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Dynamic Equilibria in the US Banking Sector: A Model and a Case Study

Ahmet Kara* & Mohamed A. Osman**

Abstract. This paper presents an applied stochastic model and a case study so as to analyze the effects of information technology in the US banking sector. The technology in question is shown to lead to moderately high performance-high satisfaction (welfare) equilibria. We propose a stochastic managerial policy rule, which enables the sector to reach higher performance-higher welfare targets and which minimizes the fluctuations around those targets.

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Key Words: information technology, the US banking sector, applied stochastic processes/stochastic equilibria.

1. Introduction

The banking sectors in modern economies have undergone major "information technology-induced" transformations in recent decades, which have been the subject of a number of works in the literature. Among the works in question are Cheng, Lam, and Yeung (2006), Consoli (2005), Davamanirajan, Mukhopadhyay and Kriebel (2002), Harris (2001), Huang (2005), Kara and Kurtulmuş (2004), Kara (2006), Mistry (2006), Nielsen (2002), Shu and Strassmann (2005), Zhu, Wymer and Chen (2002), Zhu, Scheuermann and Babineaux (2004).

* Fatih University, Istanbul, Turkey.
** University of Dubai, Dubai, UAE.

These works cover a wide variety of issues ranging from the adoption of internet banking to differential impacts of information technology on various dimension of the sector. There is, however, a rich array of new research areas focusing on the use and effects of information technology that warrant further exploration.[1] Among the areas that could be further explored is the stochastic, dynamic analysis of the transformative power of information technology in the US banking sector which we will take up in this paper. We will present an applied stochastic model of banking services, and demonstrate that the use of information technology in the US banking services leads to moderately high performance-high satisfaction equilibria. We propose a stochastic managerial policy rule which enables the sector to reach even higher performance-higher welfare levels and which minimizes fluctuations around those levels.

In the second section of the paper, we develop the model. The third section presents the empirical results. The policy implications are articulated in the fourth section and the concluding remarks follow in the fifth section.

2. The Model [2]

Consider a banking sector where suppliers provide a service, say x, to the customers.[3] For the sake of simplicity we have chosen to analyze the case of a typical supplier in the market. Let $R^p{}_t$ be the *repurchase intention* for service x supplied by a typical bank, which indicates the degree to which customers are willing to repurchase the service at time t. $R^p{}_t$ depends on the performance of information-technology-based banking (inclusive of electronic banking) at time t (P_t), anticipated service quality at time t ($A(Q_t)$) and the relative price of the service at time t (P_t^r).

i.e., $R^p{}_t = f(P_t, A(Q_t), P_t^r)$.

Let $R^s{}_t$ be the supplier's *resale intention* in the sector, which indicates the degree to which the supplier is willing to "re-supply" the service at time t. Suppose that $R^s{}_t$ depends on the present and past performances (P_t, P_{t-1}) as well as the relative price of the service (P_t^r).

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[1] The introductory part of this paper benefits from the concise description of the literature presented by Kara (2006).

[2] The model is, in part, based on Kara (2006).

[3] Banks could provide multiple services, in which case x could be conceived as "a composite service" representing these combined services.

i.e., $R^s_t = f^s(P_t^r, P_t, P_{t-1})$.[4]

(The measurement of the variables R^p_t, R^s_t, P_t, $A(Q_t)$ are based on a questionnaire given in Kara (2006)).

For analytical purposes, we have assumed that the repurchase and resale intention have the following explicit forms:

$$\ln R^p_t = \alpha_0 + \alpha_1 \ln P_t + \alpha_2 \ln A(Q_t) + \alpha_3 \ln P_t^r + u_t$$

and

$$\ln R^s_t = \beta_0 + \beta_1 \ln P_t + \beta_2 \ln P_{t-1} + \beta_3 \ln P_t^r + v_t$$

where u_t and v_t are independent, normally distributed, white noise stochastic terms uncorrelated over time. They have zero means and variances, σ_u^2 and σ_v^2 respectively.

To theorize about the movements over time (i.e., the dynamic trajectory) of service performance, we will make an assumption, which is compatible with the logic of the market process: It is the relative strength (or magnitude) of the repurchase intention compared to the resale intention that provides the impetus for performance to be adjusted upwards over time.

Formally,

$$P_{t+1} / P_t = (R^p_t / R^s_t)^k \text{, where k is the coefficient of adjustment.}$$

Taking the logarithmic transformation of both sides, we get:

$$\ln P_{t+1} = \ln P_t + k (\ln R^p_t - \ln R^s_t).$$

We call this the dynamic adjustment equation. Substituting the functional expressions (forms) for $\ln R^p_t$ and $\ln R^s_t$ specified above, setting the values of $A(Q_t)$ *and* P_t^r to their average values $A(Q_t)^{avr}$ *and* P_t^{ravr}, and rearranging the terms in the equation, we get,

[4] The repurchase intention and resale intention equations could be obtained through utility maximization and profit maximization, respectively.

$$\ln P_{t+1} + (k\beta_1 - k\alpha_1 - 1)\ln P_t + (k\beta_2)\ln P_{t-1} = k(\alpha_0 - \beta_0 + \alpha_2 \ln A(Q_t)^{avr} + (\alpha_3 - \beta_3)\ln P_t^{ravr}) + k(u_t - v_t),$$

which is a second order stochastic difference equation, the solution of which yields the following for the intertemporal equilibrium performance, P^* :[5]

$$P^* = \exp\left\{ \frac{k(\alpha_0 - \beta_0 + \alpha_2 \ln A(Q_t)^{avr} + (\alpha_3 - \beta_3)\ln P_t^{ravr})}{k(\beta_1 + \beta_2 - \alpha_1)} + \frac{\lambda_1}{\lambda_1 - \lambda_2}\sum_{j=0}^{\infty}\lambda_1^j z_{t-j} + \frac{\lambda_2}{\lambda_2 - \lambda_1}\sum_{j=0}^{\infty}\lambda_2^j z_{t-j} \right\}$$

where $z_t = k(u_t - v_t)$

$$\lambda_1\lambda_2 = k\beta_2$$
$$\lambda_1 + \lambda_2 = 1 - k(\beta_1 - \alpha_1)$$

To study whether this intertemporal equilibrium performance is high or low, and whether it remains stable over time, we need to empirically estimate the parameters involved. This is done in the next section.

3. Empirical Analysis

a) **The sample**: Data for this study was gathered using a questionnaire distributed to the customers of banking services in the United States. 100 customers were asked to respond to questions about anticipated service quality, service performance, and their repurchase intentions concerning the banking services. One observation with considerable missing values was omitted. Each item was rated on a seven-point Likert scale with 1 indicating the lowest value and 7 indicating the highest value assigned by the customers.

[5] The solution could be obtained - and the stability of equilibria could be demonstrated - in a way similar to the one described in Kara (2006).

b) **Estimation of the parameters**: To estimate the parameters involved, we formulate the following regression equations:

$$\ln R^p_t = \alpha_0 + \alpha_1 \ln P_t + \alpha_2 \ln A(Q_t) + \alpha_3 \ln P_t^r + u_t$$

$$\ln R^s_t = \beta_0 + \beta_1 \ln P_t + \beta_2 \ln P_{t-1} + \beta_3 \ln P_t^r + v_t$$

where u_t and v_t are disturbance terms.

(i) Repurchase intention equation: For the subset of the sector under consideration, two points need to be made about resale intention. First, due to competitive pressures, the price of a service provided by one bank is close to that of another bank, rendering the ratio of those prices (i.e, the relative price) close to one. Thus, $P_t^r \cong 1$ and hence, $\ln P_t^r \cong 0$. Second, minimal anticipated quality and performance induce minimal repurchase intention, i.e., if $A(Q_t)=1$, $P_t=1$, and, by virtue of the previous argument, $P_t^r = 1$, then $R^p_t = 1$, which implies that $\alpha_0 = 0$. Thus, we get,

$$\ln R^p_t = \alpha_1 \ln P_t + \alpha_2 \ln A(Q_t) + u_t$$

The regression-results are as follows:

$$\ln R^p_t = \underset{(3.203)}{0.47} \ln P_t + \underset{(3.372)}{0.451} \ln A(Q_t)$$

$R^2 = 0.95$. t-statistics are given in parentheses. Thus,

$$\alpha_0 = 0$$
$$\alpha_1 = 0.47$$
$$\alpha_2 = 0.451.$$

(ii) Resale intention equation: For the reason explained above, P_t^r drops out of the log-linear formulation of the resale intention equation. To estimate the other parameters of the resale intention equation, we conjecture that the value of the elasticity of resale intention with respect to present performance is high and the elasticity of resale intention with respect to past performance is low. Mathematically, those elasticities are, of course, nothing but β_1 and β_2 respectively. Suppose that a 1% increase in the past performance would increase the resale intention by about 0.05 %, but a 1%

increase in the present performance would increase the resale intention by about 0.95%. Thus,

$\beta_1 = 0.95$
$\beta_2 = 0.05.$

As in the case of repurchase intention, minimal anticipated quality and performance induce minimal resale intention in this subsector, i.e., if $A(Q_t)$=1, P_t =1, and, by virtue of the previous argument, P_t^r = 1, then $R^s{}_t$ =1, which implies that β_0 =0.

(iii) The coefficient of adjustment (*k*): For simplicity, we have assumed that Q_{t+1} / Q_t is proportional to the ratio of repurchase intention to resale intention, and hence, $k = 1$.

Given the empirical values of the parameters obtained above, we get,

$\lambda_1 = 0.39$
and
$\lambda_2 = 0.13$

With all the needed parameter values at hand, the intertemporal equilibrium performance is:

$$P^* = \exp\left\{1.49 + 1.5\sum_{j=0}^{\infty} 0.39^j z_{t-j} - 0.5\sum_{j=0}^{\infty}(0.13)^j z_{t-j}\right\}$$

For analytical convenience, some of our analysis is carried out in terms of logarithmically transformed performance, ln *P,* rather than *P*. Since ln function is an order-preserving transformation, analysis in terms of ln *P* and *P* will yield the same qualitative results; and the quantitative results could be transformed into one another. The expected value of the logarithmically transformed intertemporal equilibrium performance is:

$$E(\ln P^*) = \left\{1.49 + 1.5\sum_{j=0}^{\infty} 0.39^j E(z_{t-j}) - 0.5\sum_{j=0}^{\infty}(0.13)^j E(z_{t-j})\right\}$$

Since, by virtue of the assumtions about u_t and v_t, $E(u_t) = 0$ and $E(v_t) = 0$, $E(z_t) = E(u_t)-E(v_t) = 0$. Thus,

E (ln P^*) = 1.49.

In view of the logarithmically transformed performance scale of ln1=0 to ln7 ≅ 1.95, an intertemporal equilibrium expected performance of 1.71 for the information-technology-based banking is moderately high. This high performance can be shown to be stable over time in the particular sense that it has a stationary distribution with a constant mean and variance.

This high service performance has a considerable effect on service satisfaction. To analyze the performance-satisfaction relationship in a formal manner, suppose that service satisfaction (S) depends on performance and anticipated service quality in the following way:

$$\ln S_t = \theta_1 \ln P_t + \theta_2 \ln A(Q_t) + u_{ts}$$

where S_t denotes service satisfaction at time t and u_{ts} is the disturbance term. The regression results based on the data available are as follows:

$$\ln S_t = \underset{(3.147)}{0.474} \ln P_t + \underset{(3.331)}{0.457} \ln Q_t$$

$R^2 = 0.95$. t-statistics are given in parentheses.

Given the the expected value of the logarithmically transformed intertemporal equilibrium performance, E (ln P^*) = 1.71, and setting the value of quality to its average value, we get

E(ln S^*) =1.50,

which is in the moderately high range, in view of the scale of ln1=0 to ln7 ≅ 1.95. Thus, the high expected intertemporal equilibrium performance of information-technology-based banking induced a high expected intertemporal equilibrium satisfaction in the US banking sector.

The following section will propose a stochastic managerial policy rule which enables the sector to reach higher performance-higher welfare levels and which minimizes fluctuations around those levels.

4. Managerial Policy Implications

Consider a demand-side stochastic shock to repurchase intention, in the magnitude of u_t, which may come, for instance, from expectations of crisis in the financial sector, and a supply-side stochastic shock to resale intention, which may come, for instance, from anticipations of financial difficulties in the near future. Let us design the following supply-side stochastic policy response (rule) and non-stochastic demand-side policy response:

$$R_s = \delta_1 u_t + \delta_2 v_t$$

$$R_d = \delta_3$$

where δ_1 , δ_2 and δ_3 are any real numbers. Suppose that there is target performance level P**, which is higher than the current level. The values of δ_1 , δ_2 and δ_3 that enable the firms to achieve P** in a "stable" ("minimally varying") manner can be obtained through minimizing the expected loss function $E[(P_t\text{-}P^{**})^2]$ at the intertemporal equilibrium. The numerical calculations will not be pursued here.[6]

5. Concluding Remarks

This paper theorizes about and exemplifies the possibility of moderately high performance-high satisfaction equilibria induced by information-based technology in the United States. There appear to be a number of managerial policy options that could help the sector to achieve even higher levels and stabilize the performance and satisfaction at those levels. The stochastic partial equilibrium analysis presented in this paper, however, allows a limited number of such options. A wider range of policy options could be designed in a stochastic general equilibrium (or disequlibrium) framework, which is worthy of future research.

[6] For examples of expected loss minimization in different contexts, see Kara (2006).

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