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

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Conference on Innovation in Financial Services and Payments
Federal Reserve Bank of Philadelphia

May 17, 2002

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Summary

1. Market concentration in the provision of financial services is an increasingly important topic to academics, businessmen and policy makers:

a. Banking mergers
b. GSEs
c. Insurance
d. Financial conglomerates

2. This paper investigates how the rapidity with which a technological innovation is brought to market is affected by both market concentration and uncertainty over the returns to investment in that innovation.

3. Specifically, we examine the optimal exercise of *strategic* real options to invest in such an innovation, Internet banking technology.

4. We model the optimal exercise/investment decision 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.

a. Real options is a large literature, but relatively few (Grenadier, Kulatilaka and Perotti, Andersen and Sundaresan, Jones and Nickerson) have explored real option exercise in a realistic, *strategic* setting. Moreover, this is the *first* paper to empirically test the implications of a strategic real options model.

5. 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.

6. We find:

a. in theory, the probability of "early" exercise in the risky technology is increasing in market concentration, in a specific sense, but decreasing in the degree of uncertainty about the return to early investment (mean-variance)

b. in empirical tests, we find support for this hypothesis, based on the results of multivariate logit regressions on a data set taken from the tenth Federal Reserve District.

c. specifically, we find that relative bank size, as measured by either market share or asset size, and demographic information predictive of future demand, both positively influence 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.

Presentation Overview

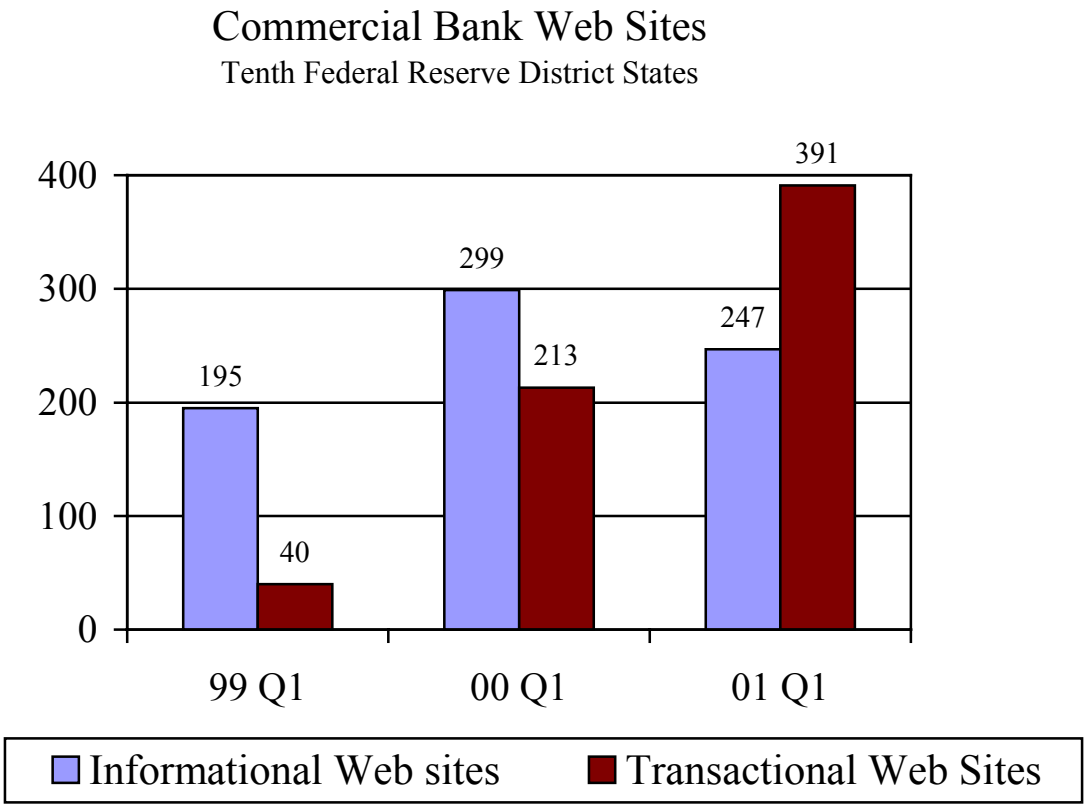
I. Background: Commercial Bank Websites

II. A Strategic Real Options Model of Investment

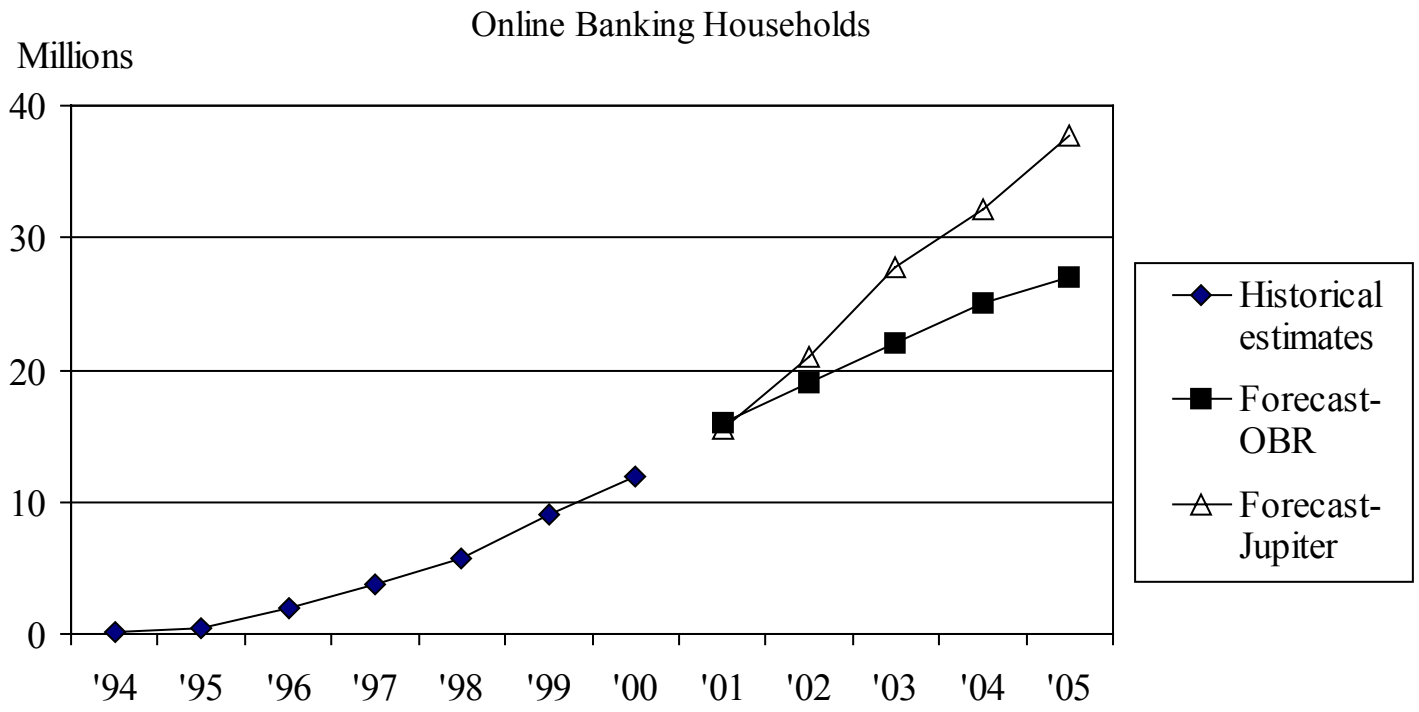
III. Empirical Hypotheses and Data

IV. Test Results

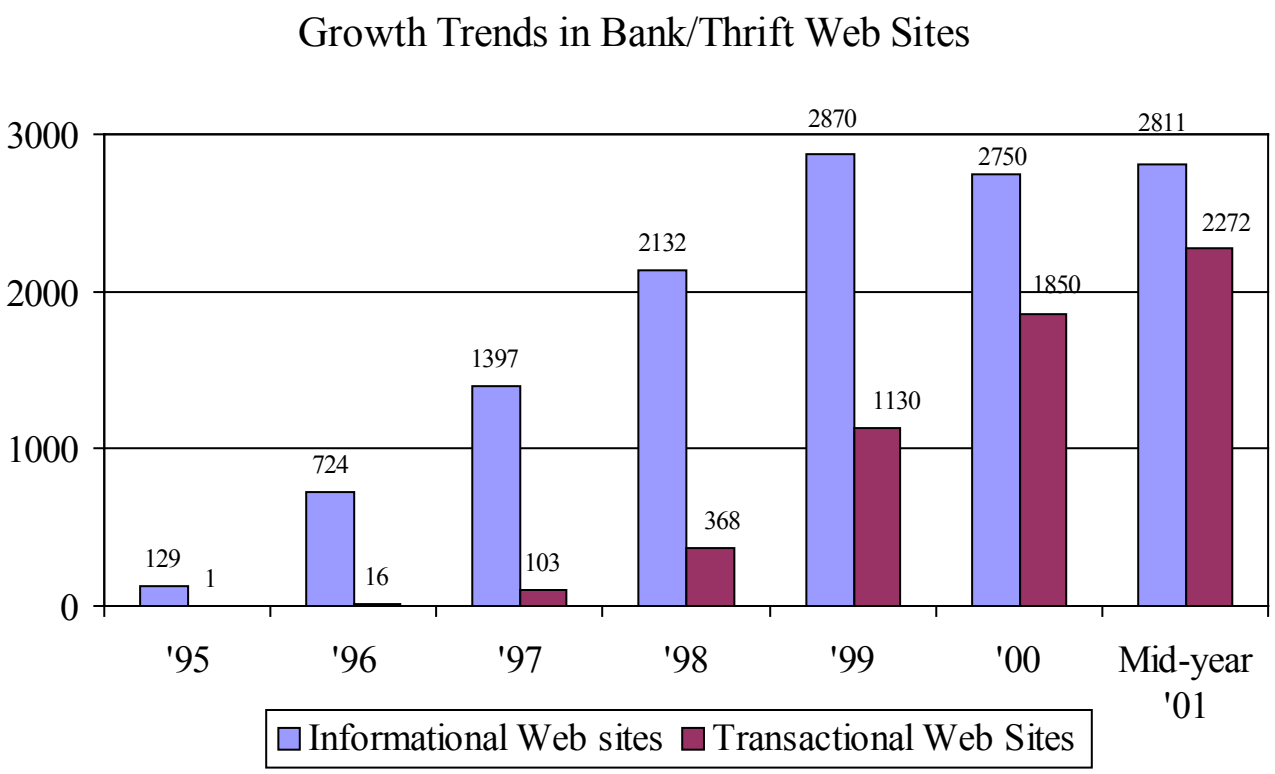
I. Background: Commercial Bank Websites



The Tenth Federal Reserve District includes Colorado, Kansas, western Missouri, Nebraska, northern New Mexico, Oklahoma, and Wyoming.



Source: *Online Banking Report,* October 15, 2001



Source: Call report data and FDIC informal estimates

II. A Strategic Real Options Model of Internet Bank Competition

Goal: in the context of strategic competition, how is the likelihood of adopting Internet banking affected by uncertainty of the demand for Internet banking and by the ex ante distribution of bank sizes?

Structure: strategic interaction in the context of game theory. Investment in Internet banking is an strategic real option, the exercise of which is controlled by the bank. Exercise timing and magnitude of investment affects returns to *all* competitors.

Uncertainty of demand for Internet banking services represented by θ

- θ = random variable with mean $E(\theta)$ and variance γ (linear-quad)
- $E(\theta)$ and γ are known to all banks
- Interpretation as state of demand, with mean-variance in a linear-quadratic world or mean-preserving spreads (convergence in measure) in merely continuous worlds

Timing--decisions are made in two periods

- Period 1: θ unknown (unrealized)
- Period 2: θ known

Demand for Internet banking, known to all banks

p=price x=aggregate supply

$$p = p(x,q)$$

Cost of providing Internet banking (could also be made random)

$$c_i(x_i)$$

Strategic alternatives

exercise option in period 1, obtain first-mover advantages through commitment to expected leader's capacity/volume but sunk cost implies possibly low returns

defer to period 2, where θ, as well as the decisions of rivals, is known; can choose investment volume conditional on true state but risks follower status in subsequent competition

Market structure (ex ante): alternative distributions of bank size

Single reference bank (always strategically important/measurable)

Other banks: alternative distributions of rival bank sizes

Case 1: one other, equally sized bank (duopoly)
Case 2: many other bank, each of equal but infinitesimal size
Intermediate: finite number of small but measurable banks

Decision is based on maximization of expected profit

quantities chosen by bank i in its strategy s_i

$$y_i(x_1,q)=\begin{cases} x_{i1}, & \text{if } x_{i1} \succ 0 \\ x_{i2}(x_{i1},q), & \text{if } x_{i1} = 0 \end{cases} \qquad (2)$$

profit of bank i in the strategy vector s is

$$p_1(s,q)= p\big(x(s,q)\big)y_i(x_1,q)- c\big(y_i(x_1,q)\big) \qquad (3)$$

expected profit of bank i in strategy vector s is

$$Ep_i(s,q) \qquad (4)$$

Equilibrium--

Continuum case: If the market is composed of a single "large" reference bank (Bank 1) and a continuum of rivals, and we represent variations in uncertainty by a sequence of distribution functions, $\{F_n(q)\}_{n=1}$ with common mean, and allow such sequences to converge in probability to that mean, then early exercise will be the strategy of the "large" reference bank (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

Finite case: If the market is composed of a single "large" reference bank (Bank 1) and a finite number of small but measurable and symmetric rivals, then for any specified level of demand uncertainty:

a. for a sufficiently large number of small but strategically significant rival banks, possibly of different *ex ante* sizes but with symmetric play in each size class, a perfect equilibrium in pure strategies 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;

b. a mixed strategy equilibrium will otherwise exist, with the probability of adoption for each size class, $\nu = \nu(\gamma)$, decreasing in the degree of uncertainty over demand.

Interpretation

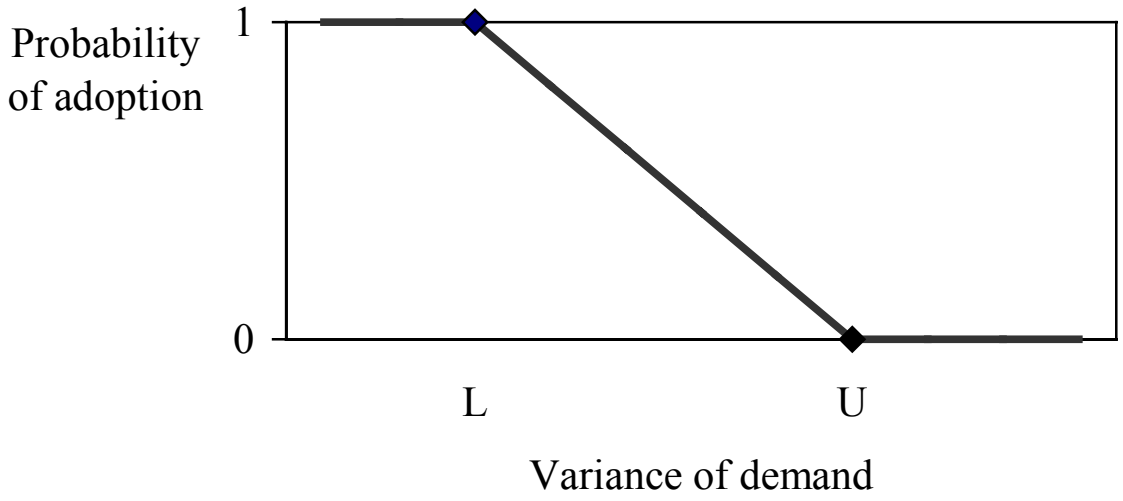
Banks that are large or have significant market power will exercise their investment options early, entering the Internet banking market first and acquiring enough capacity to ensure that they are Stackelberg leaders

Small banks will refrain from exercising until the resolution of uncertainty, and so will acquiesce to Stackelberg follower status

Prediction:

a. The return to "early" exercise (investment and commitment in first period) depends on both the "expected" return to early investment (which depends on best-reply strategies of rivals) and on volatility of investment return;

b. Consequently the probability of "early" exercise is higher, the less concentrated is the distribution of rival banks, and the lower is uncertainty.



Empirical studies on innovation in banks

Hannan and McDowell, *RAND* 1984, *Economica* 1987

Saloner and Shepard, *RAND* 1995

-adoption of automated teller machines in U.S. banks

Furst, Lang, and Nolle, OCC Working Paper 2000-9, 2000

-adoption of transactional Web sites among U.S., nationally chartered banks

Masciandaro, *J. of International Banking Regulation,* 2000

-introduction of e-banking in the first 110 Italian banks up to May 2000

Akhavein, Frame, and White, Working Paper, FRB-Atlanta, 2001

-adoption of credit scoring technology in large BHCs

III. Empirical Hypotheses and Data

Empirical hypotheses

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.*

rival concentration index =
sum of the squares of the market shares of a bank's rivals.

H_2: *An increase in observable market characteristics that should reduce the uncertainty of demand for Internet banking has a positive impact on the probability that a bank would adopt Internet banking.*

Data

- 1,618 commercial banks from the Tenth Federal Reserve District
- chartered at year-end 1999
- market either county or MSA
- Web addresses of banks were obtained from several sources
- Web sites reviewed to determine the functionality of the site

  - *transactional Web site*: allows the customer, at minimum, to initiate interaccount transfers

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%

Table 3: Adoption Rates for Transactional Internet Banking and Income per Person in Bank Markets

Income per Person (1997)	Number of Banks	Adoption Rate (Percent)
Less than $18,300	420	25.0
$18,300 to $20,600	403	26.7
$20,600 to $23,500	401	35.2
Over $23,500	394	42.7

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

IV. Test Results

Model of the probability of adoption

adoption = *f*(rival concentration, market characteristics, bank characteristics)

adoption=1 if the bank adopts a transactional Web site, and zero otherwise

market characteristics

- per capita income
- proportion of the population enrolled in college

bank characteristics

- bank size (assets, market share, relative market share)
- member of $1 billion+ organization (indicator variable)
- age 2 or younger (indicator variable)

Table 5: Descriptive Statistics of Logit Variables

Variable	Mean	Standard Deviation	Minimum	Maximum
Rival concentration index	1614	889	0	7480
Percent of total population enrolled in college (1990)	5.80	3.91	0	31.08
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

Table 6: Determinants of the Adoption of Transactional Web Sites
Logit Estimates
Dependent variable=1 or 0 if the bank has or hasn't adopted a transactional site

	(1)	(2)	(3)	(4)
Independent Variable	**Odds ratio (p-value)**	**Odds ratio (p-value)**	**Odds ratio (p-value)**	**Odds ratio (p-value)**
Rival concentration index	.999576 (0.000)	.999751 (0.051)	.999754 (0.048)	.999764 (0.067)
Market characteristics:				
Percent of total population enrolled in college	5842.897 (0.000)	1783.708 (0.000)	12238.85 (0.000)	18001.4 (0.000)
Income per person	1.000146 (0.000)	1.000086 (0.000)	1.000123 (0.000)	1.000145 (0.000)
Bank characteristics:				
Assets		1.00137 (0.004)		
$(\text{Assets})^2$		0.999999 (0.015)		
Market share			1.015122 (0.002)	
Market share / share of bank with largest market share				2.894492 (0.000)
Organization assets more than $1 billion (indicator variable)		14.75756 (0.000)	20.32064 (0.000)	18.28186 (0.000)
Bank aged 2 or younger (indicator variable)		3.668623 (0.007)	3.735332 (0.007)	4.282316 (0.003)
Goodness-of-fit:				
Log-likelihood	-557.93	-440.55	-443.62	-440.43
LR test (chi-square df)	137.0 (3)	371.8 (7)	365.6 (6)	371.98
p > chi-square	0.0000	0.0000	0.0000	(0.0000)
Pseudo R^2	.1093	.2967	.2918	.2969
Correctly classified predictions	87.08%	90.11%	90.73%	90.54%

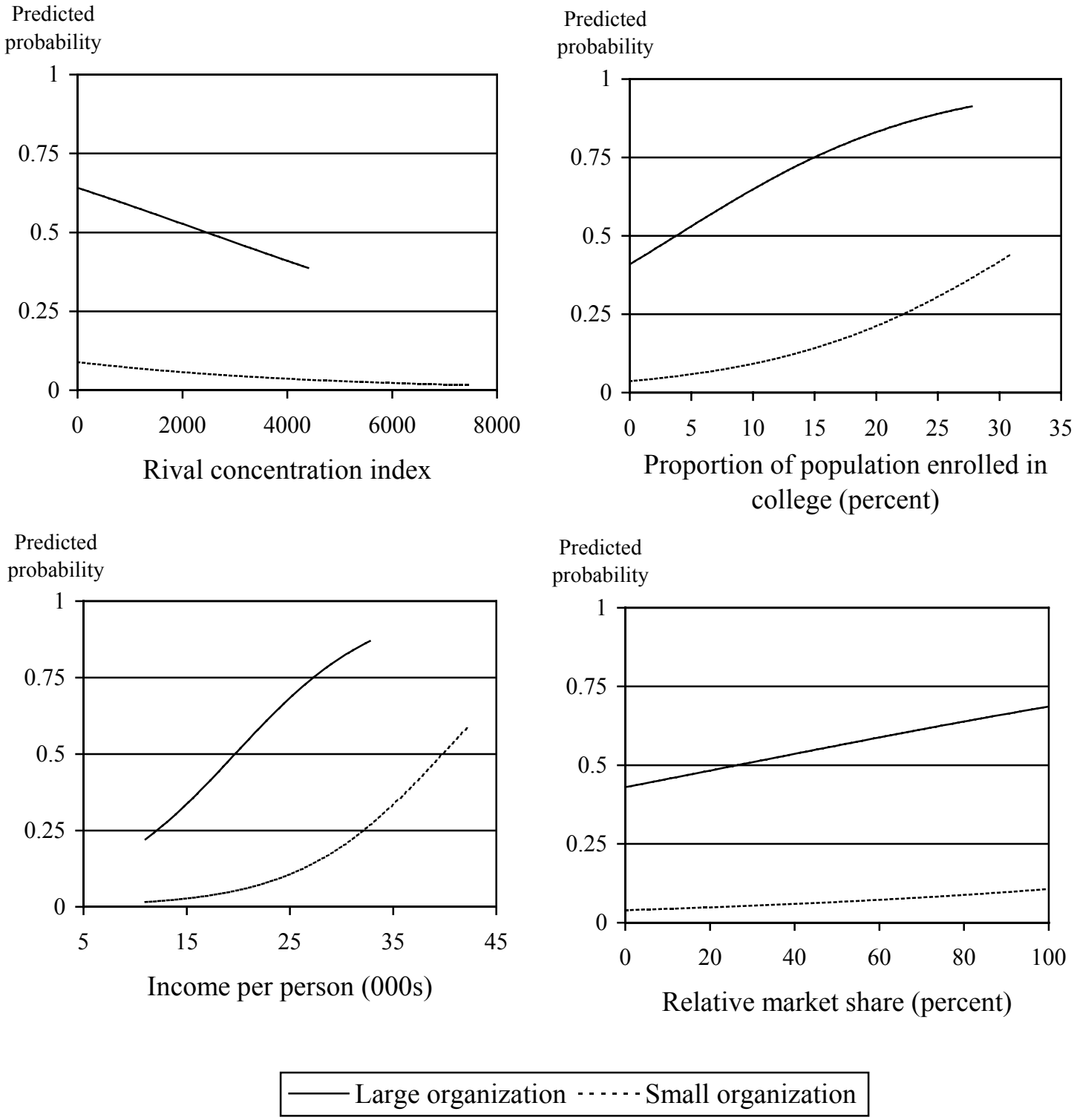
Table 7: Examples of Change in Odds Ratios for Continuous Independent Variables

Independent Variable	Mean	Standard Deviation	Using estimated coefficients from Table 6, Column (4) OR(m+sd)/ OR(m)
Rival concentration index	1614	889	0.81
Market characteristics:			
Percent of total population enrolled in college	5.80	3.91	1.46
Income per person (thousands)	21.06	4.03	1.79
Bank characteristics:			
Market share / share of bank with largest market share	45.34	37.4	1.49

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.

Predicted Probability of Adopting Internet Banking Technology



Summary and Conclusions

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

the 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.

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.

potential providers of 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.

theoretical predictions suggest that the timing of investment in Internet banking technology is a function of both *relative* firm size and the degree of uncertainty over the profitability of providing such services in a regional market.

predictions are tested using logit regression on a sample of data from 1,618 commercial banks from the Tenth Federal Reserve District

we find that that the concentration of a bank's rivals in its market has a negative effect on the probability of investment in a transactional Internet banking site

we also find that demographic variables that correlate with the a reduction in the uncertainty over the volatility of demand for Internet banking services have a positive effect on the probability of such investment