# Impact of Compensation Structure and Managerial Incentives on Bank Risk Taking: Evidence from US and Europe

Bill Francis, Aparna Gupta and Iftekhar Hasan

Lally School of Management and Technology

Rensselaer Polytechnic Institute

Troy, NY 12180

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**Abstract**

In this article, we analyze the impact of managerial compensation structure in publicly-traded banks on their risk taking behavior described by the loans extended by them, and the changes in risk taking through the changing regulatory environment for these banks. We build a simulation model to study the impact of the interaction between regulatory changes and competitiveness in the sector on managerial compensation, and in turn their joint impact on a bank's riskiness. Utilizing the simulation model, we will test the following three hypotheses, 1) increase in competitiveness after deregulation results in higher levels of risk for banks, 2) regulatory changes can result in change in the composition of managerial compensation, which creates an environment of incentives for enhanced risk taking, 3) regulatory changes accompanied by certain governance or managerial compensation controls can bring prudence in the risk taking behavior. A broad range of data from financial, managerial, competition and governance is obtained for periods of 15-20 years from the call reports of the Federal Reserve Bank of Chicago, ExecuComp and the IRRC databases to calibrate the simulation model and analyze the above three hypothesis.

Utilizing the simulation model, we achieve isolating the role of changing competition and compensation triggered by regulatory changes as sources of potential changes in bank's riskiness, and the extent of impact on a sample of different banks. The extent of impact is then correlated with the governance characteristics of the banks. We observe that competition uniformly increases the risk in firm value and shareholder-equity of all the banks, more severely for some than others. Its effect on change of firm value through regulatory changes observed is opposite from its effect on shareholder-equity for some banks. Change in competition combined with change in managerial compensation captures significantly more of the increased risk in firm value and shareholder-equity. Lastly, the governance characteristics show that risk differential between competition alone and competition combined with compensation is low for banks with good governance.

**Keywords**: bank risk taking, regulatory changes, simulation modeling, impact of competition.

## Section 1: Introduction

The impact of managerial incentives on risk taking behavior in corporations is widely studied in the literature. In the banking industry this relationship takes on unique significance due to the role banks perform in the economy as well as special regulatory features of the industry. A careful look at this relationship has become more important at this time to understand its role in the creation and propagation of the current financial crisis, as well as to understand the role of regulatory changes. In this article, we analyze the impact of managerial compensation structure in publicly-traded banks on their risk taking behavior as described by the types of loans being extended, and the changes in this behavior through the changing regulatory environment for these banks.

As opposed to other industries, in banking there are certain factors that lend themselves to convenient observation of their risk taking behavior. These factors include the individual or aggregate yield spreads of the portfolio of loans extended by the bank, the levels of non-performing loans, the maturity structure of the loans, frequency of need to acquire funds for short-term liquidity, the off-balance-sheet activities of the bank, and change of all the above with time. These risk-taking factors are influenced by how diversified the bank is in its activities, such as whether the loans in the portfolio are extended to single or multi-segment industry, the frequency, extent and quality of syndication the bank works in, diversity and innovation in products, geographical location of the bank's activities, and its regulatory environment.

It is known from earlier investigations reported in the literature that managerial compensation structure affects a firm's risk taking behavior. Studying this relationship and its change with time, specifically for the banking sector, holds merit for several reasons. Managers in banks have to act within the auspice of an exogenously created regulatory environment, changes in which have over the years created new competitive pressures. Securitization, for instance, has existed in banking for decades; however it became more popular in recent years in response to the new competitive pressures triggered by changes in the regulatory environment for banks in the US, as well as changes in Europe after the creation of the Euro-zone. Therefore, managerial decisions may be affected by not only their compensation structure, but also the implications of changes due to the exogenous regulatory shocks and competitive pressures. Studying the impact of the change in regulatory environment on managerial compensation structure, managerial risk taking behavior, or both, besides the changes in competition due to regulatory changes, will shed light on the efficacy of the regulatory structure and how it is implemented.

We build a simulation model to study the impact of the interaction between managerial compensation, regulatory changes and competitiveness in the sector on a bank's risk taking behavior. Based on the simulation model, we will examine the following three hypotheses, 1) increase in competitiveness after deregulation results in higher levels of risk for banks, 2) regulatory changes can result in change in the composition of managerial compensation, which creates an environment of incentives for enhanced risk taking, 3) regulatory changes accompanied by certain governance or managerial compensation controls can bring prudence in the risk taking behavior. We utilize the following data sources to conduct our study; the data are used to develop the structural framework for the simulation model, calibrate it, and use it for the analysis of the above three hypotheses. The broad range of data covers the financial, managerial compensation, competitive environment and governance characteristics of a sample of 45 banks for periods ranging from 15 to 20 years, obtained from the call reports of the Federal Reserve Bank of Chicago, ExecuComp and the IRRC databases.

The rest of the paper is organized as follows. In the next section, we further build the rational for the hypotheses in the context of the extant literature on the impact of regulatory changes on competitiveness, the impact of managerial compensation on risk-taking in a firm, and finally, of governance. Section 3 will be devoted to developing the mathematical model for bank's structure, asset, liabilities, firm value, growth and shareholder-equity, as well as impact of regulatory changes on these directly or indirectly due to competition and compensation structure changes. In Section 4, we will present the calibration methodology utilized for the model, as well as develop the design of simulation study to examine the hypotheses using the model. We present our analysis of the hypotheses in Section 5 in terms of the 45 banks identified in this study. Finally, we will conclude with a summary of findings and discussions for future research in Section 6.

## Section 2: Discussion of the Hypotheses and the Simulation Model

Deregulation is associated with increase in investment opportunities for a bank, as is witnessed for the United States banking sector geographical and product related deregulations of the 1990s, the 1994 Riegle-Neal Act (RNA) and the 1999 Gramm-Leach-Bliley Act (GLBA), as well as for the formation of the Euro-zone in 1999. As these new opportunities are created for all banks to participate in, competition to benefit from these new opportunities can intensify for a bank, or be made to intensify by creation of incentives for the managers to take advantage of the new investment opportunities. There is plenty of evidence of changing compensation structure in concurrence with the deregulations (Cuñat and Guadalupe, 2004).

Increased competition from deregulation can imply that a bank will need to make extra effort to stay as profitable as its pre-deregulation state. In making the extra effort, the central motivation for deregulation is that the banks will serve their customers more efficiently and effectively. However, one implication of higher effort to cope with increased competition can be that the bank's risk taking experiences an up-thrust, as shown in Jiménez et. al (2007) from their study of Spanish banks. While Jiménez et. al (2007) study the impact of competition on bank's risk taking, they don't incorporate deregulation to be the source of increased competition, where the upsurge in competition occurs as an exogeneously arrived shock. Our first hypothesis aims at addressing this question, and by creating an answer to it, sets the base-level from which the puzzles of the impact of all the factors that affect the implication of deregulation on a bank's risk taking are addressed.

Investment opportunity expansion due to deregulation are often responded to by a change in the composition of the managerial compensation in order to better align compensation with shareholder's objectives of taking advantage of the new investment opportunities (Cuñat and Guadalupe, 2004). The joint impact, however, of deregulation resulting in higher competition and change in the composition of managerial compensation on bank's risk taking is poorly understood. Understanding this relationship is crucial for effective implementation of regulatory changes in assessing the environmental factors that can make the regulatory changes improve or derail the banking system. In their recent study, Coles et al (Coles, Daniel and Naveen 2006) study the impact of incentives put in place within managerial compensation on a firm's riskiness. They find that a higher sensitivity of managerial compensation to stock volatility of a firm gives executives an incentive to both invest in riskier assets and implement more aggressive debt policy. Although their study is not specifically for banking institutions, but for a general firm, the finding is insightful and verifiable in our investigations. Coles et al, however, do not consider the competitiveness or regulatory aspects of the firm’s environment. Brewer et al (2003) study the relationship between deregulation, managerial compensation and bank risk taking. They establish the existence of a relationship between equity-based compensation to the managers with bank performance, financial leverage, and with risk. They also find that equity-based compensation is higher in the post-deregulation environment, thus providing a second evidence to Cuñat and Guadalupe's (2004) findings. However, the relationships found do not indicate any causality, temporal dependence of one on another or the relative importance in explaining the risk-taking. The analysis also does not allow decomposition or decoupling of the factors that are seen as affecting the risk taking.

Our second hypothesis, based on the past findings in the literature for general firms (Coles, Daniel and Naveen 2006), examines on a bank-by-bank basis the degree of change in performance related, stock volatility (Vega) sensitive managerial compensation, and its impact on the increase in bank riskiness relative to the base-case of first hypothesis. Here we assess the impact of the regulatory changes in a bank's environment on its compensation structure and on its managerial risk-taking. We hypothesize that an increase in competition due to deregulation has caused greater performance sensitivity in managerial compensation, which in turn has resulted in increased risk-taking by the managers, thus extending riskier loans at higher loan spreads. Therefore, for addressing our second hypothesis, we isolate the incremental effect of deregulation triggered managerial compensation restructuring on bank risk taking. Higher stock volatility sensitivity in managerial compensation arises from a reduction in fixed pay, at least as a fraction of overall compensation, and increase in the performance related, variable pay in the form of bonuses and stock options granted or long-term incentive payouts (Cunat and Guadalupe 2004). However, a stronger alignment of managerial compensation with interests of the shareholder, without unduly increasing the risk borne by the manager, can result in managers being motivated to extend more risky loans. Under the second hypothesis we examine the contribution of managerial compensation induced impact on the firm value and shareholder-equity.

The United States banking sector deregulations of the 1990s, the 1994 Riegle-Neal Act (RNA) and the 1999 Gramm-Leach-Bliley Act (GLBA), the formation of the Euro-zone in 1999, and the implementation of Basel Accord have had tremendous impact on the banking sector. Both the geographical deregulation (RNA) and product deregulation (GLBA) increased competition, reduced market power and opened up new opportunities for investments. In order to respond to the change and create incentive to take advantage of new investment opportunities, the managerial compensation structure has tilted stronger towards equity-based compensation, in the form of stocks and stock options (Brewer, Hunter and Jackson 2003) and bonuses. This change in compensation has resulted in managers being more motivated to make risky loans. Our second hypothesis will examine if this excess risk-taking due to managerial compensation restructuring is beneficial for the bank. Our third hypothesis turns to governance characteristics of the banks to examine if the governance features of a bank shielded the bank from the dual, adverse interaction of increased competition and higher performance-sensitive compensation as a result regulatory changes.

Our third hypothesis is the one that fully utilizes the capabilities of a simulation model. In a simulation model, risk factors can be silenced to observe the behavior of the overall system in their presence and absence. We will compare the scenarios when regulatory changes resulted in competitive structure modification for banks, but not compensation changes, thus silencing its effect, as opposed to when both competitive and compensation structural changes occurred. We will evaluate the difference of bank risk characteristics in the two scenarios against some of the bank's corporate governance characteristic to extract relationship governance and adverse impact of compensation structure changes. Laeven and Levine 2008, has observed that regulation will have different effects on bank risk taking depending on the bank's corporate governance structure. They show that bank risk taking varies positively with the comparative power of shareholders within the corporate governance structure of each bank. Here our focus is on connecting competitive environment changes and compensation structure changes in light of regulatory changes on the riskiness of a bank, and how the governance features can modulate this relationship, which relates to strength of shareholder rights and ownership structure.

A simulation model builds a structural relationship of the dynamic interaction between components of a system to determine the overall behavior of the system. Properties of each component of the system can be chosen to be modified or silenced, as stated earlier, to assess the impact of this change on the overall system. The simulation model to support the analysis of the three hypotheses discussed earlier is built using four major segments, whose interaction is central to the study undertaken in this article (see Figure 1). Each block in Figure 1 consists of a set of variables, evolution of which is defined by appropriately chosen models and interaction with other variables within the block or the other blocks is developed. The Asset and Liability Variables constitute the 'Asset Risk Evolution Model' and the 'Liability Risk Evolution Model', respectively, in Figure 1. The asset variables include all the loan types, investments, interest income and other income, while liability variables are all the deposit types, interest expense, and non-interest expense. The asset and liability variables are combined to determine the annual earnings for the bank, as well as the bank's firm value and firm growth. Given a structure for the managerial compensation, the earnings and firm growth information determine the actual level of the managerial compensation dispensed. As the simulation model evolves, the manager influences the exposure to various loan and deposit types, thus creating the possibility of modifying the compensation delivered to him.  Changes in the regulatory and competitiveness environment of the bank influence the loan types available, their riskiness, deposit types, their riskiness, level of regulatory capital required, as well as managerial compensation structure. Each of these changes individually and collectively have different impacts on the managerial compensation feedback loop at the bottom of Figure 1, generated by loan and deposit opportunities exploited and their impact on the earnings and growth of the firm. We next develop each component of the simulation model.

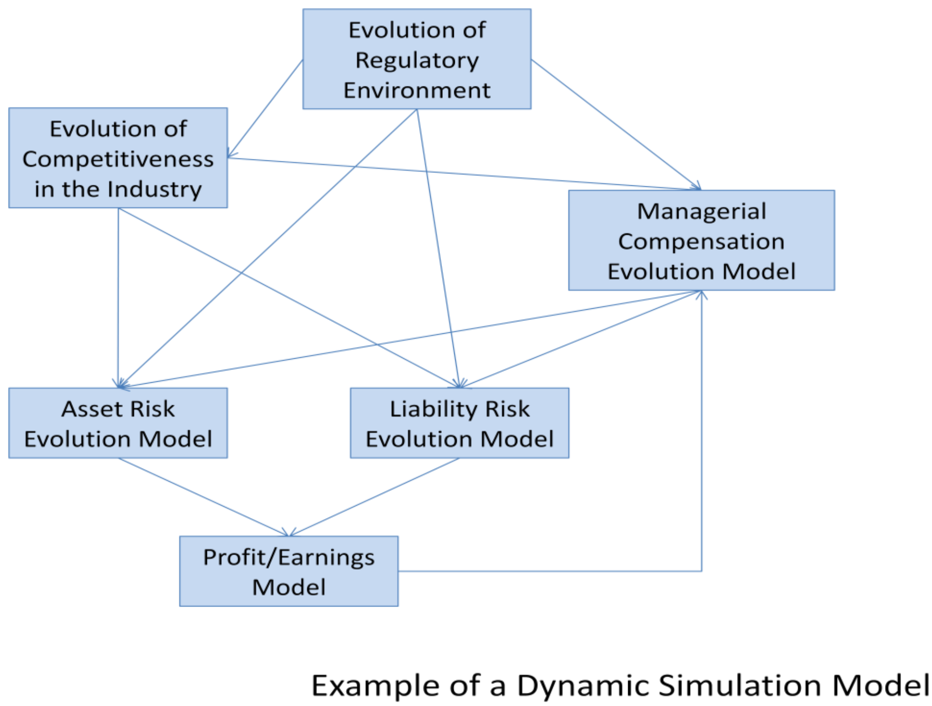



**Figure 1: The layout of the simulation model**

**Section 3: The Model**

In this section, we build the models for each component of Figure 1. We model the base interest rate for loans by a simple affine interest rate model:

$$dr(t) = (a\text{-}b\, r(t))\, dt + (c\, r(t) - d)^{1/2}\, dW(t), \tag{1}$$

where W(t) is a Wiener process under the real-world measure. The interest rates applicable to all the loan types is described as a spread, $ds_i^a(t)$, in excess of the base interest rate, r(t), given by:

$$ds_i^a(t) = (a_i^a\text{-}b_i^a\, s_i^a(t))\, dt + (c_i^a\, s_i^a(t) - d_i^a)^{1/2}\, dW_i^a(t), \tag{2}$$

for i= 1 to n, where n is the number of loan types, and $dW_i^a(t)$ is an independent Wiener process. Using these two models the values and riskiness of the loans types can be determined, as well as the interest income from each loan type. Similarly, we define the spreads, $ds_i^l(t)$, for the deposits in excess of the base interest rate as:

$$ds_i^l(t) = (a_i^l\text{-}b_i^l\, s_i^l(t))\, dt + (c_i^l\, s_i^l(t) - d_i^l)^{1/2}\, dW_i^l(t), \tag{3}$$

for i= 1 to m, where m is the number of liability (deposit) types, and $dW_i^l(t)$ is an independent Wiener process. The liability spreads provide assessment of the interest expense from the deposit types.

The actual interest income and interest expense from the various loan and deposit types depends on the extent of exposure to that loan or deposit type, or the fraction of total asset/liability the specific loan or deposit type is. The extent of exposure to each loan or deposit type, in turn, can depend on the managerial decisions as well as competitive environment of the bank, and can be constrained by the regulatory conditions. We model the exposure to each loan type (asset) by $A_i(t)$ and deposit type (liability) by $L_i(t)$. Each of these are given to change with time by the following models.

$$dL_i(t) = (c_i^l(t) - L_i(t))\, dt + \sigma_i^l(t)\, L_i(t)\, dW_i(t), \tag{4}$$

for i = 1 to m, where $W_i(t)$ is an independent Wiener process, $c_i^l(t)$ is the time-dependent target liability level maintained by the bank, as dictated by the managerial choice, competitive pressures or regulatory constraints, and $\sigma_i^l(t)$ is the volatility of the liability type, also taken to be time-dependent as dictated by managerial choice, competitive pressures or regulatory constraints. Similarly, the asset levels are given by

$$dA_i(t) = (c_i^a(t) - A_i(t))\, dt + \sigma_i^a\, A_i(t)\, dW_i(t) + NPL_i\, A_i(t)\, dN_i(t), \tag{5}$$

for i = 0 to n, where $W_i(t)$ is an independent Wiener process, $c_i^a(t)$ is the time-dependent control or constraint on the asset level maintained by the bank, as dictated by the managerial choice, competitive pressures or regulatory constraints, and $\sigma_i^a(t)$ is the volatility of the loan type, again taken to time-dependent. The asset type '0' is reserved for short-term liquid assets – cash/T-Bills. $N_i(t)$, i = 1 to n, is an independent Poisson process depicting the arrival of jumps to the asset level due to non-performing loans with a constant rate $\lambda_i$ and $NPL_i\, A_i(t)$ is the size of jump in asset level due to the non-performing loans. For the asset type '0', $NPL_0$ is set to 0. Besides the loans types, a bank's investment assets are grouped in I(t) and evolve by the following model,

$$dI(t) = (r^{inv}(t) - I(t))\, dt + \sigma^{inv}\, I(t)\, dW^i(t), \tag{6}$$

where $W^i(t)$ is an independent Wiener process, $r^{inv}(t)$ is the time-dependent mean instantaneous return from the investments, taken to be time-dependent to be able to capture changes in investment strategy of the bank with time, $\sigma^{inv}$ is the volatility of return on investments.

Using the loan and deposit types, along with their corresponding applicable interest rates, total interest income and expense, respectively, can be computed for a period as follows. For a quarter, this would be represented as,

$$Int\_income_{[t,t+0.25]} = \sum_{i=1}^{n} \int_t^{t+0.25} (r(t) + s_i^a(t)) A_i(t)\, dt, \tag{7}$$

where as the interest expense becomes,

$$Int\_expense_{[t,t+0.25]} = \sum_{i=1}^{m} \int_t^{t+0.25} (r(t) + s_i^l(t)) L_i(t)\, dt, \tag{8}$$

for any starting time, t. The income from other investments is described in terms of its capital gains and the total dividend payments, given by,

$$Invest\_income_{[t,t+0.25]} = [I(t+0.25) - I(t)] + \int_t^{t+0.25} D(t)I(t)\, dt, \tag{10}$$

respectively. Combining the interest income and investment income, total revenue for the period can be computed as,

$$Total\_revenue_{[t,t+0.25]} = Int\_income_{[t,t+0.25]} + Invest\_income_{[t,t+0.25]}. \tag{11}$$

Similarly, at the expense end, we include expenses other than interest expense in the variable OE, and track it as follows,

$$d\, OE(t) = (r^{oe}(t)\, OE(t))\, dt + \sigma^{oe}\, OE(t)\, dW^{oe}(t), \tag{12}$$

where $W^{oe}(t)$ is an independent Wiener process, $r^{oe}(t)$ is the time-dependent mean instantaneous rate of accrual in the expenses other than the interest expense, which includes salary and other operational expenses. Volatility in change in these expenses is captured by $\sigma^{oe}$. The total other expense in a period of time, say a quarter becomes,

$$Other\_expense_{[t,t+0.25]} = OE(t+0.25) - OE(t), \tag{13}$$

Now combining interest and non-interest expense, the total expense and earnings for the period can be determined as follows,

$$Total\_expense_{[t,t+0.25]} = Other\_expense_{[t,t+0.25]} + Int\_expense_{[t,t+0.25]}, \tag{14}$$

$$Earnings_{[t,t+0.25]} = Total\_revenue_{[t,t+0.25]} - Total\_expense_{[t,t+0.25]}, \tag{15}$$

respectively. The firm value and growth can be measured by accounting for all its assets as follows,

$$Firm\_value(t) = \sum_{i=0}^{n} A_i(t) + I(t), \tag{16}$$

$$Firm\_growth_{[t,t+0.25]} = Firm\_value(t+0.25) - Firm\_value(t), \tag{17}$$

respectively. Finally, shareholder's equity is computed as,

$$\text{Shareholder\_equity}(t) = \sum_{i=1}^{n} A_i(t) + I(t) - \sum_{i=1}^{m} L_i(t). \quad (18)$$

We next describe the managerial compensation variables. We include five components comprising the overall annual managerial compensation, namely, salary (MC_S), bonuses (MC_B), option (MC_O), stock (MC_E, equity), and other (MC_M, miscellaneous). The change in each component is described as follows,

$$MC\_X(t+1) = MC\_X(t) + f_X(\text{Firm\_growth}_{[t,t+1]}, \text{Earnings}_{[t,t+1]} \mid \text{regulatory/competiveness environment}). \quad (19)$$

The function, $f_X(.)$, needs to be appropriately defined for each benefit type, 'X', where the 'X' is 'S' – salary, 'B' – bonuses, 'O' – option, 'E' – Equity/stock, M – Miscellaneous/other. The total annual compensation granted to the manager can be obtained by summing the compensation components for the year as,

$$TC(t) = MC\_S(t) + MC\_B(t) + MC\_O(t) + MC\_E(t) + MC\_M(t). \quad (20)$$

Once the bank's internal variables are described from the lower four blocks of Figure 1, the exogeneous variables and their interaction with the bank's operations can be defined. These blocks are the regulatory changes and changes in the competitive environment of the bank. For the regulatory component, we would need to describe the geographical and products-based regulatory variables, such as Geographical 94, Geographical 97, Product 99, Basel I, II implementation, if we focused on these in the 1990s time-period, and the impact of their change in time, i.e., shocks delivered to the variables described thus far due to regulatory changes. The competitiveness variables to consider would include, Herfindahl Index, Lerner Index, Number of Banks, Number of M&A, Number of Offices.

The impact of these regulatory and competition factors is on defining the changes in $c_i^a(t)$, the time-dependent control or constraint on the asset 'i' level maintained by the bank , $c_i^l(t)$, the time-dependent target liability 'i' level maintained by the bank, $\sigma_i^l(t)$, the volatility of the liability type i, $\sigma_i^a(t)$, the volatility of the loan type i, and the dependence of the function, $f_X()$, describing changes in the managerial compensation due to changes in the regulatory/competitiveness environment for the bank. For instance, bonus levels are increased in the managerial compensation package to cope with the changes from regulatory shocks.

Let $T_R^i$ be the $i^{th}$ regulatory shock, the impact of the regulatory shock experienced by the bank's internal and external environment is captured by how the variables change through the shock, i.e., $\Delta c_i^a(t)$, change in a bank's asset levels, $\Delta\sigma_i^a(t)$, change in volatility of bank's assets, More importantly though, the impact of the regulatory shock experienced by the bank's internal and external environment needs to be captured in terms of how the internal and external environment of a bank affect each other. The regulatory shocks, geographical deregulation (RNA) or product deregulation (GLBA), possibly intensify competition, the intensified competition results in changes in asset/liability levels and their volatility. Changes are possibly made to the managerial compensation structure to incentivize taking advantage of new investment opportunity created by the deregulation. The changed compensation structure could in turn result in change in asset/liability levels and volatilities. We capture these relations in the following equations.

$$\Delta c_i^a(T_R^i) = f_1(\Delta\text{Lerner Index}(T_R^i), \Delta\text{Number of Banks}(T_R^i), \Delta\text{Number of Offices}(T_R^i)) + \varepsilon_1, \quad (21)$$

describes the change in bank's asset levels due to change in competitiveness of the bank's environment through the regulatory shocks. Similarly,

$$\Delta\sigma_i^a(T_R^i) = f_2(\Delta\text{Lerner Index}(T_R^i), \Delta\text{Number of Banks}(T_R^i), \Delta\text{Number of Offices}(T_R^i)) + \varepsilon_2, \qquad (22)$$

would capture the change in volatility of a bank's assets through the regulatory shock. Equations (21) and (22), and similar ones for liabilities, are fundamental to the first hypothesis, how does the increase in competitiveness after deregulation affect a bank's assets and liabilities, which in turn determine the bank's risk taking. If regulatory changes and resulting competitive environment changes is accompanied by a bank changing its managerial compensation, the resulting impact in the bank's asset/liability level is described in the following,

$$\Delta c_i^a(T_R^i) = f_3(\Delta\text{Lerner Index}(T_R^i), \Delta\text{Number of Banks}(T_R^i), \Delta\text{Number of Offices}(T_R^i), \ldots..$$

$$\Delta MC\_B(T_R^i), \Delta MC\_O(T_R^i), \Delta MC\_E(T_R^i)) + \varepsilon_3, \qquad (23)$$

where we have included only change in performance-related compensation components – bonuses, stock-options and stocks. Similarly,

$$\Delta\sigma_i^a(T_R^i) = f_4(\Delta\text{Lerner Index}(T_R^i), \Delta\text{Number of Banks}(T_R^i), \Delta\text{Number of Offices}(T_R^i), \ldots..$$

$$\Delta MC\_B(T_R^i), \Delta MC\_O(T_R^i), \Delta MC\_E(T_R^i)) + \varepsilon_4, \qquad (24)$$

would capture the change in volatility of a bank's assets through the regulatory shock and changed managerial compensations. These relationships in Equation (23) and (24) are crucial to the second hypothesis - can regulatory changes result in change in the composition of managerial compensation resulting in higher bank riskiness.

The output variable of the simulation model needs to be defined based on the objective of the analysis. Under the first hypothesis, the risk-taking characteristic in the asset-liability and investment choices is summarized by the levels and volatility in **earnings**, the **firm value**, and the **shareholder-equity**. These three output variables will be analyzed to assess the impact of competition, managerial compensation and its changes on risk-taking characteristics of a bank. For the third hypothesis, we will classify banks by their response to the regulatory changes in terms of managerial compensation, and in each category further cluster banks by the chosen governance variables to assess the bank risk characteristic in each cluster defined by its governance characteristics. Governance variables, such as Governance Index, Entrenchment Index, Anti-takeover Index, will be used.

## Section 4: Calibrating the Model and Design of the Simulation Study

Before we develop our plan for how we will utilize the simulation model laid out in Section 3 to addresses the hypotheses set out in Section 2, we need to calibrate the simulation model using appropriate data. We describe the data in detail in this section, as well as the calibration method employed for the specification of the simulation model.

### Section 4.1: The Data

The core variables in the model are the base interest rate, r(t), the spreads on loan types, $s_i^a(t)$, spreads on liability types, $s_i^l(t)$, the level of loan types, $A_i(t)$, deposit types, $L_i(t)$, and investments, I(t), maintained at a bank. We describe these data, followed by how they are used to calibrate the models from Section 2. Once these core variables are described, the remaining variable, such as, total interest income and expense, etc., are described as dependent variables. The regulatory shock variables, competitiveness variables, managerial compensation and governance variables we will use for the analysis are also described below.

The choice of base interest rate, r(t), can be picked as either short-term (3-month) T-Bill rate or LIBOR. We use the 3-month T-Bill rate data from 1986-2007 obtained from the US Federal Reserve Statistical Release Historical Data[1] to calibrate the base rate model. The rest of the data can be described as consisting of four groups of variables – bank's financial condition, competition, managerial compensation, and governance. In all, we considered over a 1000 U.S. public commercial banks, however of these only about 45 banks have the long enough time-series financial data from 1986 to 2007. We require long enough time-series data for at least the core financial variables of the bank – the asset and liability variables – to not only calibrated the core equations, Equations (2)-(12) of the model, but to also ensure there is enough data covering the pre-regulatory shocks period to establish the pre-shock settings of the bank with confidence.

Bank's financial data is drawn from quarterly call report downloaded from Federal Reserve Bank of Chicago, spanning the first quarter of 1986 through the fourth quarter of 2007. For the 45 banks, we extract the asset, liability and investment variables for calibration of rest of core of the model. Among assets, we identify real estate loans, consumer loans and commercial loans as the key asset types, and among liabilities, we identify saving deposits, core deposits and transaction accounts deposits to be the key liability types. The corresponding interest income, namely, income from real estate loans, consumer loans and commercial loans, and interest expense on transaction accounts, savings and core deposits is obtained. For other investment assets, we identify security assets, cash asset and other asset, and the corresponding non-interest income. Quarterly data for a period of 1986-2007 is obtained for all the above variables for our selected 45 small and large banks. Controls for target levels of asset-liability choices made by a bank, $c_i^a(t)$, $c_i^l(t)$, are taken to be piece-wise constant. The break-points for these piece-wise constant are the timing of the regulatory shocks. The target control levels will be estimated from the data for the asset-liability levels maintained by the bank between the regulatory shocks.

The managerial data is obtained from Standard &Poor's ExecuComp database, which provides annual data on executive compensation in S&P 1000 firms since 1992. We merge it with the 45 sample banks and primarily look at five compensation variables for both CEO and top management team (excluding CEO): Salary, Bonus, Stock, Options, and Total compensation. Stock value is calculated using end of year stock price multiplied by the aggregate number of shares held by the named executive officer (excluding stock options). Option value is defined as the aggregate value of stock options granted to the executive during the year as valued using S&P's Black-Scholes methodology. Total compensation is comprised of Salary, Bonus, Other Annual, Total Value of Restricted Stock Granted, Total Value of Stock Options Granted (using Black-Scholes), Long-Term Incentive Payouts, and All Other Total.

[1] http://www.federalreserve.gov/releases/h15/data.htm

We use four measures of industrial competition. The first is the Lerner index, which captures market power and is estimated from balance sheet accounting variables using the cost function and frontier. Since the accounting variables are available from 1986 to 2007, Lerner index is calculated annually for each bank from 1986 to 2007. The second measure of competition is the deposit concentration ratio for the top three banks in the state. In addition, we have two more competition variables: number of commercial banks and number of offices of a bank in each state. Because aggregated bank data at state level is only available from 1994, the deposit concentration ratio is from 1994 to 2007. As required for this study, this duration covers the regulatory change period.

To measure the quality of governance, we use three measures, including state antitakeover index, G-index (governance index) and E-index (entrenchment index). The antitakeover index is from zero and increases if the state has a control share statute, a fair-price statute, a no-freeze-out statute, a poison pill endorsement statute, or a constituency's statute. G-index is a point scale from zero to twenty-four, a proxy for the balance of power between shareholders and managers. Firms having higher G-index are referred to as having higher management power or weak shareholder rights, while firms with lower index value are referred to as having lower management power or strong shareholder rights. G-index is from IRRC (Investor Responsibility Research Center), an organization that has tracked the corporate governance provisions for about 3500 firms for the following seven years: 1990, 1993, 1995, 1998, 2000, 2002 and 2004. E-index is also constructed based on IRRC provisions, but only uses six entrenching provisions. It ranges from zero to six, representing the number of entrenching provisions the company has in a given year. Similar to G-index, larger E-index implies higher managerial entrenchment and lower governance quality. All three governance measures are available from 1992 to 2004. Given that governance quality does not change dramatically with time, we use the value of previous year to replace the missing years in between, and use 2004 index to fill in for years after 2004.

**Section 4.1.1: Treatment of Missing Values in Compensation Data**

There are many missing values for the compensation variables of the 45 sample banks. We replace the missing values using pseudo values as follows, (1) calculate yearly growth rate based on existing data; (2) remove growth rate outliers which are beyond 1% and 99% of the sample; (3) take the average growth rate for each bank based on the available growth rates; (4) use the average rate and nearest available year to estimate the years with missing values. For example, if the CEO salary of a bank is missing for 1999, but is available for 1996 and 2000, then we use 2000 data and average growth rate to estimate the salary in 1999. Missing values for other compensation variables are similarly handled. In the following cases, however, we retain the missing values: (1) if there are not enough values to compute average rate; (2) we find that in some banks in some years the CEO bonus is zero. If we use this number to estimate nearest years, every year would turn out to be zero, which does not make sense. As a result, some missing values are retained after the treatment.

**Section 4.2: Calibrating the Model**

We seek a Quasi-Maximum Likelihood Estimate for the parameters of the base interest rate model. For the derivation of the QMLE estimator, we discretized the model for the base interest rate by the Euler method to obtain the following.

$$\Delta r(t) = (a - b\, r(t))\, \Delta t + (c\, r(t) - d)^{1/2}\, \Delta W(t), \quad (25)$$

where $\Delta t$ is taken to be a month, to stay consistent with the quarterly data for the banks' assets and liabilities. We take the starting time for the analysis, $t_0$, to be the start of the year 1986, and $r(t_0)$ to be the T-Bill rate applicable on that day. Every subsequent month's interest rate can be described by Eqn (25) as follows,

$$r(t_k) = r(t_{k-1}) + (a - b\, r(t_{k-1}))\, \Delta t + (c\, r(t_{k-1}) - d)^{1/2}\, \Delta W(t_{k-1}), \tag{26}$$

for k = 1 to T. Given $\Delta W(t) \sim N(0, \surd\Delta t)$, we obtain that the conditional distribution of $r(t_k)$ (= $r_k$) given $r(t_{k-1})$ (= $r_{k-1}$) is approximately normal. Therefore,

$$f(r_k|r_{k-1};\theta) = \frac{1}{\sqrt{2\pi(cr_{k-1}-d)\Delta t}} e^{-\frac{[r_k - r_{k-1} - (a - br_{k-1})\Delta t]^2}{2(cr_{k-1}-d)\Delta t}}$$

with $k = 1 \dots T$ and $\theta = [a; b; c; d]$.

(27)

The likelihood function, $L(\theta)$ is given as follows:

$$L(\theta) = \prod_{k=1}^{T} f(r_k|r_{k-1};\theta) f(r_0).$$

Therefore,

$$\ln L(\theta) = \sum_{k=1}^{T} \ln f(r_k|r_{k-1};\theta) + \ln f(r_0),$$

or $\ln L(\theta) =$

$$\sum_{k=1}^{T} \frac{-1}{2} \ln[2\pi(cr_{k-1} - d)\Delta t] - \frac{[r_k - r_{k-1} - (a - br_{k-1})\Delta t]^2}{2(cr_{k-1}-d)\Delta t} + \ln f(r_0).$$

(28)

We seek the parameters, $\theta$, that maximize the likelihood function or the log-likelihood function above, therefore we differentiate the log-likelihood function with respect to the four parameters and equate each differential to zero and obtain a system of equations. The following system of four equations is solved for the QMLE estimate of the parameters, $\theta$.

$$\frac{\partial \ln L(\theta)}{\partial a} = \sum_{k=1}^{T} \frac{[r_k - r_{k-1} - (a - br_{k-1})\Delta t]}{(cr_{k-1}-d)} = 0. \tag{29}$$

$$\frac{\partial \ln L(\theta)}{\partial b} = -\sum_{k=1}^{T} \frac{[r_k - r_{k-1} - (a - br_{k-1})\Delta t] r_{k-1}}{(cr_{k-1}-d)} = 0. \tag{30}$$

$$\frac{\partial \ln L(\theta)}{\partial c} = \sum_{k=1}^{T} \frac{-1}{2} \frac{r_{k-1}}{(cr_{k-1}-d)} + \frac{r_{k-1}[r_k - r_{k-1} - (a - br_{k-1})\Delta t]^2}{2(cr_{k-1}-d)^2\Delta t} = 0. \tag{31}$$

$$\frac{\partial \ln L(\theta)}{\partial d} = \sum_{k=1}^{T} \frac{1}{2(cr_{k-1}-d)} + \frac{[r_k - r_{k-1} - (a - br_{k-1})\Delta t]^2}{2(cr_{k-1}-d)^2 \Delta t} = 0. \tag{32}$$

The above method can also be adopted for estimation of the parameters in the model for spreads for loan/asset types, $s_i^a(t)$, and deposit/liability types, $s_i^l(t)$, since the model in Eqns (2) and (3) for these are essentially identical to that of the base interest rate model. Two differences arise due to the characteristics of the data available for calibrating the spread models, first the time-step, $\Delta t$, will need to be taken as 3 months or a Quarter. Second, in contrast to base interest rate model, depending on the number of banks considered in a class, more than one trace for the spread for each loan or deposit type may be available, one representing each bank in the class. The model will need to be calibrated for the class of banks, and hence the parameters will need to be consistent for data for all banks in the class. This will be achieved by assuming the spread traces for each bank in a class are independent, identically distributed realizations of the same stochastic process model given in Eqns (2) and (3). We replace the single trace derivation for the base interest rate model by a multi-trace derivation for the loan and deposit spreads by modifying Eqn (23) to vector notation. Let $\mathbf{S}_i^a(t) = [s_{ij}^a(t)]$ j = 1..K, represent the spread for loan type 'i' for each bank, j, in the class at time t, where K is the number of banks in the class. Eqn (23) for the spread, $\mathbf{S}_i^a(t_k)$, in vector notation becomes,

$$f(\mathbf{S}_k^a | \mathbf{S}_{k-1}^a; \theta_a) \sim N(\mathfrak{M}(\mathbf{S}_{k-1}^a; \theta_a), \Sigma(\mathbf{S}_{k-1}^a; \theta_a))$$

with $k = 1 \ldots T$, $\theta_a = [a^a; b^a; c^a; d^a]$, $\mathfrak{M}$ is the mean, and $\Sigma$ is the covariance matrix. (29)

The rest of the derivation for implementing the QMLE is similar to above, but now for a K-dimensional process. To simplify this derivation, we will also consider each bank to be unique and identify its parameter separately, this will make the method of estimation of spread model parameters be identical to that for the base interest rate model parameters.

The parameters for the asset-level and liability-level models in Eqns (4) and (5), respectively, will be calibrated using the method of moments. In each of these models, there are only two parameters, the piece-wise constant in the control, $c_i^a(t)$ or $c_i^l(t)$, and the volatility parameter, $\sigma_i^a(t)$ or $\sigma_i^l(t)$. As before, we discretize the model by the Euler scheme to obtain,

$$\Delta A_i(t) = (c_i^a(t) - A_i(t))\, \Delta t + \sigma_i^a(t)\, A_i(t)\, \Delta W_i(t), \tag{30}$$

for i = 0 to n, and $\Delta t$ is taken to be 3 month or a quarter. With starting time, $t_0$, every subsequent quarter's asset level is described by Eqn (30) as follows,

$$A_i(t_k) = A_i(t_{k-1}) + (c_i^a(t_{k-1}) - A_i(t_{k-1}))\Delta t + \sigma_i^a(t_{k-1})\, A_i(t_{k-1})\, \Delta W(t_{k-1}), \tag{31}$$

for k = 1 to T. Given $\sigma_i^a(t_{k-1})\, \Delta W(t_{k-1}) \sim N(0, \sigma_i^a(t_{k-1}) \sqrt{\Delta t})$, which is independent of $t_{k-1}$ and $A_i(t_{k-1})$, the two piece-wise constant parameters in $\sigma_i^a(t_{k-1})$ and $c_i^a(t_{k-1})$ can be estimated from the first and the second moment equations. Similar derivations for calibration of the parameters in liabilities, $L_i(t)$, investment, I(t), and other expense, OE(t), models are developed.

**Section 4.3: Design of the Simulation Study**

We will first calibrate all the models from Equations (1)-(6) and (12) to describe the core financial characteristics of the bank. The calibration will break the data time-series down by the periods between regulatory changes, to allow the parameters pre- and post-regulatory change to be different. These calibrated models will be set to simulate the evolution of core financial characteristics of the bank. The core financial characteristics of a bank will be used to translate into the evolution of firm value, earnings, growth and shareholder-equity using Equations (7)-(18). Using the simulation model, we will simulate the bank's financial characteristics from 1986 through 2010. Performing many runs of simulation, large sample of scenarios will be created for the bank's earnings, firm value, growth and shareholder-equity at various time-points in the study period, 1986-2010. Averages and volatilities of bank characteristics will be computed using these set of scenarios for the key output variables, bank earnings, firm value, growth and shareholder-equity.

The base condition without interference of any other specific factors, such as, managerial compensation, competition, etc., will be the key reference characteristics to compare with under hypothesis one and two. In the next stage of the simulation study, in order to examine the first hypothesis, we will modify the change in asset/liability target levels and volatilities, $\Delta c_i^a(T_R^i)$ and $\Delta\sigma_i^a(T_R^i)$, through the regulatory shocks not by how the core financial data dictates, but instead by utilizing the formulation of Equations (21) and (22). Predicting the change in asset/liability target levels and volatilities, $\Delta c_i^a(T_R^i)$ and $\Delta\sigma_i^a(T_R^i)$, through the regulatory shocks using Equation (21) and (22), the scenarios for output variables, bank's earnings, firm value, growth and shareholder-equity will be generated. The averages and volatilities from these scenarios will be compared with those of the base reference scenario to fulfill the goal of the first hypothesis.

In the third stage of simulation study, we will modify the asset/liability target levels and volatilities, $\Delta c_i^a(T_R^i)$ and $\Delta\sigma_i^a(T_R^i)$, through the regulatory shocks again not by how the core financial data dictates, but this time by utilizing the formulation of Equations (23) and (24), which include the relation both with change in competitive environment and managerial compensation. This time predicting the change in asset/liability target levels and volatilities, $\Delta c_i^a(T_R^i)$ and $\Delta\sigma_i^a(T_R^i)$, through the regulatory shocks using Equation (23) and (24), the scenarios for output variables, bank's earnings, firm value, growth and shareholder-equity will be generated. Comparing the averages and volatilities from these scenarios with those of the base reference scenario, we will examine the second hypothesis.

In the last stage of the simulation study, we will compare the results from implementation of the simulation model using Equations (21)-(22) with those using Equation (23)-(24), against the governance characteristics of the 45 sample banks. The key question here is, if competition was the only factor changing with a regulatory shock versus competition and compensation both changing, do the levels and volatilities of a bank's output variables differ by some governance variables that can be used to capture the ability of a bank to handle the two level of changes better by creating a better risk-return trade-off in the level and volatility of the output variables. In this stage, no new simulations will be necessary. Instead our focus will be on comparing results from the previous two stages in light of the additional set of governance variables.

## Section 5: Implementation and Results of the Analysis

In this section, we begin with displays of the data used to calibrate the core of the model that describes the financial condition of a bank. This is followed by display and discussion of results from calibrating the core of the model, along with the output variable characteristics for the banks under the base reference setting. We will then start examining the three hypotheses in stages, as described in the previous section's design of simulation study plan.

### Section 5.1: Display and Discussion of Financial Data for the Banks

We display and discuss the raw data for a subsample of 10 banks in this section with the objective of collecting evidence from the data for a subsequent rigorous examination of the hypotheses. We begin with the asset data.

### Section 5.1.1: The Asset Evolution – Loans and Investments

We have identified a set of loan types and investment assets a bank decides to offer/acquire. We are interested in observing how these asset exposure levels change over time and are affected by various factors -- managerial decisions, incentives, competitive environment and regulatory changes. One implication of the asset types held by a bank is on the riskiness or volatility of the asset levels maintained, and more importantly, on the volatility of the income generated from the assets held. Volatility of assets and income, in turn, results in volatility in firm value and net earnings, both of which are crucial indicators of the perceived and actual health of the bank. We generate and present several traces of asset levels maintained by a subsample of 10 banks over the interest period of 1986-2007, as well as the income generated from these assets. The key asset types considered are: commercial loans, real estate loans, consumer loans, cash-level, security assets, and other assets. We also study the income generated from each asset type.

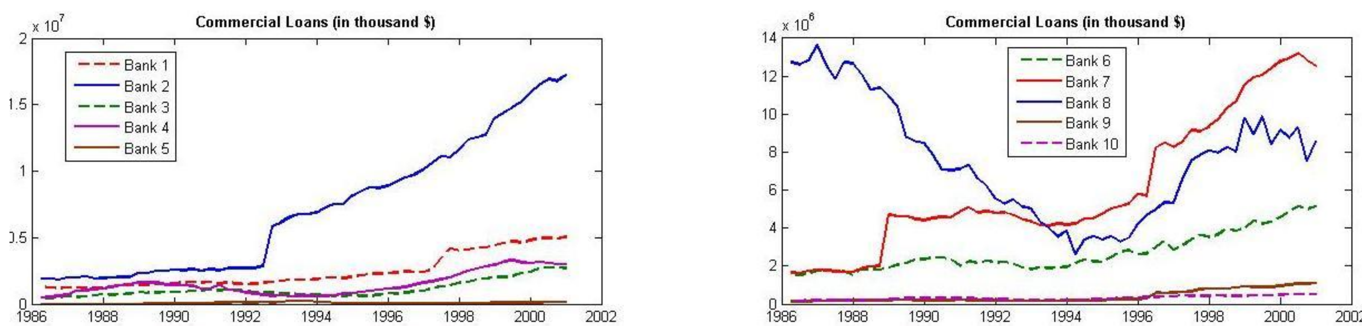



Figure 2

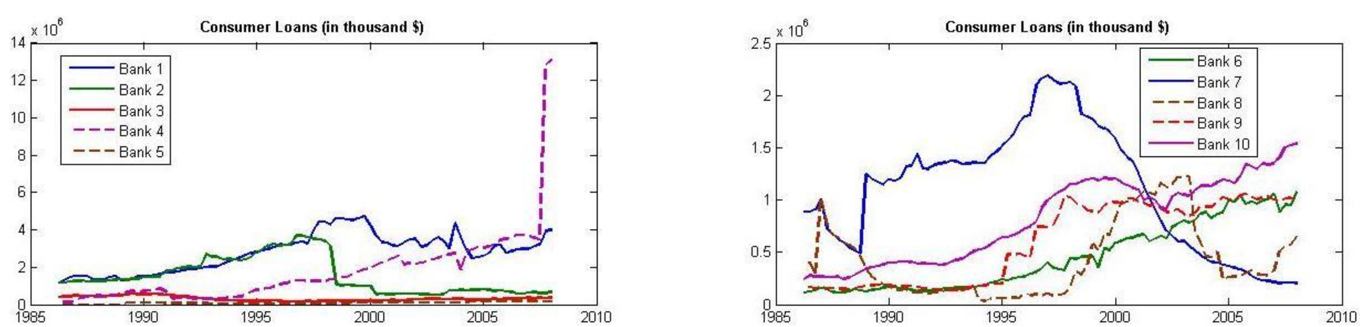



Figure 3

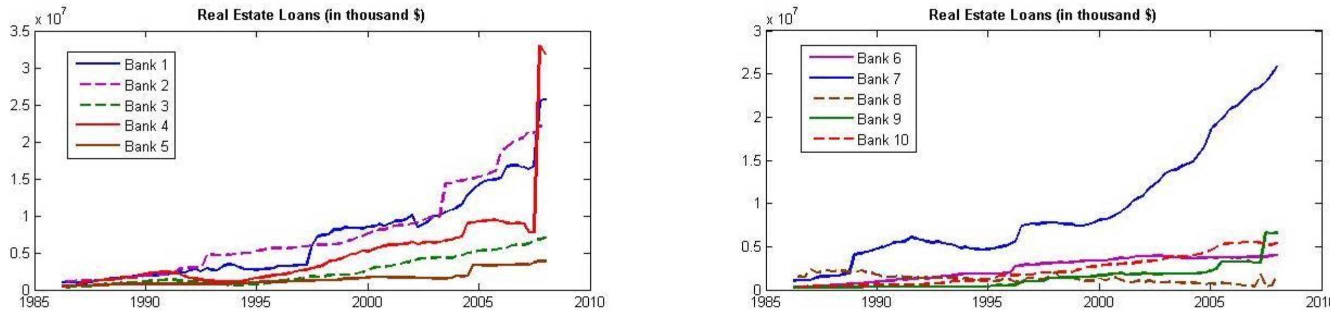



Figure 4

In Figures 2-4, we plot the commercial, consumer and real estate loan levels for the 10 banks. We observe that in general, the commercial and real estate loan levels are larger than the consumer loan levels. The commercial loan levels (Figure 2) are mostly stable and gently increasing, other than a couple of banks with a special experience, e.g. Bank 8 (for bank name, see Appendix). If we focus on the time after 1994, for all the banks the commercial loan levels have only grown, while there is a general trend of decline in the consumer loans. Bank 4 (bank name in Appendix) is weird with a very prominent order of a magnitude spike in 2006 for both consumer and real estate loans. The consumer loans in general display a greater degree of volatility. The real estate loans display a steady strong increase, especially enhanced after 1999-2000. In all the plots of Figures 2-4, there are clear time points where trends change, triggered by various reasons, therefore the definition of control, $c_i^a(t)$, is meaningful. The bank names corresponding to each bank number are provided in Table 2 in the Appendix.

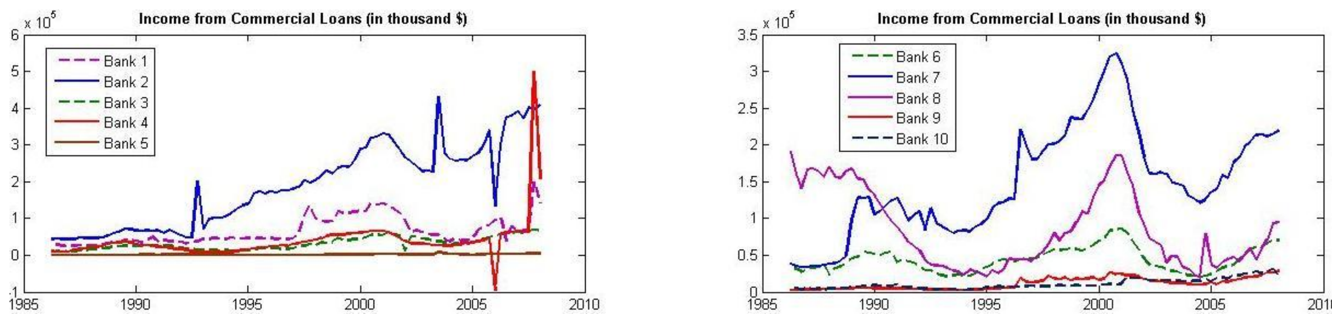



Figure 5

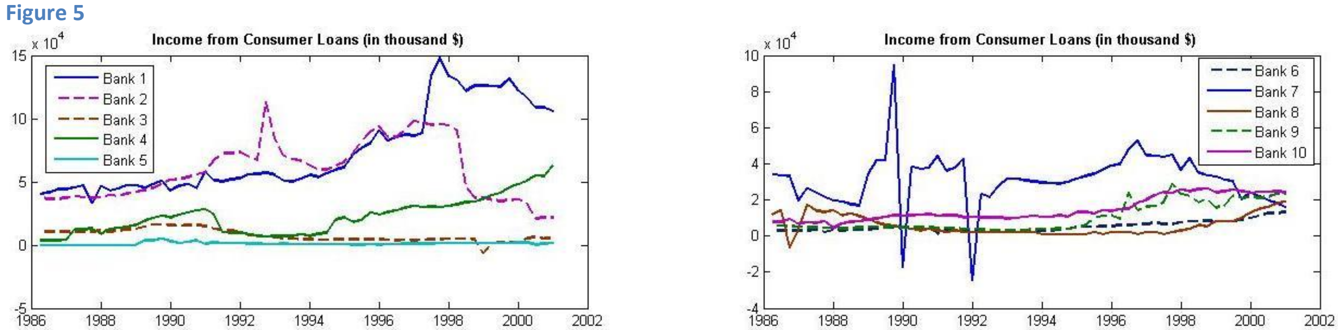


Figure 6

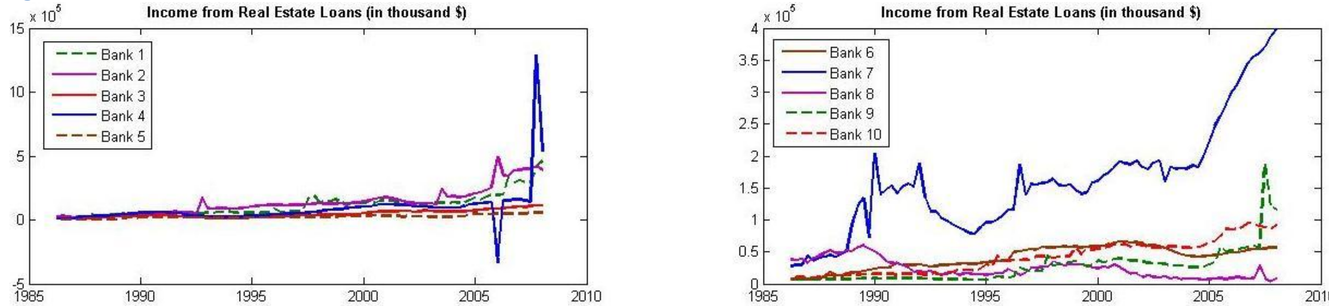



Figure 7

In Figures 5-7, the interest income from the various loan types is presented. Again in magnitude terms, the income from commercial and real estate dominates that from consumer loans. While the commercial loan levels were not as volatile, the incomes they generate are in fact found to be quite volatile, indicating the riskiness of these loans. It can be safely said that the volatility is enhanced post 1994, and quite severe for some banks post 2000. Volatility of income from consumer loans is also significant post 1990, with some severe shocks occurring to the consumer loan income of some banks, Bank 7. While the loan volume in the real estate segment has grown steadily, the income while steadily increasing has not grown that dramatically. For some banks this income has been somewhat volatile, and volatility post 2005 for Bank 4 is dramatic. The other investment assets maintained by a bank and the income these generate are discussed next.

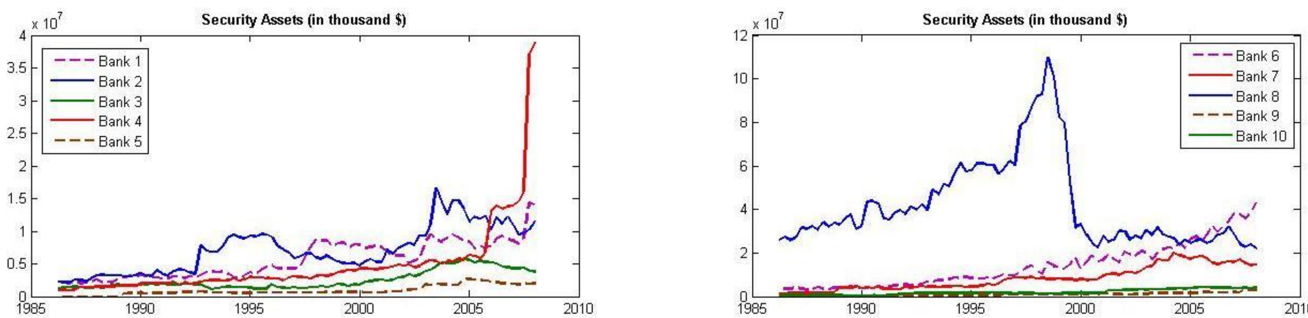



Figure 8

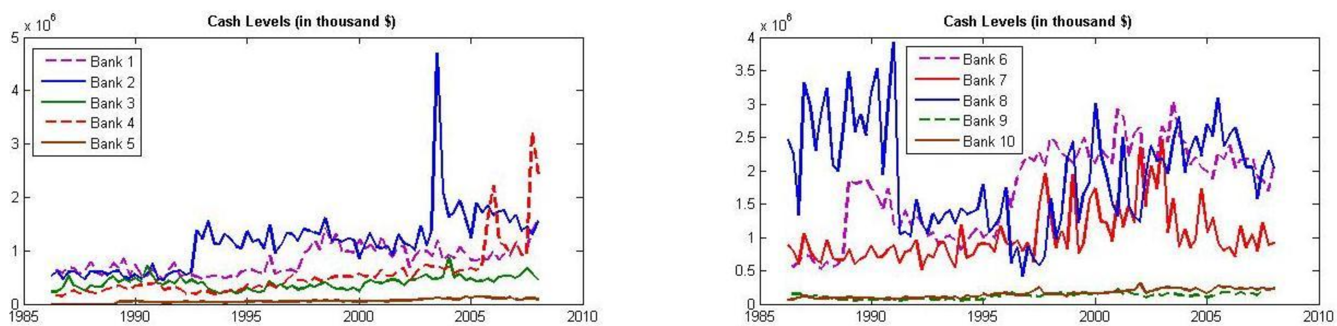



Figure 9

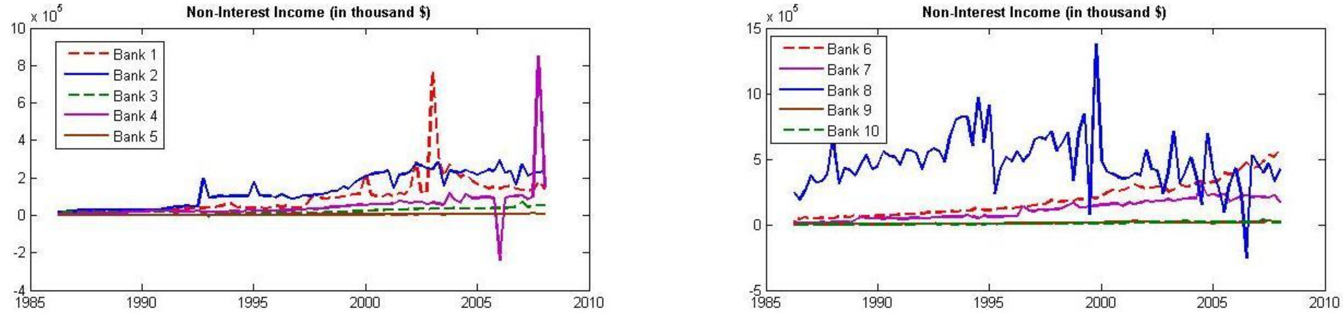



Figure 10

In Figures 8-9, the security assets and cash-levels, respectively, maintained by the banks is plotted. Figure 10 shows the evolution of non-interest income during the interest period, 1986-2007. The security assets level of the banks shows significant volatility, much obvious for some banks than for others due to a difference in the scale. A sizeable fraction of assets of a bank, when compared with the other loans type levels, is in the securities, hence this is not a component that can be ignored. The cash levels maintained by the banks are significant, albeit an order of magnitude lower than the security asset levels. The volatility in the cash level maintained is quite strong across all banks. For all banks, other than Bank 8, both the level and volatility of cash levels has risen past the mid-90s. The non-interest income is a very significant component of income for the banks, as expected given the security asset levels maintained. Moreover, the volatility in the non-interest income is significant and enhanced in the most recent decade.

**Section 5.1.2: The Liability Evolution**

While one would expect to see most interesting observation in the asset segment of the balance sheet of a bank, where significant due diligence of the underwriting process takes place, as it turns out, there is sufficient, if not more, interesting features coming up in the liability/deposits segment of the banks. We now present and discuss the major deposit types – core, saving, and transaction, and their respective interest expenses. As in the asset segment, we generate and present several traces of liability levels maintained by a subsample of 10 banks over the interest period of 1986-2007, as well as the expenses incurred due to these liabilities.

Figures 11-13 display the evolution of the three deposit types. In all deposit types, there are surges observed for several banks, that are however not sustained in time. The volatility in the demand deposits is quite large for many banks. While this may not have a very serious effect on the interest expenses, it enhances the volatility of the overall liability levels. The volume of non-interest bearing appears more or less flat for most banks. The volatility of all the deposit types does seem to have gotten enhanced after 1994.

In Figures 14 and 15, we plot the interest expense for the two deposit types. The interest expense activity from the transaction account is mostly an order of magnitude smaller than others, as expected, other than the one spike observed for Bank 4 in 2007. In its own scale, however, this expense level shows significant volatility. The overall interest expense shows ample volatility, also arising from the surges and changes in the deposit levels discussed earlier. There are no additional explicit trends observable in these variables.

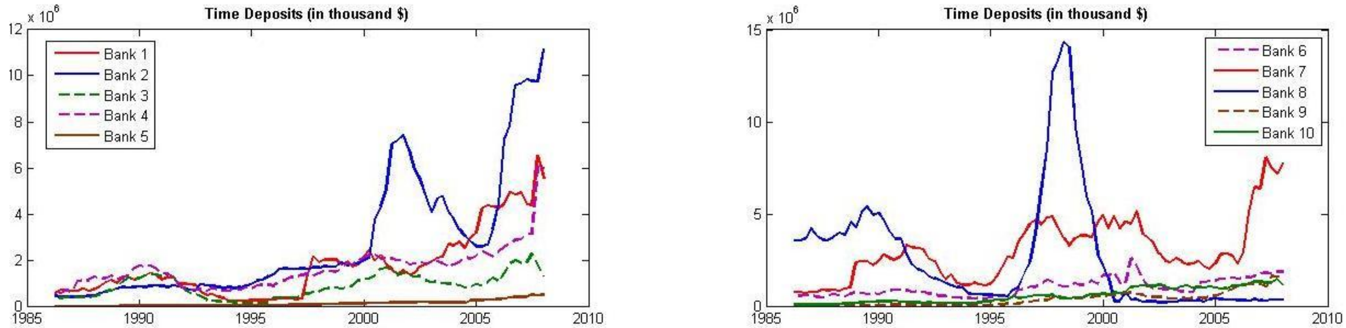



**Figure 11**

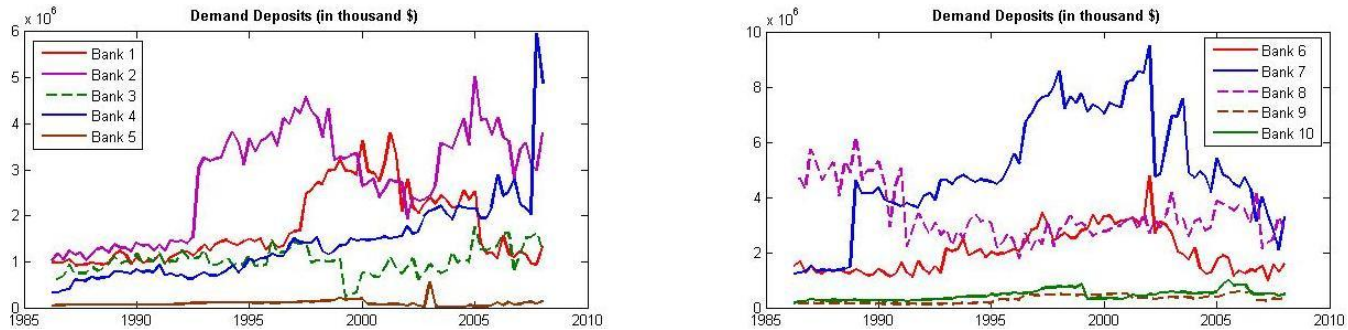



**Figure 12**

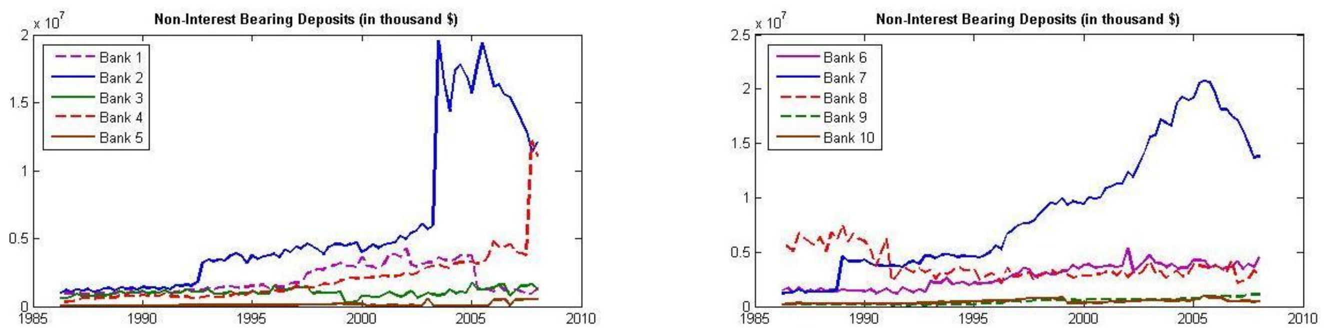



**Figure 13**

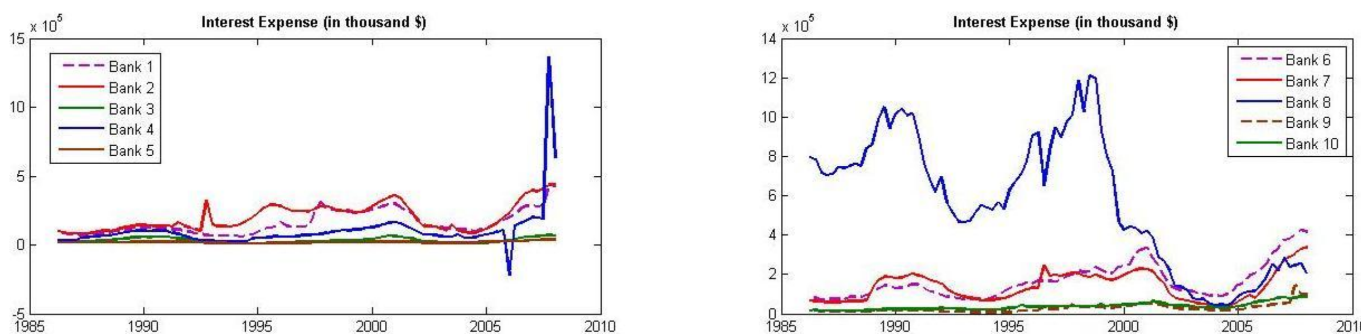



**Figure 14**

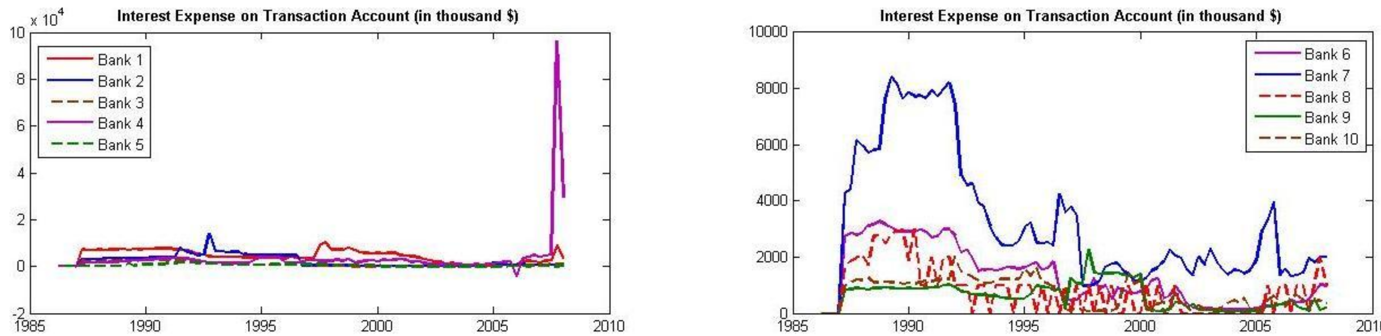



Figure 15

The stylized observations presented thus far for the assets and the liability segments of the simulation model variables can be quantitatively verified as the analysis is continued, but the observations made thus far support the building of the simulation model in the manner described in the earlier sections. Each component of the model capturing the asset-liability evolution characteristic for a bank will allow connecting them to the compensation and regulatory variables and study their interaction. We next look at the data on evolution of managerial compensation for the banking sector.

**Section 5.1.3: The Managerial Compensation Evolution**

How a firm rewards its management and incentivizes their decision making determines the long-term survivability and profitability of the firm. This is amply evidenced in the literature for a general firm and in the banking sector (Coles et al 2006, Cuñat and Guadalupe 2004, Hubbard and Palia 1995, John et al 2000). Our concern here is primarily within the banking sector and on studying how managerial compensation has changed in time, in reference to the regulatory changes, and what its impact has been on bank riskiness. We have witnessed volatility in all the displays of the asset and liability segment of banks presented in Sections 5.1.1 and 5.1.2. We now turn to the data on managerial compensation.

We plot the components of managerial compensation in the banking sector for the period of 1992-2006 in Figure 16. These components are: salary, bonuses, stock, option, and other compensation. We also plot the total granted and total exercised compensation in order to capture the impact of the stock options, when they are granted and exercised. In Figure 16 (left panel), the base salary trend for the industry is displayed (red-dots), alongside the salary, the bonuses are also plotted (yellow-dots). It is clear that beyond 1994, the timing of the RNA, the bonuses experience a significant surge, completely dwarfing the base salary levels. Prior to 1994, the salary and bonuses were quite comparable in magnitude. There is a second surge post-1999, the timing of GLBA, which declines in the 2001-2002 period due to the slow-down of the post-dot-com era, only to surge up again. In Figure 16 (right panel), the bonuses are plotted again for ease of comparison with the other components of the compensation, namely, stock and stock-options. The trend in these components of compensation is similar and much larger in scale.

Clearly, the very large modulations in the variable components of the managerial compensation package is bound to create incentives for the management to make decisions aligned with the firm's, in our case bank's, performance. The key question that the simulation model addresses is the mechanics of this dependence, i.e., how does the compensation structure affect the bank's riskiness/performance and the bank's riskiness/performance in turn affect the compensation realized. Part of the goal of our analysis is to explain what is observed in the past, and the other part is to explore alternate realities.

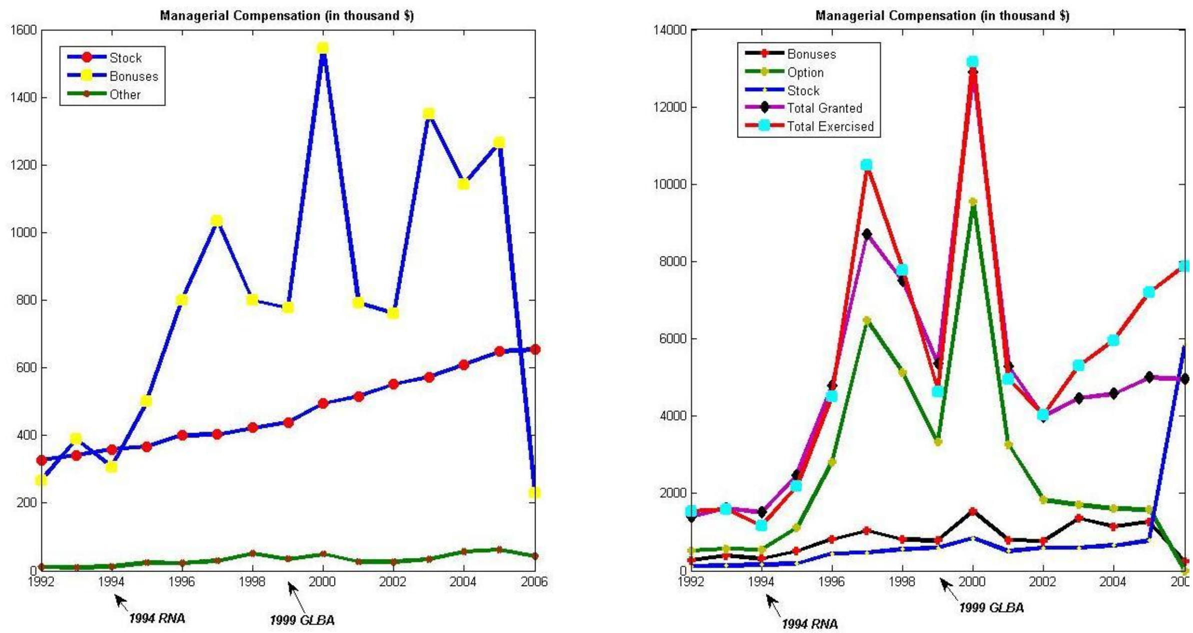



Figure 16

## Section 5.2: Results from Calibrating the Base Reference Model

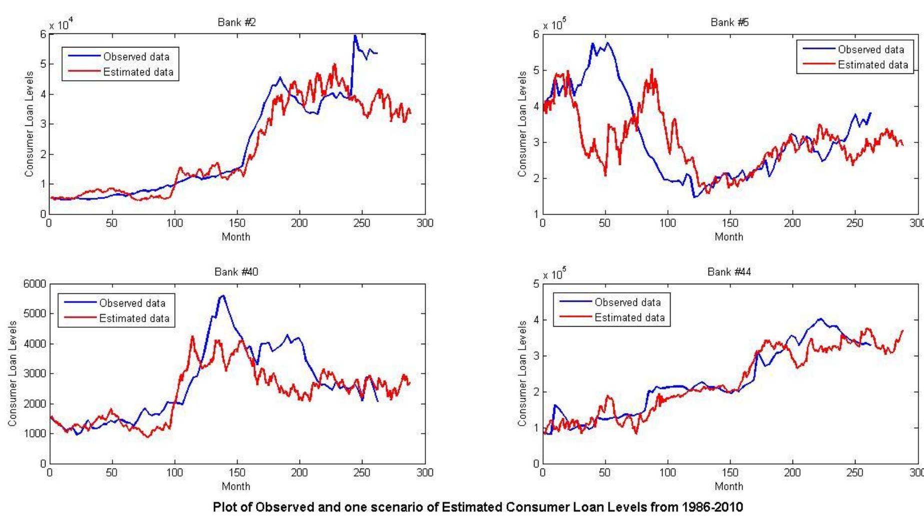



Figure 17

In this section, we display the results of calibrating the model described in Section 3 to the data displayed in the previous section. The calibrated models for asset and liability evolution are combined to simulate the evolution of firm value, shareholder-equity and bank's earning, as per Equations (1)-(18). Figure 17 plots the observed consumer loan levels for 4 of the 45 banks in the sample, bank 2, 5, 40 and 45, juxtaposing one scenario of simulated consumer loan levels for each bank. The names of the banks corresponding these number in the sample of 45 are given in Table 3. The simulated consumer loan levels correspond to shifts in the target loan levels and volatilities, $\Delta c_i^a(T_R^i)$ and $\Delta \sigma_i^a(T_R^i)$, at the times of regulatory shocks, $T_R^i$. On visual inspection, the quality of the simulated trajectory matches that of the observed data, although the simulated trajectory appear more jittery than the observed data, since the simulated trajectory is determined at the monthly interval, where as the observations are at quarterly frequency.

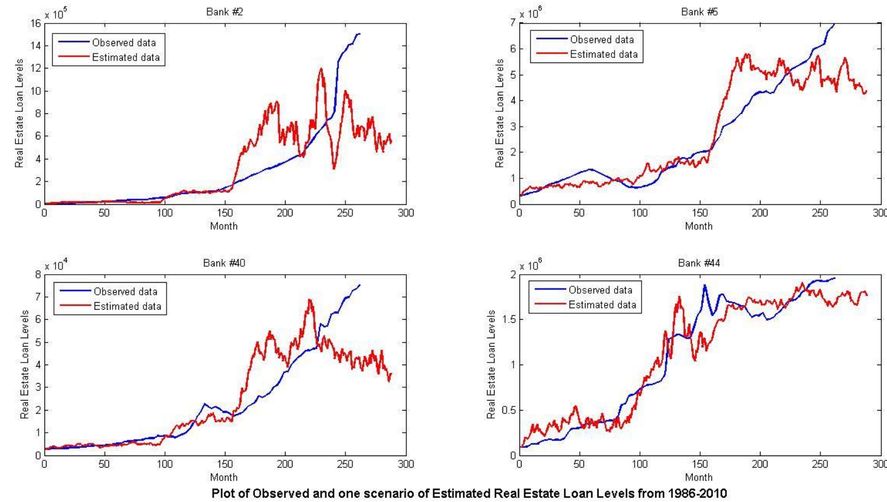



Figure 18

Figure 18 plots the observed real estate loan levels for the same 4 of the 45 banks in the sample, again juxtaposing one scenario of simulated real estate loan levels for each bank. The simulated trajectories overall capture the rapidly increasing trend of the real estate loan portfolio of the 4 banks, although in these specific scenarios, Bank 2 and 40 trajectories seem to reverse from the observed trend in the most recent years. The trajectories for rest of the asset variables show a similar quality of calibration.

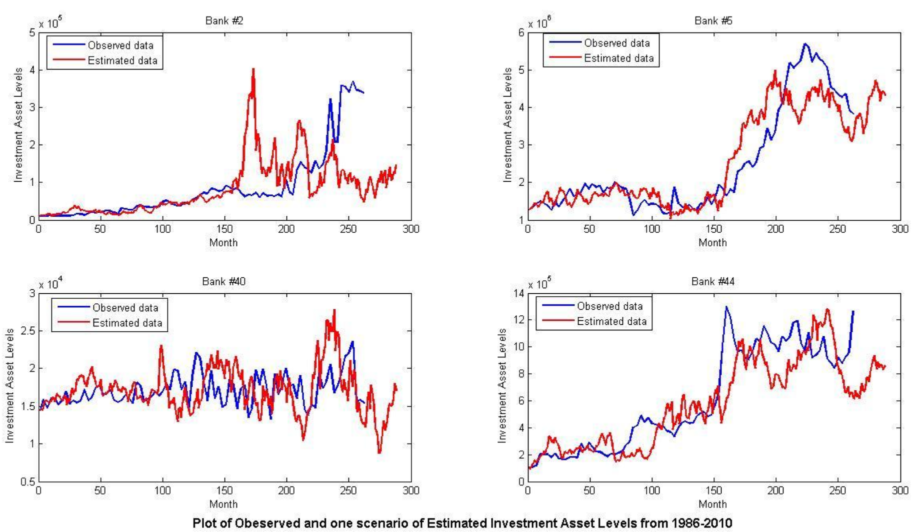
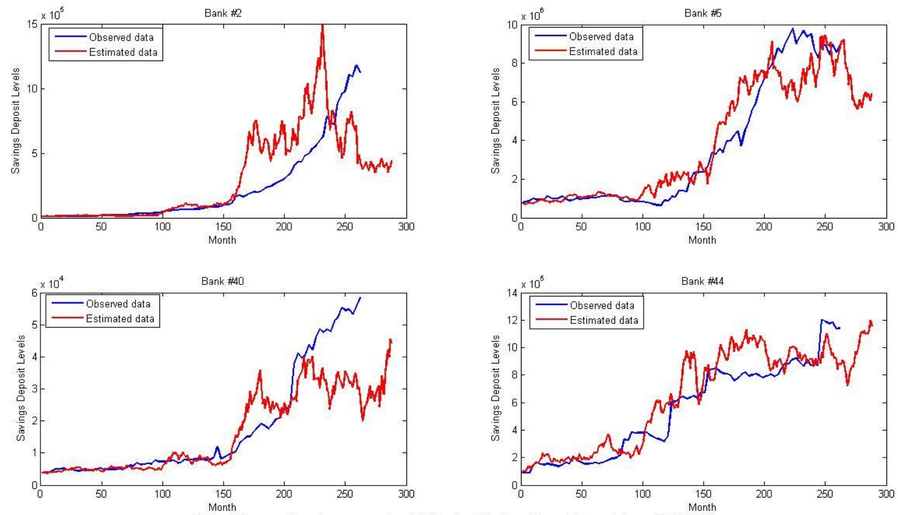



Figure 19

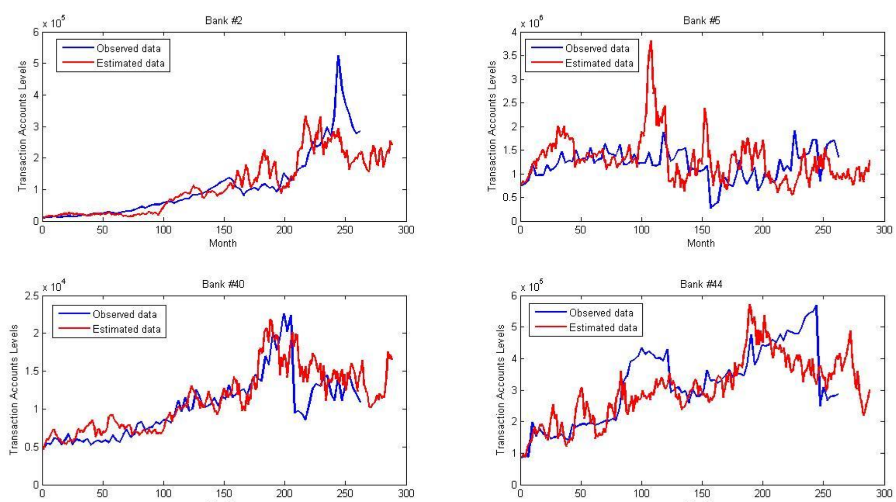
In Figure 19, we plot similar trajectories of observed and simulated data for bank's investment asset levels. In all these plots the simulated data extends beyond year 2007, thus being predictive of the future, should no fundamental conditions change for the bank. The scale on the Y-axis is also indicative of the size of the bank's activities. Bank #5, CITY NB, has an order of magnitude larger investment asset levels than all the other banks in this display.




Plot of Observed and one scenario of Estimated Savings Deposit Levels from 1986-2010

**Figure 20**

As in the case of real estate loans, on the liability end saving deposit levels have a strong increasing trend for all the four banks, which is seen in Figure 20, both in the observed and simulated trajectories of the bank's saving deposit levels. In Figures 21-22, we plot the four banks' transaction account levels and rates, respectively.




Plot of Observed and one scenario of Estimated Transaction Accounts Levels from 1986-2010

**Figure 21**

The remaining components of the base reference model show similar characteristics, which are then used to synthesize the dependent variables to describe the bank's financial status, as per Equations (7)-(18). In Figure 23, we compute the simulated trajectory of firm value for the four banks. The firm value is seen to grow rapidly at one or the other regulatory shock event, clearly coming from a changing target asset level set through the regulatory transitions.

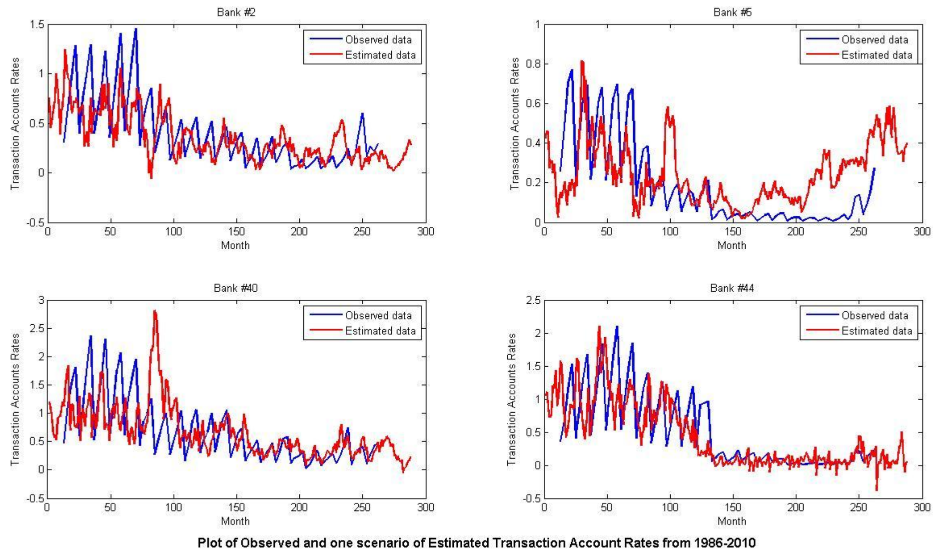



**Figure 22**

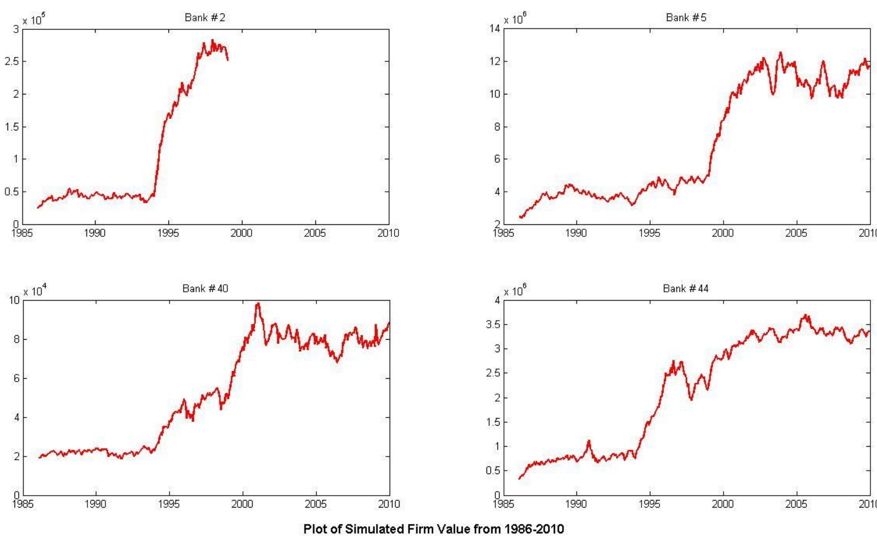
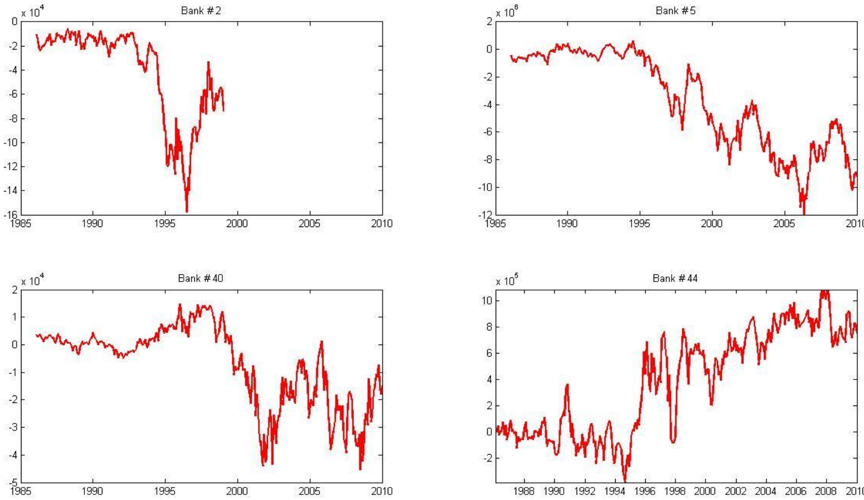



**Figure 23**

Figure 24 plots the simulated trajectory of shareholder equity for the four banks. Here is the nature of the plot reverses character. The regulatory shock time-points, at least in these trajectories, induces a sudden drop in shareholder-equity in some cases, such as for Bank #2 at RNA 1994 and Bank #40 at GLBA 1999.

We have thus set up the simulation model to perform the goal of this study – incrementally introduce the factors that are response to regulatory shocks and study their impact on the bank riskiness. In this section, we only plotted trajectories or scenarios for the components of the model. In the next section, we will generate many runs of the simulation to compute means and volatilities of the output variables.

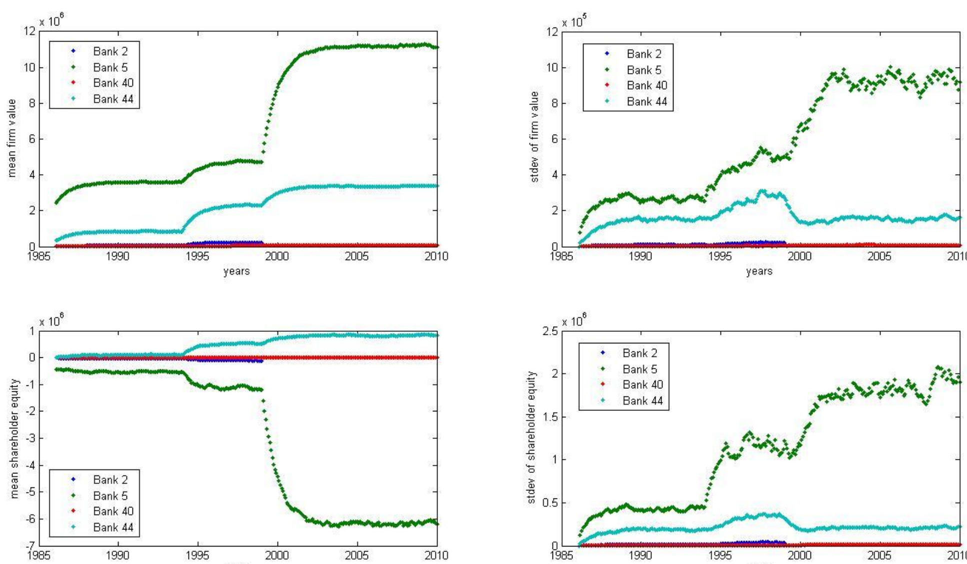



Plot of one scenario of Simulated Shareholder Equity from 1986-2010

Figure 24

**Section 5.3: Examining the Hypotheses**

We will now advance the design of the simulation study towards examining the three hypotheses. Before we introduce the role of the factors that underlie the hypotheses, in Figure 25, we re-state the base reference case, this time for the basic summary statistics of the two key output variables, firm value and shareholder-equity. We generate a large sample of evolution trajectories for firm value and shareholder-equity for the four banks and take the mean and standard deviation of these output variables at range of time-points. The evolution of mean and volatility of the firm value and shareholder-equity for the four banks is shown in Figure 25. City NB shows the interesting feature of a steadily increasing firm value with a disturbing fall in shareholder-equity. The volatilities of both output variables are seen to increase.




Mean and Standard Deviation of Firm Value and Shareholder Equity over Time for Base Reference

Figure 25

**Section 5.3.1: Hypothesis I – Impact of Competition vs. Base Reference Case**

Under the first hypothesis, we wish to study the isolated role increase in competition plays in increasing bank riskiness. In Figure 25, we saw that the volatility in bank's performance, as measured by bank's firm value and shareholder-equity, increases at the times of regulatory shock. We will now seek to describe changes in banks holdings solely by how competition may modify it by Equations (21) and (22). Using these criteria for describing the change in bank holdings, we again simulate many trajectories of bank's firm value and shareholder-equity, and compute the trajectory of mean and volatility of these output characteristics shown in Figure 26. Not surprisingly, the nature of the plot resembles closely, though not identically, with those of the base reference case. Therefore, the change captured by competitiveness change at times of regulatory shock for these banks is quite good. This is, however, not enough to make a conclusive statement regarding the extent of bank riskiness change in competition captures.

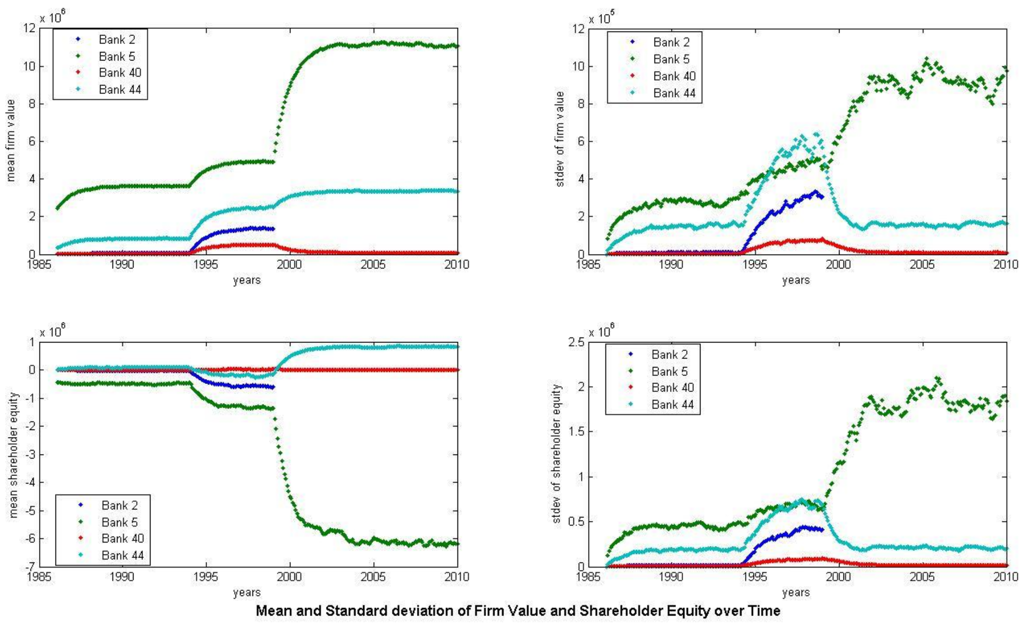
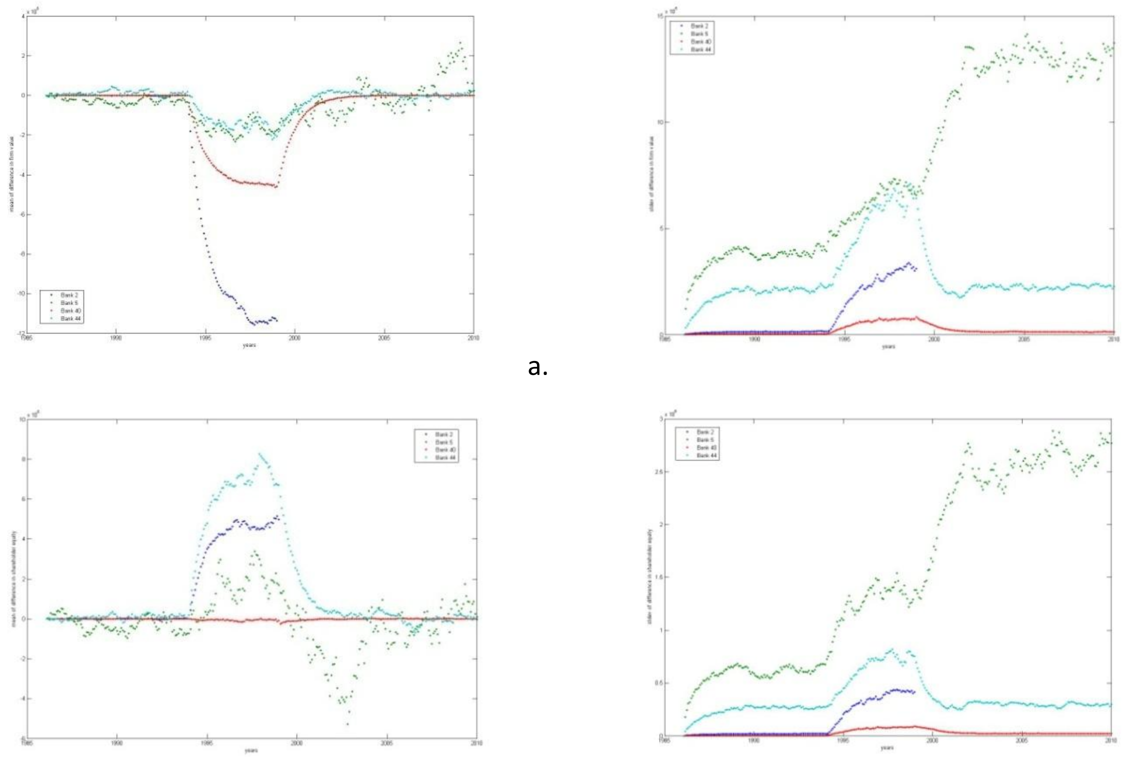



**Figure 26**

In Figure 27 (a)-(d), we plot the difference in mean firm value and difference in volatility of firm value, as well as similar quantities for shareholder-equity, between the base reference case and the competition-based case. These plots are an order of magnitude lower than Figure 25 or 26, ie. $10^6$ vs $10^5$, therefore the similarity between the plots of Figure 25 and 26 is strong, if not identical. The competition-based assessment of banks' performance over-estimates firm-value post RNA 1994 for almost all of the 4 banks chosen for display. However, the shareholder value shows the opposite characteristics, suggesting that competition-based assessment of a bank's characteristics also over-estimates the liability levels of the banks. As for competition-based assessment of bank's riskiness, it uniformly underestimates riskiness of bank's firm value and shareholder-equity for the sample of 4 banks. This is also seen for several of the other banks in the 45 bank sample. In summary, competition based assessment of bank's performance through regulatory shock captures the average levels, but misses to fully describe bank's increased riskiness.  We will next move to including managerial compensation changes accompanying regulatory changes.



a. b. c. d.

Figure 27

**Section 5.3.2: Hypothesis II – Impact of Competition and Compensation vs. Base Reference Case**

For the second hypothesis, we need to include both competition and managerial compensation changes for a bank to assess their joint impact on bank's performance. We will now seek to describe changes in banks holdings by both competition and performance-based compensation variables as given by Equations (23) and (24). Using these criteria for describing the change in bank holdings, we again simulate many trajectories of bank's firm value and shareholder-equity, and compute the trajectory of mean and volatility of these output characteristics shown in Figure 28. The nature of the plot resembles closely, though not identically, with those of the base reference case, as well as the competition-based case. However, in order to determine the difference in these cases, in Figure 29 (a)-(d), we again plot the difference in mean firm value and difference in volatility of firm value, as well as similar quantities for shareholder-equity, between the base reference case and the compensation-based case.

These plots are an order of magnitude lower than Figure 26 or 28, ie. $10^6$ vs $10^5$, therefore the similarity observed from the competition-based case are not destroyed.  The compensation-based assessment of banks' performance still over-estimates firm-value post RNA 1994 for a new set of banks. Banks 2 and 40 drop off the chart after RNA 1994, this will need to be investigated further. The shareholder value, as before, shows the opposite characteristics, suggesting that compensation-based assessment of a bank's characteristics also over-estimates the liability levels of the banks. As for compensation-based assessment of bank's riskiness, it uniformly underestimates riskiness of bank's firm value and shareholder-equity. In summary, the incremental role of compensation in capturing riskiness of the bank's performance is not conclusive. More qualitative (graphical) and quantitative analysis is needed using the simulation environment developed so far.

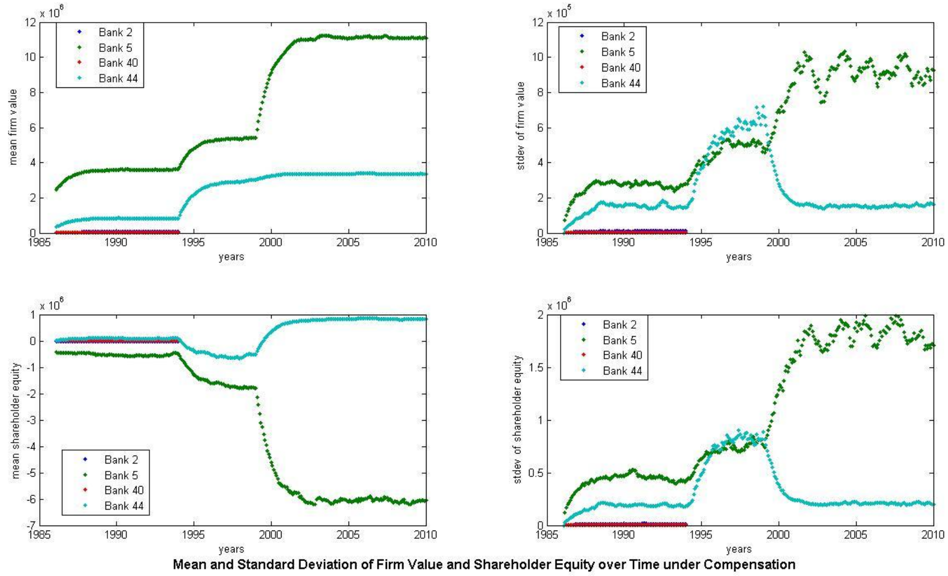



Figure 28

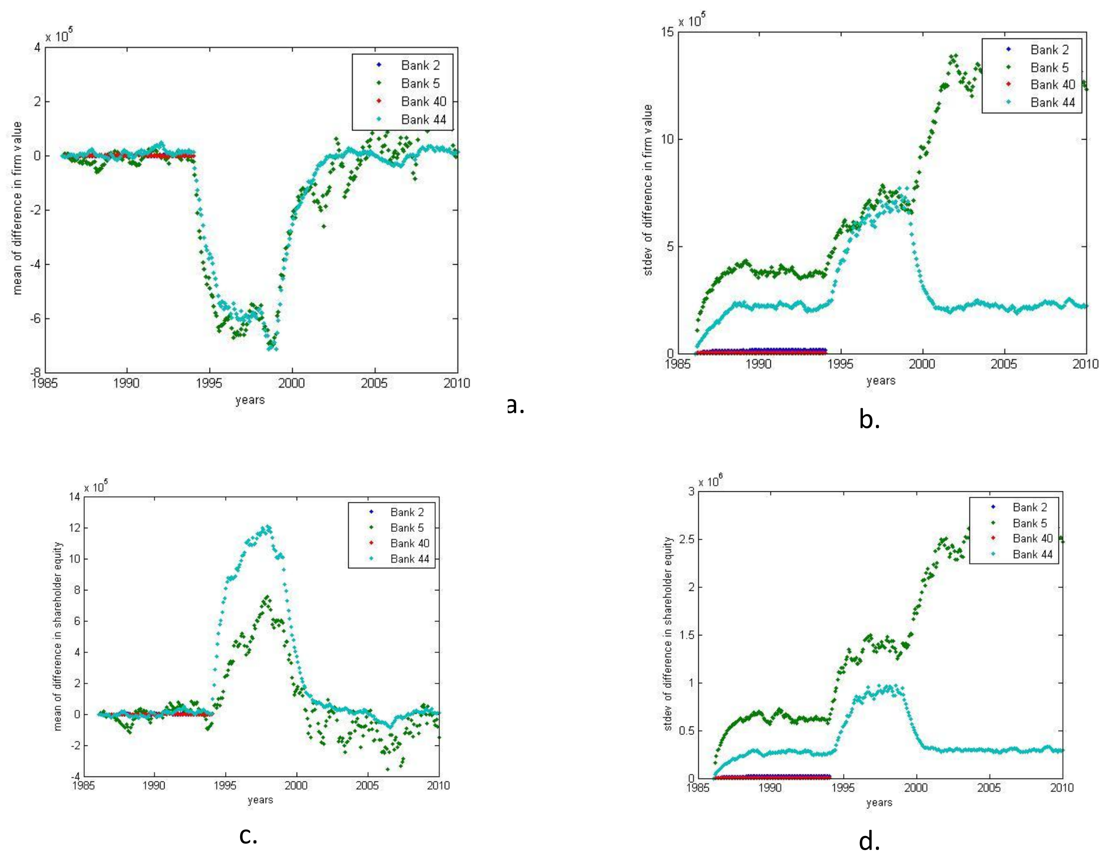



Figure 29

## Section 5.3.3: Hypothesis III – Role of Governance in Competition and Compensation vs. Only Competition

In order to address the issue underlying the third hypothesis, we need to compare the competition-based assessment of bank riskiness with compensation-based assessment of the same. In Figure 30, we plot the difference in mean firm value and volatility in firm value as capture by only change in competitiveness and as captured by both competitiveness change and compensation change put together. This plot is revealing, since it shows that compensation over-estimates firm value more aggressively than competition alone, at least for the post-RNA 1994 period. As for volatility, the compensation-based assessment introduces a higher level of volatility. But this conclusion will have to be further assessed quantitatively.

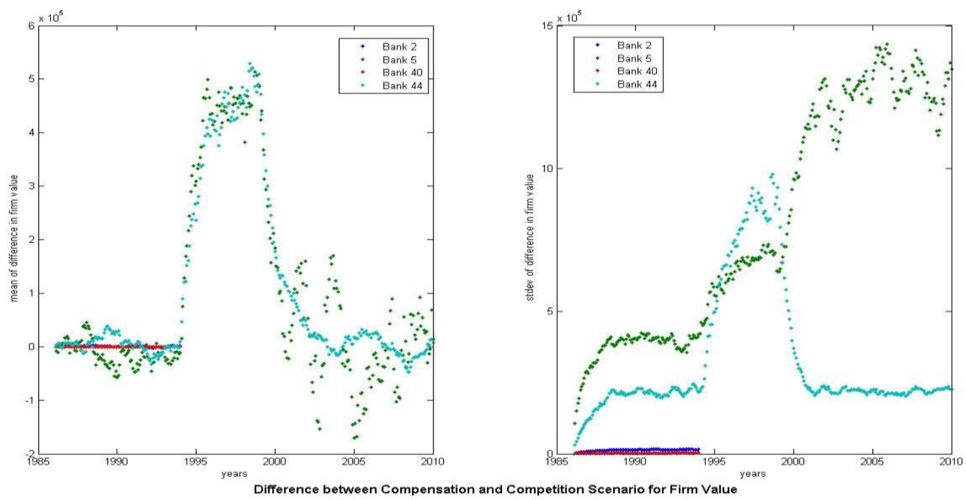



Figure 30

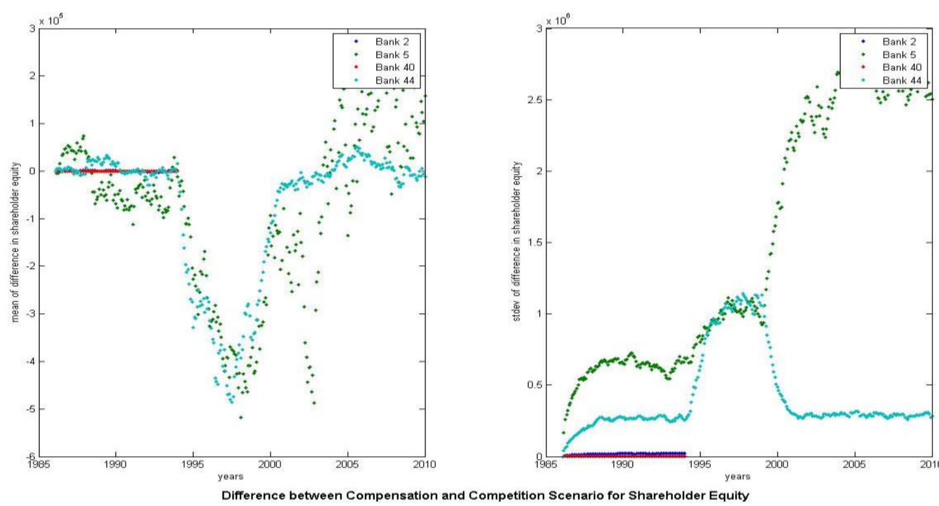



Figure 28

The mean shareholder-equity plot in Figure 31 shows that compensation-based assessment not only over-estimates firm's assets, but also firm's liabilities relative to competition-based assessment, hence making the difference in shareholder-equity on average be negative in the post-RNA 1994 period. The volatility of shareholder-equity is higher in the compensation-based assessment.

We next look at the three key governance variables, given in Table 1 below, for the sample of 4 banks plotted thus far in the displays of the analysis. Of Bank 5 and 44, which are consistently displaying interesting properties in the last several figures, Bank 44 has clearly better governance characteristics as evidenced by low G-Index and E-index. Reversal of volatility for Bank 44, as opposed to increasing volatility for Bank 5, is anecdotal evidence in favor of governance, which by no means is conclusive. More rigorous, quantitative analysis is planned as the next steps of this study.

**Table 1**

| Governance Variable | Data for the FOUR Banks |
|---|---|
| G-Index | Bank 2: missing<br>**Bank 5**: -88,9,9,9,9,9,11,11,11,11,12,12,12,12,12<br>Bank 40: -88,-88,10,10,10,10,10,10,10,10,10,10,10,10,10<br>**Bank 44**: -88,-88,-88,-88,-88,-88,-88,-88,2,2,3,3,3,3,3 |
| E-Index | Bank 2: missing<br>**Bank 5**: -88,2,2,2,2,2,4,4,4,4,4,4,4,4,4<br>Bank 40: -88,-88,3,3,3,3,3,3,3,3,3,3,3,3,3<br>**Bank 44**: -88,-88,-88,-88,-88,-88,-88,-88,1,1,1,1,1,1,1 |
| Anti-takeover Index | Bank 2: missing<br>**Bank 5**: 0,0,0,0,0,0,0,0,0,0,0,0,0,0<br>Bank 40: missing<br>**Bank 44**: 0,0,0,0,0,0,0,0,0,0 |

## Section 6: Discussion and Conclusion

In this article, we developed a simulation model to study the impact of the interaction between regulatory changes, change in competitiveness of a bank's environment and change in managerial compensation, on the bank's riskiness. We used the simulation model to develop a platform to examine the following three hypotheses, 1) increase in competitiveness after deregulation results in higher levels of risk for banks, 2) regulatory changes can result in change in the composition of managerial compensation, which creates an environment of incentives for enhanced risk taking, 3) regulatory changes accompanied by certain governance or managerial compensation controls can bring prudence in the risk taking behavior.

The article presented the simulation model in detail, the calibration methodology adopted for the simulation model, and a detailed design of the simulation study to evaluate the three hypotheses. Data from the Execucomp and the FRB Chicago call reports databases for a period of 15-20 years spanning the period 1986 to 2007, covering basic financial condition, regulatory changes, competitiveness environment and managerial compensation variables were used to calibrate the simulation model and analyze the hypothesis. The preliminary results using extensive displays of the data for the components of the simulation model -- the asset evolution model, the liability evolution model and the managerial compensation evolution, showed strong promise for the implementation of the simulation study.

After the preliminary analysis of the raw data from the period of interest, we used the data to calibrate the asset and liability evolution models to create the base reference setting for bank riskiness through the changes of the two decades. From this base reference, we developed a three-stage incremental analysis of the role change of competitiveness, compensation and governance play in bank's riskiness. The three-stage incremental analysis of the three hypotheses has provided good insights on the impact of these changes on the performance of a bank, as measured by the level and riskiness of its firm value and shareholder-value. More qualitative and quantitative analysis is required using the simulation framework developed in this study.

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## Appendix

**Table 2: Name of the subsample of 10 banks in Section 5.1**

| Bank Number | Bank Name |
|---|---|
| Bank 1 | HUNTINGTON NB |
| Bank 2 | COMERICA BK - DETROIT |
| Bank 3 | CITY NB |
| Bank 4 | HIBERNIA NB NEW ORLEANS |
| Bank 5 | PROVIDENT SAVINGS BANK |
| Bank 6 | NORTHERN TC |
| Bank 7 | CALIFORNIA FIRST BK |
| Bank 8 | BANKERS TC |
| Bank 9 | CITIZENS COMMERCIAL & SVG B |
| Bank 10 | VALLEY NB |

**Table 3: Name of the 5 banks from the sample of 45 for which results are shown in Section 5.2-5.3**

| Bank Number | Bank Name |
|---|---|
| Bank 2 | BANK OF THE CASCADES |
| Bank 5 | CITY NB |
| Bank 40 | FIRST NB OF FARMINGTON |
| Bank 44 | UNITED NB |