Financial Innovation, Strategic Real Options and Endogenous Competition: Theory and an Application to Internet Banking

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Abstract

Innovations in financial services continuously influence the scope of financial intermediation and the nature of competition between intermediaries. This paper examines the optimal exercise of strategic real options to invest in such an innovation, Internet banking technology, within a two-stage game, parameterized by the distribution of bank size and uncertainty over the profitability of investment, and empirically tests the results on a novel data set. Unlike traditional options, in which the distribution of the future value of the underlying asset is exogenous and the timing of exercise affects only the return to the option holder, the timing of the exercise of real options in a strategic context allows the option holder to manipulate the distribution of returns to *all* players. The value of the strategic investment option in our model, as a consequence, depends on both expected future profits as well as the variance of those profits. Expected profits to an entrant depend, in equilibrium, on its size, as measured by existing market share (concentration) or total assets, relative to its rivals. Conditional on the degree of uncertainty, larger banks should, as a consequence, exercise their options earlier than smaller banks, for purely strategic advantages, and act as market leaders in the provision of Internet banking services. Like ordinary options, however, the value of the strategic investment option to both large and small banks increases in uncertainty, implying that early exercise will be more likely the more information is available about potential demand. We test these hypotheses on investment in Internet banking services with data from a sample of 1,618 commercial banks in the tenth Federal Reserve District during 1999. Evidence indicates that relative bank size, as measured by either market share or asset size, positively influences the likelihood of entry into Internet banking, and trend-adjusted variation in income per person (a proxy for uncertainty of demand) negatively influences the likelihood of entry into Internet banking. In addition, market concentration of a bank's competitive rivals has a negative relationship with the likelihood of entering the market for Internet banking services. These relations are evident in both bivariate analysis and in multivariate logit regression analysis.

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1. Introduction

The advent of new technology permitting the large-scale provision of Internet banking and payments services has profound implications for many issues of concern to bankers, academics and financial policymakers. These include the nature of competition between financial intermediaries, the structure of banking regulations and changes in the legal environment resulting from changes in banking technology.[1]

Early in its adoption cycle uncertainty over the extent of consumer demand for retail Internet banking services was pervasive.[2] Each bank contemplating offering such services may be seen as holding a real option to invest in technology allowing the provision of Internet banking, the exercise of which corresponds to incurring a certain and current fixed cost in exchange for a random flow of future profits. Unlike real options in either a competitive or monopoly market, however, the profitability of exercising this option and entering the market for such services will

[1] Bankers, regulators and consumers have all increased their focus on electronic banking issues. The Federal Reserve Board, FDIC, OCC and OTS have, for example, issued a joint study (Board of Governors (2001)) on the design of regulations affecting Internet banking services. Many trade publications feature articles pertaining to various aspects of the banking technology revolution including smart cards, sophisticated point of sale (POS) and automated teller machines (ATMs), cryptography, Internet banking, electronic benefits transfers and more efficient payment systems.

[2] Despite growing demand, news stories that cite doubts about consumer acceptance of Internet banking continue to appear, citing issues of security, poor Web page design, and poor performance of Internet-only banks; see, for example, Clothier (2000), Weber (1999, 2000) and a survey in *Electronic Commerce News*, September 4, 2000. Combined with the news that as many as one-third of customers who try online banking eventually stop using the serve ("Home banking Churn Rates Stir Discord," *Financial Services Online*, October 1999), it is not surprising that bankers are uncertain about the demand for online banking. For example, in a November 1999 survey of community banks, conducted by Grant Thornton (2000), only 29 percent of respondents agreed with the statement, "Many existing community bank customers want the option to bank via the Internet." This degree of uncertainty is relevant to the timing of the adoption of new technologies by firms and to the implications of this timing on the nature of competition between banks and the structure of the market in Internet banking services.

depend on both the uncertain strength of consumer demand for Internet banking services *and* the optimal option exercise decisions of all rival banks.[3] These real options, as a consequence, are *strategic* in nature. Banks will exercise these real investment options at a time that maximizes their value, and this timing of entry by banks into the market for Internet banking services will, consequently, endogenously determine the nature of competition within this market, with the decision of each bank affecting the distribution of returns to this investment to *all* potential entrants into the market for these services.[4]

The timing of investment in Internet banking technology and the impact of this timing on subsequent competition in the market for bank deposits is an example of the more general phenomenon of the economic determinants of the adoption of new technologies and the endogenous influences of such adoption decisions on the nature of competition in affected markets. Our paper posits a model of technology adoption in the framework of strategic real options, examines how the resulting equilibrium in a product market is determined by the option exercise strategy profile of each firm holding the option to adopt the technology, and empirically tests this model for the case of Internet banking.

More specifically, consider a firm holding an option to invest in the provision of a commodity for which demand is initially uncertain and facing an array of competitors who hold similar options. Assuming that the technology involves a capacity constraint, investing in the

[3] While there is now an extensive literature on real investment options and the effects of uncertainty on the timing of their exercise, as summarized in Dixit and Pindyck (1994) and Schwartz and Trigeorgis (2001), the optimal exercise of these options in strategic situations, in which the value of the option to invest depends not only on uncertainty but on the exercise decisions of rival investors, has only begun to be examined.

[4] Although the literature on real options is now voluminous, most applications of the optimal stopping rules inherent in optimal option exercise have occurred in a non-strategic setting, as surveyed by Dixit and Pindyck (1994), Trigeorgis (1996) and Schwartz and Trigeorgis (2001) , with attention to the more interesting and realistic case of option exercise in a strategic setting exhibited only in a few studies, including Grenadier (1996), Courchane, Nickerson and Sadanand (1996, 2000), Nickerson and Sadanand (1995), Kulatilaka and Perotti (1998), and the collected papers in Grenadier (2000). Nickerson and Sadanand (1995) and Courchane, Nickerson and Sadanand

technology involves a well-defined tradeoff. If the firm delays the exercise of its investment option until demand is more fully observed, it can tailor the magnitude of its investment expenditures to suit the realized state of demand. This could, however, result in the firm being relegated to the status of a Stackelberg follower in the ensuing competition in its market, if a rival firm has already invested in the technology. If the firm chooses to invest before its rivals, under uncertainty about the strength of demand, it will choose an anticipated capacity level sufficiently large to correspond to that of a Stackelberg leader, but if the realized value of demand is weak, this may be less profitable than delay.

The timing of the investment decision, then, depends on two factors: the stochastic behavior of demand and the exercise strategies of rival firms. Simultaneously, the resulting equilibrium in the subsequent competition for the provision of the commodity will depend directly, through these capacity decisions, on the equilibrium exercise strategy of each firm. Using the market for Internet banking as our context, we characterize and test, in a two-stage game, the equilibrium exercise strategy of investment options in terms of two exogenous variables: uncertainty over demand for these banking services and the distribution of bank sizes.

We demonstrate that the optimal timing of the exercise of a strategic real option to invest in the technology for a new product with uncertain demand will depend, on both the *relative* size of a firm and on the degree of uncertainty in product demand. Assuming a positive but bounded level of demand variance, a relatively large bank, measured in terms of market share or asset size, will be more likely to choose to exercise its real investment option under uncertainty over demand for its services, finding this strategic *early* exercise and its beneficial implications for credible commitment more valuable than retaining the option until more is known about demand.

(1996, 2000) and Nickerson and Sadanand (1995) stress the implications of the optimal exercise of such strategic options on the endogenous determination of subsequent product market competition.

Since the value of the investment option remains increasing, even in this strategic setting, in the variability or risk of the underlying profitability of the product, this likelihood of early exercise will be enhanced the more predictable is product demand.[5] Relatively small banks, in the same situation, are more likely to choose to delay their investment decision until after demand uncertainty is relatively more resolved and the large bank has committed to provide a dominant share of the market.

A consequence of these choices is that the observable structure of a market, in the sense of the mode of strategic competition displayed by banks, becomes endogenous. This endogenous choice of the form of competition is induced by the presence of uncertainty, perceived by rival banks, about the eventual demand for Internet banking services, and their choice of timing over the exercise of their investment options. Information about demand unfolds during the period in which firms must decide on investment in their productive capacity, as represented by the scale of their Internet banking operations. Banks may choose to exercise their investment option before or after this information becomes available. An "early" decision corresponds to a commitment to provision of a fixed volume of electronic banking services, while a decision to delay exercise until the expiry of the option corresponds to a decision to make the quantity of services contingent upon the true state of consumer demand and the decisions of rival banks.

We test our predictions by estimating the likelihood of entry into the market for Internet banking services, using a sample of 1,618 commercial banks observed at year-end 1999 and located in the Tenth Federal Reserve District. We present characteristics of sample banks,

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[5] Like American (or European) call options on financial assets, real options in a nonstrategic context are convex in the random value of the asset upon which they are written, and consequently are more valuable as the variability of the cash flow to this asset becomes larger. Since the option is more valuable, it will be less likely to be exercised before any relevant expiry date, implying, as discussed in Dixit and Pindyck (1994), that more volatile product demand will inhibit the rate of investment in an industry. We show that this effect of volatility remains valid even when the real option is held in a strategic setting, in which the underlying cash flows are affected by the exercise

including regional market share, bank assets, and variation in regional per capita income. We estimate a logit model of whether or not a bank provides a transactional Internet banking site based on a vector of independent variables, including the qualities described above. We find that both market concentration and a bank's market share strongly influence the probability of bank investment in an Internet banking site. We also find that trend-adjusted variation in income per person (a proxy for uncertainty of demand) negatively influences the probability of investment in such a site. Both findings are consistent with the predictions of our theoretical model.

The paper is organized as follows. Section 2 describes our theoretical model, outlining the market environment and feasible strategies for banks contemplating investment in electronic banking technology and subsequent retail sales of electronic banking services. In Section 3, we describe equilibrium for our model as a function of both the stochastic specification of demand and the distribution of rival bank sizes, relative to a strategically-significant referent bank. Variation in the distribution of bank size leads to a continuum of equilibria in which the probability of a bank exercising its strategic option to invest in Internet banking technology "early" depends on both its size, relative to its rivals, and the variability in demand for Internet banking services. Section 4 describes our data and presents evidence on bank and market characteristics. Section 5 presents and interprets our Logit regression results. Concluding remarks appear in the final section.

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strategies of competitors, but that the exercise policy must also depend on the expected payoffs to commitment, which in turn are contingent on the initial distribution of firm sizes.

2. A Model of Internet Bank Competition

Consider a market for Internet banking (IB) services composed of competitive buyers and a range of alternative arrays of banks that are potential suppliers of such services.[6] These alternative arrays are distinguished by the initial distribution of bank size, with each array containing a single referent bank, strategically "large" relative to its rivals.[7] The distribution of rival sizes may vary from a single bank, of equal size to the referent bank, to a continuum of competitors. Each bank faces a common demand for Internet banking services, represented by a conventional differentiable inverse demand function $p = p(x,\theta)$, where x is the aggregate provision of Internet banking services by the banking industry and θ is a random variable representing uncertainty in consumer demand for IB services. The distribution of the state of demand θ as well as the function $p(x,\theta)$ is common knowledge to all banks. Variation in the degree of demand uncertainty is represented by mean-preserving spreads in the distribution of the state of demand.

Option exercise decisions occur in either of two decision periods, which are measured relative to the exogenous resolution of demand uncertainty. Since all banks share common initial uncertainty over consumer demand, a bank *i* that chooses to exercise its investment option "early," in the first period, will simultaneously select a capacity (volume) of IB services, x_{i1}, that will yield it first-mover advantages in subsequent sales of such services at date two. Banks may, however, defer their decision to exercise until the expiry of their investment option, at date two,

[6] Our model uses the common framework of similar models examined by Perrakis and Warskett (1983), Reinganum (1985) Golding (1986), Boyer and Moreaux (1987), Sadanand and Green (1991), Nickerson and Sadanand (1995), Maggi (1996), van Damme and Hurkens (1996), Courchane, Nickerson and Sadanand (1996, 2000), Sadanand and Sadanand (1996), Kulatilaka and Perotti (1997, 1998), among others, all of which are based on the augmentation of a standard sales game in the second period with a first period capacity investment decision under uncertainty over the realization of future payoffs.

when consumer demand is determined by the exogenous realization of the random variable θ . A bank that delays the exercise of its option until this second period will choose to invest in providing that volume of services, $x_{i2}(x_{1,}\theta)$, that maximizes its ex post profits, contingent on both the realization of θ and the investment strategies of its rivals. Each bank incurs a cost $c_i(x_i)$ of providing the volume x_i at date two.

More formally, denote the (pure) strategy vector of each bank i , s_i , as the pair of actions taken in each period, represented as the contingent choice,[8]

$$y_i(x_1,\theta) = \begin{cases} x_{i1,} & \text{if } x_{i1} \succ 0 \\ x_{i2}(x_{i1},\theta), & \text{if } x_{i1} = 0 \end{cases}, \tag{1}$$

Representing all possible alternative distributions of bank size through an index γ on the set B of banks, the aggregate supply of IB services can be written as [9]

$$x(s,\theta) = \int_B y_i(x_1,\theta) d\gamma(i), \tag{2}$$

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[7] Although strategic size is intrinsically measured by a direct ability to influence the decisions of one's rivals, we will proxy this ability by either by the volume of assets or deposits (liabilities) of potential entrants in Internet banking, for the purposes of empirical testing.

[8] Since the (irreversible) exercise of the investment option implies that a bank cannot revise a commitment to a specific capacity level chosen in period 1, each strategy s_i must satisfy the requirement that

$$\text{If } x_{i1} \succ 0, \text{ then } \forall x_1 \forall \theta \in Y^1, x_{i2}(x_1,\theta) = x_{i1}.$$

Of course, a bank delaying its exercise decision until period 2 simply selects zero as its period 1 action. Moreover, a bank need never exercise its investment option: by choosing a capacity level in each period of zero, the bank can allow its option to expire unexercised and never enter the market for Internet banking.

[9] More precisely, the index γ is a Lebesgue-Stieltjes measure, induced by choice of a monotone increasing, bounded and real valued function *f(.),* which maps the (sigma-algebra of) subsets of *B* to the unit interval, so that the strategic weight assigned to any interval of rival banks $I_0 < i < I_1$ is $\gamma(I_0, I_1) = f(I_1) - f(I_0)$. One example of such an index would be to treat all rival banks as equal in size, so that the measure of each rival bank j, $j = 2, \ldots n$, satisfies $\gamma(j) = 1/n$, although, as shown in Courchane, Nickerson and Sullivan (2002), there is no necessary reason to impose symmetry in size on these rivals. The strategic "size" of a bank represents its relative (percentage) influence on aggregate industry sales, which could be endogenized, in the current context, through consideration of the switching costs a consumer/depositor faces in choosing a provider of Internet banking services, conditioned on its current banking service provider. An empirical proxy for strategic bank size is the asset or deposit base of a bank, defined over a suitable regional banking market. See Sharpe (1997) for both an analytical and empirical examination of consumer switching costs in the market for bank deposits.

where x_1 is the aggregate volume of services offered by banks which chose to exercise their investment option at date 1, s is the vector of strategies by all banks in B, the strategic size of each bank $i \in B$ is represented by its measure $\gamma(i)$ under the index γ and where bank 1, the referent large bank, satisfies $\gamma(1) = 1$ in all alternative distributions. The realized profit of bank i in the strategy vector s is

$$\pi_i(s,\theta) = p\left(x(s,\theta)\right) y_i(x_1,\theta) - c_i\left(y_i(x_1,\theta)\right), \tag{3}$$

with expected value $E\pi_i(s,\theta)$. Consumer demand and bank costs are assumed to generate a differentiable profit function for each bank that is strictly concave in its own output and exhibits strategic substitutability in the output of its rivals.[10]

Each bank, consequently, holds an option to enter the market for IB services, which it can exercise by incurring a sunk investment cost *k* to acquire a fixed capacity to provide such services.[11] The value of this option depends on the underlying profitability of supplying such services, which, in turn, depends on both the realization of the random strength of consumer demand for Internet banking services, and on the behavior of rival banks in supplying such services. The strategy of each bank, consequently, consist of two parts: (1) an exercise date, when the bank invests in a transactional Internet banking site; and (2) a fixed capacity and output

[10] Strategic substitutability for the profit function of bank *i* requires that $\partial^2\pi_i(x_i,x_j,\theta)/\partial x_i\partial x_j < 0$, where we also assume that $\partial\pi_i(x_i,x_j,\theta)/\partial x_j < 0$, $\partial\pi_i(x_i,x_j,\theta)/\partial\theta > 0$ and $\partial^2\pi_i(x_i,x_j,\theta)/\partial x_i\partial\theta > 0$.

[11] We specifically assume that the production technology in Internet banking exhibits the quality that an irreversible investment in a specific value of capacity, as represented by server size for example, is synonymous with provision of output of that same value. More generally we could analyze the capacity and production decisions separately, which would render investment in capacity a compound option. Although this would add both realism and analytical complexity to the game, our results would continue to hold as long as capacity was costly to add after an initial investment in capacity: see Maggi (1996) for a duopoly example. One interpretation of our assumption of a fixed volume of output is that an aspect of the bank's "early" investment in Internet banking services involves the attraction of consumers with a simultaneous creation of consumer switching costs of a sufficiently high magnitude: see Sharpe (1992, 1997) for evidence on the magnitude of consumer switching costs in the market for bank deposits and DeYoung, Hunter and Udell (forthcoming 2004) on the advantage to large banks of using Internet technology to provide high volume, personalized services in a cost effective manner.

level for that site, as measured by the volume of services that site continuously provides to clients. In the current discrete time setting, this strategy requires each bank to decide in period 1 whether to invest in capacity in period 1, or delay until period 2 and, simultaneously with its decision regarding the timing of exercise, each bank must select the irreversible volume of Internet banking services it should provide.

3. Equilibrium Option Exercise and Market Structure

Equilibrium will consist of an optimal date of option exercise by each bank and a corresponding volume of IB services provided by that bank, conditional on the specified distribution of bank sizes and the stochastic specification of the random state of demand. Each alternative distribution of bank sizes will generate equilibria in terms of the strategy vector of option exercise policies represented, for each bank, by the contingent production value in equation (1). We focus here on subgame perfect equilibria in the generic case where the set of potential entrants consists of one large bank, Bank 1, and a set $\overline{B}$ of smaller rivals, assuming these rivals act symmetrically, and we allow the measure of each individual rival to decline to zero in the limit.[12] Since the equilibria for all bank size distributions will be continuous in both the state of nature and the number of firms, we can relate the equilibrium exercise strategies in this limiting distribution to all such distributions.

We consider first the exercise strategy of a representative rival bank $j \in \overline{B}$. If it decides to exercise its investment option in period two, it will choose a volume of production, x^*_{j2}, that maximizes its profits, conditional on the observed state of nature and the first period decisions of all banks:

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[12] The set $\overline{B}$ is simply the set B less the referent bank, Bank 1.

$$x^*_{j2} = \underset{x_{j2}}{\arg\max}\ \pi_j\left(x_{j2}, y_{-j}(x_1,\theta), \theta, k_j\right) \tag{4}$$

where $y_{-j}(x_1,\theta) = \int_B y_i(x_1,\theta)d\gamma(i)$ is the aggregate provision of IB services by all banks, net of bank *j*. Alternatively, its optimal production volume, x^*_{j1}, should it instead exercise its investment option in period one, satisfies

$$x^*_{j1} = \underset{x_{j1}}{\arg\max}\ \mathrm{E}\pi_j\left(x_{j1}, y_{-j}(x_1,\theta), \theta, k_j\right) \tag{5}$$

If the measure of bank *j* approaches zero, its strategic influence on the option exercise decisions of its rivals becomes negligible. Under such conditions and under our assumptions on the profit function $\pi_j(\bullet)$, the expected payoff to delaying the exercise decision until period two dominates the expected payoff to early exercise,

$$\mathrm{E}\pi_j\left(x^*_{j2}(x_1,\theta), y_{-j}(x_1,\theta), \theta, k_j\right) > \mathrm{E}\pi_j\left(x^*_{j1}, y_{-j}(x_1,\theta), \theta, k_j\right), \tag{6}$$

owing to the contingent nature of $x^*_{j2}(x_1,\theta)$.[13]

Consider now the exercise decision of the large referent bank, Bank 1, given the dominant exercise strategy of each small bank. If it decides to exercise its investment option in period one, Bank 1 will choose a volume of production, x^*_{11}, that maximizes its expected profits, conditional on this early exercise decision:

$$x^*_{11} = \underset{x_{11}}{\arg\max}\ \mathrm{E}\ \pi_1\left(x_{11}, y_{-1}(x_1,\theta), \theta, k\right) \tag{7}$$

where $y_{-1}(x_1,\theta) = \int_{\bar{B}} x^*_{j2}(x_1,\theta)d\gamma(j)$ denotes the aggregate production of the set $\overline{B}$ of rivals to Bank 1. A decision by Bank 1 to postpone its exercise date until period two, however, implies

[13] Relative to immediate exercise in period one, expected profits from investment in the contingent follower's quantity at date two, $\mathrm{E}\pi_j\left(x^*_{j2}(x_1,\theta), y_{-j}(x_1,\theta), \theta, k_j\right)$, represents the value of the strategic option held by a small bank in this context. Under our assumptions, it is convex in the state of demand and, since the small bank exerts a negligible influence on aggregate output, the value of this option will always exceed the value of expected profits from exercise in period one if the state of demand θ exhibits positive variance.

that all banks will choose their production volumes simultaneously, as Cournot competitors. Bank 1's production volume, conditional on this exercise date, satisfies:

$$x^*_{12} = \arg\max_{x_{12}} \pi_1\left(x_{12}, y_{-1}(\theta), \theta, k\right) \tag{8}$$

where $y_{-1}(\theta) = \int_{\bar{B}} x^*_{j2}(\theta) d\gamma(j)$ denotes the aggregate production of the set $\overline{B}$ of rivals to Bank 1 when all banks act as Cournot competitors in period two.

Early exercise coupled with a volume x^*_{11}, commensurate with a position as Stackelberg leader (in an expectational sense) is, however, not unequivocally a best response by Bank 1 to the dominant strategy of its rivals. Recognizing the expected value of profits from a strategy of delay and subsequent Cournot competition with its rivals, $\mathrm{E}\pi_1\left(x^*_{12}, y_{-1}(\theta), \theta, k_1\right)$, as the value of the strategic investment option held by Bank 1 in period 1, the advantage $\Phi_1\left(s, \overline{B}, \theta, k_1\right)$ to early exercise and a subsequent position as Stackelberg leader in the provision of IB services is the difference between expected profits from this strategy and the value of the foregone strategic option:

$$\Phi_1\left(s, \overline{B}, \theta, k_1\right) = \mathrm{E}\pi_1\left(x^*_{11}(x_1, \theta), y_{-1}(x_1, \theta), \theta, k_1\right) - \mathrm{E}\pi_1\left(x^*_{12}, y_{-1}(\theta), \theta, k_1\right) \tag{9}$$

This function exhibits a well-defined tradeoff: under our assumptions on the profit function of each bank, it is continuously increasing in the mean value of the state of demand θ, but continuously decreasing in the degree of uncertainty in that state, owing to the convexity of the strategic option in θ.

These properties of the difference $\Phi_1\left(s, \overline{B}, \theta, k_1\right)$ can be clearly seen if we decompose it into the sum of two distinct differences. The first difference is that between early exercise and a choice of the expected Stackelberg leader quantity, conditional on information at date 1, and delayed exercise and a hypothetical choice of the Stackelberg leader quantity, contingent on the realized value of the demand state θ:

$$\mathrm{E}\,\pi_1\left(x^*{}_{11}(x_1,\theta), y_{-1}(x_1,\theta), \theta, k_1\right) - \mathrm{E}\,\pi_1\left(x^{sl}{}_{12}\left(y_{-1}\right), y_{-1}(\theta), \theta, k_1\right) \tag{10}$$

where $x^{sl}{}_{12}\left(y_{-1}\right)$ is the quantity corresponding to a position of Stackelberg leadership, conditional on exercise in period two. This value is clearly negative and continuously decreasing in the measure of demand uncertainty, with a limiting value of zero when uncertainty disappears. The second difference is that between profits accruing to a hypothetical choice of the Stackelberg leader quantity, contingent on the realized value of the demand state θ, and the value of profits corresponding to actual Cournot play by all banks should the referent bank invest at date two:

$$\mathrm{E}\,\pi_1\left(x^{sl}{}_{12}\left(y_{-1}\right), y_{-1}(\theta), \theta, k_1\right) - \mathrm{E}\,\pi_1\left(x^*{}_{12}, y_{-1}(\theta), \theta, k_1\right) \tag{11}$$

Under our conditions on the inverse demand function, Stackelberg leadership is more profitable than Cournot play to the referent bank and, consequently, this second difference will be strictly positive in the demand state θ and, consequently, its mean value.[14]

The value of early exercise has, as a consequence, a particularly appealing expression:

$$\Phi_1\left(s, \overline{B}, \theta, k_1\right) = \lambda_1\left(\mathrm{E}_\theta\right)^2 - \lambda_2\sigma_\theta^2, \tag{12}$$

where E_θ and σ_θ^2 are, respectively, the first two moments of the distribution of θ and the terms λ_1 and λ_2 depend on the index of rival firms $\gamma(\bullet)$, the cardinality of $\overline{B}$ and the parameters of the inverse demand and cost functions, with λ_1 increasing in the relative size of Bank 1.[15]

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[14] It will, in general, also be increasing in the measure of demand uncertainty, owing to the degree of convexity assumed in the profit function of the referent bank, but this effect of uncertainty will be, under our assumptions, smaller in absolute value than that associated with the expression in (12).

[15] Derivation in the linear-quadratic case is straightforward, albeit tedious.

The difference between traditional real options and the strategic option held by Bank 1 are clear from equations (9) and (12): as in the traditional case, as the variance of the underlying asset increases, the option becomes more valuable and early exercise less attractive, but as the expected value of demand increases, the advantage of commitment increases and early exercise becomes more valuable, conditional on the strategies adopted by one's rivals. If we represent variations in uncertainty by a sequence of distribution functions, $\left\{F_n\left(\theta\right)\right\}_{n=1}$ with common mean, and allow such sequences to converge in probability to that mean, then early exercise will be the strategy of Bank 1 in a perfect equilibrium for all but a finite number of such distributions. Equivalently, we can state that early exercise is the best-reply for Bank 1 for all cases in which uncertainty is relatively small and the advantages of early exercise increase as demand uncertainty diminishes.

Most regional banking markets are composed not of a single dominant bank and a continuum of small competitors, but rather display, like most industries, a logistic distribution of firm sizes, with one large bank and a number of smaller but significant competitors.[16] Will the equilibrium in the limiting distribution of bank size described above, with one large bank and a continuum of rivals, apply to empirical distributions of bank size in which the referent large bank faces a finite number of small but strategically significant rival banks? Owing to the continuity of the equilibrium correspondence in this class of games, the answer is that, for any specified level of demand uncertainty and for a sufficiently large number of small but strategically significant rival banks, possibly of different *ex ante* sizes, a perfect equilibrium in pure strategies

[16] Incorporating multiple large banks of identical size will alter the result that a subgame perfect equilibrium exists in which relatively large banks exercise early and relatively small banks choose to exercise in period two, as discussed in Courchane, Nickerson and Sullivan (2002).

exists in which the large bank chooses to exercise its real investment option early and smaller rivals choose to delay the exercise of their investment options until period two.[17]

We summarize the results of this section in Proposition 1:

Proposition 1: *Given a single large bank competing against a finite set of rival banks that exhibit a constant aggregate proportion of market size, then for any specified distribution of demand uncertainty, there will exist a minimal number of small but strategically significant rival banks, acting symmetrically, such that a subgame perfect equilibrium exists in which the large bank exercises its investment option in period one, choosing to provide that volume of IB services corresponding to the role of Stackelberg leader, and each rival bank delays its exercise until uncertainty is resolved, with each providing the corresponding Stackelberg follower volume of IB, contingent on the realized value of demand.*

The empirical implications of Proposition 1 are that the probability of investing in Internet banking early, relative to one's potential rivals, is increasing in the relative size of the bank and increasing as the bank's uncertainty about the future profitability of Internet banking declines. We now turn to the empirical testing of these hypotheses about the strategic timing of investment, the relative size of the bank and the predictability of demand for IB services.

[17] The specified level of demand uncertainty is simply the assumption that the distribution of the demand state θ is represented by a specific distribution function $F_n(\theta)$. Using the concept of a topological family of games, as described in Green (1984) and in Sadanand and Green (1991), we offer, in Appendix A (to appear in conference paper) a proof of continuity of the best-reply correspondence in this class of games when rival banks are allowed to exhibit an arbitrarily large but finite number of alternative sizes.

4. Empirical Hypotheses and Data

4.1 Previous empirical research

Although there is a voluminous literature on adoption of new technology, only a handful of studies look specifically at the financial services industry. Furst, Lang, and Nolle (2001) study adoption of Internet banking in relation to bank characteristics such as bank size, fixed expenses, efficiency, and sources of income. Hannan and McDowell (1984) consider adoption of automated teller machines (ATMs) as a function of bank size, market concentration, local economic characteristics (such as wage levels as a measure of the incentive to substitute ATMs for tellers), and branching regulations. Akhavein, Frame, and White (2001) examine determinants of the adoption of credit scoring technology, including bank characteristics (size, portfolio composition, branch structure, and so on), market concentration, and CEO characteristics.

Because it emphasizes the interaction of a bank's decision and rival actions, a study that is in a similar spirit to ours is Hannan and McDowell (1987), who again study adoption of ATMs. Their focus is on rival precedence: whether the likelihood of ATM adoption by a bank is influenced by a rival's adoption. They do find that prior adoption by a competitor has a positive impact on the probability of ATM adoption.[18]

An important contrast between these previous studies and ours is in the interpretation of size, market power, and innovation. In each of the previous studies, bank size is positively related to adoption of new technology. This relation is typically interpreted by appealing to a Shumpeterian relation between size, market power, and innovativeness. We do not deny that a large size may endow a firm with an advantage for innovation. Our interpretation of the relation

[18] We cannot study rival precedence because we do not have panel data.

between size, market power, and innovation, however, is grounded in the future profitability of innovation as reflected in the value of a real option connected to investment in a new technology. Theoretically, the value of the option depends on strategic interaction in the market and the uncertainty of demand for the new product or service.

4.2 Empirical hypotheses

There are two basic arguments that come out of this theoretical analysis. First, greater demand uncertainty will be negatively related to the probability that a bank would be an early adopter of Internet banking and positively related to the capacity of the Internet banking system a bank installs if it chooses to do so. Second, a bank's size relative to others in the market will influence its decision to invest in an Internet banking system.

In testing these arguments our empirical strategy will focus on whether or not a bank has adopted an Internet banking system because we do not have any information of the capacity of Internet banking systems. Before reviewing data, we define empirical hypotheses implied by the theoretical analysis.

The essence of Proposition 1 says that the larger a bank is relative to rivals, the more likely it will be an early adopter of Internet banking systems. However, measures of bank size may have implications for the adoption decision beyond strategic positioning (see below, p. 22). To focus more strongly on strategy, we consider an observable variable that more effectively summarizes a bank's market position relative to its rivals. Specifically, if a bank considers its strategic position relative to rivals, then our theoretical analysis predicts that a rise in the market concentration of the bank's rivals will reduce its incentive to adopt Internet banking.

To make this relation operational, we define a *rival concentration index*. This index is a variation of the Herfindahl-Hirschman Index and is calculated by summing the squares of the market shares of a bank's rivals. Using this measure, we propose the following empirical hypothesis:

H_1: *An increase in the market concentration of a bank's rivals has a negative impact on the probability that the bank would adopt Internet banking.*

A second important determinant in a bank's decision process identified by our model is the uncertainty of demand for Internet banking. The model predicts that the greater this uncertainty, the less likely a bank will adopt Internet banking. To make this relation operational, we need to measure demand uncertainty. However, because demand uncertainty is difficult to observe, we rely on an alternative, observable variable that should be correlated with the demand for Internet banking.[19] We proxy uncertainty about demand for Internet banking using trend-adjusted variation in income per person (detailed below):

H_2: *An increase in the variation of trend-adjusted income per person has a negative impact on the probability that a bank would adopt Internet banking.*

4.3 Description of sample

To test these hypotheses, we examine a sample of 1,618 commercial banks from the Tenth Federal Reserve District that were chartered at year-end 1999.[20] Though not necessarily representative of the largest banks in the United States, banks in the Tenth District do include a

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[19] Previous research has shown that economic and demographic characteristics of markets influence the likelihood that banks adopt Internet banking. See Sullivan, "How Has the Adoption of Internet Banking Affected Performance and Risk in Banks?," pp. 5-7.

[20] The Tenth Federal Reserve District consists of Oklahoma, Kansas, Nebraska, Wyoming, Colorado, western Missouri, and northern New Mexico.

range of large, small, and medium size banks. Consequently, the findings from this sample should be relevant beyond the Tenth District. (Additional information about the sample and variable definitions is contained in the Appendix A).

Web addresses of banks were obtained from several sources, including Call Reports and online databases. Personnel from the Federal Reserve Bank of Kansas City visited each Web site to determine the functionality of the site.[21] The simplest bank Web site provides information such as branch locations and product descriptions. More advanced Web sites may offer a number of interactive services, such as financial calculators, loan or deposit applications, interactive access to account balances, and bill payment. Because it represents a fundamental change in the bank's competitive strategy, our particular interest is whether a bank's customer can initiate transactions through the Internet. The most basic types of online transactions are interaccount transfers, such as moving funds from a savings account to a checking account, or making a loan payment from a checking account. A *transactional Web site* is an Internet Web site of a bank that allows the customer, at minimum, to initiate interaccount transfers.[22]

Descriptive statistics of sample banks are presented in Table 1. With a median asset size of $50.5 million, most sample banks are small. However, with a range of assets from $2.3 million to $20 billion, the sample includes some larger banks. Most sample banks belong to small banking organizations: only 8.83 percent are in banking organizations with aggregate assets over $1 billion. The sample includes a handful of *de novo* banks, with 1.67 percent aged 2 or younger.

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[21] Our thanks to the many members of the Division of Supervision and Risk management for help in reviewing bank Web sites.

[22] In the United States there are a handful of Internet-only banks, which are distinguished by a lack of physical branches. At the time the data for this sample was prepared, however, no Internet-only bank was located in any Tenth District state (see "Net-Only Bank Watch: Six New Net-Only Banks Debut this Summer," *Online Banking Report*, August 2000, pp. 20-24). Consequently, our empirical analysis will focus on banks that offer services through physical branches as well as through the Internet.

The state of Kansas holds most sample banks, at 23.61 percent, and with 3.03 percent, Wyoming holds the least.

In the first quarter of 2000, 31.2 percent (or 504) banks in Tenth District states had Web sites, of which 13.0 percent (or 211) banks had Web sites that allowed transactions to be initiated through the Internet. Banks in Tenth District states have adopted transactional Web site technology at a rate that is similar to the national adoption rate. Unpublished estimates by the FDIC suggest that, at the same point in time, 13.2 percent of insured banks and thrifts in the United States offered transactional Web sites.

Table 2 presents adoption rates for transactional Web sites in relation to the rival concentration index. Sample banks are split into two groups, based on the median value for the rival concentration index (1463.7). The adoption rate is 7.8 percent for banks above the median and 18.3 percent for the remaining banks. A chi-square test of independence between adoption of Internet banking and whether the rival concentration index is above or below the median results in rejecting the null hypothesis of independence.[23] Consistent with H_1, higher values of the rival concentration index are associated with a lower adoption rate for transactional Web sites.

Given that uncertainty of demand for Internet banking is unobservable, we chose a proxy based on the information a banker might have about his or her market. We believe that an important variable the banker would use to forecast demand for Internet banking is income per person. Bankers would be aware of the general trends of income per person in the U.S. economy and could use that information to forecast income per person in their market. Uncertainty arises from the forecast error, which would be tied to the standard error of the estimate of a regression of local income per person on U.S. income per person. This standard error is our proxy for

[23]The Pearson chi-square test statistic, with 1 degree-of-freedom, is 39.38.

uncertainty of demand for Internet banking, and is calculated using data from the 1988 to 1997 period of time. We refer to this variable as the "trend-adjusted variation in income per person" because it adjusts local income per person for the overall trend in the economy.

Table 3 presents a bi-variate relation between adoption of transactional Web sites and trend-adjusted variation in income per person. The adoption rate is 19.0 percent when trend-adjusted variation in income per person is below its median ($302.3) and 7.2 percent for other banks. A chi-square test of independence between adoption of Internet banking and whether trend-adjusted variation in income per person is above or below its median results in rejecting the null hypothesis of independence.[24]

5. Logit Estimation of a Model of the Decision to Adopt Internet Banking

Tables 2 and 3 provide prima facie evidence in support of H_1 and H_2: both rival concentration and trend-adjusted variation in income per person are negatively related to the likelihood that a bank adopts Internet banking technology. However, the bivariate relations shown in Tables 2 and 3 do not control for the influences of other variables. To further explore determinants of the adoption of Internet banking in a multivariate context, this section of the paper provides the results from Logit analysis used to estimate models of the determinants of the adoption of transactional Web sites.

We estimate the following model of the probability of adoption:

$$\text{adoption} = f(\text{rival concentration, trend-adjusted variation in income per person, bank characteristics}) \quad (13).$$

[24]The Pearson chi-square test statistic, with 1 degree-of-freedom, is 49.72.

The left-hand variable equals 1 if the bank adopts a transactional Web site, and zero otherwise. The main focus is on rival concentration and trend-adjusted variation in income per person. We also enter bank characteristics as control variables to investigate potential confounding effects.

Bank characteristics include bank size, size of the banking organization to which the bank belongs and whether the bank is two years old or not. Previous studies have shown that adoption of transactional Web sites are related to these variables (Furst, Lang, and Nolle (2000); Sullivan (2000)). For example, Table 4 shows the relation between the asset size of sample banks and adoption rates. Only 3.24 percent of sample banks with assets less than $50 million have adopted transactional Web sites, and the rate rises with asset size, to 72 percent of banks with assets over $1 billion. Because rival concentration may be correlated with bank characteristics, it is important to control for them in the Logit regressions to rule out confounding influences and obtain clearer estimates of the relation between adoption of Internet banking and the rival concentration index.[25]

Our theory predicts a positive relation between bank size and adoption of transactional Web sites due to the strategic interaction of market competitors. There are also other reasons to expect a positive relation. If there are economies of scale in producing Internet services, a larger bank may be an early adopter because it can produce these services at a low unit cost relative to smaller banks. In addition, because of capital market imperfections, a larger bank might be more able to internally finance the investment costs (or gain more favorable terms from another lender) compared to a smaller bank.

It is unclear whether bank size should be measured in absolute or relative terms. On one hand, the previous paragraph largely applies to absolute size and we therefore present estimates using the absolute size of the bank (based on assets). We enter asset size as a quadratic to test for the possibility that the decision to adopt Internet banking may be non-linearly related to asset size of the bank. Because the domain for the probability of adoption will have an upper limit, the effect of asset size may diminish as a bank's probability of adoption approaches that limit.

On the other hand, our theory is largely expressed in relative terms, and to be consistent we present estimates using two substitute measures of relative size. The first measure is a bank's share of total deposits in the market.[26] The second measure is *relative market share*, defined as a bank's share of total deposits divided by the share of total deposits of the bank in the market with the largest market share. Relative market share places a bank along a continuum relative to the largest bank in its own market. A desirable quality of relative market share is that it measures relative bank size adjusting for differences in market shares tied to larger and smaller markets.

The bank characteristics themselves may have independent influences on a bank's decision process and are included in the Logit regressions in order to obtain a more complete empirical model. A newly established bank, for example, may decide to adopt Internet banking because it is more cost effective to install Internet banking when a bank first establishes its data processing operations compared to adding the features at a later time. In addition, because sample data are at the bank level, and the impact of size on adoption of Internet banking may reflect the size of the banking organization to which the bank belongs rather than the size of the bank itself. To account for this, we include an indicator variable for the size of the banking organization (equal to 1 if the organization has aggregate assets greater than $1 billion).

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[25] The most obvious concern is that a bank's market share may be correlated with its rival concentration index. In this sample, the correlation between market share and the rival concentration index is –0.074, and is significantly different from zero (p-value=.003).

[26] Although market share is a traditional measure of market structure, we assume that it is exogenous in the context of our theoretical and empirical analysis. Certainly an aim of many banks is to gain market share if it offers Internet

Table 1 provides summary statistics on bank assets, adoption rates, the proportion of banks that are in organizations with assets over $1 billion and for the proportion of banks aged two or younger. For completeness, Table 5 provides descriptive statistics on remaining variables.

5.1 Results

Logit estimates of equation (13) are shown in Table 6. All specifications include the rival concentration index and trend-adjusted variation in income per person. Column (1) excludes the bank characteristic control variables. Columns (2) through (4) add bank characteristics, with column (2) using assets to measure bank size, and columns (3) and (4) using market share or relative market share to measure bank size.

Results of Table 6 are consistent with H_1 and H_2. In all specifications, the odds-ratio for the rival concentration index is less than one, indicating that as the rival concentration index rises, the likelihood that a bank will adopt a transactional Web site falls.[27] The coefficient on trend-adjusted variation in income per person is also less than 1, indicating that as the variable rises, the likelihood that a bank adopts a transactional Web site decreases.[28] To the extent that this variable carries information on the uncertainty of demand for Internet banking, these results are consistent with our theoretical model.

Columns (2) through (4) add bank characteristics as control variables. The fit of the specifications improves, suggesting that important variables were omitted from the specification

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banking, but the time frame for our study is too short for most banks to realize any gain. Only a handful of sample banks would have more than one year of experience with Internet banking.

[27] The p-value associated with the hypothesis test that the odds ratios for the rival concentration index equals one is below 5 percent in all cases.

[28] The p-value associated with hypothesis tests that the odds ratios on this variable equals one is below 1 percent in all cases.

in column (1). Support for H_1 and H_2, however, is unaffected by the addition of the control variables.

Statistical tests support the hypotheses that the odds ratios for asset size, market share, and relative market share are above one, confirming that they each have impacts on the decision to adopt Internet banking. Estimates show that an increase in asset size, market share, or relative market share is associated with an increase in the probability that a sample bank adopts Internet banking. The effect of asset size is non-linear: there is a positive relation between the likelihood of adoption and bank size, but the effect diminishes as the bank becomes larger. Bank size itself does not completely explain the influence of bank structure on the likelihood of adoption. The coefficient on the indicator variable for organization size is positive and statistically significant. After controlling for bank size, membership in a large bank organization increases the likelihood that the bank adopts Internet banking.

The coefficient on the indicator variable for whether the bank is aged two or younger is also positive and significant, consistent with previous findings that *de novo* banks are more likely to adopt Internet banking.

What do these estimates suggest about the size of the relations between the independent variables and the probability of adopting Internet banking? Estimated magnitudes of the impact on odds ratios that are associated with the indicator variables can be interpreted directly from Table 6. Table 7 and Figure 1 help to interpret the magnitudes of changes to the estimated odds ratios with respect to changes in the continuous explanatory variables.[29] Table 7 calculates the extent to which an estimated odds ratio would change if a continuous variable increases from its

[29] Calculations for Table 7 and Figure 1 assume that continuous independent variables are at their mean values except for the independent variable that is illustrated.

mean by one standard deviation. Figure 1 presents predicted probability of adoption across the range of continuous independent variables.[30]

Turning to the indicator variables first, we find that young banks are much more likely than older banks to adopt Internet banking. The odds ratio for a bank aged 2 or younger is estimated to be at least 3.96 times that of an older bank. The impact of organization size is even larger. The odds ratio for banks in large organizations (over $1 billion in assets), is estimated to be at least 17.04 times that of banks in smaller organizations. The impact of organization size can also be seen in Figure 1, which presents predicted probabilities for banks in large organizations and for banks in small organizations. The predicted probability of adopting Internet banking is dramatically higher for banks in large organizations compared to those in small organizations.

A one-standard deviation increase in the continuous variables affects the odds ratio by an estimated 56 percent decrease to a 30 percent increase (Table 7). If the rival concentration index rises from its mean of 1614 by 889 points, then the estimated odds ratio would fall by roughly 23 percent. If trend-adjusted variation in income per person rises from its mean of $464.6 by $421.7, then the estimated odds ratio would fall by about 56 percent. We also estimate that the effect of a one standard deviation increase in the relative market share of a bank is to increase the odds ratio by 30 percent.

On the measure used in Table 6, it is uncertainty of demand (as proxied by trend-adjusted variation in income per person) that has the strongest impact on the likelihood of adopting Internet banking. However, because the underlying Logit model is non-linear, estimated changes in the odds ratio is sensitive to the initial value of the continuous variable in the calculation. Figure 1 provides a visual insight into the sensitivity of changes of probabilities in response to

[30] Table 7 and Figure 1 are based estimates in column (4) of Table 6, but the illustration would have similar magnitudes for other specifications of the model.

changes in the continuous variables. In our judgement, the middle graph confirms that uncertainty of demand has the strongest quantitative impact, although the impacts of the other two continuous variables are also quantitatively significant.

To summarize, our basic results are robust across a range of control variables, and at least for this sample, patterns of adoption of transactional Web sites are consistent with our theoretical model. Banks appear to take into account their position relative to rivals and variables in their particular market related to the uncertainty of demand for Internet banking when deciding to adopt Internet banking technology.

6. Concluding Remarks

The emergence of a new technology or product of uncertain profitability endows each potential producer with a real option on the future net revenues accruing to that technology or product. If the number of potential producers is finite but greater than one, so that potential competition in providing this product is neither perfectly competitive nor a monopoly, this real option has a value that depends on the exercise strategies of the producers, as well as the volatility of the flow of future revenue. Moreover, the equilibrium in the timing and magnitude of investment will *endogenously* determine the nature of competition in the ensuing market for sales of the new product.

This paper considers the advent of technology allowing the provision of banking services on the Internet as an example of the general phenomenon of real option exercise in the adoption of new technologies and the provision of new products. Potential providers of such Internet banking services, within a regional market defined by existing banking relationships, hold an option to invest 'early' in a transactional Internet banking site or to delay such investment until more is known about the extent of demand for Internet banking services and the profitability of such an investment.

We provide theoretical predictions about the timing of investment in Internet banking technology as a function of both *relative* firm size and the degree of uncertainty over the profitability of providing such services in a regional market. We test these predictions on a sample of data from 1,618 commercial banks from the Tenth Federal Reserve District. Specifically, we test two predictions. First, that the concentration of a bank's rivals in its market should have a negative effect on the probability of investment in a transactional Internet banking site. Second, by reducing uncertainty over the volatility of demand for Internet banking services, favorable economic characteristics, such as low variation in income per person around its trend, should also have a positive effect on the probability of such investment. Using Logit regression techniques, we find results consistent with both predictions.

Appendix A:

Proof of Proposition 1 with Measurable Rival Bank Size

(forthcoming)

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Appendix A: The Data

Banking Web sites. Several sources were used to identify the Internet addresses of banks: the Bank Web Internet site, the Online Banking Report Internet site, Call Reports (which began collecting bank Internet addresses as of June 1999), an FDIC database on electronic banking, and the Web sites of the state banking associations in Oklahoma, Missouri, Kansas, and Nebraska. Although this data set may exclude some bank Web sites, it is likely a reasonably complete compilation of Web sites for banks in Tenth District states.

To determine the functionality of Web sites, personnel from the Federal Reserve Bank of Kansas City visited the Web sites and searched for specific services. We reviewed 427 total Web sites and 144 transactional Web sites. The number of banks served by Web sites is greater than the number of sites because many multi-bank bank holding companies use a single Web site for several separately chartered banks.

Commercial banks in Tenth District states. The sample includes banks that are chartered in Tenth District states. Branches that operate in Tenth District states but are part of banks chartered elsewhere are excluded from the study. Pure trust companies, credit card banks, and banker's banks were also excluded from the sample.

Other data. Financial data come from Call Reports. Per capita income is provided by the Bureau of Economic Analysis' Regional Economic Information System database. Market shares are based on the FDIC's Survey of Deposits for June 1999.

Definitions. A *transactional Web site*, at minimum, allows the customer to initiate an interaccount transfer on the Internet. Banks designated as not having a transactional site may either not have a Web site or may be operating an information-only Web site.

A *bank* organization is either a bank holding company or if a bank is independent (not part of a bank holding company), the bank itself.

A *market* is the metropolitan statistical area (MSA), or if not in an MSA, the county in which a bank is headquartered. Statistics for income per person are calculated by averaging data for the markets of all the Internet and non-internet banks. The same market may be counted in both averages because some markets contain both Internet and non-internet banks.

Rival concentration index, *market share, and relative market share* are based on commercial bank and S&L deposits in a market. The rival concentration index is the sum of the squares of the market share for all of the bank's competitors in the market. The relative market share is defined as a bank's market share divided by the market share of the bank with the largest share in the market.

Table 1: Descriptive Statistics of Sample Banks

Number of banks*	1618
Assets (millions):	
Average	$151.5
Median	$50.5
Standard deviation	$724.9
Minimum	$2.3
Maximum	$20,027
Percentage of banks:	
in organizations with assets of more than $1 billion	8.83
age 2 or younger	1.67
with Web sites (first quarter 2000)	31.2
with transactional Web sites (first quarter 2000)**	13.0
Percentage of banks in:	
Colorado	11.0
Kansas	23.6
Missouri	22.3
Nebraska	18.5
New Mexico	3.2
Oklahoma	18.4
Wyoming	3.0

* Sample includes commercial banks who have charters located in Tenth District states (CO, KS, MO, NE, NM, OK, WY). Excludes pure trust companies, credit card banks, and banker's banks. Statistics are for year-end 1999 unless otherwise indicated.
**A transactional Web site allows the customer, at minimum, to initiate an inter-account transfer through the Internet.
Sources: Call reports, Federal Reserve Board National Information Center database, and Federal Reserve Bank of Kansas City.

Table 2: Adoption Rate for Transactional Internet Banking and the Rival Concentration Index

Rival Concentration Index*	Number of Banks	Adoption Rate**
Less than 1463.7	809	18.3%
More than 1463.7	809	7.8%

*Categories for rival concentration index were chosen to split the sample banks in half.
**The hypothesis that a bank's adoption of transactional Web site is independent of whether its rival concentration index is above of below the median is rejected at least at a 1% significant level in a chi-square of independence. (Pearson chi-square test statistic=39.38 with 1 degree-of-freedom.)
Source: Rival concentration index based on the FDIC Survey of Deposits for June 1999, and includes deposits of both commercial banks and S&Ls.

Table 3: Adoption Rates for Transactional Internet Banking and Trend-adjusted Variation in Income per Person*

Trend-adjusted Variation in Income per Person (1997)**	Number of Banks	Adoption Rate***
Less than $302.3	807	19.0%
More than $302.3	811	7.2%

* Trend-adjusted variation in income per person is measured by the standard error from regression of income per person on U.S. income per person.
**Categories are based on the median value of trend-adjusted variation in income per person.
***The hypothesis that a bank's adoption of transactional Web site is independent of whether its trend-adjusted variation in income per person is above of below the median is rejected at least at a 1% significant level in a chi-square of independence. (Pearson chi-square test statistic=49.72 with 1 degree-of-freedom.)
Source: Income per person is from the Bureau of Economic Analysis' Regional Economic Information System database.

Table 4: Adoption Rates for Transactional Internet Banking by Size of Bank

Asset Size of Bank	Number of Banks	Adoption Rate (Percent)
Less than $50 million	803	3.24
$50 million to $150 Million	558	12.01
$150 million to $1 billion	232	43.10
Over $1 billion	25	72.00

Table 5: Descriptive Statistics of Logit Variables*

Variable	Mean	Standard Deviation	Minimum	Maximum
Rival concentration index**,***	1614	889	0	7480
Trend-adjusted variation in income per person****	$464.5	$421.7	$86.0	$5256.4
Income per person (1997)	$21,059	$4,031	$10,915	$42,311
Market share (percent)**	16.9	18.8	0.2	100.0
Market share / share of bank with largest market share (percent)**	45.3	37.4	0.007	100.0

* The market is defined as the county or metropolitan statistical area (MSA) in which the bank is located. Averages for population, schooling, and income per person are calculated over the sample bank observations.
**Commercial banks and S&L deposits are in calculations for rival concentration index, market share, and relative market share.
***Sum of the squared market shares of a bank's rival.
**** Standard error from regression of income per person on U.S. income per person.
Sources: Rival concentration index and market share based on the FDIC Survey of Deposits for June 1999; population and schooling information from the Census Bureau's USA Counties database; per capita income from the Bureau of Economic Analysis REIS database.

Table 6: Determinants of the Adoption of Transactional Web Sites

Logit Estimates

Dependent variable=1 or 0 if the bank has or has not adopted a transactional Web site*

Independent Variable	(1) Odds ratio (p-value)	(2) Odds ratio (p-value)	(3) Odds ratio (p-value)	(4) Odds ratio (p-value)
Rival concentration index	.999447 (0.000)	.999728 (0.039)	.999723 (0.030)	.999708 (0.026)
Trend-adjusted variation in income per person**	.998390 (.000)	.998750 (0.001)	.998069 (0.000)	.998070 (0.006)
Bank size characteristics:				
Assets		1.00152 (0.002)		
$(\text{Assets})^2$		0.999999 (0.010)		
Market share			1.014077 (0.006)	
Market share / share of bank with largest market share				1.006993 (0.006)
Other bank characteristics:				
Organization assets more than $1 billion (indicator variable)		17.03936 (0.000)	25.21911 (0.000)	24.14742 (0.000)
Bank aged 2 or younger (indicator variable)		3.957713 (0.004)	4.021125 (0.005)	4.265413 (0.003)
Goodness-of-fit:				
Log-likelihood	-585.38	-440.55	-452.40	-452.25
LR test (chi-square df)	82.1 (2)	357.4 (6)	348.1 (5)	348.4(5)
p > chi-square	0.0000	0.0000	0.0000	0.0000
Pseudo R^2	.0655	.2853	.2778	.2780
Correctly classified predictions	86.96%	90.36%	90.73%	90.79%

*A bank is classified as adopting a transactional Web site if it offers a Web that allows, at minimum, a customer to initiate an inter-account transfer.

**Standard error from regression of income per person on U.S. income per person.

NOTES: Reported p-value is for a two-tailed hypothesis test.

Sample size: 1618. Sample includes commercial banks who have charters located in Tenth Federal Reserve District states.

Table 7: Selected Illustrations of the Change in Odds Ratios for Continuous Independent Variables*

Independent Variable	Mean	Standard Deviation	OR(m+sd)/ OR(m)
Rival concentration index	1614	889	0.77
Trend-adjusted variation in income per person**	$464.6	$421.7	0.44
Market share / share of bank with largest market share	45.34	37.4	1.30

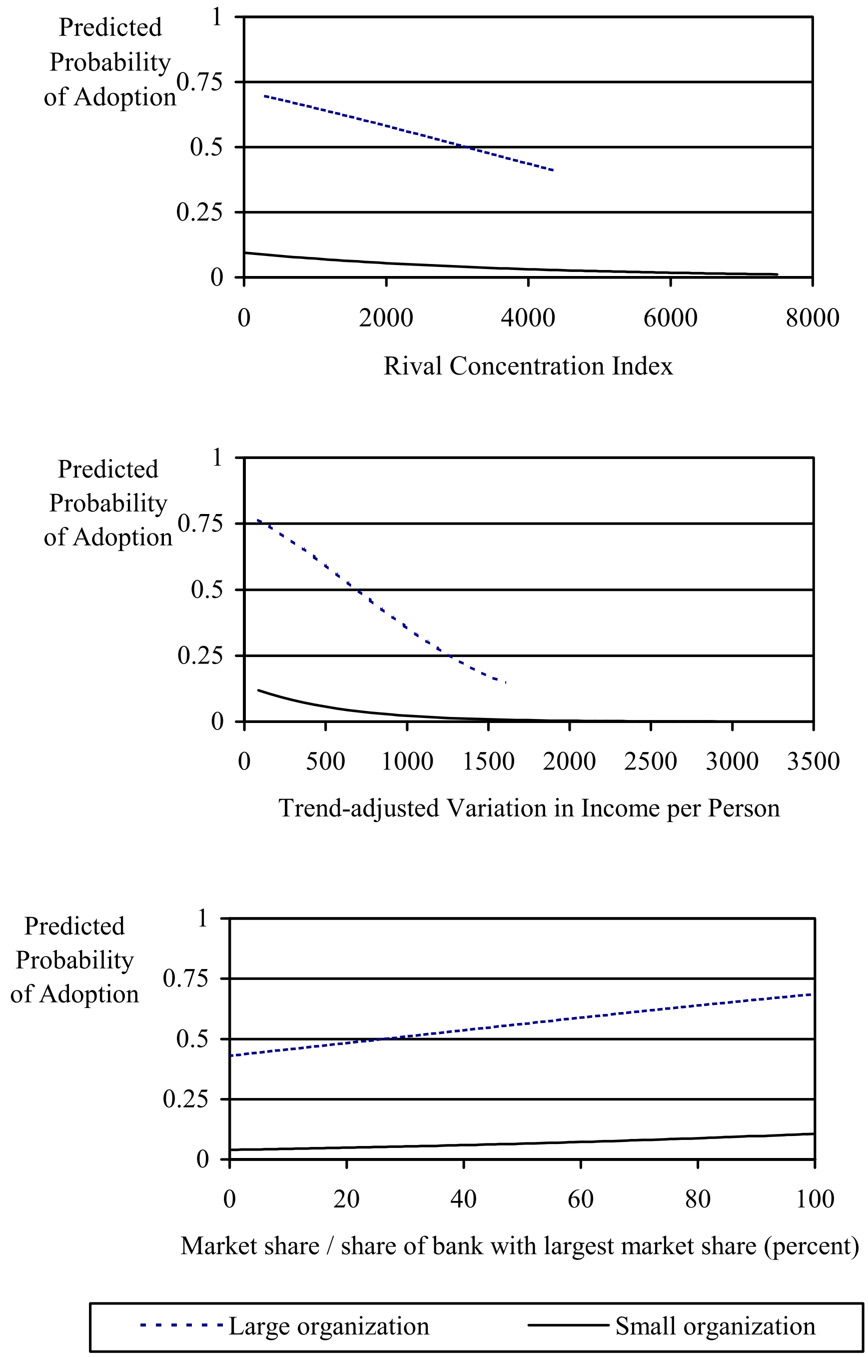
*Based on estimated coefficients from Table 6, Column (4).

**Standard error from regression of income per person on U.S. income per person.

OR(m+sd)/OR(m)=odds ratio for the independent variable at its (mean plus one standard deviation) / odds ratio for the independent variable at its mean.

Calculations assume that continuous independent variables are at their mean values except for the independent variable for the row of this table. Calculations are independent of the two indicator variables used in Logit regression 4. That is, the change in the odds ratio would be the same if the aged 2 or younger indicator variable is set to either 0 or 1. Similarly, the change in the odds ratio would be the same if the large organization indicator variable set to 0 or 1.

Figure 1: Predicted Probability of Adopting Internet Banking Technology



Notes: Calculations are based on the Logit estimation reported in Table 6, column 4. Calculations assume that continuous independent variables are at their mean values except for the independent variable graphed on the horizontal axis. Calculations also assume the bank is older than age 2 (the indicator variable for whether the bank is aged 2 or younger is set to zero). The indicator variable for whether the bank is in an organization of $1 billion in assets or larger is set to 1 for "large organization" and equal to zero for "small organization" (all other banks). The range graphed for the independent variable is based on the minimum and maximum for the variable in the sample, with the exception of trend-adjusted variation in income per person, which was truncated at an upper bound of 3500. This exception eliminates one observation (whose value for trend-adjusted variation in income per person 5256) and allows the graph to better reveal relationships. Elimination of the observation makes no essential difference in estimation results.