IMPACT OF TECHNOLOGY ON THE PERFORMANCE OF INDIAN COMMERCIAL BANKS: A CLUSTERING BASED APPROACH

K.R. Shanmugam[1] and Rakesh Nigam

Abstract

This study empirically analyzes the impact of technology on the financial performance of 50 banks in India during 2011-12 to 2016-17. It utilizes the Kmeans algorithm, a popular machine learning method for clustering data and develops a novel geometrical representation called the technology performance square, formed by lines of constant performance and technology to cluster the banks in different states of technology and performance. It also tracks the movement of banks across the different states by means of transition matrices from one year to the next.

Results indicate that in 2011-12, the technology has a positive impact on the performance of about 11 banks and most other banks clustered in the low technology and low performance state. One could also reason that with passage of time, the technology becomes cheaper and most of the banks can acquire the technology. Therefore, there is very little difference between most of the banks when it comes to technology. Hence there may not be any significant impact of technology on performance of the bank with passage of time.

Introduction

Globally, the technological development in the banking sector started in the 1950s with the installation of the first automated book keeping machine in banks. The automation in banking became widespread over the next few decades as bankers quickly realized that much of the labor intensive information handling processes could be automated using the computers. In 1967, Barclays Bank in UK introduced the first Automated Teller Machine (ATM) in the world, while IBM introduced the magnetic stripe plastic cards in 1969. Subsequently, banks in many counties including India invested huge capital on the Information and Communication Technology (ICT) solutions like ATM, internet banking, mobile banking, digital currencies, point of sale terminals, computerized financial accounting and reportingetc(Ovia, 2005).

e-banking or online banking is a notable development due to the internet availability.[2] It has enhanced the customer satisfaction by providing anywhere anytime banking and also enabled banks to reduce cost, increase penetration enhance the customer base, thereby improving their profits (Porteous and Hazelhurst, 2004).[3]

In India,the use of ICT in some private sector banks started in the late nineties. Initially, many viewed that the internet banking was insecure.However, internet banking grew faster in the 2000s because of initiatives of government and Reserve Bank of India (RBI), falling internet costs and

[1] Professors, Madras School of Economics

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[2] e-banking means a system through which financial service providers, customers, individuals and businesses are able to access their accounts, do transactions and obtain latest information on financial products/services from the public/private networks such as the internet. Using personal computers, ATMs and personal digital assistant (PDA), the customers can access e-banking services and do their transactions with less effort as compared to the branch based traditional banking.

[3] Bill Gates in 2008 announced that "banking is essential, banks are not".

increased awareness.[4]In 2012-13, the Indian banks deployed the technology-intensive solutions to increase revenue, enhance customer experience, optimize cost structure and manage enterprise risks.

Despite the recent NPAs stress, Indian banks work towards a Digital India. There exist wide variations in technology agendas and implementation capability across different players of bank industry.Further, the development of new products andbusiness practices has led to the emergence of new security risks like cybercrime, hacking etc. Thus, the evolving banking technology brings opportunities as well as challenges.

Therefore, many raise the question: what is the impact of IT onbanking performance? This question is not new. In fact, it began as a major literary trend in 1987 when Robert Solow, the Nobel Laureate in Economics, proposed his famous "*productivity paradox*"during his Nobel speech: "*You can see the computer age everywhere but in the productivity statistics!"*.[5]

Countless studies emerged in the UnitedStates and Europe emerged to provide varied explanations on this. Some of them show a negative impact of ICT on the performance of banks (Loveman (1994), Licht and Moch (1999), Oluwagbemi, Abah and Achimugu (2011) and Abubakar*et al.,*(2013)). Some others found a positive relation between IT investments and productivity of banks (Prasad and Harker, 1997) and a positive impact of e-banking on bank performance (Alawneh and Hattab, 2009).Studies by Sathye (2003), Mittal and Dhingra (2007) and Oyevole et al. (2013) showed no impact of IT investments and bank profitability. Thus, the results of the existing studies are mixed.

In India, there are not many studies on the topic. A few studies have highlighted the importance of customer satisfaction and the management of customer relations in the success of banking businesses (Singh (2004), Krishnaveni and Prabha (2006) and Mishra and Jain (2007). Malhotra and Singh (2006) found no significant impact ofinternet banking on the profitability of Indian commercial banks. However, Malhotra and Singh (2009)showed thatthe internet banks have better operating efficiency and profitability as compared to the non-internet banks.

Thus the results in existing studies vary due to the type of methodology employed (Data Envelopment Analysis, Stochastic Frontier techniques, Panel Data model techniques etc.), the data period, the usage of IT indicators and performance indicators (single, multiple, composite or discrete) etc. The lessonfrom them is that the relation of IT input(s) and bank performance is a tricky one. It needs proper metrics or quantification of these two set of prime indicators. Studies like Bansal (2015) made an attempt in this direction, but used some crude method to index them. Therefore, the present study is a step ahead to fill this gap in the literature. Specifically, itemploys the Kmeansclustering method (Bishop 2006), a popular algorithm from unsupervised machine learning for clustering data to construct the composite indices of ICT and bank performance and analyze the role of ICT on the performance of 50 scheduled commercial banks in India during 2011-12 to 2016-17. To our knowledge this is the first study in applying themachine learning technique to analyze the impact of ICT on banking performance.

[4]Indian banks continuously invested on digital banking (DB). Key innovations in DB are: Digital-only/Virtual Banking, Biometric Technology, Artificial Intelligence (AI), Block Chain Technology, Bitcoin and Robotics. The digital-only bank provides end-to-end services through digital platforms like mobile phones, tablets and internet. It is paperless, branchless and signature-less banking offering 24*7 services to its customers. The biometric authentication provides simple and secure banking experience to its customers. In India, only large banks introduce AI in their services. The key components of AI are machine learning, computer vision and natural language processing. The use of robotics in the Indian banking sector is not yet widespread. Robotics is expected to automate processes which are repetitive, rule based and require less human judgment.

[5]Basel Committee on Banking supervision also remarked that "Financial innovations generated by technologies that can lead to the creation of new business models, applications, processes or products, will subsequently affect the financial markets, institutions or the production of financial services".

The paper is organized as follows. Section 2 gives a short note on the Indian banking industry and its technology adoption. Section 3 provides a brief review of literature. Section 4 explains the data, variables and methodologyused in this study. While Section 5 presents and discusses the empirical results, Section 6 provides the concluding remarks and policy implications.

Banking and Technology in India

In India, banking as an institution originated in the late 18th century and primarily catered to needs of the British. The nationalization of major private banks in 1969 was an important milestone in the banking system, whichmadebanking accessible to the unbanked population of India.

The Indian banking sector comprises Scheduled commercial banks (SCBs), cooperative banks, regional and rural banks (RRBs) and local area banks. The SCBs account for nearly 95 percent of the banking system assets. The SCBs in turn comprise of (i) public sector banks, which include the nationalized banks (majority equity holding being with the Government) and the State Bank of India (SBI) and its associate banks (majority holding being with SBI), (ii) private domestic (old and new) banks and (iii) private foreign banks.

The public sector banks acquired a place of prominence in the financial intermediation process over the years. They made significant strides in expanding geographical coverage, mobilizing savings and providing funds for investments in agriculture/small-scaleindustry. Tremendous progress was achieved within a highly regulated environment with interest rates, credit allocation and entry being controlled by the RBI. However, during the late 1980s, most banks were plagued with poor profitability and under capitalization with a high proportion of non-performing assets and huge administrative expenditures.They lagged behind the international standards in introducing computers, communication technologies and product innovations and the quality of consumer service was unsatisfactory (Shanmugam and Das, 2004).

Government of India set up the Narasimham Committee to review the functioning of the entire financial services industry in the country. Based on the recommendations of the committee (submitted in November 1991), the RBI initiated major reform/liberalization measures that sought to improvebanking efficiency through entry deregulation, branch de-licensing and deregulation of interest rates, and to allow public sector banks to raise their equity in the capital market. The reform also sought to improve banking profitability through gradual reduction of cash reserve ratio, statutory liquidity ratio and relaxation of several quantitative restrictions on the composition of selected portfolios.

The economic liberalization in the early 1990s ushered an era of privatization where in many new private banks-the new generation tech-savvy banks-were launched. A few foreign banks commenced their India operations as well. All these banks were quick to leverage the emerging technology and were competitive in attracting customers. This helped infuse a sense of urgency in the public sector as well as the old private banks to mend their ways, which in turn completely revitalized banking operations in India.

After the initiation of financial liberalization process in 1991-92, the Indian banking system has undergone significant changes.[6]It has adopted the international best practices. Several prudential

[6] With deregulation of the interest rate, the Indian Banking system has become more market oriented since 1991.

and provisioning norms have been introduced and these norms pressurize banks to improve their efficiency and trim down their Non-Performing Assets (NPAs) to improve the financial health of the banking system.

With their major role in credit intermediation process, payment and settlement system and monetary policy transmission, and additional responsibility of achieving the Government's social agenda, the banking industry acts as a catalyst for the economic development of the country.[7]In spite of various acts promulgated by the Government of India and guidelines passed by the RBI, the NPAs continue to increase in the Indian Banking sector. The state-run banks are on the verge of a crisis due to their high NPAs which constitute over 90 percent of the total bad loans of the industry. Many of them have reported losses on account of high NPAs. 9 out of 10 most stressed banks are government banks.[8] The RBI gave a deadline of March 2017 for all banks to clean up their balance sheets which also require their lenders to set aside a huge chunk of capital in the form of provisioning.[9]

In the Indian banking industry, the foremost breakthrough started with the use of Advanced Ledger Posting Machines (ALPM) in 1980s. In late 1980s,theTotal Bank Automation (TBA) was introduced, followed by the establishment of mechanized cheque processing systems, using the Magnetic Ink Character Recognition (MICR) technology (Bansal, 2015).Consolidation of IT based effortsin banks happened in 2006-07. Theseefforts include the establishment of data centers, a shift towards centralized systems and large scale implementation of core banking systems across bank branches. The Payment and Settlement Systems (PSS) Act was also legislated in December 2007. The RBI has authorized the payment system operators of pre-paid payment instruments,card schemes, cross-border in-bound money transfers, ATM networks andcentralized clearing arrangements. These efforts have resulted in deeper acceptance and penetration of non-cash payment modes in India.

Brief Review of Literature

Globally,the banking sector has made a massive investment on technology. However, the impact of technology on banking performance is still a paradox. While numerous studies on the topic have emerged, theirfindings produce conflicting results. Some have shown positive impact,while others have shown a negative impact and some others have indicated no impact. We briefly review some of these (but selective) studies below.

(i) Studies on Positive Impact of ITC

- Parsons, Gotlieb and Denny (1993) using the translog cost model show a 17-23 percent increase in productivity due to IT use in Canadian banking industry during 1974-1988.

- Leckson and Leckey (2011) find that use of IT levelsin banksin Ghana increased their profitability.
- Malhotra and Singh (2009) show that during 1998-2005 the internet banks are larger banks and have better operating efficiency and profitability as compared to the non-internet banks in India.Uppal (2011)also shows that the growth of ICT led to high bank performance in various bank groups in India during 2008 –09.

[7] Commercial banks improve allocation of resources by lending money to priority sectors of the economy. They also provide finance to the infrastructure and support the economic growth.

[8]Finance Ministry's 2015-16 Annual Report reveals that Gross NPAs of banks could soar to 6.9 percent by March 2017 in a severe stress scenario.

[9]In his monetary policy speech, Dr.RaghuramRajan, then Governor of RBI also suggested to sell NPAs to asset reconstruction companies to clean up their balance sheets to keep moving forward.

- Aghdassi (2008) shows that the bank manager's performance through e-banking is quite positive and effective in Iran.
- Betterymarch (2003) uses a panel of 600 Italian banks during 1989-2000 and employs the stochastic cost and profit frontier functions approach to show that both cost and profit frontier shifts are strongly correlated with IT capital accumulation.
- Alawneh and Hattab (2009) assess the value of e-business in Jordanian banks using survey data collected from 140 employees in seven pioneered banks and find that e-banking has a significant positive influence on bank performance. Akram and Hamdan (2010) using the regression model also shows a significant positive impact of ICTonthe Market Value Added (MVA), Earning Per Share (EPS), Return on Assets (ROA) andNet Profit Margin (NPM) of Jordanian banksduring 2003–07.
- Jun (2006) finds a significant positive association between the IT adoption and the financial performance of Korean banks.
- Madume (2010) analyses the impact of ICT on the productivity of the Nigerian banking sector using CAMEL and the translog production function and shows that bank outputs (loans and other assets) increase significantly due to increased expenditure on ICT. Evans (2008) also shows a significant positive impact of ICT on banking operations in Nigeria.
- Shaukat (2009) examines the impact of IT investments on profitability and employee productivity in the Pakistani banking sector during 1994-2005 and finds a positive impact of IT on the banking performance. Muhammad and Muhammad (2010) uses the regression and ratio analysis and primary data collected through in-depth interviews and field surveys, and finds a positive impact of ICT on the performance 24 banks in Pakistan during 1994-2005.
- Hernando and Nieto (2005) examine the performance of banks in Spain between 1994 and 2002 and find higher profitability due to the use of internet banking.
- Using panel data methodology, Deyoung (2006) finds that IT has a positive impact on banks' profitability in UK through several factors such as reducing labor andtransactions costs.

- By regressing the bank's ROE on a set of controlled variables including an explanatory binary variable for the presence or absence of internet banking, Carlson et al., (2001) finds a positive impact of internet banking.Lin (2007) also supported this finding. Ekata (2012) shows that the technological change lowered the real costs by about 1 percent per year, increased the cost, minimizing the scale of outputs and affected the product mix of US commercial banks.

(ii) Studies on Negative Impact of ITC

- Beccalli (2006) uses the data from 737 banks during 1993- 2000 in France, Germany, Italy, Spain and United Kingdom and finds no significant relationbetween the IT (measured in hardware cost, software costs and services cost) and the profitability (measured in ROA and ROE).
- lgado et al. (2006) use data from 15 primarily internet banks (PIBs) and 335 Traditional banks during 1994-2002 for Euro Countriesand find a lower profitability of PIBs as compared to newly chartered non-Internet banks.
- Shirley and Mallick (2008) test the cost effect and the network effect of IT by applying a differentiated model to 68 US banks using 20 years data. They concluded that bank profits declined due toadoption anddiffusion of IT investment, reflecting negative network effect in this industry.
- Abubakar*et al.,*(2013) study the impact of ICT on banks performance in Nigeria during 2001-2011 usingthe fixed and the random effects models and show a negative impactof ICT on banks performance.

- Likewise, studies such as Al-Smadi and Al-Wabel (2011) Brynjolfsson and Hitt (1996), Loverman (1994), Morrisson and Brendt (1990), Licht and Moch (1999), Siegel and Griliches (1992), and Oluwagbemi, Abah and Achimugu (2011) show a negative impact of ICT on the banking performance in various nations.

(iii) Studies on No Impact of ITC

- Egland et al. (1998) was the first study to show no impact of internet banking on the performance of banks in US.
- Loveman(1994) also shows an insignificant contribution ofIT expenditure on the output of US banks. Prasad and Harker (1997) too indicate that no real benefits accrued due to additional investments in IT in US retail banking sector.
- Sathye (2005) shows that similar to the results of Sullivan (2000), internet banking variable is not significantly associated with the performance as well as with the operating risk variable of banks in Australia.
- Mittal and Dhingra (2007) who evaluate the impact of computerization on the performance of Indian banks using the DEA find that the benefits of computerization in boosting productivity and performance of banks is difficult to quantify.
- Oyevole et al. (2013) finds a positive impact of ITC on ROA and NIM of banks in Nigeria during 1999-2010, but no impact on ROE.
- Wadud (2016) uses the data for 30 commercial banks listed in the Dhaka Stock Exchange and shows that the impact of technology on the performance of commercial banks in Bangladesh is mixed.

While the results of the above studies are mixed, none of themhave employed amachine learning technique.

Data, Variables and Methodology

This study usesthe secondary data taken from the RBI website. While the performance indicator variables areavailable for almost all commercial banks in India, we restrict our analysis to 50 Banks for the period 2011-12 to 2016-17 due to the non-availability/missing data of technology indicators.Since the annual data on technology indicator variables are not directly available, they are computed using their monthly figures. We have compiled the bank wise and year wise monthly data on (i) number of debit cards issued outstanding (after adjusting the number of cards withdrawn/cancelled), (ii) number of financial transactions using the debit cards at ATMs, (iii) amount (or volume) of transactions with the debit cards at ATMs , (iv) number of transactions using the debit cards at Point Of Sale (POS) and (v) amount of transactions using the debit cards at POS from the website:https://www.rbi.org.in/Scripts/ATMView.aspx). Adding the respective data for the financial year, i.e., from March to April, we get the annual figures for these variables.

The monthly data on the National Electronic Funds Transfer (**NEFT**)data of respective banks are drawn from the RBI's website: https://www.rbi.org.in/Scripts/NEFTView.aspx. Bank wise and year wise annual data on(i) the number of NEFT transaction and (ii) the volume of transaction (by adding outward and inward transactions data) are computed using the monthly series as explained above. Bank wise and year wise annual data on performance indicators: Return on Assets (ROA), Return on Equity (ROE) and Net Interest Margin (NIM)are drawn directly from RBI's statistical tables relating to banks in India available in https://dbie.rbi.org.in/DBIE/dbie.rbi?site=publications#!4. Table 1 shows the descriptive statistics of the study variables and their definitions.

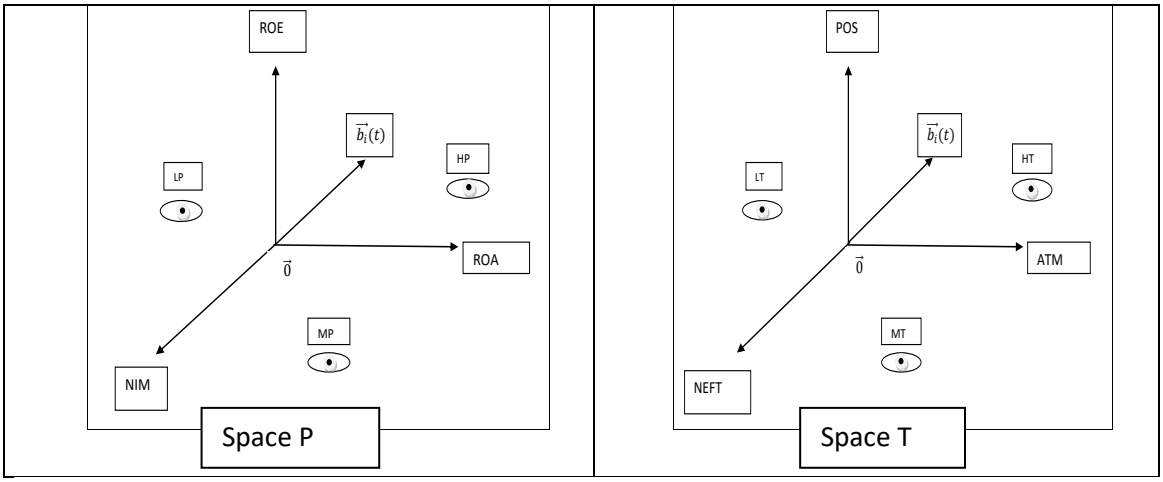
Table 1: Descriptive Statistics (means) of the Study Variables

Variables	Definition	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
NDC	No. of Debit Cards	5544892	6600497	7859693	11034654	13066664	15229358
NDCT (ATM)	No.of Debit Card Transactions in ATMs	100951861	105699335	120305613	139283222	157023721	181803140
NDCT (POS)	No. of Debt Card Transactions in POS	6519678	9299742	12378748	16064210	23454036	47713573
ADCT (ATM-Rs. Million)	Amount of Debit Card Transaction in ATMs	278106	332471	389639	442261	506550	464667
ADCT(POS)-Rs. Million)	Amount of Debit Card Transaction in POS	887	14785	18882	24124	31799	65589
NDT (NEFT)	Number of NEFT Transactions	8787766	15325096	25499163	35401896	47575006	61408223
ADT (Neft-Rs. Million)	Amount of NEFT Transactions	264220	1199774	1219883	2187033	3045820	4407237
ROA	Return on Assets	1.14	1.04	0.77	0.78	0.29	0.21
ROE	Return on Equity	14.23	13.51	9.05	8.36	1.35	-0.80
NIM	Net Interest Income Margin	2.90	2.84	2.76	2.70	2.70	2.53

It is noticed that the mean values of number of debit cards transactions through ATMs (NDCT – ATM), through point of sale (NDCT – POS) and thorough NEFT continuously increased over the years. Similarly the average values of the amounts of transactions through ATM, POS and NEFT increased over the years. However, the mean values for ROA, ROE and NIM decreased over the years due various reasons including the NPAs issues, low growth of economy, etc.

As stated earlier, this study uses the Kmeans cluster analysis in which the sample 50 banks in the set B = {b1, b2, …, b50} are represented as points in a 3-dimensional performance (profitability) space P(as shown in Figure 1). Each bank has 3 coordinates namely,three performance indicators ROA, ROE, and NIM. So in the space P, the i^{th} bank is represented as b_i = (ROA, ROE, NIM).The 50 banks in the space P are clustered into 3 clusters using the Kmeans clustering algorithm. Cluster 1 consists of banks that are consistently high in 3 coordinates: ROA, ROE and NIM. We therefore label the cluster 1 as high performing (HP), the cluster 2 as medium performing (MP) and the cluster 3 as low performing (LP). The set of performance clusters is denoted as C_P = {HP, MP,LP}.To capture the temporal behavior, b_i is a function of time t and is written as: $b_i(t)$, with t = 1,2,3,4,5,6 time period represented by 2011-12, 2012-13, 2013-14, 2014-15, 2015-16 and 2016-17 respectively.

Figure 1: 3-D Financial Performance Space P and Technology Space T (with 3 Clusters (HP,MP,LP) &ithBank$b_i(t)$)



The space P is complemented by a 3-dimensional technological space T(in Figure 1), where each bank has 3 coordinates namely: Amount of Debit card transaction at ATM per transaction (denoted as ATM), Amount of POS per POS transaction (denoted as POS) and Amount NEFT transaction per on-line transaction (denoted as NEFT). These are the technology indicators used in this study. In the space T, the ith bank is represented as $b_i(t)$ = (ATM, POS, NEFT). As stated above, we have similarly clustered the 50 banks into 3 clusters using Kmeans in the space T, with cluster 1 representing banks where ATM, POS and NEFT are consistently high. The cluster 1 is labeled as HT for high technology. Similarly, the cluster 2 is labeled MT for medium technology and the cluster 3 is LT for low technology. The set of technology clusters is C_T = {HT, MT, LT}

The advantage of this procedure is that we have decoupled the 3 performance indicators (ROA, ROE, NIM) from the 3 technology indicators (ATM, POS, NEFT). Now consider any bank say $b_i(t)$, it will be in any one of the performance clusters and any one of the technology clusters. For example if $b_i(t)$ is in performance cluster HP and technology cluster LT, it will be labeled as (HT, LP) = (1, 3). This procedure leads to 3x3 = 9 states: S_1 = (HT, HP), S_2 = (HT, MP), S_3 = (HT, LP), S_4 = (MT, HP), S_5 = (MT, MP), S_6 = (MT, LP), S_7 = (LT, HP), S_8 = (LT, MP) and S_9 = (LT, LP). The set of these 9 states is S = {S_1, S_2, S_3, S_4, S_5, S_6, S_7, S_8, S_9} = C_T x C_P, the Cartesian product of the two cluster sets in the spaces T and P.

Each bank in a given year t is in any one of the 9 states. Each state is a composite of the performance and technology characteristic. This method is useful in studying the trajectory of any particular bank bi(t). For example, bi in year 1 is bi(1) is in state S_2, bi in year 2 is bi(2) is in S_4, bi(3) is in S_2, bi(4) is in S_8, bi(5) is in S_6, bi(6) is in S_2. The trajectory of bi(t) is (S_2, S_4, S_2, S_8, S_6, S_2) in the 6 year period.

This approach, thus, provides 9x9 transition matrices-TM (Grimmett andStirzaker, 2001). The (i,j)th entry of a one period TM represents a transition from state S_i at time t to state S_j at time t+1, with i,j = 1,..,9. This entry can represent the set of banks with this property or it can represent the number of banks with this property. This concept can be extended to multi-period transition matrices for example from state S_i at time t = n to state S_j at time t = n+k. This will now represent a k period TM.

Kmeans Algorithm for Clustering: Kmeans is a popular method from unsupervised machine learning for clustering data comprising of several features. The features bring dimensionality to the data. In this study, we specify the number of clusters as 3 for both spaces. The Kmeans algorithm starts by randomly assigning the 50 banks to 3 random clusters, whose means are then computed. The Euclidean distance of each bank from the 3 cluster means is then computed and the bank is assigned to a cluster by virtue of its distance from the respective cluster mean. A bank is assigned to the cluster with the smallest distance. The clusters are then updated and their means re-computed. This process is repeated until all the clusters are stable, that is, there is no movement of banks among clusters in subsequent iterations. to create using an iterative process. Each observation is assigned to the group whose mean is closest, and then based on that categorization, new group means are determined. These steps continue until no observations change groups.

Representation of States:The 9 states can be represented as two dimensional points (x,y) with the X-axis representing the technology and Y-axis representing the performance with the mapping that HP = HT =1, MP=MT=0, LP=LT=-1. This leads to S_1 = (HP, HT)=(1,1), S_2 =(HT, MP) = (1,0), S_3 =(HT, LP) = (1,-1), S_4 =(MT, HP) = (0, 1), S_5 = (MT,MP) = (0,0), S_6 = (MT,LP) = (0, -1), S_7 =(LT,HP) = (-1,1), S_8 = (LT,MP) = (-1,0) and S_9 =(LT, LP) = (-1,-1). To see the impact of technology on performance, we identify banks lying in the first quadrant I (x >=0, y >=0) that are in states S_1,S_2,S_4,S_5, while for banks lying in the second quadrant II (x <=0, y >0) are in states S_7,S_8 and banks in IV quadrant (x>=0,y<0)are in states s3,s6; there is no impact of technology on performance (see Figure 2). In quadrant III (x < 0, y <0) the banks are both low in technology and low performance. In short all the banks lie on a square of length 2 with the banks performing medium in both technology and financial performance lie on the origin and other banks lie on the lines of constant performance and constant technology called the isolines as seen in Fig.2 This is a geometrical object called the technology performance square.

Empirical Results

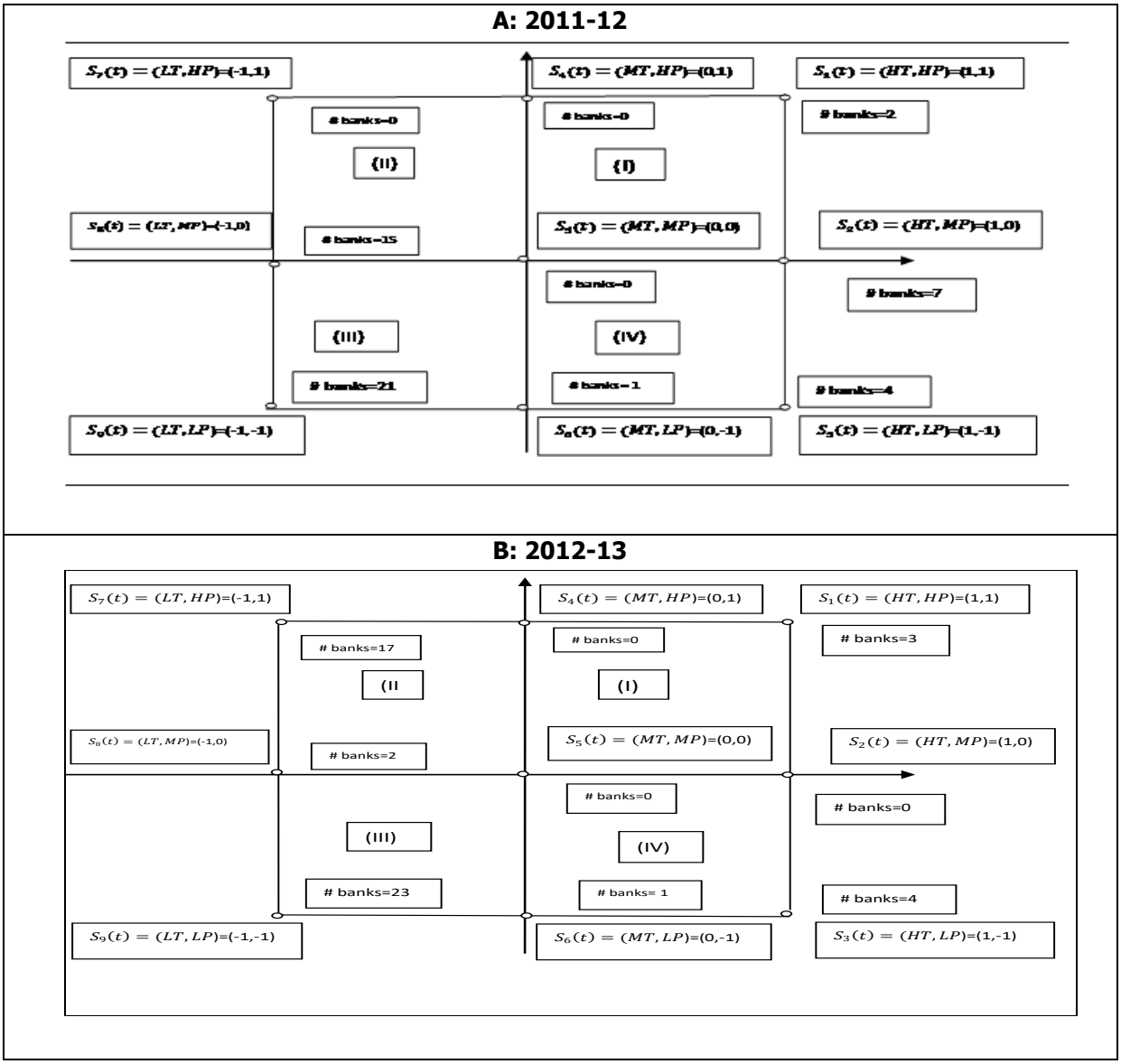
In Figure 2 (A-F), we capture the collective behavior of the 50 banks as to whether technology affects the financial performance during 2011-12 to 2016-17.In 2A for the year,2011-12, 2 banks b7 and b18 are in state S1, hence for these banks, the technology affects performance (positively). We also note that along the constant HT side of the square involving states S_1, S_2 and S_3,we see that there are 2 banks in the S_1 state, 7 banks in S_2 and 4 in S_3. This shows that technology selectively affects the performance of some banks. It is interesting to note that there are 15 banks in state S_8 and 21 in S_9. As S_8 and S_9 are low technology states, the technology does not have any impact on the performance of these banks. There are 11 banks in the HT isoline of the square and 36 banks in the LT insoline.

In Figure 2B for 2012-13, 3 banks b11, b26, b35 are in S_1 and 4 banks were in S_3, which shows at a collective level technology is not affecting performance. There are 23 banks in the S_9 state, which is low for both technology and performance, while in state S_7 which is connected to S_9 by the LT side of the square there are17 banks. These 23 + 17 = 40 banks are low in technology but their performance ranges from high to low. In this period we have 7 banks in the HT isoline and 42 banks in the LT isoline.

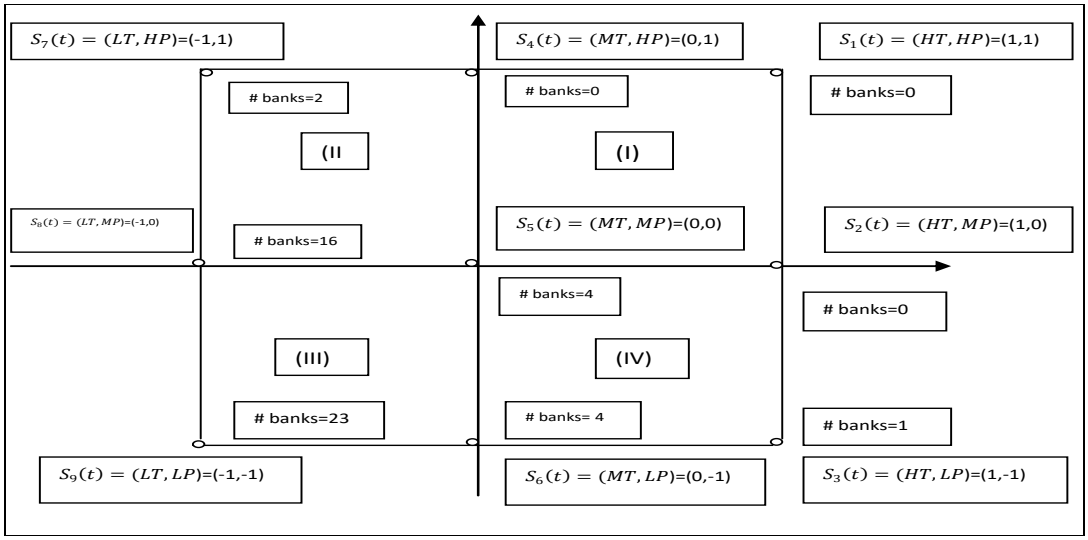
In Figure 2 C for 2013-14, we do not see any appreciable impact of technology on performance. In this period majority of the banks are low to medium performing in the low technology state that is states S_8 and S_9.Here we have 8 banks in the MT isoline and 41 in the LT isoline. In Figure 2D for 2014-15, the status of banks are more or less similar to that for 2013-14. For

2015-16 year seen in Figure 2 E, there are 2 banks b7,b14 in state S_2, 6 banks in state S_5 that are medium in technology and performance and majority of the banks on the LT isoline in states S_7, S_8 and S_9. In Figure 2 F which represents the 2016-17 year, bank b7 is in S_2 and most of the banks lie on the LT isoline.

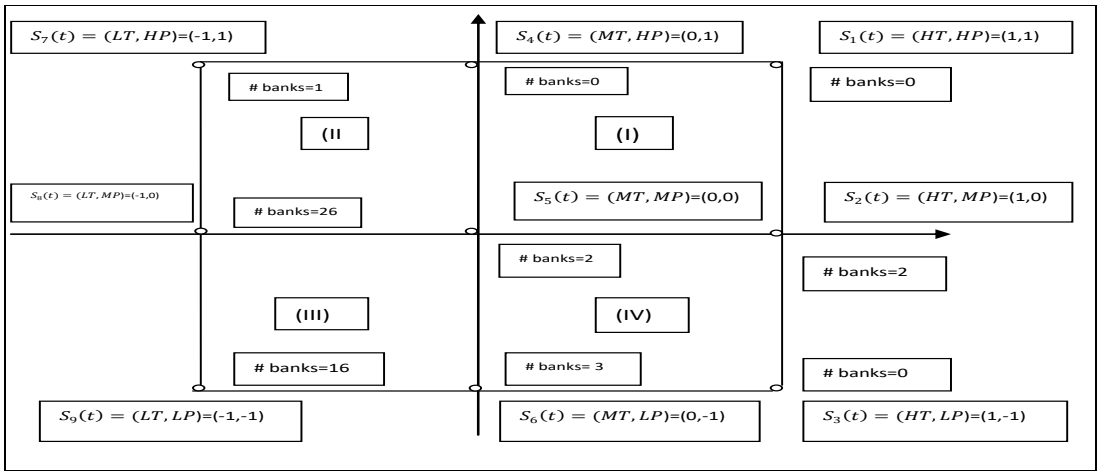
Fig. 2: Number of Banks in Different States for the Years 2011-12 to 2016-17



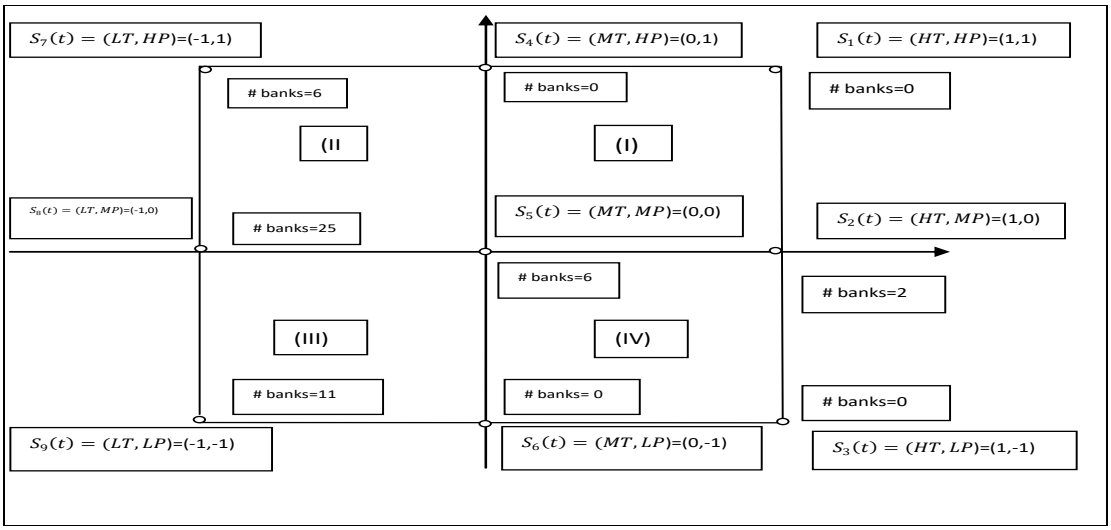
C: 2013-14

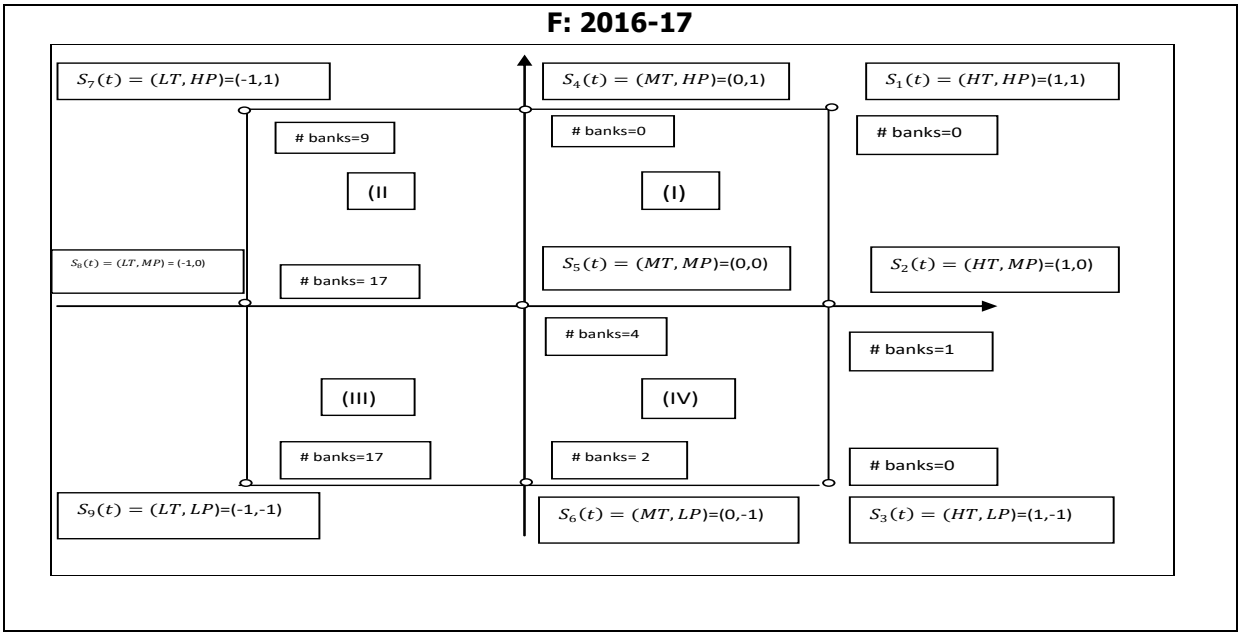


D: 2014-15



E: 2015-16





From Table 3, we see there is impact of technology on performance for b7 as it is in state S_1 or S_2 in 4 out of the 6 years. From 2014-16 both b7 and b14 were in state S_2 on the HT isoline. Hence there is some indication that technology had some affect on the financial performance for these banks. In 2011-12, there were about 9 banks in the S_1 and S_2 states on the HT isoline that performed well, and there was impact of technology on these banks.

Table 2: Transition Matrices for the Six year period (2011-12 to 2016-17)

Transitions from 2011-12 to 2012-13

State	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9
S_1	0	0	0	0	0	1	0	1	0
S_2	2	0	0	0	0	0	2	0	3
S_3	1	0	**3**	0	0	0	0	0	0
S_4	0	0	0	0	0	0	0	0	0
S_5	0	0	0	0	0	0	0	0	0
S_6	0	0	1	0	0	0	0	0	0
S_7	0	0	0	0	0	0	0	0	0
S_8	0	0	0	0	0	0	**9**	0	6
S_9	0	0	0	0	0	0	**6**	**1**	**14**

Transitions from 2012-13 to 2013-14

State	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9
S_1	0	0	0	0	0	0	0	3	0
S_2	0	0	0	0	0	0	0	0	0
S_3	0	0	0	0	0	1	0	0	3
S_4	0	0	0	0	0	0	0	0	0
S_5	0	0	0	0	0	0	0	0	0
S_6	0	0	0	0	0	1	0	0	0
S_7	0	0	0	0	4	0	0	**13**	0
S_8	0	0	0	0	0	0	2	0	0
S_9	0	0	1	0	0	2	0	0	**20**

Transitions from 2013-14 to 2014-15

State	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9
S_1	0	0	0	0	0	0	0	0	0
S_2	0	0	0	0	0	0	0	0	0
S_3	0	0	0	0	0	0	0	1	0
S_4	0	0	0	0	0	0	0	0	0
S_5	0	0	0	0	0	0	0	1	3
S_6	0	2	0	0	0	0	0	2	0
S_7	0	0	0	0	0	0	1	1	0
S_8	0	0	0	0	1	1	0	**4**	**10**
S_9	0	0	0	0	1	2	0	**17**	**3**

Transitions from 2014-15 to 2015-16

State	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9
S_1	0	0	0	0	0	0	0	0	0
S_2	0	2	0	0	0	0	0	0	0
S_3	0	0	0	0	0	0	0	0	0
S_4	0	0	0	0	0	0	0	0	0
S_5	0	0	0	0	2	0	0	0	0
S_6	0	0	0	0	3	0	0	0	0
S_7	0	0	0	0	0	0	1	0	0
S_8	0	0	0	0	0	0	**4**	**12**	**10**
S_9	0	0	0	0	1	0	1	**13**	1

Number of Transitions from 2015-16 to 2016-17

State	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9
S_1	0	0	0	0	0	0	0	0	0
S_2	0	1	0	0	0	1	0	0	0
S_3	0	0	0	0	0	0	0	0	0
S_4	0	0	0	0	0	0	0	0	0
S_5	0	0	0	0	**4**	1	0	1	0
S_6	0	0	0	0	0	0	0	0	0
S_7	0	0	0	0	0	0	1	1	4
S_8	0	0	0	0	0	0	**6**	**15**	**4**
S_9	0	0	0	0	0	0	**2**	0	**9**

Note : s1= HT, HP; s2= HT, MP; s3= HT, LP; s4= MT, HP; s5= MT, MP; s6= MT, LP; s7= LT, HP; s8= LT, MP; s9= LT, LP.

As seen in Tables 2-3 majority of the banks transitioned among the states S_8 and S_9 which lie on the LT isoline. This suggests that technology has very little impact on performance for these banks.

Table 3: Individual Banks in Different States during 2011-12 to 2016-17

	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
S_1	b7, b18	b11,b26,b35				
S_2	b1,b15,b26, b27,b35,b3, b42			b7,b14	b7,b14	b7
S_3	b11,b16,b21 , b37	b14,b16,b 21,b37	b9			
S_4						
S_5			b29,b36, b38, b39	b21,b35	b11,b16,b21, b26,b35,b37	b11,b16,b21, b37
S_6	b14	b7	b7,b14,b15, b33	b11,b16,b37		b14,b35
S_7		b3,b4,b12, b17,b19,b20, b22,b27,b29, b30,b31,b36, b38,b39,b44, b46,b50	b18,b48	b18	b5,b9,b18, b20 b25,b46	b6,b23,b25, b27b38,b39, b41,b42,b43
S_8	b2,b3,b4,b1 2, b13,b20,b24 , b29,b34,b36 , b39,b40,b44 , b45,b50	b18,b48	b3,b4, b11, b12, b17, b19, b20, b22,b26, b27, b30, b31, b35,b44,b46, b50	b1,b2,b4, b5,b6,b8,b9, b10,b13,b15 ,b23,b24,b2 5,b27,b31,b 32,b33,b34, b36,b41,b42 ,b43,b46,b4 7,b48,b49	b2,b3,b6, b12,b17,b19, b22,b24,b27, b28,b29,b30, b31,b32,b33, b36,b38,b39, b40,b41,b43, b45,b47,b49, b50	b3,b12, b17,b19,b20, b22,b24,b26, b28,b29,b30, b31, b36,b40, b45,b49,b50
S_9	b5,b6,b8,b9, b10,b17,b19 , b22,b23,b25 , b28,b,30,b3 1, b32,b33,b41 , b43,b46,b47 , b48,b49	b1,b2,b5, b6,b8,b9, b10,b13,b15, b23,b,24,b25 b28,b32,b33, b34,b40,b41, b42,b43,b45, b47,b49	b1,b2,b5,b6, b8,b10,b13, b16,b21,b23, b24,b25,b28, b32,b34,b37, b40,b41,b42, b43,b45,b47, b49	b3,b12,b17, b19,b20,b22 ,b26,b28,b2 9,b30,b38,b 39,b40,b44, b45,b50	b1,b4,b8, b10,b13,b15, b23,b34,b42, b44,b48	b1,b2,b4,b5, b8,b9,b10, b13,b15,b18, b32,b33,b34, b44,b46,b47, b48

In order to check the robustness of our results, we have also an econometric exercise. For each bank in each year we have computed a composite performance index (P_i) using the Euclidean norm formula: $P_i = \sqrt{ROA^2 + ROE^2 + NIM^2}$ and a composite technology index (T_i): $T_i = \sqrt{ATM^2 + POS^2 + NEFT^2}$. Then we estimate the following standard panel data model equation to analyze the impact of technology on bank performance: $P_{it} = \beta_0 + \beta_1 T_{it} + \lambda_i + \mu_t + \epsilon_{it}$, where λ is

individual bank effect, μ- time effect and ϵ -stochastic error term. As the Hausman statistics, Lagrangian multiplier statistics and Chow test results support the two way random effects model, the estimation is estimated using the feasible GLS procedure and results are shown in Table 4. The technology index has a negative but not a significant coefficient. Therefore, the technology does not play a role on banking performance.

Table 4: 2 way Random Effects Model Estimation Results of Performance Equation

Variables	Coefficient (t value)
Technology Index (T_{it})	-0.00001 (1.357)
Time Effect	Included
Individual Effect	Included with Error
Hausman Statistics	1.98
LM Statistics	29.08
R Square	0.0748
N	300

Conclusions

We have used a clustering based approach from machine learning to study the impact of technology on the performance of 50 Indian banks during 2011-12 to 2016-17. We have developed a geometrical representation, the technology performance square that gives a snapshot of the different technology performance states of the banks in a given year. In 2011-12 we find that there is positive impact of technology on the performance of about 9 banks. It is also seen that in tow more banks, banks b7 and b14, there may be a positive impact of technology. It is also observed that there are many banks in the low technology and low performance state. One could also reason that with passage of time, the technology becomes cheaper and most of the banks can acquire the technology. Therefore, there is very little difference between most of the banks when it comes to technology. Hence there may not be any significant impact of technology on performance of the bank with passage of time.

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Appendix

Transition of Banks from 2011-12 to 2012-13

State	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9
S_1	-	-	-	-	-	b7	-	b18	-
S_2	b35,b26	-	-	-	-	-	b27,b23	-	b1,b15, b42
S_3	b11	-	b16,b37,b21	-	-	-	-	-	-
S_4	-	-	-	-	-	-	-	-	-
S_5	-	-	-	-	-	-	-	-	-
S_6	-	-	b14	-	-	-	-	-	-
S_7	-	-	-	-	-	-	-	-	-
S_8	-	-	-	-	-	-	b3,b4,b12, b20,b29,b36 b39,b44,b50	-	b2,b13,b24, b34,b40,b45
S_9	-	-	-	-	-	-	b17,b19,b23, b30,b31,b46	b48	b5,b6,b8, b9, b10, b22, b25,b28,b32, b33, b41, b43, b47,b49

Transition of Banks from 2012-13 to 2013-14

State	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9
S_1	-	-	-	-	-	-	-	b11,b26, b35	-
S_2	-	-	-	-	-	-	-	-	-
S_3	-	-	-	-	-	b14	-	-	b16,b2,b37
S_4	-	-	-	-	-	-	-	-	-
S_5	-	-	-	-	-	-	-	-	-
S_6	-	-	-	-	-	b7	-	-	-
S_7	-	-	-	-	b29,b36, b38,b39	-	-	b33,b4,b12, b17, b19, b20,b22, b27, b30,b31, b44, b46, b50	-
S_8	-	-	-	-	-	-	b18,b48	-	-
S_9	-	-	-	-	-	b15,b33		b48	b1,b2,b5,b6, b8,b9,b10,b13, b23,b24,b25,b28, b32,b34,b40,b41, b43, b45,b47,b49

Transition of Banks from 2013-14 to 2014-15

State	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9
S_1	-	-	-	-	-	-	-		-
S_2	-	-	-	-	-	-	-	-	-
S_3	-	-	-	-	-	-	-	b9	-
S_4	-	-	-	-	-	-	-	-	-
S_5	-	-	-	-	-	-	-	b36	b29,b38,b39
S_6	-	b7,b14	-	-	-	-	-	b15,b33	-
S_7	-	-	-	-	-	-	b18	b48	-
S_8	-		-	-	b35	b11	-	b4,b27, b31,b46	b3,b12,b17,b19,b20, b22,b26,b30,b44, b50

S_9	-	-	-	-	b21	b16,b37	-	b1,b2,b5, b6, b8, b10, b13,b23,b24, b25,b32,b34,b41, b42,b43,b47,b49	b28,b40, b45

Transition of Banks from 2014-15 to 2015-16

state	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9
S_1	-	-	-	-	-	-	-		-
S_2	-	b7,b14	-	-	-	-	-	-	-
S_3	-	-	-	-	-	-	-	-	-
S_4	-	-	-	-	-	-	-	-	-
S_5	-	-	-	-	b21,b35	-	-	-	-
S_6	-	-	-	-	b11,b16, b37	-	-	-	-
S_7	-	-	-	-	-	-	b18	-	-
S_8	-	-	-	-	b35	-	b5,b9,b25, b46	b2,b6,b24,b27, b31,b32,b33, b36,b41,b43,b47, b49	b1,b4,b8, b10,b13,b15, b23,b34,b42, b48
S_9	-	-	-	-	b21	-	b20	b3,b12,b17,b19, b22,b28,b29,b30, b28,b39,b40,b45, b50	b44

Transition of Banks from 2015-16 to 2016-17

State	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9
S_1	-	-	-	-	-	-	-		-
S_2	-	b7	-	-	-	b14	-	-	-
S_3	-	-	-	-	-	-	-	-	-
S_4	-	-	-	-	-	-	-	-	-
S_5	-	-	-	-	b11,b16, b21	b35	-	b26	-
S_6	-	-	-	-	-	-	-	-	-
S_7	-	-	-	-	-	-	b25	b20	b5,b9,b18, b46
S_8	-	-	-	-	-	-	b6,b27, b38, b39,b41, b43	b3,b12,b17,b19, b22,b24,b28, b29, b30,b31,b36,b40, b45,b49,b50	b2,b32,b33, b47
S_9	-	-	-	-	-	-	b23,b42	-	b1,b4,b8, b10,b13,b15, b34,b44,b48