopoly power and innovation. Schumpeter (1942, p. 87-90) suggests that monopolistic power helps firms secure strategic resources and attract prospective customers which are vital to justify the investment in innovation. Without the two conditions, it is difficult for a firm to make commitment to the highly risky investments in new products, new production method and new markets. In the case of NETDE, large institutions are able to get more customers than small ones due to market friction. In other words, the market imperfection gives large institutions more monopolistic power than small institutions in the sense that the former can attract more customers. In turn, this larger body of secured customers reduces the firm's investment risk and tends to make larger institutions adopt NETDE earlier.

Another possible factor causing size advantage is that the efficient adoption of NETDE very likely requires a minimum scale. For example, an institution would not have much incentive to adopt NETDE to serve an expected enrollment of 10 students. Since large institutions face large demand as discussed above, they are more likely to reach the minimum efficient scale.

This explanation of size effect based on market imperfection and minimum efficient scale in adop-

tion may help explain some contradictory findings in the literature. For example, Oster (1982) finds a negative effect of firm size on the adoption of Basic Oxygen Furnace (BOF) by U.S. steel firms. Her explanation of the finding is based on the idea of Adams and Dirlam (1966) that "structural and behavioral characteristics of oligopolized industries prevent the dominant (firm) from pioneering." Based on the argument above, another possible explanation is that steel products are highly standard, and buyers' search costs are relatively low. Consequently, large firms cannot secure more customers for its new capacity (due to the adoption of BOF) than their smaller rivals, and hence large firms do not have more incentive to adopt the innovation. Further, capital investments in steel industry are highly sunk. For the reasons discussed in section 3.2, to protect the rent of previous capital stock, large steel firms tend to delay the adoption of BOF.

In both Cox estimations, variables *Pop* and *Density* are both insignificant, not supporting Hypotheses 4a and 4b. Like Levin, Levin and Meisel (1985), our results suggest that market size has no significant effect on technology adoption. If institutions primarily compete in local markets as discussed before, then state population is not a good proxy for the market demand an institution faces, and this may explain why state population is insignificant. The insignificance of *Density* may be due to the distinct advantages of adoption realized separately by urban and rural establishments as discussed in the ICT literature (Forman and Goldfarb, 2005; 2006).

Using only public institutions, variables *Coll* and *Herf* are both insignificant. Variable *Num50* is insignificant in both Cox estimations. When using all institutions, *Dn* is also insignificant. However, when using only public institutions, *Dn* is significant. The likelihood ratio suggests that a 10 mile decrease in distance to closest competitor would increase the probability of adoption by 4%. This result is contradictory to Hypothesis 5 which suggests that *Dn* should have a positive sign. A possible explanation is that when the distance to the nearest competitor is large, an institution may have more organizational inertia to change due to less competitive pressure. Combining the discussion of institution size and distance, it seems that market power obtained from different sources may have different effects on innovative activities.

In both Cox estimations, variable *Grate* is insignificant. That is, education quality has no significant impact on NETDE adoption. The result is somewhat counter-intuitive because, compared to low-quality institutions, high-quality institutions may fear NETDE to negatively affect their quality reputation and hence be more reluctant to adopt NETDE. A possible explanation is that an institution with high quality in classroom instruction may also be able to offer high quality NETDE courses. Thus, while high-quality institutions may be concerned with the low teaching quality of NETDE, low-quality institutions may also be concerned that NETDE may lower their quality even further. It may also be that NETDE is as effective as in-class learning as the technology-mediated learning literature suggests (Fjermestad et al., 2004).

The results we obtain in Weibull estimations are similar to those of Cox estimations with two exceptions.[10] The two exceptions are that, in Table 2, Weibull estimation gives the results that variables *Grate* and *Num50* are both significant. However, these results are not robust across different specifications because in the other three estimations we cannot find similar results. Further more, since Cox model is less restrictive in model specification than Weibull model, we suggest that the results in Cox models are more reliable.

In both Weibull estimations, α is significantly greater than 1, the magnitude is also large (greater than 6).These results suggest that institutions are more likely to adopt NETDE as time elapses, supporting the existence of strong epidemic effects in technology diffusion as some models suggest (Forman and Goldfarb, 2006).

6   FURTHER DISCUSSION AND CONCLUSION

This study investigates the adoption of NETDE technology by U.S. associate educational institutions. Three findings are of primary interest. First, we find that an institution with experience in using earlier generations of distance education technology tends to adopt NETDE significantly earlier than institutions without such experience. This result is consistent to the argument of Co-

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[10]We note that the assumption of a Weibull model in the diffusion process is appropriate. Please see Appendix 2 for details. We thank the referees for the suggestion to investigate the issue of time dependence in diffusion.

hen and Levinthal (1990) that an organization's absorptive capability is important in its innovative activities.

Second, we suggest a linkage between significant size effect and Schumpeter's hypothesis. A large associate college's internal resources may not be the main reason for the size effect in the diffusion of NETDE. Instead, we believe that an important source of the size effect may be monopolistic power caused by market friction (Klemperer, 1987). As discussed before, an originally large organization is more likely to get more customers in a related new market. This ability to have a larger secured customer base might be interpreted as a kind of monopolistic power over customers because customers are "stuck" to the institution not because of better service or lower price, but because of costliness in accessing alternative (unfamiliar) choices. In this situation, we believe size results in monopolistic power, and the significance of variable *size* is evidence supporting the hypothesis that monopolistic power facilitates innovation.

Third, we find that, when using only public institutions in the estimation, the distance to the nearest institution has a negative effect on the probability of adoption. To link the monopolistic power explanation to the size effect above, it seems different kinds of monopolistic power have different effects on innovative activities. Monopolistic power caused by market friction tends to keep more customers for a large associate college, and facilitate its NETDE adoption. In contrast, monopolistic power due to fewer competitors results in organizational inertia and retards NETDE adoption.

We also find that NETDE markets are still very local. When information costs are minimal, potential NETDE students are less likely to prefer local institutions to distant institutions. However, our estimation shows that this is not the case, supporting our conjecture that there is considerable friction in the NETDE market and that institutions attract students primarily from their local communities. The popular prediction that NETDE technology will remove traditional geographical boundaries separating regional markets does not seem to be fully realized yet. Researchers usually use Herfindahl index and the total number of firms in a market as a proxy for the degree of market

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competition. These measures are primarily based on Cournot competition model which requires firms to compete in one market. If firms primarily compete in distinct regional markets, as is the case for NETDE, then Herfindahl index and the total number of firms may be inaccurate measures for the degree of competition in the greater, combined market. We suggest that this may be one of the factors that lead to inconclusive results about market competition in the literature.

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APPENDIX 1

Evidence from many sources indicates that in-state students account for most of the student body in public institutions. For example, Illinois Virtual Campus, a state wide distance education consortium, reports that Illinois public associate institutions have only 3% of the total NETDE students from outside Illinois in the Spring/Winter term 2005. At the same time, 97% percent of the associate college students study in public institutions.

NETDE students rarely cross state borders primarily because public associate institutions charge different tuition for in-state students (low) and out-state students (high), due to the strong support from state governments (on average, state funds account for 44% percent of the total revenue of public associate colleges. [11] The difference between the two tuition levels is considerable, compared to the income level of the students and the value of the education. Consequently very few students attend an associate college located out of his or her residential state.

Another reason may be that the recognition and reputation of an associate college are largely confined to the local community and its home state. Traditional ties between in-state employers and colleges could be important to a student's chance on a local job market. A student earning an NETDE degree or certificate from an out-state associate college is likely disadvantaged in the local job market because employers in the local community may have little experience to judge the quality of the education provided by an unfamiliar institution. Further, the mission of a public associate college is to serve home state and local communities. This limits the allocation of resources and attention (for example, the marketing of the NETDE courses) to explore out-state market opportunities.

The last reason lies in information spreading channels for NETDE courses. In a survey conducted

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[11]Data source: http://www.aacc.nche.edu.

by the California Chancellor's office of Distance Education in 2003, the most important channels through which a student obtains NETDE course information are catalogs, teacher recommendations, and recommendations of friends. Only 0.5% of the NETDE students in California became aware of the distance education courses they took through advertisements. Less than 8% of the NETDE students in California became aware of the distance courses they took through website visits. In this situation, students in an area are more likely to take NETDE courses offered by local and in-state institutions than courses offered by unfamiliar out-state institutions.

Though the evidence above tends to support the view that the boundaries of a NETDE market do not exceed a state, it may be the case that a state contains several distinct regional markets. For example, Ivy Tech in Lafayette City of Indiana state may have very few or almost no NETDE students from Evansville or South Bend of Indiana. In this case, a proper market should be a county or city, and subsequently the counting of institutions in a state loses its meaning to measure market concentration. To deal with this problem, we also use the distance between an institution and its nearest institution, the number of institutions within 50 miles of an institutions geographical location to measure the degree of market competition.

Compared to public associate institutions, private institutions are likely to enroll a higher percentage of out-state students primarily because of their flat tuition rate. For this reason, we exclude observations of private institutions from the sample in the analysis of the market competition effect. When we count the number of competitors in a state market, we also exclude private institutions for the similar reasons. This treatment should have little effect on the measurement of market competition because private institutions account for only around 3% of the total associate education market. Our survey data show private institutions remain a similar marginal status in the segment of NETDE market.

APPENDIX 2

For both Weibull estimations, we use Cox-Snell residuals to assess the fit of the models. If a model fits the data, then the plot of Cox-Snell residuals versus the Nelson-Aalen estimator of the cumulative hazard should be a straight line with slope 1 (Klein and Moeschberger, 2003, pp. 414-419). By the principle, figure 3 and 4 suggest that Weibull specification is proper for out data.

Figure 3: Weibull Assumption Check All Institutions

Figure 4: Weibull Assumption Check Public Institutions