Journal of the Operational Research Society (2010) 61, 211–221

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The impact of information technology on the banking industry

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This paper analyses the effects of investment in information technologies (IT) in the banking sector using bank-level data from a panel of 68 US banks over the period 1986–2005. Although IT can improve bank's performance by reducing operational cost (supply side), it can bring in competition among banks in order to embrace new technology (demand side). Since most empirical studies have adopted the production function approach, it is difficult to identify which effect has dominated. In a differentiated model with network effects, this paper characterizes the conditions to identify these two effects. The results suggest that (at individual firm levels) the bank profits can decline due to adoption and diffusion of IT investment, reflecting negative network competition effects in this industry. Using panel cointegration tests, we confirm that the estimated profit equation is indeed a long-run equilibrium relation.

Journal of the Operational Research Society (2010) **61,** 211–221. doi:10.1057/jors.2008.128
Published online 7 January 2009

Keywords: information technology; heterogenous competition; banking services

1. Introduction

It has been much debated whether or not investment in information technology (IT) can provide improvements in productivity or business efficiency (Willcocks and Lester, 1997; Tam, 1998; Oliner and Sichel, 2000). Businesses have spent increasingly high levels of IT (see Figure 1), and yet the evidence has shown *no* conclusive answer to whether or not their productivity has gone up. For example, Loveman (1994) analysed data from the management productivity and IT database in a Cobb–Douglas production function framework and concluded that there is no significant contribution to output from IT expenditure (see Khoury and Rolland, 2006). On the other hand, Jorgenson (2001)[1] showed that a substantial part of the American growth resurgence after 1995 can be attributed to IT (see Dewan and Kraemer, 2000; Eyadat and Kozak, 2005).

Most of the existing empirical studies[2] have adopted the production function approach, describing business profits (outputs) as a specific function (ie, Cobb–Douglous) of inputs. Hence, some authors have attributed the inconsistency in empirical results to differences in measurement and econometric methodologies (see Berger, 2003; Shao and Shu, 2004; Camanho and Dyson, 2005). When studying the effects of IT in the US banking sector, we find that this production function approach might have simplified the IT effects in the banking sector, by presenting a mixture of IT effects on both demand and supply sides. Specifically, in most banking or other service industries in general, IT is first expected to reduce banks' operational costs (*supply side*). For example, internet helps banks to conduct standardized, low value-added transactions through the online channel, while focusing their resources into specialized, high value-added transactions through branches. Second, IT can facilitate transactions among customers within the same network (*demand side*). For example, stock exchanges and derivatives exchanges feature a network effect. As the number of buyers and sellers on an exchange increases, liquidity increases, and transaction costs decrease. This then attracts a larger number of buyers and sellers to the exchange.[3]

Despite these two seemingly positive effects, some studies have recorded that the mixture of the two results can be nonpositive! For example, Shu and Strassmann (2005) studied 12 banks operating in the US for the period of 1989–1997 in a production function approach. They found that although IT has been one of the most marginal productive factors among all inputs, there is no conclusive evidence on the relation between investment in IT and banks' profits. The main purpose of this current paper is to provide an interpretation

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[1] For updated data until 2006, see http://www.economics.harvard.edu/faculty/jorgenson/recent_work_jorgenson/html.

[2] Computers may affect productivity because they are a specific capital input to the production process. This is the approach taken in most existing studies, including both the national and industry-level studies just cited, as well as studies at the plant or firm level, such as Brynjolfsson and Hitt (2000), Dunne *et al* (2000), Stolarick (1999) and McGuckin *et al* (1998).

[3] See Rohlfs (1974) and Milne (2006). Also see http://en.wikipedia.org/wiki/Network_effect#Benefits.

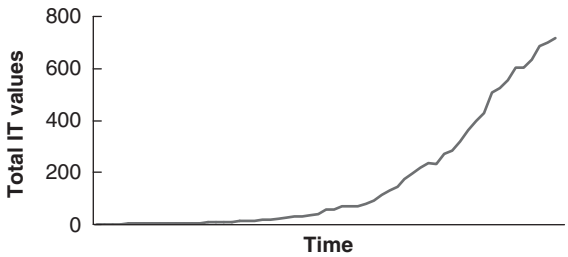

Figure 1 Values of IT capital services in the US during 1948–2006.

by stressing heterogenous competition in banking services. To justify the heterogenous competition among banks, Chiappori *et al* (1992) provided the following three reasons. First, for locational reasons their services are not perfect substitutes. Differences in size and products and specialized knowledge also make them imperfect substitutes. The secon essential imperfection arises from the fact that a bank's customers have incomplete information about the services offered by a bank and the prices at which these services are offered, at the time when the relationship has begun. A third important feature is the fact that banks offer a variety of services. The simplest example of this is the case of a bank with a large number of branches. Since customers have different preferences over branch location, branches at different locations are offering different services. This means that a bank with many branches is offering a bundle of different services to their customers.

Overall, this paper first follows the literature by using a modified Hotelling model (due to Rohlfs, 1974) to describe the heterogenous competition among banks with networks. We are able to separate the IT effects from demand and supply sides, and then address the equilibrium effect on individual banks. It is then clear that the key point to understand the inconsistency in empirical studies is to examine the equilibrium effects of IT. That is, for individual bank, it seems intuitive that both supply and demand effects are positive. When all banks in the industry have the same access to this cost-saving technology, the price competition in banking services can offset the cost saving from adopting IT. These theoretical conclusions are tested on a panel data set of 68 US banks for the period 1986–2005.

The main findings are summarized as follows. First, we derive a simple test on the existence of network effect by checking the relation between market share and IT expenditure. If there is only a cost effect, each bank's market share will increase with IT; however, if there is also a network effect, the market share can increase or decrease with IT. This result can be useful when a proxy variable for the size of network is invalid (Saloner and Shepard (1995) use the number of branches possessed by a bank as a proxy for its expected ATM network size in equilibrium). Our test on US banks shows that market share is insignificantly related to IT spending. In other words, one could conclude that the industry average effect of IT on the market share is likely to remain unchanged, which then indicates that some banks' gain in market share could be offset by other banks' loss. This supports the IT profitability paradox in the US banking sector. In this context, despite the inconclusive evidence of IT productivity gains, Khoury and Rolland (2006) explain why heavy investment in IT continues amid conflicting evidence of positive returns, by proposing a set of three exogenous forces: (1) technological turbulence, (2) market turbulence, and (3) regulatory turbulence as key drivers behind IT investments by banks. Thus IT investments in banks can be guided either by the need for creating competitive advantages (strategic) or by the operational requirements of a bank.

Second, since the equilibrium price can decrease with IT expenditure, if we can isolate this impact on prices by treating price[4] as one of the explanatory variables in the model, then we can demonstrate that when the overall impact of IT on profits is negative, the cost effect is negative (Proposition 2). As the market share increases with IT, this negative result will reflect Berger's (2003) observation that banks may have essentially 'given away' the benefits from IT as the industry became more competitive due to deregulation, and rents from market power shifted to consumers (see Berger, 2003, p 142). Our estimation using data from the US banks also shows that if prices are treated as an explanatory variable, the overall impact of IT on profits is negative, indicating that the cost-saving effect has become negative due to severe competition.

Finally, in line with both sides of the existing literature, our model predicts that banks' profits can be positively or negatively related to IT expenditure. In the equilibrium, each bank's price decreases with its IT expenditure, but the impact on the profits will have to depend on whether its market share has increased. The overall effect on the whole industry, however, will depend on the relative sizes of weighted sum of IT and the average of IT. Here, the weight is measured by each bank's market share. For the US banks, we conclude that banks' profits are negatively related to IT expenditure, showing that the weighted sum of IT is less than the average of IT. As the impact on market share is insignificant, the average IT expenditure appears to have a negative effect in influencing profitability.

The remainder of the paper is organized as follows. Section 2 presents the modified Hotelling model with network effects and derives testable results concerning the relation between IT and the performance variables. Section 3 describes the data set and Section 4 sets up the empirical model. The theoretical propositions are tested on a panel data of 68 US banks for the period of 1986–2005 and Section 5 discusses our main results and managerial implications. Section 6 concludes the paper.

[4] We provide the rationale for treating prices as explanatory variables in Section 2.

2. IT and banking industry

As discussed earlier, we adopt a simple differentiated model (due to Hotelling, 1929) with two competitive banks and infinitely many heterogeneous consumers, to describe the heterogenous competition among firms. We follow the standard explanation in the Hotelling model by assuming that the consumers are heterogeneous in their preferences or their demand for banking service, and hence every bank's service is different to each consumer.

2.1. The setup

It is assumed that there are two competitive banks (1 and 2) in the industry, charging services prices p^1 and p^2, respectively. There is a continuum of potential consumers, indexed by x, located on the unit[5] interval [0,1]. Consumers are different in terms of preferences indicated by a location in the unit interval. For our purpose of examining the impact of IT, we simplify the analysis by assuming that bank 1 is located at 0, while bank 2 is located at 1.

We follow the setup in the R&D literature (see Reinganum, 1989) in assuming the following two-stage framework; that is, before the price competition, each bank invests T^i, $i=1, 2$, in IT equipment. For an individual bank, the adoption of IT has two effects: to reduce the operational cost and to create a network effect to customer services. For the former, we assume that the adoption of IT will cut the operational cost from c^i to $c^i - \phi(T^i)$, $i = 1, 2$. $\phi(T^i)$ is assumed to be increasing and convex. For the latter, we follow Rohlfs' (1974) setting in assuming that the valuation of service is positively related to the number of consumers in the same service. That is, let $v^i(T^1, T^2)$ denote the customers' valuation for consuming bank i's service. $v^i(T^1, T^2)$ is an increasing function of T^1 and T^2. Let v^i_j denote the partial differentiation of v^i with respect to T^j, and we assume that $v^i_i > v^i_j > 0$, for $i, j = 1, 2$.

The sequential stages of the game proceeds as follows. At the start of the game, each bank invests T^i, $i=1, 2$, in IT. Then, each bank determines its service charge (p^i, $i = 1, 2$). After observing the service charges, each consumer then chooses a bank according to her valuation of the bank service and service charges. The subgame perfect equilibrium (Selten, 1975) will be derived by backward induction. We first calculate consumers' choices of banks, then we determine the market equilibrium (prices), followed by each bank's optimal decision on IT investment.

[5] [0,1] can be interpreted as proportion of population. Our analysis will remain the same even if we consider population growth.

2.2. Banks' demand functions

Let $x \in [0, 1]$ denote an arbitrary consumer, and her utilities for using the two banks' services are given by

$$U^x = n^1 v^1(T^1, T^2) - (x) - p^1, \quad \text{if she uses bank 1's service;}$$
$$= n^2 v^2(T^1, T^2) - (1 - x) - p^2, \quad \text{if she uses bank 2's service.}$$

When joining bank i's service, there will be a net benefit $n^i v^i(T^1, T^2)$, which depends on the sizes of IT investment and the overall number of consumers (n^i, $i=1, 2$) that use the same network. The negative terms $-x$ and $-(1-x)$ indicate the preference difference between this consumer x and banks 1 and 2, respectively. The service charges for the two banks are p^1 and p^2, respectively.

In particular, we consider a consumer $\hat{x}$, who is indifferent between consuming services from bank 1 or 2. That is, $n^1 v^1(T^1, T^2) - (x) - p^1 = n^2 v^2(T^1, T^2) - (1-x) - p^2$. It can be easily checked that for consumers located at $x < \widehat{x}$, they will choose bank 1's service; while for consumers located at $x > \widehat{x}$, bank 2's service will be chosen. Hence, we know that $n^1 = \widehat{x}$ and $n^2 = 1 - \widehat{x}$. Replacing n^i in the indifferent condition, we have $\widehat{x} = [(1 - v^2(T^1, T^2)) - (p^1 - p^2)]/2 - (v^1(T^1, T^2) + v^2(T^1, T^2))$. Given each bank's demand n^1 and n^2, bank i's profit π^i is given by: $\pi^i(p^1, p^2) = (p^i - (c^i - \phi(T^i)))((1 - v^j(T^1, T^2)) - (p^i - p^j)/2 - (v^1(T^1, T^2) + v^2(T^1, T^2))) - T^i$, for $i \neq j$. IT spending can reduce operational cost from c^i to $c^i - \phi(T^1)$, and create an extra value to bank services.

2.3. Market Equilibrium and IT investment

The characterization of the equilibrium is standard, that is, each bank chooses p^i to maximize its profit $\pi^i(p^1, p^2)$. The equilibrium prices are $p^i = (3 - 2v^j(T^1, T^2) - v^i(T^1, T^2)) + 2(c^i - \phi(T^i)) + (c^j - \phi(T^j))/3$, for $i \neq j$. Bank 1's equilibrium demand will be

$$n^1 = \frac{(1 - v^2(T^1, T^2)) - (v^1(T^1, T^2) - v^2(T^1, T^2)) + (c^1 - \phi(T^1)) - (c^2 - \phi(T^2))/3}{2 - (v^1(T^1, T^2) + v^2(T^1, T^2))},$$

and similarly, we can calculate bank 2's demand. Finally, each bank's equilibrium profits are $\pi^i(T^1, T^2) = p^i 3 - v^i(T^1, T^2) - 2v^j(T^1, T^2)/6 - 3(v^1(T^1, T^2) + v^2(T^1, T^2)) - T^i$, for $i \neq j$.

We can calculate each bank's IT investment by solving the first-order conditions $\partial\pi^i(T^1, T^2)/\partial T^i = 0$, for $i = 1, 2$, simultaneously. Note that the IT investments are endogenously determined in the model. However, since our focus is on the relation between (equilibrium) IT and banks' (equilibrium) profits, we will not distract the readers by addressing more about the factors that affect IT investments, instead we refer to the related literature on IT adoption for further discussion (see eg, Cooper and Zmud, 1990; Barua *et al*, 1991; Bhatt and Grover, 2005).

2.3.1. Implications Proposition 1[6] helps us to examine the existence of network externality through checking the relation between market share and IT.

Proposition 1 (i) *If IT has only a cost effect* (*ie*, *we temporarily drop the assumption that* v^i *is increasing in* T^i), *then bank i's equilibrium price will decrease with* T^i *and the market share increases with* T^i; (ii) *If IT has both cost and network effects*, *then bank i's equilibrium price also decreases with* T^i *but the market share can increase or decrease with* T^i.

The contribution of Proposition 1 is to provide a first step check on the existence of network effect. If the relation between market share and IT is negative, then it implies that there exists a network effect; but if the relation is positive, there is no unambiguous conclusion about the relation between market share and T^i. However, the existence of network effects is not enough to judge the overall impacts of IT. Our next result shows that it is possible to distinguish the cost effect from the network effect. Note that the overall impact of IT is a combination of price, cost and market share (demand) effects; IT has the most direct impact on cost, less direct effect on market share, and least direct effect on prices. Since Proposition 1 has shown that the equilibrium price will decrease with IT expenditure, if we could isolate this price effect by treating price as one of the explanatory variables in profit regression, then the effects will be limited on cost and market share. Moreover, since normally the service charges are given at competitive rates that are certain percentages of the overall volume of deals (ie, mark-up), treating price as an explanatory variable is also justifiable in reality. For example, the fees charged for investment funds are usually 1.5% of the total amount. After treating the prices as explanatory variables, we can show that the market share can increase with IT. Therefore, if the relation between profits and IT is negative, then we can conclude that the negative network competition effect via price has dominated the positive cost advantage.

Proposition 2 *If we isolate the impact on prices, then the network competition effect will be higher than the cost effect*, *when IT has negative effect on profits*.

Finally, in line with both sides of the existing literature, we predict that banks' profits can be positively or negatively related to IT expenditure. The overall impact consists of effects on prices, cost and market share (demand). For the individual bank, Proposition 1 has shown that equilibrium prices will decrease with IT. Next, the cost effect is a combination of two parts: IT expenditure as cost, and the reduction of operational cost due to IT. This term could be positively or negatively related to IT, depending on whether the reduction on the operational cost is competed away in the market competition. Lastly, we have proved in Proposition 2 that if the price effect is isolated, IT has positive impact on market share. However, since equilibrium price will be decreasing in IT, through the definition in (1), there is no conclusive result concerning the effect on market share.

Although the valuation of consumer service will change with IT, the total size of consumers is fixed (ie, restricted to the unit interval). If one bank's market share increases with IT, the other bank's market share cannot increase simultaneously. Since the empirical tests are examined with bank-level data, it is useful to recall from the basic econometric text about the sign for the parameter of IT in the regression. That is, if we run the regression of profits (π^i) on IT expenditures (T^i), the sign for the parameter of IT will depend on whether $\sum(\pi^i - \overline{\pi^i})(T^i - \overline{T^i}) \gtrless 0$, where $\overline{\pi^i} = \sum \pi^i / N$ and $\overline{T^i} = \sum T^i / N$. After rearranging, this condition becomes $\sum(\pi^i / \sum \pi^i) T^i - \sum T^i / N \gtrless 0$. Here N denotes the number of sample banks. In other words, the overall effect on the whole industry will depend on whether IT can change the relative sizes of weighted sum of IT and the average of IT. If there are scale economies in adopting IT, then the sign will be positive. Berger (2003) observed that in the US, although large banks have significant scale economies associated with back-office operations (cost reduction), small banks are often able to share in the benefits of technological progress (network effect). The overall impact on profits in the industry is therefore ambiguous.

3. Data description

In this section, we discuss the data set for the empirical exercise. The data have been extracted from *Company Accounts* in the *Worldscope* database in *Datastream*. The cross-sectional and time series nature of the available data (68 banks for a time period of 20 years) allows us to make use of a sufficiently broad sample dimension, giving a pooled total sample of 1293 observations. We have selected 68 banks that were operational during the 'entire' sample period, although these banks might have acquired other banks, but there is no overlap in our sample. Banks that were functional for a limited number of years or did not have long time series were excluded from our sample. This suggests that the excluded banks might have been consolidated with the banks for which we have sufficiently long time series. In that sense, we are covering most banks in the US, representing the banking industry. The list of banks is given in the Appendix in Table A1. The list highlights the diversity of the banks in the sample, suggesting that size or the degree to which the bank has engaged in M&A activity are equally important. Regulatory changes in the US banking industry beginning in the early 1980s along with the Interstate Banking and Branching Efficiency Act of 1994 increased merger (marriage) rates of US commercial banks from 1978 to 2004 (see Jeon and Miller, 2007).

[6] To save space, we have omitted proofs of the propositions, which are available from the authors.

The definitions of the variables are given as follows. We use superscript i to denote bank i and subscript t to denote time t. A summary of statistics for those variables is presented in the Appendix (Table A2).

IT_t^i: *IT expenditure* represents equipment expenses by bank i, excluding depreciation cost. Since there is no exact data for IT in the bank-level company data set we have used, we need a proxy for this variable. As banking industry is a service industry, a big proportion of the equipment spending in a bank can be IT related. Bank-level equipment investment can include computers (hardware and software), ATM, network systems, fax machines, telecommunication and internet equipment. Hence, we use equipment expenses by each bank as a proxy for IT.

p_t^i: *Average price* is calculated as bank i's interest expense over net revenue. Interest expense represents the total amount of interest paid by the bank. In the banking industry, the IT value-added activity helps to effectively generate funds from the customer in the form of deposits. Profits then are generated by using deposits as a source of investment funds (Chen and Zhu, 2004). In this sense, price should reflect interest expenses incurred by the bank to procure these funds. It is worth noting that due to the heterogeneity and multiple product properties of bank service, it is difficult to find a conclusive method to measure output (and price) in service industry (see Sherwood, 1994). In the banking industry, banks provide various services including internet banking and credit loans. All these services could involve different qualities and even several services bundled in a complex way. Nevertheless, we need a proxy for average price to examine the network externalities of IT. Hence, we consider interest expenses data that mainly comprise what a bank pays to its depositors and other borrowing obligations. All these interest expenses plus a mark-up (or interest margin) will be equal to interest revenue. This mark-up or margin will depend on its level of IT investment, or in other words, IT investment can influence this mark-up. So our interest expense per unit of revenue as a proxy for the cost side of the pricing is an appropriate measure of an average price for the multi-product services that a bank offers.

π_t^i: *Net revenue* represents the total operating revenue of company i.

m_t^i: *Market share* is calculated as the share of bank i's revenue over the total revenue of the banking industry (in this case 68) and multiplied by 100.

HHI_t: Herfindahl–Hirschman Index is a measure of market structure and it is defined as $HHI_t = \sum (m_t^i)^2$.[7]

W_t^i: *Non-interest expenditure*, which includes both labour and non-labour expenses. If non-labour (or capital related) expenses exceed the labour cost, then this variable can have a positive impact on banks' revenue.

E_t^i: *Other operating expenses* have been used as another control variable in the regressions. This is expected to have a negative impact on banks' revenue.

C_t^i: *Capital expenditure* as a per cent of total assets.

S_t^i: *Staff or labour cost*, which includes wages and benefits paid to employees and officers of the company.

Finally, since the above variables are collected from one single database, an important methodological issue relating to data comparability that normally arises with IT data has been resolved. As is well known, the US banking industry has undergone major structural changes with frequent mergers and acquisitions and, consequently, all banks do not have extensive historical expenditure data. Therefore, our sample only covers 68 banks that have data for a relatively longer time period. The banks in our sample have an average of \$2.2 billion in terms of annual revenues and \$72 million in terms of average equipment investment.

Shu and Strassmann (2005) discussed several problems associated with IT-related data either from the US Bureau of Economic Analysis or other government agencies. Thus, researchers have used different sets of IT spending data, for example, the data from the International Data Group survey on about 300 companies (Brynjolfsson and Hitt, 1996). But, the reliability of such a data set is still questionable because it used mail-in questionnaires or telephone surveys that are either incomplete or from interpretations that deal more with the views of the respondents than the facts. We chose the banking industry because it is part of the service industry that has been suspected of having one of the lowest IT productivity (Brynjolfsson and Hitt, 1996). Thus, the objective of this paper is to analyse the banking industry using bank-level data on equipment expense with reasonably long time dimension as a suitable proxy for IT spending.

4. The empirical model

Since most existing research on US banks has adopted the production[8] function approach, it is not easy to distinguish the network effect from the demand side and the cost effect from the supply side, or to characterize the effect from competition in this highly diversified industry. Our theoretical discussion above directs us with three steps to unravel the overall impacts. Note that except for market share and average price (which are expressed in terms of ratios), all other variables are measured in logarithms to adjust for heteroskedasticity and to detrend the variables measured in different units in terms of US\$; thus the coefficients measure the elasticity of prices, market shares and profits.

First, we can check the existence of network effect by examining the relation between market share and IT. According to Proposition 1, we test the following empirical models, where the subscripts denote time t for the period 1986–2005.

$$m_t^i = \alpha_0 + \alpha_1 \ln IT_t^i + \varepsilon_t^i,$$

[7] The original *HHI* is a summation over the whole industry, but since our sample covers only 68 large banking firms, the index we calculate is not the *HHI* in original definition. However, we still use *HHI* to indicate an index for concentration.

[8] See Shu and Strassmann (2005) for a review.

where ln denotes the logarithm of a variable. This equation tests whether there is a network effect: if α_1 is negative, then there is a network effect, but if α_1 is positive, then nothing conclusive can be said about its existence.

Second, in order to distinguish the cost effect from the network effect, we isolate the price effect by treating prices as one of the explanatory variables in profit regression, and test the following model:

$$\ln \pi_t^i = \beta_0 + \beta_1 p_t^i + \beta_2 \ln IT_t^i + \beta_3 \ln W_T^i + \beta_4 \ln E_t^i + \varepsilon_t^i.$$

If β_2 is negative, then following Proposition 2, we can conclude that the cost effect is negative.

Third, we test the overall impacts of IT on profits, by testing the following model, having controlled for the two key bank-specific expenditure variables:

$$\ln \pi_t^i = \lambda_0 + \lambda_1 \ln T_t^i + \lambda_2 \ln W_T^i + \lambda_3 \ln E_t^i + \varepsilon_t^i.$$

If λ_1 is negative, then the overall impact (cost effect and network effect) of IT is negative; if λ_1 is positive, then the overall impact of IT is positive.

Moreover, we also consider the same set of regression specifications for two sub-periods (ie, 1986–1995 and 1996–2005) to examine possible changes in the coefficients. The justification for this sub-period analysis is given as follows. According to Gordon (2002), the early IT-based innovations have been historically grouped into four distinct periods: early adoption (1864–1945), specific application (1945–1965), emergence (1965–1980) and diffusion (1980–1995) periods (also see Morris, 1986). Since the late 1970s, there have been major changes in the regulatory regime affecting banks operating in the US, particularly in terms of expansion of bank powers and liberalization of interstate banking and branching rules. Legislation passed by the federal government during the 1980s has diminished the distinctions between banks and other financial institutions in the US. The major impact of the tremendous deregulation, beginning in the early 1980s, has been greater degree of consolidation of the banking industry, as a consequence of elimination of financially unsound banks and M&A activity. Jeon and Miller (2007) found evidence that failures lead to mergers. Such banking revolution in the mid-1980s has brought in information technologies in banking, ending the role of the traditional monopoly in banking. These banks have embraced technology to remain competitive against a diverse array of competitors. Since 1996, the US has experienced the major era of branching deregulation, the introduction of surcharges at ATMs (in 1996) and the evolution away from shared, nominally non-profit, ATM networks to publicly owned, for-profit payment networks.

So the starting point of our hypothesis examining the role of IT is appropriate and it appears that the big IT spending took place in the first 10 years of such a revolution (1986–1995 – pre-IT revolution) and subsequently the IT investment might have saturated – the second sub-period (1996–2005 – post-IT revolution). We estimate our regressions for the two sub-periods to show how the effect of IT might have changed instead of being constant for the whole sample.

5. Results and discussion

Based on the above analysis, we estimate the contribution of *bank-level* equipment investment in IT to the financial performance of banks. The cross-sectional and time series nature of the available data (68 banks for a time period of 20 years) allows us to make use of a sufficiently broad sample dimension, giving a pooled total sample of 1293 observations. The parameters that are to be estimated are assumed to be constant across banks and over time, as it is common with a regression model. Given the time dimension of 20 years, we also run the regressions for the two sub-samples discussed earlier in order to capture any change in the coefficients in each of the two key equations. The estimation has been carried out using pooled regression method in *Eviews*.

As we have formulated the regression model according to our theoretical results (hence we cannot remove any variable ad hoc), we have tried to correct any endogeneity in the regressors using instrumental variable method. We use pooled time series cross-section regression as opposed to panel techniques, because the number of cross-sections is not significantly higher than the time dimension. Whichever

Table 1 Pooled IV/2SLS regressions for market shares

	C	*ln IT*	*m* (−1)	*Adjusted* R^2	*s.e. of regression*	*Observations*
	Full sample 1986–2005					
Coefficient	−0.408	0.044	0.978*	0.964	0.680	1225
Std. Error	0.300	0.035	0.026	Instrument list: *C*, *p*, ln IT(−1)		
	First sub-sample 1986–1995					
Coefficient	−1.069	0.128	0.917*	0.954	0.704	545
Std. Error	0.740	0.092	0.062	Instrument list: *C*, *p*, ln IT(−1)		
	Second sub-sample 1996–2005					
Coefficient	0.080	−0.011	1.022*	0.968	0.680	680
Std. Error	0.586	0.066	0.048	Instrument list: *C*, *p*, ln IT(−1)		

Note: *Indicates significance at 1% level.

methods we use, the results, however, do not significantly differ, but pooled regression is the appropriate estimation method.

The estimation results for market share appear in Table 1, whereas Table 2 presents results drawing inferences for bank profits, uncovering network effects and the role of competition. It is apparent from results in Table 1 that for the industry average, the market share is insignificantly related to IT spending for the full sample and for the two sub-periods, even after having taken account of any possible dynamics via including a lagged term of the market share. In both periods, market shares remain insensitive to IT spending, and this suggests that the average network externalities of IT is not significant. In other words, market share is likely to remain unchanged across the industry, although it could mean some banks' gain in market share could be offset by other banks' loss. A bank's market share increases when the bank is fast enough in embracing new technology; while others those who cannot keep up with the technological progress will eventually drop out of the race or they are taken over by big banks. This dimension, which we characterize as the demand-side effect, has not been considered by the production-function-based approaches used in this line of literature.

In Table 2, to distinguish the network effect from the cost effect, we present the revenue effects of IT spending, after having controlled for the effects of average price, non-interest expenditure and other operating expenses. We find consistently a negative effect of IT on revenue and the result is robust over two sub-periods (see Table 2). This means bank profit for the industry does not increase in response to higher IT spending. The coefficients are of similar magnitude as theoretically predicted in the model. Overall, the results support our theoretical notion of possible network effect derived in the propositions. The magnitude of the IT term remains nearly stable around 0.1 in Table 2, even when we drop the price term. The overall relationship between the dependent variable and the independent variables is strong, with the t-values being significant at 1% level. The values obtained for R^2 is satisfactory, as they are fairly high. The negative effect of IT on profit holds, indicating the presence of network effect, in the sense that some banks benefit from more customers; while others are actually losing their customers.

On average, IT and bank profits are negatively correlated. Out of 68 banks, majority banks have a negative and significant effect, whereas some have positive effect and others have insignificant effect, when we examine the cross-section-specific effects.[9] The average negative effect across banks reflects the industry effect. Similarly, over time, the magnitude of the IT coefficient in the profit equation improves

Table 2 Pooled IV/2SLS regressions for bank profits

	Full-sample 1986–2005					*First sub-sample 1986–1995*					*Second sub-sample 1996–2005*				
	C	*p*	*ln W*	*ln E*	*ln IT*	*C*	*p*	*ln W*	*ln E*	*ln IT*	*C*	*p*	*ln W*	*ln E*	*ln IT*
Coefficient	−0.268*	1.887*	1.377*	−0.278*	−0.097*	−0.347*	2.164*	1.414*	−0.318*	−0.110*	−0.093	2.110*	1.251*	−0.170*	−0.081*
Std. Error	0.085	0.064	0.038	0.030	0.015	0.123	0.102	0.057	0.047	0.020	0.111	0.095	0.05	0.039	0.022
Instrument list: C, $p(-1)$, ln IT(-1)						Instrument list: C, $p(-1)$, ln IT(-1)					Instrument list: C, $p(-1)$, ln IT(-1)				
Observations	1225					545					680				
Adjusted R^2	0.981					0.979					0.982				
s.e. of regression	0.237					0.218					0.239				
Excluding average price variable in the above regressions															
Coefficient	0.962*	—	1.175*	−0.101*	−0.10*	0.802*	—	1.353*	−0.283*	−0.095*	0.824*	—	1.165*	−0.058	−0.126*
Std.Error	0.096	—	0.049	0.039	0.020	0.147	—	0.077	0.063	0.026	0.139	—	0.067	0.053	0.030
Instrument list: C, $p(-1)$, ln IT(-1)						Instrument list: C, $p(-1)$, ln IT(-1)					Instrument list: C, $p(-1)$, ln IT(-1)				
Observations	1293					613					680				
Adjusted R^2	0.964					0.956					0.967				
s.e. of regression	0.322					0.315					0.322				

Note: * Indicates significance at 1% level; p: average price; ln IT: log of IT; ln W: log of non-interest expenditure; ln E: log of other operating expenditures.

[9] To save space, we have not presented these results, but they are available on request from the authors.

marginally in the second period relative to the first period. This improvement suggests that the cost effect is higher than the network effect in the second period according to Proposition 2. This also indicates the benefit from a higher degree of market concentration, which we observe in the *HHI* variable (see Figure 2). Going forward, this implies that there could be a point where profits no longer negatively respond to increases in IT expenditure because the negative network effect from competition is exactly offset by the cost advantage from IT, thus producing a neutral or insignificant effect on profit. The coefficients associated with non-interest expenses and operating expenses have been in line with expectations. The positive coefficient associated with non-interest expenses suggests that in the banking industry, more IT requires more highly skilled labour, which although comes at higher wages, with higher labour productivity they contribute to higher profit. Also non-labour expenses could contribute to higher capital productivity, thus justifying the positive coefficient associated with non-interest expenses. But the negative coefficient associated with other operating expenses suggests operational efficiency.

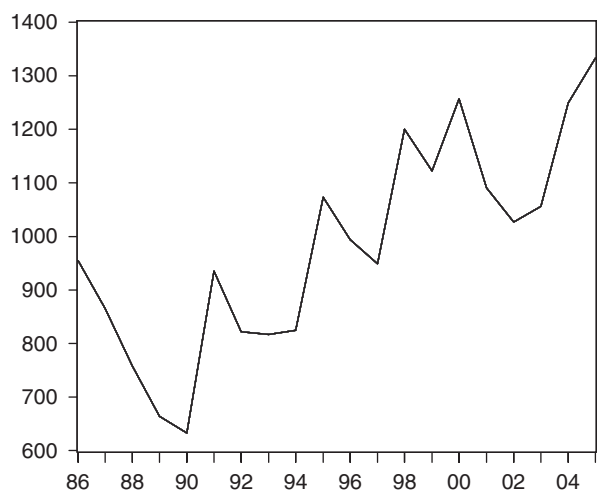

Figure 2 Market concentration (*HHI*) during 1986–2005.

Now we test whether the profit equation (with or without the price series) provides a long-run equilibrium relation statistically. Panel cointegration methods are directed at studying such questions that surround long-run economic relationships. The cointegration test from Pedroni (1999) labels the 'within-dimension' statistic or Panel *t*-statistic and the second one is the 'between-dimension' statistic or Group *t*-statistic. The test is based on the residuals of the OLS estimate. Hence we apply Pedroni's residual cointegration test for the two testable profit equations. We find that the profit equation with price series suggests that the variables involved in this equation do represent a long-run equilibrium relation as opposed to the one without the price series (see Table 3).

5.1. Managerial implications

The relationship between IT expenditures and bank's financial performance or market share is conditional upon the extent of network effect. If the network effect is insignificant, IT expenditures are likely to (1) reduce payroll expenses, (2) increase market share, and (3) increase revenue and profit. The evidence, however, suggests that there is significant network effect in the US banking industry, implying that although banks use IT to improve competitive advantage, the net effect is not as positive as normally expected. In a broader context, the innovation in IT, deregulation and globalization in the banking industry could reduce the income streams of banks, and thus the strategic responses of the banks, particularly the trend towards mega-mergers and internal cost-cutting, are likely to change the dynamics of the banking industry. Given the two effects of IT, the net effect would depend on which effect is dominating. It is commonly believed that IT will have a positive effect on profitability. But the negative effect found in our sample of banks does suggest that the ongoing changing banking environment could still make it insufficient to offset any reduction in revenue due to the competition effect.

Given the size and growth of investments in IT by the banking sector, knowledge about whether such investments contribute to profitability and when they may represent over-investment is important for managers. This paper investigates

Table 3 Pedroni residual cointegration test

Sample: 1986–2005 *Banks: 68* *Null hypothesis: No cointegration*	*Testing with price variable*		*Testing without price series*	
Pedroni	*Statistic*	*Sig. level*	*Statistic*	*Sig. level*
Panel v-Statistic	0.096	0.397	0.888	0.269
Panel rho-Statistic	7.225	0.000	6.313	0.000
Panel PP-Statistic	−3.618	0.001	−0.096	0.397
Panel ADF-Statistic	2.676	0.011	−2.013	0.053
Group rho-Statistic	10.828	0.000	10.153	0.000
Group PP-Statistic	−6.539	0.000	1.662	0.100
Group ADF-Statistic	2.816	0.008	−0.301	0.381

Table 4 Testing for the link between capital spending and labour cost

Sample: 1986–2005	*Dependent variable: Capital spending as a percent of total assets*					
Banks: 68	*Full sample*		*First sub-sample*		*Second sub-sample*	
	Statistic	*Sig. level*	*Statistic*	*Sig. level*	*Statistic*	*Sig. level*
C	0.143	0.039	0.032	0.806	0.219	0.001
$\ln S$	0.012	0.039	0.025	0.037	0.004	0.443
Observations	1293		613		680	
s.e. of regression	0.353		0.438		0.253	

Note: $\ln S$ – log of salaries.

the profitability issue to IT investment in the context of a possible network competition effect that may erode profitability. Our study finds that the contribution of IT investment to bank profitability is negligible due to pressures of competition by rival banks. It is believed that IT has both cost and network effects, but these seemingly positive effects are not fully supported by empirics. The key reason underlying the network (demand) effect dominating the cost (supply) effect is due to the severe heterogenous competition in the banking industry with regard to demand for and supply of banking services. When providing IT-enabled products, we suggest that a bundle of products can attract more heterogeneous consumers than a single product, similar to the strategies suggested in Bakos and Brynjolfsson (1999). A single IT-enabled product can encourage other banks to compete and offer the same product, whereas a bundle of IT-supported products is less likely to be offered by each bank, in which case we might not observe a negative effect of IT spending on bank profitability. IT-enabled products can also be more readily combined than physical–physical or physical–IT enabled.

Another managerial implication of our result is that while higher labour cost could induce greater IT-related equipment spending, such labour saving capital spending may not increase profitability in the banking sector under the current setting, although this cannot be generalized to non-financial sectors, where there is limited use of IT as opposed to banks. We run a regression of capital expenditure as per cent of total assets (C) on total wage bill for our sample of banks to illustrate whether higher capital spending is due to higher wage cost. The empirical model is given by

$$C_t^i = \delta_0 + \delta_1 \ln S_t^i + \varepsilon_t^i.$$

We find that $\delta_1 > 0$, indicating that the higher the salary cost, the higher the capital expenditure, thus supporting the possibility of capital being substituted for labour. The results in Table 4 suggest that higher capital spending occurred only in the first sub-period due to higher wage cost, but in the second sub-period the increase in capital spending has not been significant enough in response to changes in wage cost. This might suggest either a saturation level of capital spending in the second period or capital expenditure being less sensitive to changes in salary cost, which reflects only skilled workers being employed and their contributions get augmented due to higher capital without creating any displacement of labour.

6. Conclusion

This paper is concerned with the impact of IT on the banking industry, as banks are the intensive users of IT. The usage of IT can lead to lower costs, but the effect on profitability remains inconclusive owing to the possibility of network effects that arise as a result of competition in financial services. The paper analyses both theoretically and empirically how IT-related spending can affect bank profits via competition in financial services that are offered by banks. The paper utilizes a Hotelling model to examine the differential effects of the IT in moderating the relationship between costs and revenue. The impact of IT on profitability is estimated using a panel of 68 US banks over 20 years. Further we have tested for cointegration whether there is a long-run relationship between the variables involved in the profit regression. The results document the role of IT on the cost and revenue in banking and show the impact of network effects on bank profitability. While IT might lead to cost saving, we show that higher IT spending can also create network effects lowering bank profits. Besides, IT spending has insignificant effect on market share. Overall, our results are consistent with the testable implications of the theoretical propositions:

(1) Market share remains insignificant with higher levels of IT, reflecting the possibility of network effect. (2) Prices contribute positively to firm profitability and there exists a negative relation between IT investment and bank profits. (3) Banks with higher levels of IT have lower profitability due to the possibility of network competition effect, and the impact remains consistently negative, even if price as a control variable is not considered. This means that profit from cost reduction is not sufficient to offset the loss from the negative network competition effect, making the overall effect of IT on revenue as negative, although the magnitude of the effect is small. (4) As the IT investment over the years has completely rejuvenated the banking sector, with currently low labour intensity due to a high level of automation, our results

suggest that there has been displacement of unskilled workers in the banking sector in the late 1980s and early 1990s.

This study contributes to the understanding of how IT contributes to the banking industry in the US or the service industry in general. Prior research has linked IT to productivity, while this research provides evidence that IT is also related to profitability. Our results are also consistent with prior assertions that IT innovations could create network effects but that may not be easily captured in the productivity approach adopted in previous studies. Thus our results do lend evidence that IT can have a negative effect on profitability and the consistency over time gives us greater confidence in our results. Beccalli (2007) also finds that although banks are the major investors in IT there is little relationship between total IT investment and improved bank profitability or efficiency, indicating the existence of a profitability paradox. In our paper, we explain this paradox via emphasizing the competition effect of IT investment both theoretically and in an empirical sense.

Acknowledgements— The constructive comments made by two anonymous referees of this journal are gratefully acknowledged. An earlier version of the paper was presented at the European Economics and Finance Society Annual Conference, 31 May–3 June 2007, Sofia, Bulgaria, and at the Workshop on Knowledge Flows at Queen Mary University of London, 23 March, 2007, London, UK; and we acknowledge the participants for their comments. The usual disclaimer applies.

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Appendix

See Tables A1 and A2.

Table A1 List of banks

	Code	*Bank*		*Code*	*Bank*
1	1ST	1st Source Corp	41	MER	Mercantile Bankshare
2	AMF	Ameriserv Financial	42	NAT	National City Corp
3	AMB	Amsouth Bancorp	43	NTL	Natl Penn Bancshares
4	ARF	Arrow Financial Corp	44	NFB	North Fork Bancorp
5	ABC	Associated Banc-Corp	45	NTC	Northern Trust Corp
6	BAM	Bank of America Corp	46	ONB	Old National Bancorp
7	BGC	Bank of Granite Corp	47	PNC	Pnc Finl Svcs Group
8	BHA	Bank of Hawaii Corp	48	POP	Popular, Inc.
9	BMB	Bryn Mawr Bank Corp	49	REG	Regions Financial
10	CPF	Central Pacific Fin	50	SEA	Seacoast Banking
11	CFC	Chemical Fin'l Corp	51	STB	Sterling Bancorp
12	CHC	Chittenden Corp	52	SUS	Susquehanna Banc
13	CNC	City National Corp	53	SYN	Synovus Financial
14	CBI	Commerce Bancorp Inc	54	TOM	Tompkins Trustco
15	COM	Comerica Inc.	55	TBC	Trustco Bank Corp Ny
16	COB	Commerce Bancshares	56	TRU	Trustmark Corp
17	CBA	Compass Bancshares	57	UMB	UMB Financial Corp
18	CRB	Corus Bankshares	58	UNI	Unionbancal Corp
19	CUL	Cullen/Frost Bankers	59	UNF	United Financial
20	CVB	CVB Financial Corp	60	USB	U. S. Bancorp
21	DOW	Downey Financial	61	VAL	Valley National Banc
22	FIF	Fifth Third Bancorp	62	WAC	Wachovia Corp
23	FIR	First Fin'l Bancorp	63	WAS	Washington Federal
24	FFH	First Fin'l Hldgs	64	WAM	Washington Mutual
25	FHN	First Horizon Natl	65	WES	Wesbanco, Inc.
26	FIC	First Indiana Corp	66	WEB	Westamerica Bancorp
27	FMB	First Midwest Banc	67	WIL	Wilmington Trst
28	FRB	First Regional Banc	68	ZIB	Zions Bancorporation
29	FRS	Firstmerit Corp			
30	FUL	Fulton Finl Corp			
31	GLA	Glacier Bancorp Inc			
32	GOL	Golden West Finl			
33	HAR	Harleysville Natl			
34	HUN	Huntington Bancshr			
35	INT	Interchange Finl Svc			
36	IRW	Irwin Fin'l Corp			
37	JPM	JPMorgan Chase & Co			
38	KEY	KeyCorp			
39	MTB	M&T Bank Corporation			
40	MAR	Marshall & Ilsley			

Table A2 Descriptive statistics

	m_t	π_t	IT_t	p_t	W_t	O_t	C_t	HHI_t
Mean	1.55	2 197 034	72 021.4	0.37	841 847.5	272 652.9	0.28	981.25
Median	0.33	400 651	12 608	0.37	144 595	45 351	0.22	974.5
Maximum	26.22	83 024 000	2 828 000	0.89	35 548 990	12 202 000	8.94	1333
Minimum	0.0	1869	106	0.07	1898	571	0.0	633
Std. Dev.	3.58	6 910 087	237 236.8	0.13	2 739 125	874 188	0.35	191.55
Skewness	4.25	6.8	7.0	0.09	7.0	7.3	12.35	0.0
Kurtosis	22.68	58	61.1	2.98	62.4	70.3	280.26	2.18
Jarque–Bera	24 756.9	172 830.9	192 286.5	1.76	200 678.2	255 830.7	4 174 458	38.02
Probability	0.0	0.0	0.0	0.41	0.0	0.0	0.0	0.0
Observations	1293	1293	1293	1293	1293	1293	1293	1360

Received August 2007;
accepted September 2008 after three revisions