ARTICLES

IMPACT OF IT INVESTMENTS IN THE OPERATING INCOME OF BRAZILIAN BANKS

IMPACTO DOS INVESTIMENTOS EM TI NO RESULTADO OPERACIONAL DOS BANCOS BRASILEIROS

IMPACTO DE LAS INVERSIONES EN TI EN EL RESULTADO OPERACIONAL DE LOS BANCOS BRASILEÑOS

ABSTRACT

IT has transformed the banking industry in recent years, becoming strategic and vital for business. Given this context, the main objective of this study was to analyze the impact of IT investments in the operating income of Brazilian banks. The econometric model was based on a Cobb-Douglas production function with three variables, namely, the operating income, IT investments and personnel expenses. Data were collected from COSIF system, operated by the Brazilian Central Bank, and the study covered the period from 1997 to 2008. After specifying the model, four analyses on the impact of IT investments were conducted: cross section analysis, longitudinal analysis (panel data), comparative analysis of IT investments by both domestic and foreign banks, and the analysis of behavior of these investments within the context of the millennium bug (Y2K) and the implementation of the Brazilian Payment System (SPB).

KEYWORDS IT investment, operating income, Cobb-Douglas, cross section, panel data.

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RESUMO A TI transformou a indústria dos bancos nos últimos anos e tornou-se estratégica e vital para o negócio. Considerando essa premissa, o objetivo principal do trabalho foi analisar o impacto dos investimentos em TI no resultado operacional dos bancos que operam no Brasil. O modelo utilizado baseou-se em uma função de produção Cobb-Douglas com três variáveis, o resultado operacional, os investimentos em TI e os gastos com pessoal. Os dados são provenientes dos saldos contábeis extraídos do sistema Cosif do Banco Central, e a pesquisa abrangeu o período de 1997 a 2008. Após a especificação dos modelos econométricos, foram realizadas quatro análises sobre o impacto dos investimentos em TI: análise cross section (cortes transversais anuais), análise longitudinal (dados em painel), análise comparativa dos investimentos em TI pelos bancos nacionais e estrangeiros, e análise do comportamento desses investimentos nos marcos do bug do milênio (Y2K) e da implantação do Sistema de Pagamentos Brasileiro (SPB).
Palavras-chave Investimento em TI, resultado operacional, Cobb-Douglas, cross section, painel de dados.

Resumen La TI ha transformado la industria de los bancos en los últimos años y tornóse estratégica y vital para el negocio. Considerando esa premisa, el objetivo principal del trabajo fue analizar el impacto de las inversiones en TI en el resultado operacional de los bancos que operan en el Brasil. El modelo utilizado se basa en una función de producción Cobb-Douglas con tres variables, el resultado operacional, las inversiones en TI y los gastos con personal. Los datos son provenientes de los saldos contábiles extraídos del sistema Cosif del Banco Central del Brasil, y la investigación cubrió el período de 1997 a 2008. Después de la especificación de los modelos econométricos, fueron realizados cuatro análisis sobre el impacto de las inversiones en TI: análisis cross section (cortes transversales anuales), análisis longitudinal (datos en panel), análisis comparativa de las inversiones en TI por los bancos nacionales y estranjeros, y análisis del comportamiento de esas inversiones en los marcos del bug del milenio (Y2K) y de la implantación del Sistema de Pagamentos
Palabras clave Inversión en TI, resultado operacional, Cobb-Douglas, cross section, panel de datos.

INTRODUCTION

The analysis of impacts of Information Technology (IT) investments has been the subject of studies and discussions among professionals and researchers, particularly because of the difficulties to measure their results (GUNASEKARAN et al, 2005; HEIM and PENG, 2010). Studies have been conducted in order to measure whether IT investments contributed to improve organization performance, results or even efficiency. Although findings have not been unanimous regarding the effect of IT investments, organizations continue to invest large sums of money in IT in order to improve their performance.

Banking is one of the industries with highest investments in IT worldwide, which is not surprising, considering that banks need to continuously improve their efficiency in order to remain competitive (JONAS and KING, 2008). In Brazil, the banking market is the largest consumer of IT products and services. According to the Brazilian Federation of Banks (Febraban, 2009), in 2008, the total IT budget of banks was over R$ 16 billion reais, with 6.4 billion reais of investments.

In recent years, technology has been the factor that has changed the financial services of banks, allowing the creation of new customer relation channels. The increasing sophistication, flexibility and complexity of banking products and services make IT a key factor to manage risks related with the business.

The studies by Mahmood and Szewczak (1999) and Maçada (2001) found the necessity to develop new studies to assess both economic and strategic impacts of IT investment on organization productivity and performance. Several papers were later published in Brazil in order to meet this demand; the studies by Becker, Lunardi and Maçada (2003, 2005), Santos, Andrade and Macedo (2005), Sanchez and Albertin (2009) and Gartner, Rodder and Zwicker (2009) are among such studies. The techniques used to assess the impact of IT investments are classified as parametric and nonparametric (Berger and Humphrey, 1997). One example of a parametric technique is the Cobb-Douglas production function; data envelopment analysis (DEA) is a nonparametric technique.

The objective of this paper is to analyze the impact of IT investments in the operating income of Brazilian banks. In order to test the relationship between the variables involved, econometric quantitative instruments had to be used, since they allow to build models and to mathematically represent the real world (PINDYKC and RUBINFELD, 2004). Econometrics was applied because it allows, among other possibilities, to confront economic theory with facts and to test hypotheses involving economic behavior (RAMANA-THAN, 1992).

LITERATURE REVIEW

This review section approaches IT investments in the banking business, the employment of Cobb-Douglas function to measure the impact of such IT investments, the studies on IT investment that have been conducted in Brazil and the research model used.

IT investments in banks

Technology is increasingly present in banking activities, and it is making a difference in issues that are sensitive to banks, such as mobile banking, branch automation, security and compliance. In recent years, innovative technologies have become an increasingly important element in banking industry's competitive scenario, as they have allowed the development of multiple access channels and have made new banking services viable to customers. In order to maintain and create competitive edge, banks are continuously trying to expand their capabilities (LUO et al., 2010).

In the banking sector, investing in (and modernizing) IT has been essential to business survival. According to Ho and Mallick (2010), IT can improve banks performance by reducing operating costs. In this respect, the Internet has allowed banks to provide banking services at much lower costs and with no physical presence required in branches (HERNANDEZ-MURILLO et al., 2010).

This paper provides evidence that the IT investments made by banks operating in Brazil are significant, and that IS literature has used the Cobb-Douglas function as a means to assess the impacts of these investments on organizations.

The Cobb-Douglas function

The Cobb-Douglas function has been the best, most widely used method in studies about return on investments (LICHTENBERG, 1995; BRYNJOLFSSON and HITT, 1996; STOLARICK, 1999).

It is a production function relating final product variation to the variation in the application of a particular production factor, or the variation of all factors simultaneously. According to Mittal and Nault (2009), a production function is a mathematical relation between the quantities of inputs and outputs. This relationship is tested using regression analysis, which statistically measures the relationship between independent variables (production factors) and the dependent variable (final product). Prasad and Harker (1997) found production functions to be both valid and successful in a number of empirical studies. The properties of a production function are described in detail in the study by Chambers (1988).

One of the simplest, most widely used production functions is Cobb-Douglas. It has interesting properties for a quantitative study, e.g., the ability to become linear, which allows using multiple regression. In addition, the Cobb-Douglas function can be adapted in order to relate various inputs to the result or product. Therefore, many studies have used multiple regression models to measure the impact of different, IT investment-related variables for the productivity of companies (GURBAXANI, MELVILLE and KRAEMER, 1998; KO and OSEI-BRYSON, 2006; KO, CLARK and KO, 2008). These studies normally used productivity or added value as the dependent variable, and IT capital, non-IT capital and labor as independent variables.

Studies on IT investments in Brazil

A literature review was conducted involving Brazilian journals (*RAC*, *RAE*, *RAUSP*, *REAd*) and congresses (Enad, EnANPAD and CATI) in the last five years, in order to find the studies conducted and methods used to analyze the relationship between IT investments and organization productivity, product, efficiency and performance. The result of this review is summarized in Exhibit 1.

Table 1 shows that researchers used different methods to measure the relationship between IT and organization productivity or products. Among those methods are: data envelopment analysis (DEA) (MAÇADA, BECKER and LUNARDI, 2005; SANTOS, MACEDO and ANDRADE, 2005; SANTOS et al., 2007); case study (CORREIA NETO, 2007; SANCHEZ

Exhibit 1 - Summary of studies in Brazil on the relationship between IT investments and the result.

Author	Year	Information/ Period	Data / Period	Variables	Result
Gartner, Zwicker e Rodder	2009	Cobb-Douglas	100 Most Connected Companies according to INFO Magazine, from 2000 to 2006	Number of IT employees; IT investments; Number of microcomputers; Number of servers	Productivity paradox was refuted, since a significant, positive relation was found between increase in IT investment and increased production
Sanchez e Albertin	2009	Case Study study	MATIF Mar 2005 to Apr 2006	Potential Value; Perceived Value; Realized Value	Effectiveness achieved using IT is actually related to managers ability to identify previous economic inefficiencies in the dynamics of business and to mitigate them by using IT
Mendonça, Freitas e Souza	2009	Cobb-Douglas	Industrial Research (PIA), Annual Social Information Report (RAIS), Industrial Technology Innovation Research (PINTEC) 26,776 production units with at least 30 workers; 2001 to 2003	Personnel Employed; Capital stock; Information Technology; Foreign capital; Export; Average study time, Employee retention rate Absorptive capacity	At least in average, IT is now a critical success factor in the industry

(conclusão)

Santos, Silva e Chamon	2008	Cobb-Douglas	Data from VPP industry disaggregated from PIA-Empresa full questionnaire; 1996 to 2005	IT capital; Work in IT and non-IT	IT investments were found not to positively impact productivity in the industrial sector in the area of Vale do Paraíba, São Paulo. Investment in non-IT Work enhances productivity
Santos, Macedo, Benac e Amorim	2007	DEA	Ranking by Info-Exame Magazine; Balanço Financeiro Magazine, from Gazeta Mercantil; 10 companies in 2003	IT investments; Revenue; Return on equity (ROE); Operation efficiency (EOP)	Results indicate the validity of DEA use to assess comparative efficiency In converting investments in Brazilian banks
Correia Neto	2007	Method Monte Carlo	Single case of Brazilian company	Incremental cash flows	Monte Carlo method allows to simultaneously estimate financial benefits expected and risks. It applies primarily to analysis of quantitative returns
Brito e Ferreira	2006	Variance components Technique; Multiple Regression	200 largest IT Companies in Brazil by InfoExame magazine; 2000 to 2004	Size; Productivity	No significant impact of the 'size' variable over performance was found. A positive, statistically significant relation between variable 'productivity' and performance was found for all of its forms of measure.
Maçada, Becker e Lunardi	2005	DEA	41 Brazilian banks; 1995 to 1999	IT investments; Personnel Expenses; Other administrative expenses; Costs of internationalization; Net revenue from financial intermediation, services and international operations	Banks with highest IT investment enhanced efficiency over the period
Santos, Macedo, e Andrade	2005	DEA	Data from banks and insurance companies in Brazil collected from Info-Exame Magazine; 2003 and 2004	IT investments; Revenue; Number of microcomputers; Number of servers Number of professionals; Internet connection	DEA has the ability to distinguish efficient from inefficient companies regarding IT investments
Menezes e Moura	2004	Cobb-Douglas Prasad and Harker test	A state-owned multi-bank; 1995 to 2002	Product; IT capital; Non-IT capital IT Work; non-IT Work;	No evidence was found to support that that additional investments in IT have contributed to improve productivity in the company studied

and ALBERTIN, 2009); Monte Carlo method - MCM (CORREIA NETO, 2007); multiple regression (BRITO and FERREIRA, 2006); and Cobb-Douglas (MENEZES and MOURA, 2004; SANTOS, SILVA and CHAMON, 2008), MENDONÇA, FREITAS and SOUZA, 2009), GARTNER, ZWICKER and RODDER, 2009).

A few studies measured the relationship between IT and productivity in banks; among these, only the

Menezes and Moura (2004) study used the Cobb-Douglas function to conduct the analysis. In summary, according to Brazilian studies, the methods to measure the impact of IT investments and company results or productivity were the following: DEA, case study, Monte Carlo, multiple regression and Cobb-Douglas.

Study model

The variables used in this work are: operating income, IT investments and personnel expenses. Figure 1 details the model used in the study in order to relate IT investments to operation income for the organizations. The actual conversion of inputs into income was measured using multiple regression, based on a Cobb-Douglas function.

Since this paper studies the banking industry, it is known that banks play a financial intermediation role between those who have capital and the borrowers, which makes the businesses of banks largely dependent on information. While estimating a Cobb-Douglas function for the sector, the relationship between the inputs and results of banks must be considered. This function must necessarily include factors related to capital and labor. Today, banks are fully dependent on IT resources. Therefore, IT investments (capital), as well as the people (labor) who make the organization work, were defined as the main inputs in order to compose an econometric model that aims to assess the impact on operating income. The Cobb-Douglas production function is:

$$ROP = e^{\beta_0} ITI^{\beta_{ITI}} GP^{\beta_{GP}} \qquad (1)$$

Where: OI (OBS.: substituir ROP por OI em todas as fórmulas)= Operating Income; IIT (ITI)= IT invest-

ments; PE (OBS.: substituir GP por PE em todas as fórmulas)= Personnel Expenses.

This study took income (OI) into consideration because it directly reflects the operating incomes of institutions; it is the direct result of the difference between operating revenues and expenses. The operating revenues are the fees that banks charge for their credit and service operations, i.e., those referring to typical, routine activities. Operating expenses are the result of costs related to their typical, routine activities.

METHOD

Study design

Figure 2 shows the study design, including its different steps. On step 1, a literature review was conducted in order to get deeper knowledge about how the impact of IT investments on organization results are assessed. Moreover, it was necessary to turn to the production theory and econometrics for the elements that should specify the Cobb-Douglas model used. Step 2 comprehends the collection, analysis and preparation of data. On this step, *STATA* software was chosen for the analysis. The dashed line, which involves the first and second steps, shows that they occurred in parallel. On step 3, the econometric model specified was pre-tested with data for 2007 and 2008. Once the model was validated and the data prepared, the study proceeded to step 4, on which 4 different types of analysis were conducted regarding IT investments in banks.

The cross-section analysis was conducted using multiple regression and ordinary least square (OLS).

The longitudinal analysis was completed by designing a panel of non-balanced data; multiple re-

Figure 1 – Detailed model of regression variables
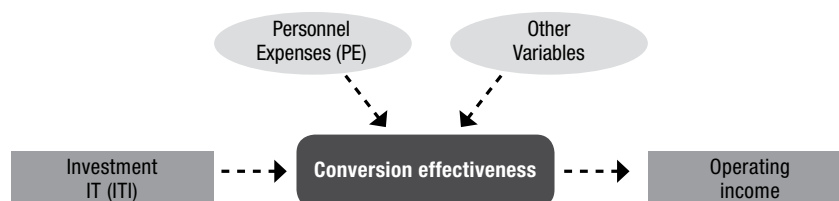
Source: Adapted from McKeen, Heather and Parent (1999).

gression and generalized least squares (GLS) were used in the analysis. The comparison between Brazilian and foreign banks was conducted using a different econometric model, with dummy (or binary) variables, and it used regression combined with the GLS method. The Y2K and SPB events were analyzed using of a direct analysis of figures in a time series for IT investments.

## Data sources and unit of analysis

The data used in this study were collected from CO-SIF, a database system of the Brazilian Central Bank (2009a). COSIF keeps the records of every ledger of every Brazilian financial institution since July 1994. The study by Faria (2010) details the specifications for the COSIF accounts that form each of variable in our model; they are designated as operating income (OI), IT investment (ITI) and personnel expenses (EP).

The unit of analysis is the Bank, and the population in this study is formed by banking conglomerates and joined institutions, totaling 42 financial institutions registered with the Brazilian Central Bank as independent and normally operating in the period from 1997 to 2008. Within this group are: commercial banks, development banks, investment banks, multi-banks, savings banks and state-owned Banco do Brazil and Caixa Economica Federal.

Table 1 shows the samples used in the cross section and longitudinal analyses as well as Y2K and SPB events. N refers to the number of banks selected for the year, and n refers to the number of banks that were actually included in the calculation of regressions. This difference is due to the fact that banks with a negative OI or zeroed values for ITI or PE were not considered in the calculations due to the use of logarithms.

A group of 8 banks from a ranking provided by the Brazilian Central Bank and designated in this study as

Figure 2 – Study Design
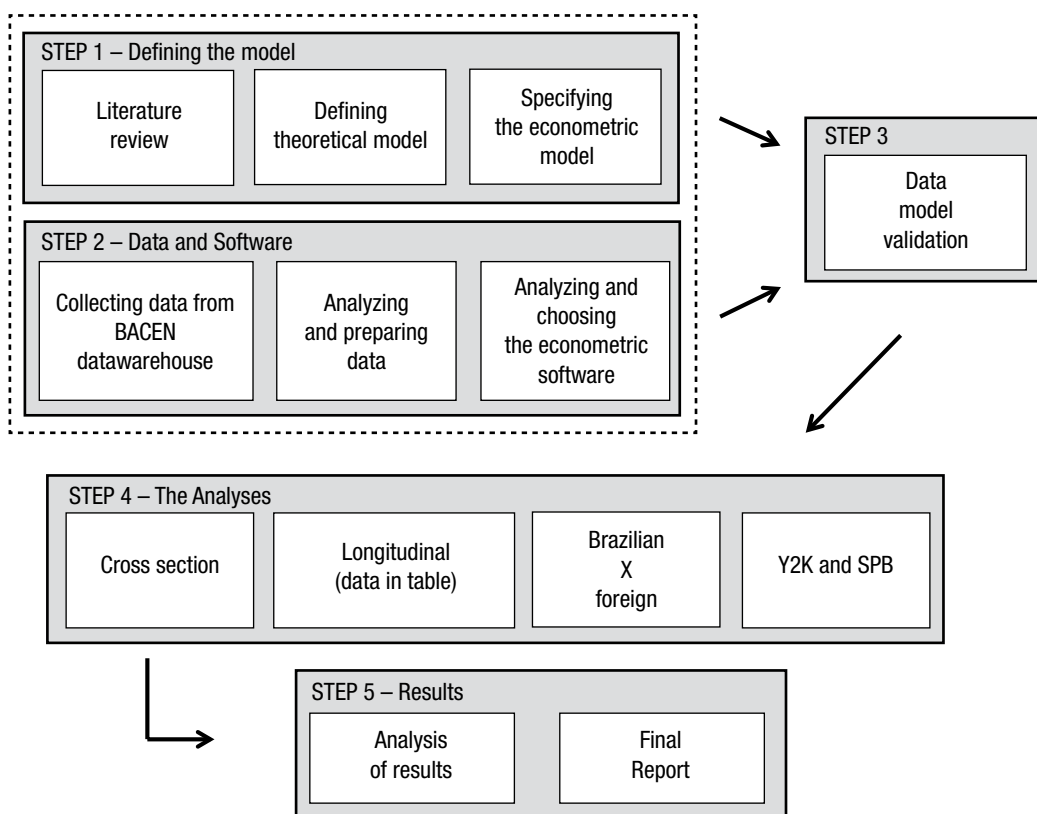
"Group 8" was designed in order to assess IT investments more accurately. The group is formed by eight of the ten largest banks in the country. The consolidated figures for "Group 8" are compared with the consolidated figures for the whole sample, year by year, providing an accurate view of changes in IT investments over the period. In addition, IT investments were studied individually for four banks from "Group 8", which allows to accurately assess variations in the period.

The banks forming the sample of this study represent almost all institutions - both in terms of quantity and trading volume – that were operating in the country from 1997 to 2008.

Estimating the econometric models for the analyses

This study proposes four analyses, namely, cross section analysis, longitudinal analysis (panel data), comparative analysis of IT investments made by domestic and foreign banks, and the analysis of IT investments for the Y2K and SPB events. The cross section analyses were conducted from expression (1); after a logarithmic transformation to make it linear, it resulted in:

$$ROP = \beta_0 + \beta_1 ITI + \beta_2 GP + e \qquad (2)$$

Where: β_0 is the intercept;
1 and β_2 are the partial elasticities for ITI and PE, respectively;
"e" = error term;
OI, ITI and PE represent the natural logarithms of their respective values.

The longitudinal analysis used a panel of unbalanced data. Random effects was used as the estimation method, since no correlation was found between the unobserved effect and the explanatory variables in the period from 1997 to 2008. Therefore, the econo-

metric model is:

$$ROP_{it} = \beta_0 + \beta_1 ITI_{it} + \beta_2 GP_{it} + v_{it} \qquad (3)$$

Where: vit = ai + eit ↔ composition error = unobserved effects + idiosyncratic errors;
i = 1, 2, ..., N (N = total of institutions);
t = 1, 2, ..., T (T = total of years).

A variation of the model above was used in order to compare Brazilian and foreign banks, withdrawing personnel expenses (EP) and including both intercept and slope dummy (or binary) variables. Therefore, it was possible to distinguish the impact of IT investments on operating income for Brazilian and foreign banks. The expression (4) details the new model.

$$ROP_{it} = \beta_0 + \beta_1 D\_NE_{it} + \beta_2 ITI_{it} + \beta_3 D\_NE_{it} ITI_{it} + v_{it} \quad (4)$$

Where: D_NE = dummy variable indicating the control (1= foreign, 0 = Brazilian)
β_0 = Brazilian bank intercept ;
$\beta_0 + \beta_1$ = foreign bank intercept;
β_2 = straight slope ITI regression for Brazilian bank
$\beta_2 + \beta_3$ = straight slope ITI regression for foreign bank

In order to analyze IT investments for the millennium bug (Y2K) and Payment System (SPB), the time series of IT investments was directly studied.

RESULTS

In this study, four analyses were proposed, all of which considered data for the period from 1997 to 2008. The four analyses are: annual cross section analysis; longitudinal analysis; comparative analysis between domestic and foreign banks; and the analysis of IT investments for Y2K and SPB.

Table 1 – Sample size

Year	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997
N	128	128	131	144	144	146	157	170	183	184	190	205
n	98	110	111	114	113	115	121	128	141	144	133	143

Cross section analysis

Before presenting the results of regressions, the data collected from COSIF and which form the basis of our calculations are listed below. Table 2 shows a summary with the values of consolidated balances in real terms (base year 1997) for both Brazilian- and foreign-controlled banks operating in Brazil during the period. IGP-M index, from the Getulio Vargas Foundation's, was used to convert OI and ITI values. With regard to EP, the salary adjustment index specific for Brazilian bank employees was used.

The consolidated operating income (OI) of banks was found to vary significantly over the period, alternating growth and retraction results, as well as changing levels in 1998, 1999, 2002, 2005 and 2007. Banks were found to have improved their operating performance, which may have been caused by reduced spending, revenue growth or, more likely, both. The consolidated operating incomes of banks in real terms were found to significantly vary their levels from 1997 to 2008, from a R$2.726 billion negative result in 1997 to R$22.102 billion in 2008.

IT investments (ITI) were found to continuously increase from 1998 to 2001; these increases were caused by the events Y2K and SPB, as found in this study. In subsequent years, the changes were all negative, except for 2005 which saw a positive variation of 6.87 percent. However, it is clear that ITI for 2001 reached another plateau regarding the consolidated amount invested yearly by banks, as it increased by 17.79 percent in real terms from 2000 to 2001, reaching unprecedented R$ 4.142 billion reais. Considering the series analyzed, ITI annual consolidated values increased from R$ 2.512 billion reais in 1997 to R$ 3.540 billion reais in 2008, meaning a real growth of 41 percent.

By analyzing the consolidated personnel expenses (EP), we found that personnel expenses continued to decrease after 1998 and followed a downward trend until 2004.

We found a small PE increase for the period from 2005 to 2007, which was reversed in 2008. Additionally, negative effects from the global financial crisis which erupted in the second half of 2008 were found; those effects are reflected in the figures for the three

Table 2 – Summary of consolidated data (base year 1997) for cross section analyses, in thousand reais

Year	Nac	Banks	Tot	(Base 1997)	Δ%OI	ITI (Base 1997)	Δ%ITI	PE (Base 1997)	Δ%PE
1997	165	40	205	-2,725,629.89	0.00	2,511,786.42	0.00	33,838,337.63	0.00
1998	148	42	190	3,139,801.22	215.20	2,832,214.19	12.76	25,078,526.52	-25.89
1999	141	43	184	12,716,725.51	305.02	3,150,008.54	11.22	24,339,767.98	-2.95
2000	139	44	183	8,121,035.10	-36.14	3,517,037.84	11.65	23,216,955.90	-4.61
2001	128	42	170	4,614,503.40	-43.18	4,142,740.04	17.79	23,157,365.96	-0.26
2002	115	42	157	16,763,120.21	263.27	3,812,839.61	-7.96	22,221,917.94	-4.04
2003	103	43	146	16,578,017.76	-1.10	3,763,623.58	-1.29	20,965,283.42	-5.65
2004	115	29	144	14,714,136.93	-11.24	3,617,690.52	-3.88	20,658,698.33	-1.46
2005	105	39	144	22,088,589.01	50.12	3,866,163.81	6.87	21,302,469.47	3.12
2006	95	36	131	24,066,773.00	8.96	3,820,960.07	-1.17	22,275,264.91	4.57
2007	94	34	128	30,324,180.82	26.00	3,771,763.36	-1.29	23,333,269.99	4.75
2008	93	35	128	22,102,339.16	-27.11	3,540,096.99	-6.14	22,131,170.84	-5.15

variables for that year: -27.11 percent for OI, -6.14 percent for ITI and -5.15percent for PE.

Table 3 summarizes the results found in all cross section analyses conducted for the period from 1997 to 2008, using equation (2) in STATA. Because natural logarithms were used, banks with negative OI values were not considered in the regressions. In the twelve years studied, the calculated coefficients of determination R^2 were significant (p 0.05 <) and ranged from 0.5647 to 0.6866. According to Kennedy (2008), a high R^2 value does not necessarily mean that the model is strong. According to Gujarati (2006), the researcher should worry about the relevance logic of explanatory variables in relation to the dependent variable and its statistical significance.

The results found were analyzed in economic and statistic terms. According to the statistical significance of the two explanatory variables, determined by their t-statistics, the results showed that they were statistically significant for all years analyzed, as they had values above 2 for all years. Besides its relevance to test the hypothesis, the fact that t-statistic presents values above 2 is relevant to deal with the question of multicolinearity in Cobb-Douglas functions. According to Kennedy (2008, p. 196), the existence of multicolinearity in a Cobb-Douglas production function is natural, and although capital and labor variables have a high collinearity, solid estimations are produced. According to the economic significance suggested by the coefficients of regression (or betas) and their signs, evidence was found that variations in IT investments (ITI) or in personnel expenses (EP) have a significant, positive impact on the operating income (OI) of banks. The coefficient for IT investments (β_1) varied from 0.2665 the 0.3671, and the coefficient for personnel expenses (β_2) varied from 0.3597 to 0.5647. Betas β_1 and β_2 represent the partial elasticities of the dependent variable (OI) in relation to the independent variables (ITI and PE).

With regard to scale incomes, the addition of the coefficients varied from 0,7268 to 0,8445, and they were found to have decreased for all years during the studied period ($\beta_1 + \beta_2 < 1$). Importantly enough, the presence of decreasing incomes does not imply that it is bad to invest in IT or personnel expenses. It only implies that incomes are decreasing, i.e., the investment in the first unit provides a given revenue, the second one provides a slightly lower revenue and so on. In economic terms, the company would have to invest until marginal return is zeroed.

Therefore, the cross section analyzes found statistic evidence that for all years in the period from 1997 to 2008, IT investments, as well as personnel expenses, had a positive impact on the operating income of banks. It is noteworthy that banks invest in IT not only for financial return; they seek other factors that imply strategic edges, like service quality improvement, or the use of new technologies that will allow them to create more sophisticated products (BECCALLI, 2007, p. 4). The figures suggest that investing in IT became critical for the survival of businesses, as banks continue to invest large amounts in IT in the country.

Longitudinal analysis

The longitudinal analysis with unbalanced panel was conducted in order to observe the impact of IT investments on the operating income of banks. Choosing an unbalanced panel increased the number of observations, which is relevant in a study using a panel data. Banks with a negative OI were not considered in the regression. This analysis was conducted using expression (3) in STATA.

According to Asteriou and Hall (2007), the Hausman test helps to choose between the fixed and random effect approaches, testing if values for ai (non-observable error) are correlated to the regressors (independent variables) of the model. Its result (Prob > chi2 = 0,3066; p > 0,05) suggested that the random effect model should be used. The Breusch-Pagan test, which is, according to Wooldridge (2006), a heterocedasticity test (the variance of the term of error is not constant) where OLS (Ordinary Least Squares) square residuals are regressed over the explanatory variables of the model, resulted in (Prob > chi2 = 0,0000; p < 0,05), which suggested that the errors were heterocedastic; therefore, the robust regression was used.

Regression in panel was used for 1,471 measures regarding the 12 years of the analyzed period. The coefficient (or beta, which indicates partial elasticity) calculated for ITI was 0.3059 and the PE coefficient was 0.4962. R^2 was 0.6339, which is significant and suggests that the model explains 63.39 percent of the variation in operation income (OI). The coefficient calculated for IT investment showed that if these investments increase by 1 percent, the operating income will increase by 0.3059 percent.

The intercept in the multiple linear regression straight line (β_0) was 4.2166. This number is fundamental to build the estimated equation, which allows

to simulate the impacts of both IT and personnel expenses investments on the operating income of banks.

The inclination coefficients for IT and personnel expenses investments were 0.3059 (β_1) and 0.4962 ($\beta2$), respectively. The sum of elasticities, which was 0.8021 (below 1), suggested decreasing scale incomes.

The regression was calculated using the method of generalized least squares (random effects). The resulting estimator is:

$$ROP = 4,2166 + 0,3059\ ITI + 0,4962\ GP \qquad (5)$$

The same equation in the form of a Cobb-Douglas function is:

Table 3 – Summary of the results of regressions in the cross section analyses

Reference			Model			Constant		
Year	N	n	R²	p	F	Constant	p	t
2008	128	98	0.6795	0.000	100.69	3.769264	0.000	3.72
2007	128	110	0.6067	0.000	82.54	3.909247	0.001	3.52
2006	131	111	0.5823	0.000	75.29	4.925352	0.000	4.53
2005	144	114	0.6739	0.000	114.7	3.649822	0.000	3.94
2004	144	113	0.6430	0.000	99.07	5.023023	0.000	5.57
2003	146	115	0.6524	0.000	105.09	4.83063	0.000	5.62
2002	157	121	0.6814	0.000	126.19	4.196835	0.000	5.07
2001	170	128	0.5663	0.000	81.60	5.871773	0.000	6.64
2000	183	141	0.6250	0.000	115.02	4.742057	0.000	6.02
1999	184	144	0.5954	0.000	103.73	4.254184	0.000	4.73
1998	190	133	0.6866	0.000	142.43	4.103593	0.000	5.58
1997	205	143	0.5647	0.000	90.80	5.271265	0.000	6.42

ITI			GP			Rend. Escala
β_1	p	t	β_2	p	t	$\beta_1 + \beta_2$
0.2744643	0.046	2.02	0.5629205	0.000	4.09	0.8373848
0.3118164	0.039	2.09	0.5317614	0.001	3.52	0.8435778
0.3518532	0.020	2.36	0.4291151	0.007	2.76	0.7809683
0.2797652	0.023	2.30	0.5646925	0.000	4.46	0.8444577
0.3440457	0.004	2.93	0.416663	0.001	3.37	0.7607087
0.3079453	0.021	2.35	0.464223	0.001	3.58	0.7721683
0.2665247	0.037	2.12	0.5409746	0.000	4.29	0.8074993
0.2712984	0.024	2.28	0.4240085	0.001	3.51	0.6953069
0.3123635	0.005	2.86	0.4471324	0.000	4.15	0.7594959
0.2861371	0.041	2.06	0.5137421	0.000	3.68	0.7998792
0.2988453	0.020	2.36	0.4910291	0.000	4.11	0.7898744
0.3670576	0.004	2.93	0.3597122	0.002	3.18	0.7267698

$$ROP = 67,80\ ITI^{\,0,3059}\ GP^{\,0,4962} \qquad (6)$$

The intercept 67.80 is the value of the Neperian anti-logarithm of β_0, and the exponents for the explanatory variables ITI and PE are the elasticity coefficients-products estimated, and they measure their relative impact on OI. The equation (6) represents an estimator of the impacts caused on OI because of inverted values in ITI and GP; this estimator is generated by the regression using the data from the unbalanced panel.

Assessment of IT investments in banks

The longitudinal analysis was complemented by directly examining the IT investments in banks using the same data from the unbalanced panel, which allowed a few interesting comparisons regarding the realized figures in the country. In order to conduct this analysis, an online report on the 50 largest banks in the country (Brazilian Central Bank website) with the position for September 2008 was created and used. In order to preserve bank identity, the study discretionarily selected 8 of the 10 largest banks in the report; we designated these 8 banks "Group 8." All banks in "Group 8" are in the unbalanced panel.

Table 4 shows the consolidated figures in absolute terms for the IT investments (ITI) made by the institutions that form "group 8" – and participate in the unbalanced panel (UP). These figures allowed studying how the concentration of IT investments progressed in Brazil. The total invested in IT by "group 8" in 2008 accounted for 82.44 percent of total consolidated IT investment of all 222 institutions that formed the unbalanced panel, which means that the other 214 institutions in the panel invested only 17.56 percent of the overall total.

From 1997 to 2008, the number of institutions in the sample decreased by approximately 38%, sharply decreasing from 205 to 128. This fact shows that a significantly smaller number of institutions is investing a significantly larger amount in IT in 2008, since the consolidated values for ITI in absolute terms increased from R$ 2.512 billion reais to R$ 9.995 billion reais. This may suggest that banks are individually investing more in IT in real terms in 2008 than they were in 1997. In order to clarify this point, four banks were selected from the 6 largest banks in the country (among the participants in "group 8"); this was made in order to analyze indi-

vidual behavior regarding IT investments. Table 5 shows the consolidated ITI data for these four banks, identified as Banks A, B, C and D. All values were transformed for base year 1997, using IGP-M index from the Getúlio Vargas Foundation (FGV) in order to compare them in real terms.

A variation of 118,75 percent in real terms was found for Bank A from 1997 to 2008.

It is noteworthy that the last was found to have invested more constantly in IT in the analyzed period.

Therefore, Brazilian large banks were found to have reached another plateau in IT investments in 2008 compared to the values employed in 1997. Figure 3 shows the evolution of IT investments for the four banks listed in Table 5.

Bank D was clearly found to have invested most in IT, and to have had the most constant IT investment trajectory. Bank A was also found to have a significant growth trajectory. Bank B had an expressive growth in ITI investments until 2002, then had a significantly decreasing trajectory in its annual sums.

Bank C was found to have grown significantly until 2001; then, a gradual decrease was found until

Year	ITI	ITI	%Particip.
	Group 8	PNB	Group 8 no PNB
1997	1,368,202,432.93	2,511,786,422.00	54.47
1998	1,768,485,644.85	2,882,627,602.00	61.35
1999	2,455,480,608.15	3,850,500,506.00	63.77
2000	3,276,100,284.00	4,726,914,296.00	69.31
2001	4,394,292,816.08	6,145,247,972.00	71.51
2002	5,130,654,732.53	7,086,818,959.00	72.40
2003	5,796,459,257.28	7,603,237,753.00	76.24
2004	6,494,837,669.78	8,216,131,513.00	79.05
2005	6,861,918,584.66	8,885,804,115.00	77.22
2006	7,069,902,932.70	9,119,135,353.00	77.53
2007	7,252,678,403.73	9,698,455,376.00	74.78
2008	8,239,483,500.64	9,994,835,145.00	82.44

Table 4 – Comparison of consolidated ITI

2005; a sharp, remarkable recovery in IT investments was found for 2008.

Comparison between Brazilian and foreign banks

A comparison between IT investments made by Brazilian institutions (those with Brazilian control) and foreign ones (those with foreign control) was also conducted. The same data from the above mentioned unbalanced panel were used to conduct this analysis. IT investments (ITI) are separated in Brazilian and foreign in Table 6. ITI values were transformed for base year 1997 using IGP-M index from FGV.

Tabela 5 – ITI de 4 grandes bancos, em R$ mil (ano-base 1997)

Year	Banco A	Δ%A	Banco B	Δ%B	Banco C	Δ%C	Banco D	Δ%D
1997	287,673.11	0.00	106,748.60	0.00	223,155.32	0.00	463,240.74	0.00
1998	339,313.90	17.95	188,840.47	76.90	252,838.86	13.30	589,689.72	27.30
1999	390,272.69	15.02	380,807.10	101.66	278,313.26	10.08	558,873.54	-5.23
2000	462,373.94	18.47	393,477.78	3.33	352,961.50	26.82	576,229.14	3.11
2001	470,199.15	1.69	513,215.40	30.43	408,572.02	15.76	545,266.55	-5.37
2002	415,333.01	-11.67	525,475.46	2.39	371,968.22	-8.96	565,489.36	3.71
2003	441,896.98	6.40	493,255.29	-6.13	301,911.16	-18.83	556,806.48	-1.54
2004	504,191.39	14.10	427,991.29	-13.23	249,948.03	-17.21	565,252.68	1.52
2005	634,014.64	25.75	428,116.28	0.03	219,369.70	-12.23	604,354.33	6.92
2006	617,569.80	-2.59	271,860.19	-36.50	325,048.72	48.17	687,183.09	13.71
2007	576,042.33	-6.72	211,303.60	-22.27	260,494.81	-19.86	731,594.39	6.46
2008	629,283.73	9.24	238,140.11	12.70	523,044.11	100.79	686,912.85	-6.11
TOTAL	**5,768,164.65**		**4,179,231.56**		**3.767.625.70**		**7.130.892.88**	

Figure 3 – ITI evolution for 4 large banks
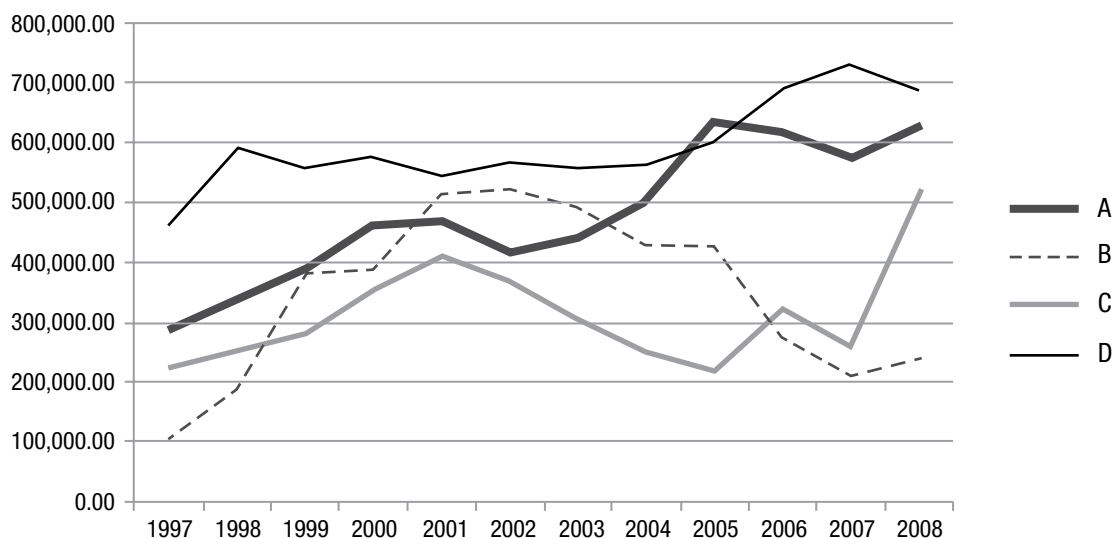
An increased participation of foreign financial institutions in the total of financial institutions (FIs) was found from 1997 to 2008, from 19.51 percent in 1997 to 27.34 percent in 2008. It is noteworthy that the number of Brazilian institutions was found to have significantly decreased during the period, from 165 to 93, which contrasts with a small reduction in the number of foreign institutions, from 40 to 35. These numbers are evidence that the ongoing process of banking concentration in the Brazilian system had more impact on Brazilian institutions than foreign ones during the analyzed period. Still, Brazilian institutions have always had a predominant role in IT investments, ranging from a 67.35 percent minimum participation in 2003 to a 78.91 percent maximum participation in 2000.

Brazilian banks were found to have significantly increased their total annual investment from R$ 1.876 billion reais in 1997 to R$ 2.519 billion reais in 2008, which represents an increase of roughly 34 percent in the period. Foreign banks increased their annual amount of investments from R$ 636 million reais to R$ 1.021 billion reais, which was a 61 percent increase. According to this figures, a 44 percent smaller group of Brazilian institutions invested a 34 percent higher amount in real terms in 2008 compared to 1997. On the other side, a 13 percent smaller group of foreign banks invested a 61 percent higher amount in real terms in 2008 compared to 1997. Foreign participation in the total invested was found to increase in real terms from 25.3 percent in 1997 to 28.8 percent in 2008.

Brazilian and foreign institutions were also compared using dummy variables, as demonstrated in equation (4). Due to the use of natural logarithms, banks with a negative OI were not considered in the regression.

According to the econometric model proposed, it can be deduced that:

$$ROP = (\beta_0 + \beta_1) + (\beta_2 + \beta_3)\,ITI \rightarrow \text{ for foreign institutions}$$

and

$$ROP = \beta_0 + \beta_1\,ITI \rightarrow \text{ for Brazilian institutions.}$$

After replacing the coefficients by their respective values calculated in the regression, we have:

$$ROP = 9,1675 + 0,5467\,ITI \text{ (foreign) and}$$
$$ROP = 6,4250 + 0,7007\,ITI \text{ (Brazilian)}$$

Table 6 – ITI for Brazilian and foreign institutions, in R$ thousand

Year	IF´s					ITI (Base 1997)							
	Nac	%	Est	%	Total	Nac	%	Δ%	Est	%	Δ%	Total	Δ%
1997	165	80.49	40	19.51	205	1,875,923.92	74.68	0.00	635,862.50	25.32	0.00	2,511,786.42	0.00
1998	148	77.89	42	22.11	190	2,166,829.43	76.51	15.51	665,384.76	23.49	4.64	2,832,214.19	12.76
1999	141	76.63	43	23.37	184	2,424,075.17	76.95	11.87	725,933.36	23.05	9.10	3,150,008.54	11.22
2000	139	75.96	44	24.04	183	2,775,341.30	78.91	14.49	741,696.54	21.09	2.17	3,517,037.84	11.65
2001	128	75.29	42	24.71	170	2,988,028.35	72.13	7.66	1,154,711.70	27.87	55.69	4,142,740.04	17.79
2002	115	73.25	42	26.75	157	2,685,312.21	70.43	-10.13	1,127,527.41	29.57	-2.35	3,812,839.61	-7.96
2003	103	70.55	43	29.45	146	2,534,751.53	67.35	-5.61	1,228,872.05	32.65	8.99	3,763,623.58	-1.29
2004	115	79.86	29	20.14	144	2,460,609.81	68.02	-2.93	1,157,080.70	31.98	-5.84	3,617,690.52	-3.88
2005	105	72.92	39	27.08	144	2,680,906.07	69.34	8.95	1,185,257.74	30.66	2.44	3,866,163.81	6.87
2006	95	72.52	36	27.48	131	2,725,402.94	71.33	1.66	1,095,557.13	28.67	-7.57	3,820,960.07	-1.17
2007	94	73.44	34	26.56	128	2,964,572.84	78.60	8.78	807,190.52	21.40	-26.32	3,771,763.36	-1.29
2008	93	72.66	35	27.34	128	2,519,200.69	71.16	-15.02	1,020,896.31	28.84	26.48	3,540,096.99	-6.14

Figure 4 – Regression lines for Brazilian x foreign
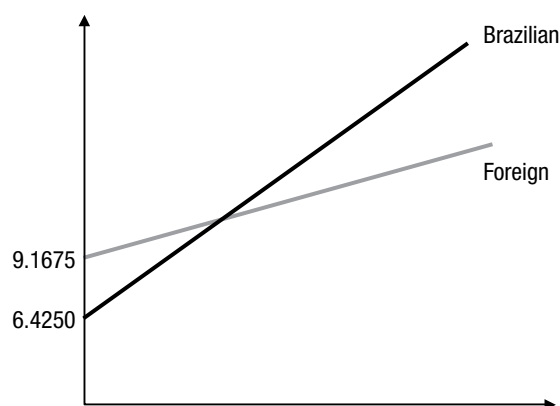
This result suggested that foreign banks started from a higher intercept, but because they have a lower inclination, they are less efficient in transforming IT investments in their operating income. Figure 4 shows the two lines generated.

Analysis of IT investments for Y2K and SPB

This study also assessed what occurred to IT investments (ITI) in both the millennium bug and SBP implementation. Table 6 relates the consolidated values in absolute terms for ITI and the values in real terms for ITI (base year 1997). The periods when banks conducted their IT projects related to both Y2K and SPB are represented on the right of the table. Figure 4 was generated using data from table 6, and it shows the evolution curves for both time series for IT investment consolidated values. The consolidated values in real terms that banks invested in IT were found to have been kept on an annual level that started to be produced from 2000 to 2001.

The Y2K event

The millennium bug (Y2K) was an event that occurred in the turn of 1999 to 2000; it mobilized all sections in banks, especially those related to IT. Many systems had been built with no concern for treating the datum 'year' with four digits or in a date format, which imposed a complete review of compu-

ter program codes and the redesigning of files and databases.

From 1998 to 2000, Brazilian banks invested large sums in projects related to Y2K. From 1998 to 1999, their projects were being followed by the Brazilian Central Bank, and in 2000 they completed many projects related to Y2K. There is no connection between Y2K projects and the implementation of SPB, since banks only started their projects related to payment system in 2001.

The figures suggest a movement in Brazil similar to what Anderson and others (2006) found in the United States. Many IT managers from banks turned Y2K into an "opportunity" for other investments, in order to modernize the technology in their computing resources. This explains the real variations in the consolidated amounts invested in IT, which were 12.76 percent in 1999 and 11.65 percent in 2000. IT annual investments increased sharply from R$ 2.512 billion reais in 1997 to R$ 3,517 billion reais in 2000, which means a real increase of 40 percent. Such an increase was not only caused by software adjustments.

The SPB event

The implementation of the Brazilian Payment System (SBP) took place on April 22, 2002. The project, conducted by the Brazilian Central Bank (Bacen) (2009b) was the result of a partnership between Bacen and Bank Associations and Clearing Houses, and it was developed between July 2000 and April 2002. In the SPB event, investments involved high sums of money in *hardware*, *software* and services. The investments in hardware involved new data communication equipment, new contracts with data transmission operators and new computers capable of supporting the new technologies incorporated by the system. Investments in software involved rebuilding or buying many vital internal systems such as bank account, treasure and *back office* support. According to Lowenthal (2005), the impact on technology was considered greater than that caused by the millennium bug, and its implementation required no less monumental an effort. Obviously, SPB required high IT investments from banks - much more than Y2K did.

Table 7 shows that, for 2001, the variation index for consolidated IT investments (base year 1997) was 17.79 percent in real terms. This is the highest figure in the analyzed series, and it reveals that IT

investments were significant in that year. The volume of consolidated IT investments increased sharply from a R$3.517 billion-real level to R$ 4.143 billion reais by the end of 2001. In 2000, investments were still very much related to Y2K projects, but in 2001, investments were driven by the beginning of SPB. Many financial institutions completed investments

related to SPB in 2002. This occurred because the large majority of banks only became involved in SPB projects from 2001.

FINAL REMARKS

This study aimed to generally analyze the impact of IT investments on the operating income of Brazilian bank

In order to accomplish this goal, we proposed a model based on a Cobb Douglas production function, which used IT investments (ITI) and personnel expenses (PE) as capital and labor inputs, respectively. The data used in this study are from the Cosif System of the Brazilian Central Bank, and they cover the period from 1997 to 2008. Four major analyses were performed: cross section and longitudinal analyses, a comparative analysis between investments by Brazilian and foreign banks, and finally, the analysis of Y2K and SPB events.

In the cross section analyses, the results of all regressions provided evidence of relevant coefficients of determination (R2) and significant coefficients (beta) for the 2 explanatory variables, indicating the impact of IT investments and personnel expenses on

Table 7 – consolidated ITI, R$ thousand

Ano	IFs	ITI	Δ%ITI	ITI (Base 1997)	Δ%ITI	
1997		2,511,786.42	0.00	2,511,786.42	0.00	
1998	190	2,882,627.60	14.76	2,832,214.19	12.76	← Y2K
1999	184	3,850,500.51	33.58	3,150,008.54	11.22	← Y2K
2000	183	4,726,914.30	22.76	3,517,037.84	11.65	← Y2K
2001	170	6,145,247.97	30.01	4,142,740.04	17.79	← SPB
2002	157	7,086,818.96	15.32	3,812,839.61	-7.96	← SPB
2003	146	7,603,237.75	7.29	3,763,623.58	-1.29	
2004	144	8,216,131.51	8.06	3,617,690.52	-3.88	
2005	144	8,885,804.12	8.15	3,866,163.81	6.87	
2006	131	9,119,135.35	2.63	3,820,960.07	-1.17	
2007	128	9,698,455.38	6.35	3,771,763.36	-1.29	
2008	128	9,994,835.15	3.06	3,540,096.99	-6.14	

Figure 5 – ITI Evolution
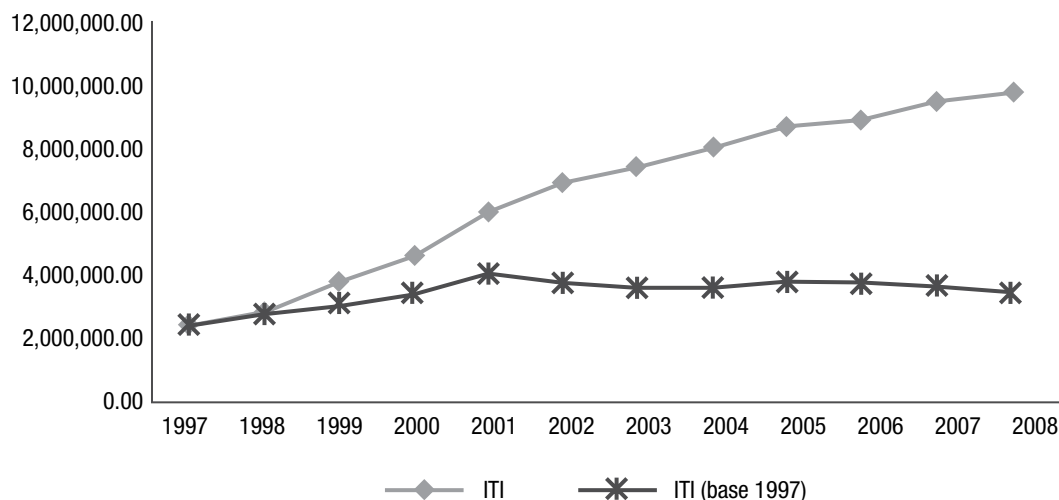
the operating income of banks. In the longitudinal analysis using the unbalanced panel, the coefficient of determination (R2) for the regression was significant; the coefficient for the ITI was also significant. The panel result also suggested real, positive impact of IT investments on the operating result of banks during the analyzed period. Still regarding the longitudinal analysis, and using the same data from the unbalanced panel, a specific assessment about IT investment amounts in banks was conducted. This assessment found a process of concentration of these investments in large Brazilian banks in the period from 1997 to 2008.

With regard to the comparison between total IT investments by Brazilian and foreign banks, two different yet complementary ways were used to conduct it. In the first one, foreign participation was found to have increased its total investments slightly, and although the number of Brazilian institutions was found to have decreased significantly in the analyzed period, their total IT investment amounts were found to have been significantly high. In the second way of comparing Brazilian and foreign banks with regard to IT investments, an econometric model with dummy variables was used. The regression with dummies suggested that Brazilian institutions were more efficient than foreign ones in "transforming" IT investments to benefit their operating incomes in the analyzed period. This finding allowed to infer that Brazilian banks had a better knowledge of the market they operated in, and were therefore able to direct their IT investments in a better way.

The last analysis in this study assessed the behavior of IT investments by banks at two particularly relevant times for the financial system, namely the millennium bug (Y2K) and the implementations of the Brazilian Payment System (SPB). Figures were found to provide unmistakable evidence that banks increased their amounts invested in IT in real terms in the years immediately preceding both events. The most significant of them in terms of financial amounts invested was SPB. This was not surprising, considering that in order to participate in the new payment system banks had to invest heavily both in hardware and software and services. New processes were created and new technologies implemented.

In the case of Y2K, IT investments were also considerable. The figures for the period from 1998 to 2000 suggested that Y2K led banks to take advantage of the event as an "opportunity" to modernize their IT and computing resources. This event allowed a few banks to conduct projects involving much more than simply buying or adapting software for year 2000. This occurred not only in Brazil, and it was also the subject of studies abroad.

The model of this study, with only 3 variables, could be said to limit it; however, although its model is quite simple, the independent variables selected (ITI and PE) are currently the most relevant ones in defining the operating income of a bank. It is noteworthy that no mathematic artifice was used that could allow including into regressions the institutions excluded for having a negative OI; the institutions used in the calculations were found to represent the majority and they comprehended the largest ones.

Future research could provide a sequence to this study, considering the refinement of the econometrical model and finding other explanatory variables (including macroeconomic ones), or even proposing a new, dependent variable that can be related to IT investments.

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