Corporate Governance: A Game Theory Based Mechanism Design Approach

By

Choirunnisa Arifa
Universitas Gadjah Mada
Indonesia
and
ISILC
Victoria University, Australia
Melbourne 3000, VIC, Australia

and

Sardar M. N. Islam[1]
ISILC
Victoria University, Australia
Melbourne 3000, VIC, Australia

[1]Corresponding author. Tel: +61 3 9919 1338
E-mail Addresses: choirunnisa_a@ugm.ac.id,
Choirunnisa.Arifa@live.vu.edu.au (C. Arifa);
Sardar.Islam@vu.edu.au (S. M. N. Islam)

Corporate Governance: A Game Theory Based Mechanism Design Approach

Abstract

As corporate governance involves designing a set of different mechanisms to mitigate agency problems through providing incentives to achieve an efficient organisational structure and performance of public corporations. It therefore can be conceived as a mechanism design (design a game) problem where the concepts, methods and principles of game theory and mechanism design can be applied to build effective corporate governance. However, it is controversial whether corporate governance can be considered as a mechanism design problem or not (Zingales 2008). This paper argues the suitability for, and specifies and establishes a new framework for good corporate governance principles and practices as a mechanism design problem. Adopting the principal-agent relationship (a non-cooperative principal-agent game theory) framework in a modern corporation, this study develops a new integrated applied mechanism design model to design a framework for corporate governance as an optimal contract problem that can mitigate agency problems, achieve good corporate governance and maximise firm value. Employing an optimisation method, this approach explicitly quantifies and incorporates the necessary principles and mechanisms to specify good governance, including incentive contracts, accounting policies, corporate control, risk management and regulatory environments. This study concludes that the integrated corporate governance model based on a mechanism design approach can provide a framework to specify good corporate governance framework for providing managers' incentives to act on behalf of shareholders and support the efficient allocation of the company's resources. Hence this study argues that in order to specify a good governance model, there is a need for implementing a new framework based on a mechanism design approach. This study provides original contributions to the multidisciplinary literature of corporate governance, mechanism design and management science.

Keywords: corporate governance, mechanism design, company value, optimisation model, mathematical programming

1. Introduction

It is argued in this paper that corporate governance is essentially a mechanism design problem, as corporate governance requires the design of a game and game rules that can mitigate the underlying conflicts between shareholders and managers, develop cooperation among them and leads to an efficient organisation. Corporate governance has emerged as important instrument for achieving good governance practices in modern corporations, particularly when the alignment of interests between managers and shareholders become a necessity. Therefore, it is essential to define and specify what corporate governance really is. The exact nature of the principles of corporate governance is controversial. For example, Zingales (2008) defines corporate governance as a complex set of constraints that shape the *ex-post* bargaining over the quasi-rents generated by a company. Others argue that corporate governance is a set of contracts or regulations to align the interests of shareholders, management and other stakeholders, to set the objectives of the company as well as the means of attaining those objectives, and to monitor the performance managers (Larcker et al. 2007; Klapper and Love 2004; La Porta et al. 2000; Shleifer and Vishny 1997). Therefore, corporate governance is also viewed as a set of mechanisms to resolve the problem of information asymmetry, including agency problems, that can create agency conflicts between a principal and an agent (a non-cooperative principal-agent game) in modern corporations (see also Samuelson and Marks 2015; McGuigan et al. 2014; Hurwicz and Reiter 2006).

Based on the above literature, the purpose of this paper is to analyse the exact nature of corporate governance. Although (1) the background institutions of corporate governance as a principal-agent game has been widely discussed in the literature (see for example Samuelson and Marks 2015; McGuigan et al. 2014), and (2) corporate governance has been established as a set of mechanisms or contracts instruments for solving the principal-agent problem as stated above, a formal, especially large scale real-life corporate governance mathematical model as a mechanism design has not be developed. We can think that corporate governance is a mechanism design problem for designing a principal-agent game to manage the asymmetric information problems through the creation of incentive compatible mechanisms, institutions, regulations and organisations. This study therefore develops an approach and a corporate governance model based on the principles and theory of mechanism design, believing that corporate governance can be defined and specified as a formal mechanism design problem (or a mathematical model for mechanism design). By defining the exact nature of corporate governance, this paper makes a substantial contribution to the literature, because this approach will help define the exact nature of corporate governance to formulate appropriate principles that will make corporate governance more effective in achieving the objectives of corporations, especially efficient organisational design. Moreover, by defining corporate governance as a mechanism design problem, this study will help undertaking theoretical studies in corporate governance within the framework of mechanism design theory, thus enabling corporate governance research more rigorous and scientific.

To establish the above argument, and to demonstrate the plausibility and feasibility of the proposed approach, this paper is structured as follows: section 2 presents a review of the literature on the intensive discussion of the non-cooperative game nature of corporate governance without referring it as a game formally; section 3 discusses (a) the concept and approach of mechanism design, and (b) the view whether corporate governance can be specified as a mechanism design problem or not; section 4 presents the framework for modelling the mechanism design for corporate governance; section 5 specifies the theoretical model, its numerical computation approach and simulation tools, and results of the model simulation; sections 6 discusses the implications of the model results, particularly on the new framework of incentive-compatible corporate governance principles; section 7 presents the benefits of the new mechanism design-based approach to corporate governance; section 8 concludes the study.

2. Existing Concepts and Definitions of Corporate Governance: Game Theory Foundations

By definition, corporate governance is a complex set of constraints that shape *ex-post* bargaining over the quasi-rents generated by a company (Zingales 2008; Williamson 1988). In the business context, the main concern of corporate governance is to protect the interest of investors when they cannot fully control the organisation and hence delegate responsibility to the managers (Larcker et al. 2007; Klapper and Love 2004; La Porta et al. 2000; Shleifer and Vishny 1997). Tirole (2001) argued that corporate governance supports an effective organisation that induces management to internalise the welfare of shareholders into the economic and financial system. Corporate governance can also be defined as a mechanism that is developed to reduce agency conflict by aligning the interests of shareholders, management and other stakeholders, and to provide "the structure through which the objectives of the company are set, and the means of attaining those objectives and monitoring performance are determined" (OECD 2004). Hence it can be said that corporate governance is a Principal-Agent Game or a Multi-Agent Stakeholder Game, which has specific aspects as discussed below, although corporate governance has not been formally defined in a game theory framework or model.

In a general agency setting, the principal–agent relationship is characterised by the following framework:

1. Two parties (principal and agent) interact in a relationship and both parties act opportunistically (i.e. both strive to maximise their own utility).
2. The sequence of events starts with the principal designing the agent's incentive contract, which must depend on verifiable variables that the principal specifies. The use of verifiable variables enables the contract to be attested by an independent arbitrator to guarantee the fulfilment of the contract. In this way, with sufficient proof of a breach, the contract design allows either of the parties to present a case before a court of law in order to demand the contract to be fulfilled (Macho-Stadler and Pérez-Castrillo 2001).
3. Based on the proposed contract, the agent decides to accept or reject the contract. Commonly, the agent will accept the contract whenever the utility obtained from it is greater than the utility that the agent would have obtained if he/she rejected the offer. If the agent decides to sign the contract, then he/she must carry out the actions for which he/she had been contracted. The agent must decide the company's strategy, for example decisions regarding its operations, financing and investment, which implies certain efforts that determine the final outcome (Macho-Stadler and Pérez-Castrillo 2001).
4. Next, the performance measures and final outcome are observed. The agent is paid according to his/her compensation contract and the principal gets to keep the difference between the final outcome and the agent's compensation.

Despite a growing literature defining corporate governance, a generally accepted understanding of corporate governance has not yet evolved. In general, corporate governance can be discussed when incomplete contracts exist, the quasi-rents must be distributed ex-post and real decisions must be made, and hence suggests that the mechanism design approach (which will be discussed later in Section 3) is incompatible to solve the incomplete contract problems (Zingales 2008). In order to serve those conditions, an effective corporate governance system is needed, based on the formal principles of the theory of mechanism design (the theory of designing games or inverse game theory), through its goals, which are: 1) to maximise the incentives for company value improvement, that is, through an incentive-compatible contract (Zingales 2008; Shleifer and Vishny 1989); 2) to minimise possible inefficiency in ex-post bargaining, that is, through the alignment of stakeholders' interests (Hansmann 1996); and 3) to minimise any governance risk and to effectively allocate risk to the least risk-averse parties (Fama and Jensen 1983).

In a business context, the corporate governance mechanism leads to efficient organisational design and optimal incentives contracts, which can reduce agency costs and significantly increase a company's performance, as represented by the shareholders' value (e.g. Samuelson and Marks 2015; McGuigan et al. 2014; George Yungchih 2010). Dallas (2004) argues that good corporate governance promotes the efficiency of company-wide operational processes, increases company gains in terms of a better flow of funds and lower cost of capital, hence providing investors with a fair return on their invested capital and promoting wealth for other stakeholders. The assurance on stakeholders' wealth might establish a good company reputation in financial markets and create further confidence from potential investors and creditors, hence maintaining sustainability in the long run (e.g. Brown et al. 2011; Van Greuning and Bratanovic 2009; Ho and Lee 2004).

3. Corporate Governance as a Mechanism Design Problem

In view of above discussions of the intuitive aspects of corporate governance, a formal model of corporate governance for efficient organisational design can be presented as below.

In view of the above discussions of the institutive aspects of game theory as foundation of corporate governance, the argument in this paper is that corporate governance is one aspect of organisational design (e.g. Samuelson and Marks 2015; McGuigan et al. 2014; George Yungchih 2010), and it can be formally repressed as a game theory based mechanism design problem (Islam 2016).

Game theory presentation of the mechanism design model for strategic interactions aspect of corporation governance can also be given (as an organisational design problem) in the following form:

> designing a game form (S,g), where S = S_1x …..xS_n, S_1 = set of agent i's strategies, = organisational outcome/design, g: S is a mapping from S to A (Marschak, 1989).

3.1. Designing a Game: Mechanism Design Concept and Approach

The concept of mechanism design (the theory of designing games or inverse game theory), is a branch of microeconomics that analyses the way economic decisions in an organisation are crafted as the function of the information that is known by individuals (e.g. Mas-Colell et al. 1995; Myerson 1989). This concept has been developed particularly to solve the incomplete information problem that can create agency conflicts between a principal, who chooses the payoff structure, and the agents, who have more information relevant to the principal's payoff and thus might not provide their best efforts to satisfy the interests of the principal (Hurwicz and Reiter 2006). The concept specifies the maximisation of the principal's utility as an objective function, subject to the agents' compensations for achieving the goal of the principal (i.e. incentive constraints) in efficient and effective ways (i.e. resources allocation constraints). The model designs an optimal mechanism that can align the interests of both principal and agents to ensure the efficient allocation of resources and an effective organisational design which leads to improved organisational performance. Accordingly, agents are encouraged to agree to participate in the mechanism and to reveal more information to the principal (McGuigan et al. 2014; Laffont and Martimort 2002; Kreps 1990; Myerson 1989). Therefore, mechanism design is a formal framework for specifying corporate governance issues, principles, mechanisms and rules.

3.2. Other Views and Our Arguments

In spite of the extensive discussions of the mechanism design institutions of corporate governance given above, a corporate governance has not been formally established as a mechanism design problem. Moreover, some authors have rejected this possibility, arguing that the mechanism design concept only provides a set of decisions that are made *ex-ante* and allocates all quasi-rents *ex-ante* as well, hence there is no opportunity for *ex-post* bargaining and negotiation (Zingales 2008). The neoclassical approach suggests that the mechanism design is utilised to construct all contracts, which are contingent on all publicly observable variables, hence providing the agents with the best possible incentives to exert efforts, encouraging the agents to publicly disclose the information and enabling them to receive compensation contingent to this disclosure. Consequently, allocation of the agents' discretion over certain decisions is always dominated by a fully-centralised mechanism, where all decisions are made *ex-ante* by the designer and only executed *ex-post*, hence all conflicts are resolved and all rents are allocated *ex-ante* (Myerson 1979). In this way, there is no room for the mechanism design to mitigate the *ex-post* behaviour after the contract is concluded and the decisions are made. Consequently, mechanism design cannot represent corporate governance, and hence the incentive contract mechanism should also be supported by other governance mechanisms that can discipline agents to not violate the contract, including direct monitoring and efficient organisational designs.

As discussed above, the mechanism design concept only provides a set of decisions that are made *ex-ante* and allocates all quasi-rents *ex-ante* as well, hence there is no opportunity for *ex-post* bargaining and negotiation (Zingales 2008). Thus, in an incomplete contracts world, where it is necessary to allocate the right to make *ex-post* decisions, the mechanism design alone cannot resolve the problem of moral hazard, where hidden actions and hidden information occur after the contract is concluded (Voigt 2011). Societal goals can be specified and enforced in a corporate governance system to make mechanism design effective in implementing post contractual opportunism. Scott (2011) suggests that good corporate governance practices can mitigate this problem by employing the *ex-post* use of accounting information to design an incentive contract that can control the managers' behaviour in carrying out their actions in the future, even though their immediate interest is their own wealth (see also Campbell 2006). Thus, corporate governance principles and policies can support the mechanism design function in mitigating incomplete contract problems by ensuring the *ex-post* efficiency of an organisational design (see also McGuigan et al. 2014; Varian 2014).

Moreover, different game theory based rules, strategies and modelling mechanics can be adopted in a mechanism design exercise to achieve cooperative outcomes among all stakeholders to mitigate ex-post post contractual opportunistic behavior and asymmetric information problems. For example, in the context of the use of game theory for addressing the issues of agency theory, different forms of game, game theory and organisational behaviour can be used for resolving agency conflicts for achieving corporate governance.

Cooperative game theory based mechanism design for achieving corporate governance can be achieved through the modelling and implementation of the following rules of cooperative game theory if a corporate governance model: subgame perfect equilibrium, repeated game, Folk theorem, cooperation – altruism, fairness, equity, reciprocity, etc.

Cooperative game based mechanism design for achieving corporate governance does not have to be in the form of complete contract. It can be in the form of incomplete contract where desired objective can be achieved through laws and interventions from public authorities.

However, the existing models for mechanism design are developed to address the specific problem of the principal-agents incentive conflicts from an *ex-ante* perspective (e.g. Macho-Stadler and Castrillo 2001; Montet and Serra 2003), without analysing the implications of the model on the contemporary issues of corporate governance from an *ex-post* perspective, in an integrated way. Accordingly, there is a need for the further development of a new integrated applied mechanism design model that represents a full spectrum of incentive-compatible contract to mitigate agency problems, ensure good corporate governance and achieve the highest possible company performance. This study strives to fill this gap by formulating a new corporate governance model based on a mechanism design approach that integrates all essential governance principles and mechanisms of a modern corporation, and analyses the availability of mechanism design in resolving the agency problem from both *ex-ante* and *ex-post* perspectives.

3.3. Corporate Governance as a Mechanism Design Problem

The existing literature on information economics reveals that the best way to model mechanism design and resolve principal-agent problems is by imposing a game theoretic-based analysis that accommodates the interests of all related parties into a strategic game or interaction (e.g. McGuigan et al. 2014; Narahari 2014; Barron 2013; Gardner 2003). From an agency theory perspective, this approach can be used to solve principal–agent conflict by designing an incentive contract that specifies the utility of principal as an objective function, subject to the agents' incentives in achieving the goals of the principal as constraints. Such a contract is powerful in establishing the optimal mechanisms that can align the interests of principals and agents, and achieve cooperation between both parties, and therefore supports a strong governance structure and ensures the efficient allocation of resources (Demski 2008; Besanko et al. 2003; Holmstrom and Tirole 1989). Myerson (1989) argues that a mechanism design can be solved as an optimisation problem, particularly when the problem deals with the maximisation of the principal's utility. Focussing, as it does, on designing a contract that can maximise the utility of shareholders as the principal, therefore, this study employs the optimisation method with the integration of principles and concepts of corporate governance.

The mechanism design concept in the optimisation model is concerned with the way system-wide solutions should be implemented into problems that involve multiple, self-interested and rational parties and are characterised by asymmetric information (e.g. Narahari et al. 2009; Voigt 2011; Narahari 2014). For example, a mechanism design problem can be represented as follows (Macho-Stadler and Pérez-Castrillo 2001), which is mathematically similar to the corporate governance model as specified in Heinrich (2002), Tirole (2001) and Hermalin (2001).

$$\underset{[\{w(x_i)\}_{i=1,\dots,n}]}{\text{Max}} \sum_{i=1}^{n} {p_i}^H [x_i - w(x_i)] \tag{1.1}$$

Subject to:

$$\sum_{i=1}^{n} {p_i}^H u\big(w(x_i)\big) - v(e^H) \geq \underline{U} \tag{1.2}$$

$$\sum_{i=1}^{n} [{p_i}^H - {p_i}^L] u\big(w(x_i)\big) \geq v(e^H) - v(e^L) \tag{1.3}$$

The maximisation problem for a mechanism design model above represents the interest of principals in optimising their utility as a function of their expectation that the agents will provide their high efforts (${p_i}^H[x_i - w(x_i)]$). However, the agents usually have the right to refuse to participate hence the principal needs to motivate agents to willingly provide their contribution in the system. If $\underline{U}$ denotes the utility that the agents would get if they refused to participate in the system, then the principal should set a scheme, in which the incentives for the agents to provide the high effort e^H must satisfy the minimum threshold of agents' expected compensation if they participate in the system (equation 1.2). This constraint is commonly called participative or individual rationality constraint. Furthermore, as agents are not always keen to take more risks in their actions, the principal needs to formulate a constraint that depicts the trade-off between risk-sharing mechanism and incentives in the optimal contracts. Equation (1.3) depicts an incentive compatibility constraint, which prevents the agent to be indifferent between the choice of high effort e^H and low effort e^L. The constraint motivates the agent to take more actions on effort that can provide high impact on his/her wage, than low effort that only give him/her marginal returns ($[p_i{}^H - p_i{}^L]u[w(x_i)]$), and challenge the agent to execute the actions hence the pay-off can be greater than the cost of providing high effort ($v(e^H) - v(e^L)$), which can also result in high profit/return from the actions. Therefore, the above mechanism design model, which is represented as an optimisation problem, is a formal specification of the issues, principles and goals of corporate governance.

4. The Mechanism Design Approach to Corporate Governance in this Study

In this study, the mechanism design model formalises the corporate governance system from both *ex-ante* and *ex-post* perspectives, in the form of designing the governance and control mechanisms for aligning the interests of shareholders and managers, and providing incentives for cooperation, through an optimal contract based on the framework of principal-agent relationship. The contract designs the performance-based incentive-compatible mechanisms that ensure greater incentives for the managers who can provide the best effort and act on behalf of shareholders' interest, i.e. share value maximisation (Samuelson and Marks 2015). The incentive-compatible contract links the incentive plans with the company's observable performance and, therefore, the incentives received by managers are compatible with the incentives of shareholders, in which company value is maximised, and thus the interests of managers and shareholders are aligned. This mechanism can motivate managers to reveal more information to the shareholders; which prevents managers from manipulative and opportunistic behaviour, and leads to good corporate governance practices (Shleifer and Vishny 1997). Consequently, the outcomes of an optimal incentive-compatible mechanism might benefit a company in resolving problems and reducing costs arising from a principal–agent relationship leading to improved company performance.

In the accounting and finance literature, corporate governance is defined as the set of rules, structures and procedures to ensure that the funds provided by the investors will not be misused by the managers, hence they can rest assured of getting a return on their investment (e.g. Shleifer and Vishny 1997). This study incorporates corporate governance as a complementary apparatus of mechanism design for controlling the managers from ex-post opportunistic behaviours after signing the contract (i.e. moral hazard problem) into the mechanism design model. In the model, corporate governance principles are integrated as mechanisms to guarantee that the managers do not breach the contract and hence they will act in the best interest of shareholders, that is, maximising value for the owners of the company (e.g. Kaen 2005). Accordingly, a set of principles and rules is imposed as the model constraints to motivate and control the managers in performing their best actions, achieving the highest company performance and ensuring that the interests of all stakeholders, not only the investors, are fulfilled. Following the concepts of financial management for modern corporations (e.g. Rezaee 2011; Van Greuning and Bratanovic 2009; Mullineux 2006; Tirole 2006, 2001), this study incorporates governance principles as mechanisms for achieving good corporate governance practices, including corporate control policies (dividend policy, financing policy and financial performance constraints), regulatory environments and risk management strategies, into the model.

A general setting for formulating, analysing and solving mechanism design problems in this study is given as follows (adapted from Narahari 2014; Voigt 2011):

1. This study assumes that the strategic interaction between shareholders and managers takes the form of a non-cooperative game, where the shareholders (as the principal) set up the rules or mechanisms, and the managers (as the agent) decide to sign the contract or not. Once the managers sign the contract, they must obey the rules or mechanisms specified in the contract, or else they will be punished for violating or breaching the contract. As the designer of the contract is the principal,

the mechanism is designed to maximise the utility of the principal, subject to the incentives of the agents to participate in the mechanism.

2. There are N numbers of rational and intelligent parties involved in the strategic interaction, with $N = (1,2 \dots, n)$. In this study, there are two parties involved: the principal, i.e. shareholder (P), and the agent, i.e. managers (A), who are assumed to be rational, and hence both strive to maximise their utilities and achieve their interests.
3. Each party will obtain certain payoffs based on the outcomes of the interaction. In this case, the agent will obtain a payoff in the form of wages (w) while the principal's utility is in the form of net profits distribution ($\pi - w$). The ultimate objective of the mechanism is the maximisation of company value.
4. There is a set of alternatives or strategies, denoted by X, which should be made or provided by the mechanism. As this study adopts the mechanism design framework to develop a financial optimisation model, the set of strategies is reflected through a set of optimal solutions produced by the financial model (i.e. decision variables $X_1, X_2, \dots, X_n$). The financial strategies depict the actions/strategic decisions taken by managers (the agent), which can determine all the parties' payoff, i.e. the agent's wage (w) and the principal's utility ($\pi - w$).
5. This study assumes that there is a problem of moral hazard, where the agent's actions are unobservable to the principal, hence the leeway of post-contractual opportunism exist. Accordingly, the principal designs rules or mechanisms based on the observable outcomes of the agent's actions (X), which relate incentive contracts with the agent's performance, to ensure that the agent will act in the best interests of the principal (further discussed in the next section). This study also assumes that the principal has a risk-neutral preference and the agent acts as a risk-averse party hence the specified incentive contract can be applied in the model.
6. The mechanism is aimed to assign the agent's message $S \in (S_1, S_2, \dots, S_n)$ to a contract (q, Z), where q is the agent's decisions and Z is a transfer function from the principal to the agent, or vice versa. If the Z for the agent is reflected by wage (w) and the agent's decisions are represented by X, the mechanism is formally defined by $S \to \langle X, w \rangle$. The utility of the agent is, then, denoted by $u(X, w, \theta)$, where u will be increased as w increases.

7. Outcomes of the mechanisms include the company value, and other accounting and financial performance indicators, which depict the utility of payoffs for all related parties. In a broader sense, these outcomes represent optimal solutions provided by an optimal contract design that can help align the interest of shareholders and managers, and achieve efficient organisational design in a company characterised by agency conflicts and incentive issues.

5. A Quantitative Corporate Governance Model as a Mechanism Design Problem[2]

5.1. The Model[3]

5.1.1. Objective Function

In developing a mechanism design model for achieving good corporate governance practices, the objective function should be defined in terms that directly relate to the concepts and parameters that are systematically essential for stakeholders to evaluate management's performance (Van Horne and Wachowicz 2005; Stern 1972). This study specifies the objective function that can reflect the long-term benefit of corporate governance: maximising the shareholders' wealth. The objective function is also relevant for evaluating the management's stewardship in a modern corporation based on agency theory, as it is tempered by a set of incentive constraints to ensure that managers act on behalf of their shareholders' interests. The objective function also reflects another objective of good corporate governance practices, which by improving the company's value can inform current investors and provide a positive signal to external parties (i.e. potential investors and creditors) about the current condition of the company, and hence provide them with more confidence to make any financial-related decisions (Fama and French 1998). Accordingly, this model accommodates the integration of value-based management and stakeholders' approaches (Nuryanah and Islam 2015).

This study specifies the Free Cash Flow (FCF) valuation as the objective function, as discussed above. The FCF valuation reflects the common solution for agency

[2] **Acknowledgment:** Originally, this model is developed in Arifa and Islam (2016). The model has different forms, versions, as discipline areas of implications and application, including accounting, finance, corporate governance, risk management, organisational design and so on. In the present paper, the model is reformulated and reinterpreted as a corporate governance model.

[3] A complete list of variables and parameters definition is given in Appendix 1.

conflict, in a shareholder–managers relationship, by measuring the real cash flows for the owner, narrowing the gap between the interests of the owner and managers, and ensuring the sustainability of the company (see for example Nuryanah and Islam 2015; Koller et al. 2010; Douma and Schreuder 2008). Specifically, this study defines the free cash flow to shareholder equity as a proxy, adjusted to the banking context (i.e. the value per share of equity (VSE) as argued by Damodaran 2012). Following the dividend discount model, the value per share of equity (VSE) is specified by the sum of the expected dividend paid to shareholders discounted on the cost of equity capital over the observation periods, plus the present value terminal price of equity discounted by the cost of equity capital at the end of observation period T. Therefore the mathematical equation of the objective function is expressed as follows:

$$Maximise\ VSE = \sum_{t=1}^{n} \left[\frac{DPS_t}{(1+ke)^t}\right] + \left[\frac{TV_n}{(1+ke)^n}\right] \qquad (2.1)$$

where $DPS_t = \frac{d_t}{N_t}$ and $TV_T = \frac{d_T(1+g)}{(k_e-g)}$

5.1.2. Decision Variables

This study focuses on developing a corporate financial model that aims to be prescriptive and applicable for a global banking company, particularly to address the issues arising in the banking sector, hence the variables of the model are derived to serve these purposes. Existing literature on the applications of management science in banks shows that the main purpose of financial modelling in a banking company is essentially for balance sheet management (for example Birge and Júdice 2013; Chi et al. 2007; Güven and Persentili 1997; Sheldon and Shaw 1981; Brodt 1978). As the elements in the balance sheet of a banking company mainly consist of interest earnings assets and interest bearing liabilities, which become the sources of earnings and the uses of funds in financial institutions (see for example Rezaee 2011; Van Greuning and Bratanovic 2009), the variables of the developed model are excerpted from balance sheets accounts in the accounting statement, i.e. assets and liabilities, as discussed below.

From the objective function presented in equation (1), dividend (d_t) becomes the decision variable which is directly related to the objective function of the model. However, consistent with the relationship among the accounting statements discussed previously, the number of dividends paid to shareholders depends on the profit earned, which becomes the underlying driving forecast for most financial planning (Ho and Lee 2004). As the commercial banks' profits are derived from interest income (yields on interest earning assets) and interest expenses (costs of interest bearing liabilities), therefore, this model also determines the decision variables which are derived from interest earning assets and interest bearing liabilities. In summary, the decision variables of the model are identified as follows:

1. Decision variables of the objective function

   $\boldsymbol{d_t}$: dividend paid in period t

2. Decision variables representing assets

   $\boldsymbol{L_t}$: loans, bills discounted and other receivables in period t

   $\boldsymbol{CL_t}$: cash and liquid assets in period t

   $\boldsymbol{R_t}$: receivables due from other financial institutions in period t

   $\boldsymbol{Sec_t}$: securities in period t

3. Decision variables representing liabilities

   $\boldsymbol{D_t}$: deposits and other public borrowing in period t

   $\boldsymbol{AP_t}$: payables due to other financial institutions in period t

   $\boldsymbol{LFV_t}$: liabilities at fair value to profit and loss in period t

   $\boldsymbol{Db_t}$: debt issues in period t

   $\boldsymbol{cDb_t}$: carrying value of debt issues in period t, as result of full fair value accounting adjustment

   $\boldsymbol{LC_t}$: loan capital in period t

4. Other variables

   $\boldsymbol{REx_t}$: remuneration paid for executives in period t

Aside from the fact that the decision variables above directly contribute to the objective function, the choice of variables is also justified under the main assumptions that: 1) the company consistently pays dividends to its shareholders annually; 2) other elements in the assets and liabilities categories, including non-interest earning assets and non-interest bearing liabilities, are known; and 3) the company does not issue new shares hence there is no change in its share capital.

5.1.3. Model Constraints

1) Accounting Definitional Constraints: A Reliable Financial Accounting System as an Internal Corporate Governance Mechanism

In a modern corporation, the economic activity of an entity is accounted for separately from its owners (Berle et al. 1932). The separation of ownership and control can create an inherent conflict that involves a control mechanism problem as highlighted in the classic agency perspectives (Jensen and Meckling 1976). As discussed in the literature review, this problem can be mitigated through a reliable financial accounting system that provides the accounting information as a direct input to strengthen the corporate control mechanism, as well as an indirect input by contributing to the information implied by share prices (Bushman and Smith 2001). The reliable accounting information provides a sound basis for designing the optimal contract mechanism among the stakeholders in a company which can mitigate agency problems, reduce agency costs and ensure good corporate governance leading to better company performance and higher shareholders' value (e.g. Bushman and Smith 2003; Gompers et al. 2003; La Porta et al. 2000; Shleifer and Vishny 1997; Jensen and Meckling 1976).

As a product of the accounting system, financial statements have a significant benefit by providing reliable, publicly-disclosed audited quantitative data informing the financial position, financial performance and cash flows of a company. This information is useful to a wide range of users for making economic decisions about providing resources to the company, by allowing them to assess the company's prospects for future net cash inflows and estimate the value of the reporting entity (Scott 2011; Christensen and Demski 2003). The financial statements supply the users with relevant information on the resources of the entity, claims against the entity and the ability of the entity to fulfil their obligation to compensate those claims. The financial statements also disclose the results of the management's stewardship, and the company's effectiveness, efficiency and accountability in managing and governing the resources entrusted to it.

The following sets of constraints show the relationships among the decision variables included in the financial model. The relationship is defined based on the accounting system that shows the interrelation among accounts in the financial statements. In order to reflect the flow of the accounting system, the constraints start with the performance of operational activities (i.e. income statement), followed by the financial position (i.e. balance sheet) and the financial flow (i.e. the cash flows).

An income statement depicts the company performance during an accounting period *t*. In a banking context, this is represented by net income (NI_t), which is calculated by the sum of the interest revenue generated from the assets ($IntInc_t$) and the interest expense paid for all the funding sources ($IntEx_t$), with all operating expenses, remuneration expense and related taxes deducted. If the tax rate in period t is τ_t, this relationship is presented as follows:

$$NI_t = [(1-\tau_t)(IntInc_t - IntEx_t + OInc_t - ImpEx_t - OpEx_t - REx_t) - PTax_t] \quad (2.2)$$

The net income should be sufficient to be distributed as a dividend for shareholders and to be added as a capital source of equity (Van Greuning and Bratanovic 2009). Therefore, net income in period t (NI_t) cannot be less than zero, or $NI_t \geq 0$. Therefore, the net income relationship is depicted as follows:

$$(1-\tau_t)\big[(y_l L_{t-1} + y_r R_{t-1} + y_{cl} CL_{t-1} + y_{sec} Sec_{t-1}) - \big(i_d D_{t-1} + i_{ap} AP_{t-1} + i_{db} cDb_{t-1} + i_{lfv} LFV_{t-1} + i_{lc} LC_{t-1}\big) + OInc_t - ImpEx_t - OpEx_t - REx_t\big] - PTax_t \geq 0 \quad (2.3)$$

This constraint represents the sources and uses of funds reported in the balance sheet that depicts the composition of assets and liabilities of the company and the residual interest of the assets (Ho and Lee 2004). The basic accounting equation specifies the relationship of financial flows in year *t* as follows:

$$Assets_t - Liabilities_t = Equity_t \quad (2.4)$$

$$Assets_t = L_t + CL_t + R_t + Sec_t + NonIA_t \quad (2.5)$$

$$Liabilities_t = D_t + AP_t + LFV_t + cDb_t + LC_t + NonIL_t \quad (2.6)$$

$$Equity_t = SC_t + Res_t + RP_{t-1} + \Delta RP_t \quad (2.7)$$

Thus, the balance sheet identity relationship, or also called the fund availability (Brodt 1978) constraint for the model is presented as follows:

$$(L_t + CL_t + R_t + Sec_t) - (D_t + AP_t + LFV_t + cDb_t + LC_t) + d_t = SC_t + Res_t + RP_{t-1} + NonIL_t - NonIA_t + NI_t \quad (2.8)$$

The cash flows represents the relationship between income and the balance sheet, and become the crucial element for maintaining the equilibrium of the financial model (Morris and Daley 2009). It summarises all company activities, including operating, financing and investing; reflected in net cash inflow (NCI) available to be added to the cash account or to be paid as a dividend (Hamilton and Moses 1973). There are three elements of NCI: 1) net cash flow from operations (CFO); 2) net cash flow from investments, assumed to be negative due to active investment activities (CFI); and 3) net cash flow from financing (CFF), and written as:

$$NCI_t = CFO_t - CFI_t + CFF_t \tag{2.9}$$

Inserting the accounting elements of CFO, CFI and CFF into NCI, the cash flow identity relationship is:

$$[(1-\tau_t)(IntInc_t - IntEx_t + OInc_t - OpEx_t - REx_t) - PTax_t - (\Delta L_t + \Delta R_t + \Delta Sec_t) + (\Delta D_t + \Delta AP_t + \Delta LFV_t)] - [(PPE_t - PPE_{t-1}) + (IntAs_t - IntAs_{t-1})] + [(cDb_t - cDb_{t-1}) + (LC_t - LC_{t-1}) + \Delta SC_t - d_t] \geq 0 \tag{2.10}$$

2) Corporate Governance Mechanisms: Incentive Contracts and Corporate Control

Incentive contract constraints

The agency problem arises due to the tendency for the agent to have hidden information, more than is known by the principal, or as it is commonly known, asymmetric information (Ross 1973; Holmstrom 1979). In a moral hazard situation, one way to mitigate this problem is to design an incentive contract that can motivate managers to act on behalf of shareholders' interests (McGuigan et al. 2014; Samuelson and Marks 2015). This study specifies a remuneration scheme as one of the incentive mechanisms to motivate managers to exert their best efforts. However, as the managers' efforts are unobservable to the shareholders, the contract must be based on verifiable variables, i.e. managers' performance, to guarantee the fulfilment of the contract (Macho-Stadler and Pérez-Castrillo 2001). The remuneration contract is given as follows:

$$REx_t = \chi_t NI_t \tag{2.11}$$

where REx_t is the managers' incentives and NI_t represents the performance, which is measured by net income (Scott 2011). The parameter χ_t symbolises the amount of incentives that is tied to the managers' performance (NI_t), which value depends on the willingness of the managers to take risks.

Furthermore, the shareholders should offer the managers the minimum level of incentives that can motivate the managers to cooperate and enter the contract, or commonly known as the participative constraint (Samuelson and Marks 2015). However, the incentives paid should not exceed the maximum amount which can be paid to management without decreasing the efficiency level (Bryan et al. 2000). Furthermore, while the low salary level might discourage the managers to take risks, the very high salary level can lead the managers to aggressively take too many risks and transfer the risks to the principal; hence the risk taking behaviour equilibrium will be shifted (Varian 2014). These constraints can be formulated as follows:

$$REx_t \geq REx_{\min(t)} \tag{2.12}$$

$$REx_t \leq \overline{REx_{\max(t)}} \quad (2.13$$

Capital structure (loan capital to equity capital ratio)

Restriction on the capital structure is essential for preventing agency costs arising from the shareholders' predatory behaviour in increasing investment risk after debt that can potentially decrease the value of debtholders (Jensen and Meckling 1976; Leland 1998). Therefore, Carleton et al (1973) suggest that a company must maintain the capital structure and set maximum leverage as a constraint of the financial model. This constraint restricts the upper limit of the loan capital level to satisfy the optimal capital structure, as follows:

$LC_t \leq 1.0\ Equity_t$; or

$$LC_t - NI_t + d_t \leq Equity_{t-1} + \Delta SC_t + \Delta Res_t \tag{2.14}$$

Dividend policy constraints

The dividend payment might lead to criticisms from different points of view. The opponents of dividends suggest that company profits are best reinvested back into the company as research and development, capital investment, business expansion, and so on. This view also argues that an eagerness to pay the fraction of company profits to shareholders might provide a signal of the management indifference about the future of the company. However, the proponent of dividends demonstrates that the dividend payments might be the evidence for managerial confidence in earnings growth and sufficient profitability to fund future business expansion (see for example Arnott and Asness 2003). This conflicting perspective suggests that there is a need for a dividend policy that not only signals the excellence of company performance in terms of the ability of the company to fulfil its shareholders' interest, but also ensures the long-term profitability and company growth (Dickens et al. 2002). The policies related to the dividend payment are discussed below.

<u>Minimum dividend policy</u>

Following the flow of funds in the net cash inflow (NCI) equation, NCI_t represents the net cash inflow in period t which is usually available to be added to cash accounts and to be distributed as a dividend in period t (Hamilton and Moses 1973; Morris and Daley 2009). The minimum dividend policy constraint can be formulated as follows:

$$NCI_t - \Delta Cash_t - \delta_t NI_t \geq 0 \quad (2.15)$$

Maximum dividend policy

The amount of retained earnings is determined by the company's net profit and the payout ratio of dividends. In order to ensure that the company can make retained earnings available for investment in the future (ΔRP_t) and pay dividends for shareholders (Damodaran 2013), the net income generated in the current period must be sufficient for both purposes. This can be expressed as follows:

$$NI_t \geq d_t + \Delta RP_t \quad (2.16)$$

Financial performance constraints

In the context of corporate governance, financial performance measures, as products of the accounting system, provide important roles in an incentive contract. Specifically, profitability measures have an explicit use in formulating annual bonuses and long-term incentive plans of executives, and an implicit use in monitoring the managers' performance (Ittner et al. 1997; Indjejikian 1999; Scott 2011). To ensure that managers do not violate the minimum performance required by the contract, shareholders need to set a policy that restricts the minimum profitability achieved by the managers. This policy can be represented by requiring the company's return on equity (ROE) to be higher than the ROE of the industry average (Rezaee 2011), or mathematically depicted as follows:

$$\frac{NI_t}{Average\ total\ equity_t} \geq ROE_{ind(t)} \quad (2.17)$$

Operational efficiency constraint

The efficiency ratio depicts the efficiency of managers in carrying out operating activities, as it assesses how much of its income the company spends on operating expenses. A high efficiency ratio indicates either high operating expenses or lack of managers' ability to generate income (Gardner et al. 2005). To ensure that the managers will efficiently allocate the company resources for exerting the operational activities, shareholders must restrict the maximum level of the efficiency ratio for at least lower than or equal to the efficiency ratio of the industry average (Rezaee 2011):

$$\frac{OpEx_t + REx_t}{(IntInc_t - IntEx_t) + OInc_t} \times 100\% \leq ER_{ind(t)} \quad (2.18)$$

Financial sustainability constraint

One of the main goals of corporate financial management is to protect shareholders' wealth in the long-term by securing future company growth (Titman et al. 2014; Van

Horne and Wachowicz 2005); hence it requires managers to maintain financial sustainability. Moreover, banking regulations restrict banks to secure the long-term safety and sustainability of the financial system in order to continuously protect other stakeholders' interest and provide financial services to other businesses (Lange et al. 2013; Mulbert 2013). To satisfy this requirement, managers should maintain revenue (measured by net interest income, NII) over period t to be higher than the revenue in the previous period (t−1), at least by the required minimum revenue growth. It is presented as follows:

$$NII_t - (1 + \varphi NII_t)NII_{t-1} \geq 0 \tag{2.19}$$

3) Corporate Governance Policies: Regulatory Environments and Risk Management Strategies

Liquidity risk: Balance sheet quality

Liquidity management by maintaining the balance sheet quality is important for banks as, at macroeconomic level, the liquidity problems of a single bank can spread promptly, influence other banks externally and aggravate systemic risks (Freixas and Rochet 2008). Generally, the best way to assess the quality of the balance sheet is over on-site inspection and asset-liability management on the maturity of outstanding loans and deposits. (Lange et al. 2013). However, in the absence of this opportunity, some accounting and financial ratios can be used to quantitatively assess the balance sheet quality, including the loans ratio and the loan-to-deposit ratio (Van Greuning and Bratanovic 2009).

The loans ratio depicts the proportion of loans compared to the total assets of a bank. To preserve the high quality of loans as the most profitable asset in a bank and hence sustain the long-run profitability, the company should maintain its loans ratio within the optimal range, typically based on historical data or the industry average, or expressed as follows:

$$LR_t \geq LR_{\min(t)} \tag{2.20}$$

$$LR_t \leq \overline{LR_{max}} \tag{2.21}$$

The loan-to-deposit ratio (LTDR) is one of the liquidity management policies of a bank that depicts the ratio between loans held by borrowers and deposits earned from customers (Lange et al. 2013). Managers are required to set an optima range of this ratio in order to protect borrowers and depositors from liquidity risk. If the borrowers and/or depositors believe that this ratio reveals the illiquidity of the bank, managers need to place an upper limit on the permitted value for this ratio, or otherwise the bank might not have enough liquidity to cover any unforeseen fund requirements. On the other hand, managers also need to set a lower limit of allowable value of this ratio to provide sufficiency of funding sources to pay all the deposits on demand, even if the bank is not in a profitable condition (Gardner et al. 2005). The constraints are presented as follows:

$$\frac{L_t}{D_t} \times 100\% \geq \min \overline{LTDR_t} \quad (2.22)$$

$$\frac{L_t}{D_t} \times 100\% \leq max\, \overline{LTDR_t} \quad (2.23)$$

Financial distress and bankruptcy risk

Financial distress is a condition where a company suffers a loss of value that can be attributed to the company's deteriorating financial strength (Brealey et al. 2014; Titman et al. 2014). In a banking context, the probability of financial distress can be predicted through the ability of a bank in maintaining its positive asset growth. This can be used as a signal for the related parties about the success of the bank in protecting its future financial position, and hence avoiding financial distress and bankruptcy risk in the long term (Morris and Daley 2009). Therefore, the total assets in period t (TA_t) must be greater than or equal to the minimum assets growth required in period t compared to the previous period (t−1). The asset growth constraint for the model can be mathematically written as follows:

$$TA_t - (1 + \varphi Assets_t)TA_{t-1} \geq 0 \quad (2.24)$$

Capital adequacy constraint

Financial distress and bankruptcy might be costly especially for creditors, including depositors, shareholders and other banks (Altman and Hotchkiss 2006). Moreover, a bank failure may also endanger the solvency of nonfinancial companies. In order to protect the entity against the risk of insolvency and financial failure, the banking regulators requires banks to maintain their minimum capital level. The required capital absorbs unanticipated losses with enough margin to ensure that the institution continues its operations as a going concern and hence protects stakeholders' rights in the long term (BCBS 2011). To ensure that the mechanisms specified in the model do not violate the regulation, the model incorporates minimum capital adequacy as a constraint. Adopting the regulatory framework imposed by BCBS and APRA, the capital adequacy requirement constraints are presented as follows:

$$\frac{Total\ regulatory\ capital}{Total\ risk - adjusted\ assets} \geq 8.0\% \quad (2.25)$$

5.2. Numerical Implementation of the Corporate Governance Model

The model's specification, simulation and analysis assume that all the parameters and variables are known with certainty, and hence the numerical model is assumed to be a deterministic financial optimisation model. The developed model is analysed by using the data sample of a bank in order to observe the applicability of the model in a real case company. The numerical model is presented by inserting the unknown decision variables into the Left-Hand Side (LHS) of the equations and the known variables and parameters, into the Right-Hand Side (RHS) of the equations. The analysis of the model uses secondary data based on the historical financial data of the chosen company and other relevant economic parameters obtained from publicly available reports provided by international and national financial institutions, including the World Bank, Standard & Poor, central bank and other data repositories such as Bankscope and Yahoo! Finance. Any data which cannot be obtained from public sources are calculated and simulated based on reasonable assumptions from historical data and previous studies. The complete version of the numerical mechanism design model is given in the Appendix 2.

The results of the model testing are expected to provide comprehensive answers for the research questions of this study. In order to grasp the significance of the mechanism design in reducing agency problems, achieving good corporate governance and improving company value, the model is simulated and analysed in two models: the basic model without mechanism design constraints (MDCG-0); and the complete mechanism design model (MDCG-1). Further, the model is analysed by comparing the optimal results of the two models and the book value performance measures based on the company's financial statement. This structured analysis process is performed to ensure that this study has succeeded in designing an optimal incentive contract and corporate governance principles integrated in a large-scale applied optimisation model based on the mechanism design framework.

This study employs Analytical Solver Platform v12.5 developed by Frontline Systems for Microsoft to simulate and analyse the financial model. This software is fully compatible for the solver bundled with Microsoft Excel. Specifically, Risk Solver

Platform (RSP) as one of the subsets of the Analytical Solver Platform will be used to solve the programming problem and model. RSP provides the combination of optimisation and simulation capabilities for model solving (Frontline 2013). This software has powerful technical support for conventional optimisation with its simplex LP solver engine which is able to handle linear programming problems with up to 2,000 variables and 2,000 constraints. The software also includes five built-in solvers, i.e. LSGRG Nonlinear, Evolutionary, LP/Quadratic, Interval Global and Second Order Cone Programming (SOCP) Barrier for solving the full spectrum of the optimisation model.

5.3. Results of the Model Simulation

A comprehensive comparison of optimal objective value and decision variables resulting from the mechanism design model implementation is presented in Table 1. Based on these results, Table 2 summarises the strategic financial performance indicators which depict the excellence of a core business model, as adopted in previous studies in banking (Demirgüç-Kunt and Huizinga 2010; Beck et al. 2013). Table 2 presents a comparison of optimal financial outcomes produced from two versions of the model, i.e. the basic model without mechanism design constraints (MDCG-0); and the complete mechanism design model (MDCG-1). Based on a comparison between optimal results and actual outcomes, in summary, the mechanism design model produces generally improved outcomes, shown by the higher average values of all financial indicators compared to the average book values of actual financial performance based on historical data. The results reveal that the mechanism design model can specify incentive-compatible implementation for a company characterised by agency problems.

Table 1. Optimal Results of the Model Testing

	Optimal results based on:		
	MDCG-0	**MDCG-1**	**Baseline**
Objective Value	53.8768	55.6865	38.3138
Decision Variables			
Value d1	2,412.86	2,493.90	1,738.35
Value d2	3,571.03	3,690.98	2,621.55
Value d3	3,963.84	4,096.99	2,918.27
Value d4	4,162.04	4,301.83	3,123.00
Value d5	4,536.62	4,689.00	3,211.71

Value L1	617,870.15	631,951.15	466,631.00
Value L2	636,414.98	636,907.45	493,459.00
Value L3	639,893.69	635,209.81	500,057.00
Value L4	751,161.82	729,819.07	525,682.00
Value L5	804,626.72	755,935.38	556,648.00
Value CL1	9,843.29	9,843.29	11,340.00
Value CL2	10,254.74	10,254.74	10,119.00
Value CL3	12,012.33	24,762.38	13,241.00
Value CL4	67,915.71	26,626.98	19,666.00
Value CL5	72,458.13	31,430.34	20,634.00
Value R1	8,886.44	39,847.49	14,421.00
Value R2	37,228.36	49,483.26	10,072.00
Value R3	47,125.42	58,843.15	10,393.00
Value R4	50,673.96	63,274.04	10,886.00
Value R5	53,141.78	72,858.92	7,744.00
Value Sec1	177,007.10	152,470.64	49,629.00
Value Sec2	190,282.46	178,833.86	57,910.00
Value Sec3	205,409.80	188,030.33	68,176.00
Value Sec4	220,877.16	238,336.57	77,521.00
Value Sec5	231,633.88	252,169.89	82,406.00
Value D1	427,421.37	458,494.45	368,721.00
Value D2	475,175.07	486,004.12	374,663.00
Value D3	489,437.04	495,746.26	401,147.00
Value D4	528,592.00	535,405.96	437,655.00
Value D5	577,683.47	567,530.31	459,429.00
Value AP1	199,126.14	215,572.94	15,109.00
Value AP2	211,073.71	228,512.68	12,608.00
Value AP3	215,295.18	233,082.94	15,899.00
Value AP4	354,093.65	343,637.84	22,126.00
Value AP5	375,339.27	364,256.11	25,922.00
Value LFV1	20,339.06	20,339.06	16,596.00
Value LFV2	21,559.40	21,565.06	15,342.00
Value LFV3	21,990.59	21,996.56	10,491.00
Value LFV4	23,749.84	23,756.47	6,555.00
Value LFV5	25,174.83	25,181.86	8,701.00
Value cDb1	107,989.64	82,247.01	101,819.00
Value cDb2	112,530.52	85,705.44	130,210.00
Value cDb3	119,279.87	90,845.88	118,652.00
Value cDb4	118,344.65	90,133.60	124,712.00
Value cDb5	118,400.99	90,176.50	132,808.00
Value LC1	15,142.29	15,142.29	12,039.00
Value LC2	16,050.83	16,050.83	13,513.00
Value LC3	16,371.84	16,371.84	11,561.00

Value LC4	17,681.59	17,681.59	10,022.00
Value LC5	18,742.49	18,742.49	9,687.00
Value REX1	671.65	58.00	58.00
Value REX2	0.00	68.00	68.00
Value REX3	1,095.61	80.00	71.00
Value REX4	0.00	78.44	55.00
Value REX5	0.00	78.93	50.00

Table 2. Comparison of the Optimal Financial Outcomes

Optimal Results of the Model without Mechanism Design (MDCG-0)

Year	FBI	LTDR	OHC	CIR	ATO	ETA	NIM	ROE	CAR	ROA	LR	TA	NI	NII	Dividend
1	0.9031	1.3783	0.0079	0.1255	0.0181	0.0125	0.0273	0.2289	0.0894	0.0128	0.6919	1,012,152.53	9,588.42	18,358.80	2,412.86
2	0.8753	1.3115	0.0095	0.1697	0.0179	0.0114	0.0198	0.2494	0.0909	0.0093	0.6696	1,054,838.35	9,649.01	18,913.40	3,571.03
3	0.8976	1.2739	0.0092	0.1520	0.0199	0.0124	0.0218	0.3134	0.0920	0.0114	0.6420	1,090,069.95	12,204.37	21,727.13	3,963.84
4	0.8995	1.3500	0.0079	0.1371	0.0213	0.0140	0.0245	0.3726	0.1178	0.0140	0.6382	1,255,002.55	16,454.68	26,706.47	4,162.04
5	0.8848	1.3412	0.0073	0.1456	0.0180	0.0123	0.0198	0.2957	0.1060	0.0117	0.6401	1,317,765.06	15,076.17	23,724.51	4,536.62
Ave.	**0.8920**	**1.3310**	**0.0084**	**0.1460**	**0.0191**	**0.0125**	**0.0226**	**0.2920**	**0.0992**	**0.0119**	**0.6564**	**1,145,965.69**	**12,594.53**	**21,886.06**	**3,729.28**

Optimal Results of the Complete Version of the Mechanism Design (MDCG-1)

Year	FBI	LTDR	OHC	CIR	ATO	ETA	NIM	ROE	CAR	ROA	LR	TA	NI	NII	Dividend
1	0.8938	1.3783	0.0087	0.1367	0.0210	0.0145	0.0308	0.2436	0.0899	0.0123	0.6918	913,510.57	10,226.44	19,199.91	2,493.90
2	0.8642	1.3105	0.0092	0.1606	0.0206	0.0141	0.0229	0.2791	0.0964	0.0118	0.6692	951,739.30	11,041.64	19,586.44	3,690.98
3	0.8867	1.2813	0.0092	0.1513	0.0223	0.0146	0.0246	0.3071	0.1118	0.0135	0.6452	984,589.66	13,064.76	21,909.57	4,096.99
4	0.8910	1.3631	0.0087	0.1499	0.0236	0.0155	0.0275	0.3561	0.1160	0.0156	0.6377	1,144,428.66	16,617.92	27,011.00	4,301.83
5	0.8743	1.3320	0.0081	0.1602	0.0195	0.0133	0.0216	0.2925	0.1059	0.0126	0.6294	1,201,119.53	14,827.27	23,460.13	4,689.00
Ave.	**0.8820**	**1.3330**	**0.0088**	**0.1518**	**0.0214**	**0.0144**	**0.0255**	**0.2957**	**0.1040**	**0.0132**	**0.6546**	**1,039,077.54**	**13,155.60**	**22,233.41**	**3,854.54**

Actual Outcomes based on the Book Values of Financial Statements

Year	FBI	LTDR	OHC	CIR	ATO	ETA	NIM	ROE	CAR	ROA	LR	TA	NI	NII	Dividend
1	0.8362	1.2655	0.0128	0.2108	0.0166	0.0126	0.0216	0.1651	0.0807	0.0086	0.7522	620,372.00	4,753.00	10,301.00	1,738.35
2	0.8139	1.3171	0.0135	0.2202	0.0184	0.0125	0.0215	0.1695	0.0915	0.0090	0.7635	646,330.00	5,680.00	11,922.00	2,621.55
3	0.8460	1.2466	0.0136	0.2055	0.0189	0.0115	0.0217	0.1760	0.1001	0.0098	0.7487	667,899.00	6,410.00	12,607.00	2,918.27
4	0.8405	1.2011	0.0130	0.2050	0.0183	0.0114	0.0215	0.1802	0.1001	0.0103	0.7319	718,229.00	7,106.00	13,122.00	3,123.00
5	0.8201	1.2116	0.0128	0.2285	0.0185	0.0117	0.0215	0.1767	0.1024	0.0105	0.7384	753,876.00	7,693.00	13,934.00	3,211.71
Ave.	**0.8313**	**1.2484**	**0.0131**	**0.2140**	**0.0181**	**0.0119**	**0.0216**	**0.1735**	**0.0950**	**0.0096**	**0.7469**	**681,341.20**	**6,328.40**	**12,377.20**	**2,722.58**

6. Incentive Compatible Corporate Governance Principles

This study analyses the mechanism design model, which is designed by the principal (i.e. the shareholders) and offered to the agents (i.e. the managers) from the information economics perspectives, and investigates the extent to which the model can design an incentive contract that can mitigate the underlying agency problem that occur in the principal–agent relationship. The contract is designed to provide managers with the optimal incentives to motivate them to exert more than the minimum level of effort when performing strategic actions on behalf of the shareholders, for aligning the interests of both parties, alleviating agency conflicts, improving the company's performance and maximising the shareholders' value (Bebchuk and Fried 2003). Through this contract, the managers choose the optimal strategic decisions that can maximise the utility of the shareholders (the value per share of equity), subject to a set of constraints that reflect the mechanisms and incentives offered by the shareholders.

The results of the model simulation reveals that the corporate governance model based on the mechanism design framework (MDCG-1) motivate the managers to increase the level of the Fee-Based Income (FBI) within the optimal range. However, the models give no further incentives for managers to increase their activity to more than the optimal FBI level proposed by MDCG-1 (as indicated by the 0 incentives value resulting from MDCG-0). This is because a high level of FBI reflects the actions of managers maximising returns and diversifying risks at the same time. The incentive contracts offered by the shareholders motivate the managers to exert strategic decisions that can maximise the utility of the shareholders, yet restricts them to perform those strategies within the risk preference level that the managers can accept or, otherwise, their incentives will diminish. The optimal business combination proposed by the mechanism design-based financial model embeds the most optimal strategic decisions that need to be implemented in a safe and sound manner to protect the shareholders' rights, as well as to provide incentives for the managers to exert those decisions (Beck et al. 2013).

This study develops a mechanism design model that designs an incentive contract between the shareholders and managers, which establishes strategic interactions between both the shareholders and their managers that can align the interests between both parties in an optimal way and hence reduce agency costs occurring from such a relationship (e.g. Scott 2011). This postulate is supported by the results of this study, which show the increase in the Asset Turnover Ratio (ATO) produced by MDCG-1, that depicts the improvement in the managerial efficiency of managing the assets entrusted by the investors to generate earnings for the company (as argued by McKnight and Weir 2009; Singh and Davidson 2003; Ang et al. 2000). The results of the model simulation also show that the managerial discretionary in spending company resources can be reduced through the decrease in the Cost-Income Ratio (CIR). This implies that the mechanism design embedded in the financial model can prevent the managers from any actions that might benefit themselves through an excessive salary payment; hence, it can increase operational efficiency, leading to an improved company performance and the reduced agency costs arising from the managers and shareholders relationship.

Furthermore, apart from the interest alignment between the managers and shareholders, the integrated mechanism design model developed in this study also proposes the optimal financial strategies that can accommodate the interests and support of all the stakeholders comprehensively, as stated in the stakeholder theory (Freeman 2010; Jensen 2010). The developed mechanism design model proposes that, within the lower and upper bounds proposed by the mechanism design model, the company should increase the level of its Loans-To-Deposit Ratio (LTDR). In the presence of agency and information asymmetry problems among all the related decision makers, this strategy is essential for the bank's financial management as it balances the solvency risk and strengthens its financial position. The strategy also ensures the banks do hold a sufficient level of capital contributed by their shareholders to cover any shortage in the interest payments promised to the depositors and creditors (Gup and Kolari 2007; Koch and MacDonald 2006). Moreover, the financial performance constraints, incorporated in the model as corporate control mechanisms, ensure that the managers can allocate company resources in the most optimal and efficient way that can achieve the interests of all the stakeholders. The results of the model simulation suggest that the optimal solutions proposed by the mechanism design model represent the most optimal business strategies that can increase the company's performance in a more efficient way. This is shown by the increase in net income, Net Interest Income (NII) and Return On Equity (ROE), and the decrease in the Overhead Cost Ratio (OHC) and Cost-Income Ratio (CIR). These results suggest that the mechanism design model facilitates managers to exert the optimal strategies that can improve efficiency in generating income, enhancing profitability, supporting shareholders' value creation and securing all stakeholders' interest by maintaining the financial sustainability in the long- term.

7. Benefits of This New Approach to Corporate Governance

This study has demonstrated corporate governance can be conceived, specified and modelled as an operational mechanism design problem for formulating the required corporate governance mechanisms, rules and incentives. As discussed in the previous section, mechanism design is an approach for finding a set of rules of the game that can achieve the objective of the designer (e.g. Narahari 2014; Barron 2013). The mechanism design model developed in this study integrates several important aspects of a modern business, including financial and accounting policies, corporate governance principles and risk management strategies, as a set of mechanisms that can achieve good corporate governance. The model is designed from the shareholders perspective and offered to the managers; hence, it resembles a non-cooperative game that aims to maximise the single objective of the designer. The mechanism design model in this study incorporates an incentive contract that can motivate the managers to cooperate and join the contract, and perform their acts to achieve the best interests of the shareholders. The model is solved as a financial optimisation problem to obtain the optimal solutions as an incentive feasible set that represents the outcomes of the strategic interactions between the shareholders and managers in the most efficient way (Myerson 1989).

The model simulation produces a set of strategies, which can be conceived as a set of mechanisms, including the optimal level of the fee-based income and the proportion of loans to deposit, that needs to be exerted to achieve the highest possible company performance reflected in the objective function. The solutions of model simulation also show that the optimal mechanisms proposed by the model produce the enhanced financial performance in more efficient ways, shown by the increase in the company's profitability indicators (i.e. net income, net interest income and return on equity) and the decrease in managerial discretion for company spending (i.e. overhead cost ratio). These results imply that the mechanism design problem embedded in the model can be formulated to specify an efficient organisation leading to improved performance. Furthermore, the mechanism design model in this study can also establish an incentive contract that can reduce the agency cost and hence minimise agency and information asymmetry problems. This postulate is supported by the results of the model simulation which shows the improvement in several indicators of agency cost, that is, the increase in the Asset Turnover (ATO) and the decrease in the Cost-Income Ratio (CIR). As this solution set is moderated by a set of constraints involving several key aspects of financial management (i.e. accounting policies, corporate governance principles and risk management strategies), it therefore provides new insights into the way a company should design an incentive-compatible contract and resource efficient organisation, within the mechanism design and game theoretic frameworks.

8. Contributions and Conclusion

It is argued in this paper that corporate governance is essentially a mechanism design problem (designing a principal-agent game, game rules, mechanisms and incentives for achieving efficient cooperation). Consequently, this study develops and implements an operational quantitative and numerical framework for corporate governance based on the concept of mechanism design by formulating a corporate governance mechanism design model for designing incentive-compatible mechanisms and governance. The model is illustrated with a numerical implementation that shows that the mechanism design model can represent optimal incentive contracts to mitigate agency problems, good corporate governance and the process of the improvement of company value. Alternatively, the corporate governance model developed in this study shows that corporate governance issues can be modelled as a mechanism design problem. The results of this study show that corporate governance mechanisms embedded in the model gives the managers incentives to act on behalf of the shareholders and support an efficient allocation of the company's resources. Thus, this study argues that corporate governance is essentially a mechanism design problem in modern business, and hence this finding is contradicted with the arguments by Zingales (2008). Specifically, the incentive contract constraints within the mechanism design framework in this study are specified to address both information asymmetry (i.e. to reveal the correct information) and moral hazard (i.e. to achieve the goals of the principal) problems. The incentive contract incorporated in the mechanism design model plays a significant role as corporate governance mechanisms by giving an incentive for the managers to exert their best efforts in the interests of the shareholders in effective and efficient ways.

The developed operational applied corporate governance model is a fundamental contribution to the literature on corporate governance and mechanism design, since the proposed framework for integrating theory and principles of corporate governance with the theory of mechanism design will enable us to study the issues of corporate governance in a relatively more advanced conceptual framework of mechanism design theory compared to the current state of the art.

However, there are still areas of possible future research to investigate the usefulness of mechanism design in addressing contemporary issues in real business. Firstly, different game theory modelling principles and mechanisms for achieving sustained post contractual cooperation among all stakeholders leading to good corporate governance should be experimented and implemented to show the formal relevance of mechanism design for the corporate governance framework (as discussed in Section 3.2). Secondly, for integrating the mechanism design concepts in the model, this study incorporated the incentive contract, which is specified through the remuneration scheme based on the observable performance. This contract does not include the managers' risk aversion and the level of effort, hence the current model cannot relate the outcomes of the strategic interactions with the level of actions exerted and the risk taken by the managers, as was originally suggested by Holmstrom and Milgrom (1987). Therefore, any studies in mechanism design that include the managers' risk aversion and effort level as input parameters for determining the managers' payoff in the incentive compatibility constraint can fill the limitation of this study. Furthermore, in addressing the moral hazard issues, direct monitoring policies are another mechanism for monitoring unobservable efforts, and motivating the managers to reveal their private information directly and truthfully. The optimal monitoring policies are stochastic rather than deterministic, as they include the managers' risk aversion and the probability of the managers to exert their efforts, and the outcomes related to those efforts, hence the principal can directly monitor the agent's efforts and performance. As the model proposed in this study is simulated through the deterministic assumption, current implementation of the model is inadequate to accommodate the direct monitoring policies, particularly when the incentive problem concerns the direct revelation of hidden information in addition to the moral hazard problem. Therefore, further studies that consider the stochastic behaviour of direct monitoring policies, by incorporating the managers' risk aversion function and the probability of managerial efforts, can enhance the significance of the current study particularly for adequately monitoring managerial efforts and motivating the managers to reveal any private information directly and truthfully, as suggested by the revelation principle of the mechanism design.

References

Altman, E. I., and E. Hotchkiss. 2006. *Corporate Financial Distress and Bankruptcy: Predict and Avoid Bankruptcy, Analyze and Invest in Distressed Debt*. 3rd ed. Hoboken, N.J.: Wiley.

Ang, J. S., R. A. Cole, and J. W. Lin. 2000. Agency costs and ownership structure. *Journal of Finance* 55 (1):81-106.

Arnott, R. D., and C. S. Asness. 2003. Surprise! Higher dividends = higher earnings growth. *Financial Analysts Journal* 59 (1):70-87.

Barron, E. N. 2013. *Game Theory. An Introduction*. 2nd ed. Hoboken: Wiley.

BCBS. 2011. Basel III: A Global Regulatory Framework for More Resilient Banks and Banking Systems. Switzerland: Bank for International Settlements.

Bebchuk, L. A., and J. M. Fried. 2003. Executive compensation as an agency problem: National Bureau of Economic Research.

Beck, T., A. Demirgüç-Kunt, and O. Merrouche. 2013. Islamic vs. conventional banking: Business model, efficiency and stability. *Journal of Banking and Finance* 37 (2):433-447.

Berle, A. A., G. C. Means, and S. H. William. 1932. *The Modern Corporation and Private Property*. New York: Macmillan Co.

Besanko, D., D. Dranove, and M. Shanley. 2003. *Economics of Strategy*. 3rd ed. Hoboken, NJ: Wiley.

Birge, J. R., and P. Júdice. 2013. Long-term bank balance sheet management: Estimation and simulation of risk-factors. *Journal of Banking and Finance* 37 (12):4711-4720.

Brealey, R. A., S. C. Myers, and F. Allen. 2014. *Principles of Corporate Finance*. New York: McGraw-Hill Irwin.

Brodt, A. I. 1978. A dynamic balance sheet management model for a Canadian chartered bank. *Journal of Banking and Finance* 2 (3):221-241.

Brown, P., W. Beekes, and P. Verhoeven. 2011. Corporate governance, accounting and finance: A review. *Accounting and Finance* 51:96-173.

Bryan, S., L. Hwang, and S. Lilien. 2000. CEO stock-based compensation: An empirical analysis of incentive-intensity, relative mix, and economic determinants. *The Journal of Business* 73 (4):661-693.

Bushman, R. M., and A. J. Smith. 2001. Financial accounting information and corporate governance. *Journal of Accounting and Economics* 32:237-333.

———. 2003. Transparency, financial accounting information, and corporate governance. *Federal Reserve Bank of New York Economic Policy Review* 9 (1):65-87.

Campbell, D. E. 2006. *Incentives. Motivation and The Economics of Information*. 2nd ed. Cambridge [England] ; New York: Cambridge University Press.

Chi, G. T., H. C. Dong, and X. Y. Sun. 2007. Decision making model of bank's assets portfolio based on multi-period dynamic optimization. *Systems Engineering - Theory and Practice Online* 27 (2):1-16.

Christensen, J. A., and J. S. Demski. 2003. *Accounting Theory: An Information Content Perspective*. Boston: McGraw-Hill/Irwin.

Dallas, G. S. 2004. *Governance and Risk: An Analytical Handbook for Investors, Managers, Directors, and Stakeholders*. New York: McGraw-Hill.

Damodaran, A. 2013. Valuing financial service firms. *Journal of Financial Perspectives* 1 (1):59-74.

Demirgüç-Kunt, A., and H. Huizinga. 2010. Bank activity and funding strategies: The impact on risk and returns. *Journal of Financial Economics* 98:626-650.
Demski, J. S. 2008. *Managerial Uses of Accounting Information*. Vol. 4. New York: Springer.
Dickens, R. N., K. M. Casey, and J. A. Newman. 2002. Bank dividend policy: Explanatory factors. *Quarterly Journal of Business and Economics* 41 (1/2):3-12.
Douma, S. W., and H. Schreuder. 2008. *Economic Approaches to Organizations*. 4th ed. Harlow, England; New York: Financial Times/Prentice Hall.
Fama, E. F., and K. R. French. 1998. Taxes, financing decisions, and firm value. *The Journal of Finance* 53 (3):819-843.
Fama, E. F., and M. C. Jensen. 1983. Separation of ownership and control. *Journal of law and economics*:301-325.
Freeman, R. E. 2010. *Strategic Management: A Stakeholder Approach*. U.K.: Cambridge University Press.
Freixas, X., and J. C. Rochet. 2008. *Microeconomics of Banking*. Cambridge, Mass: MIT Press.
Frontline. 2013. *Frontline Solver Version 12.5 User Guide*. Nevada: Frontline Systems, Inc.
Gardner, M. J., D. L. Mills, and E. S. Cooperman. 2005. *Managing Financial Institutions*. London: South-Western.
Gardner, R. 2003. *Games for Business and Economics*. Hoboken, New Jersey: Wiley.
George Yungchih, W. 2010. The impacts of free cash flows and agency costs on firm performance. *Journal of Service Science and Management* 3 (04):408-418.
Gompers, P., J. Ishii, and A. Metrick. 2003. Corporate governance and equity prices. *Quarterly Journal of Economics* 118 (1):107-155.
Gup, B. E., and J. W. Kolari. 2007. *Commercial Banking: The Management of Risk*. Milton, Qld: John Wiley & Sons.
Güven, S., and E. Persentili. 1997. A linear programming model for bank balance sheet management. *Omega* 25 (4):449-459.
Hamilton, W. F., and M. A. Moses. 1973. An optimization model for corporate financial planning. *Operations Research* 21 (3):677-692.
Hansmann, H. 1996. *The Ownership of Enterprise*. Cambridge, MA: The Belknap Press of Harvard University Press.
Ho, T. S. Y., and S. B. Lee. 2004. *The Oxford Guide to Financial Modeling: Applications for Capital Markets, Corporate Finance, Risk Management, and Financial Institutions*. Oxford: Oxford University Press.
Holmstrom, B. 1979. Moral hazard and observability. *Bell Journal of Economics* 10 (1):74-91.
Holmstrom, B. R., and J. Tirole. 1989. The theory of the firm. In *Handbook of Industrial Organization*, edited by R. Schmalensee and R. D. Willig. Amsterdam: Elsevier Science Publishers B. V., 61-133.
Hurwicz, L., and S. Reiter. 2006. *Designing Economic Mechanisms*. Cambridge; New York: Cambridge University Press.
Indjejikian, R. J. 1999. Performance evaluation and compensation research: An agency perspective. *Accounting Horizons* 13 (2):147-157.
Ittner, C. D., D. F. Larcker, and M. V. Rajan. 1997. The choice of performance measures in annual bonus contracts. *The Accounting Review* 72 (2):231-255.

Jensen, M. C. 2010. Value maximization, stakeholder theory, and the corporate objective function. *Journal of Applied Corporate Finance* 22 (1):32-42.
Jensen, M. C., and W. H. Meckling. 1976. Theory of the firm: Managerial behaviour, agency cost and ownership structure. *Journal of Financial Economics* 3 (4):305-360.
Kaen, F. R. 2005. Risk Management, Corporate Governance and the Public Corporation. In *Risk Management*. Berlin, Heidelberg: Springer Berlin Heidelberg, 423-436.
Klapper, L. F., and I. Love. 2004. Corporate governance, investor protection, and performance in emerging markets. *Journal of Corporate Finance* 10 (5):703-728.
Koch, T. W., and S. S. MacDonald. 2006. *Bank Management*. Mason, Ohio: Thomson Higher Education.
Koller, T., M. H. Goedhart, and D. Wessels. 2010. *Valuation: Measuring and Managing the Value of Companies*. Hoboken, N.J: Wiley.
Kreps, D. M. 1990. *A Course in Microeconomic Theory*. Princeton, N.J.: Princeton University Press.
La Porta, R., F. Lopez-de-Silanes, A. Shleifer, and R. Vishny. 2000. Investor protection and corporate governance. *Journal of Financial Economics* 58 (1):3-27.
Laffont, J.-J., and D. Martimort. 2002. *The Theory of Incentives: The Principal-Agent Model*. Princeton, N.J.; Oxford: Princeton University Press.
Lange, H. P., A. Saunders, and M. M. Cornett. 2013. *Financial Institutions Management*. 3rd ed. North Ryde, N.S.W: McGraw-Hill Australia.
Larcker, D. F., S. A. Richardson, and I. Tuna. 2007. Corporate governance, accounting outcomes, and organizational performance. *The Accounting Review* 82 (4):963-1008.
Leland, H. E. 1998. Agency costs, risk management, and capital structure. *The Journal of Finance* 53 (4):1213-1243.
Macho-Stadler, I., and J. D. Pérez-Castrillo. 2001. *An Introduction to the Economics of Information: Incentives and Contracts*. 2nd ed. Oxford; New York: Oxford University Press.
Mas-Colell, A., M. D. Whinston, and J. R. Green. 1995. *Microeconomic Theory*. New York: Oxford University Press.
McGuigan, J. R., R. C. Moyer, and F. H. Harris. 2014. *Managerial Economics: Applications, Strategy, and Tactics*. 13th ed. Stamford, CT, USA: Cengage Learning.
McKnight, P. J., and C. Weir. 2009. Agency costs, corporate governance mechanisms and ownership structure in large UK publicly quoted companies: A panel data analysis. *Quarterly Review of Economics and Finance* 49 (2):139-158.
Morris, J. R., and J. P. Daley. 2009. *Introduction to Financial Models for Management and Planning*. Boca Raton: CRC Press.
Mulbert, P. O. 2013. Corporate Governance of Banks. In *Risk Management and Corporate Governance*, edited by A. Jalilvand and A. G. Malliaris. Hoboken, N.J.: Taylor and Francis.
Mullineux, A. 2006. The corporate governance of banks. *Journal of Financial Regulation and Compliance* 14 (4):375-382.
Myerson, R. B. 1979. Incentive compatibility and the bargaining problem. *Econometrica* 47 (1):61-73.

———. 1989. Mechanism Design. In *The New Palgrave: Allocation, Information, and Markets*, edited by J. Eatwell, M. Milgate and P. Newman. New York: The Macmillan Press Limited, 191-206.

Narahari, Y. 2014. *Game Theory and Mechanism Design*. Singapore: IISc Press, World Scientific.

Narahari, Y., D. Garg, R. Narayanam, and H. Prakash. 2009. *Game Theoretic Problems in Network Economics and Mechanism Design Solutions*. London: Springer.

Nuryanah, S., and S. M. N. Islam. 2015. *Corporate Governance and Financial Management: Computational Optimisation Modelling and Accounting Perspectives*. United Kingdom: Palgrave Macmillan.

OECD. 2004. OECD Principles of Corporate Governance. France: The Organisation for Economic Co-operation and Development

Rezaee, Z. 2011. *Financial Services Firms: Governance, Regulations, Valuations, Mergers, and Acquisitions*. Hoboken, N.J: Wiley-Blackwell.

Ross, S. A. 1973. The economic theory of agency: The principal's problem. *American Economic Review* 63 (2):134-139.

Samuelson, W., and S. G. Marks. 2015. *Managerial Economics*. 8th ed. Hoboken, NJ: John Wiley & Sons, Inc.

Scott, W. R. 2011. *Financial Accounting Theory*. 6th ed. Toronto, Ontario Pearson Canada.

Sheldon, D. B., and D. Shaw. 1981. An application of linear programming to bank financial planning. *Interfaces* 11 (5):77-83.

Shleifer, A., and R. W. Vishny. 1989. Management entrenchment: The case of manager-specific investments. *Journal of Financial Economics* 25 (1):123-139.

Shleifer, A., and R. W. Vishny. 1997. A survey of corporate governance. *The Journal of Finance* 52 (2):737-783.

Singh, M., and W. N. Davidson, III. 2003. Agency costs, ownership structure and corporate governance mechanisms. *Journal of Banking and Finance* 27 (5):793-816.

Stern, J. M. 1972. The Dynamics of Financial Planning. In *Applications of Management Science in Banking and Finance*, edited by S. Eilon and T. R. Fowkes. Essex: Gower Press, 25-48.

Tirole, J. 2001. Corporate Governance. *Econometrica* 69 (1):1-35.

———. 2006. *The Theory of Corporate Finance*. Princeton, NJ: Princeton University Press.

Titman, S., A. J. Keown, and J. D. Martin. 2014. *Financial Management: Principles and Applications*. Upper Saddle River: Pearson.

Van Greuning, H., and S. B. Bratanovic. 2009. *Analyzing Banking Risk: A Framework for Assessing Corporate Governance and Risk Management*. Washington, DC: World Bank.

Van Horne, J. C., and J. M. Wachowicz. 2005. *Fundamentals of Financial Management*. Harlow, Essex, England: FT Prentice-Hall.

Varian, H. R. 2014. *Intermediate Microeconomics: A Modern Approach*. 9th ed. New York, US: WW Norton & Company.

Voigt, G. 2011. *Supply Chain Coordination in Case of Asymmetric Information. Information Sharing and Contracting in a Just-in-Time Environment*. Heidelberg: Springer.

Williamson, O. E. 1988. Corporate finance and corporate governance. *The Journal of Finance* 43 (3):567-591.
Zingales, L. 2008. Corporate Governance. In *The New Palgrave Dictionary of Economics*, edited by S. N. Durlauf and L. Blume. Basingstoke: Palgrave Macmillan.

Appendix 1. List of Variables and Parameters

I. Unknown Variables

A. Variable of the objective function

d_t : Dividend paid in period t

B. Constraint variables

1) L_t : Loans, bills discounted and other receivables in period t
2) CL_t : Cash and liquid assets in period t
3) R_t : Receivables due from other financial institutions in period t
4) Sec_t : Securities in period t
5) D_t : Deposits and other public borrowing in period t
6) AP_t : Payables due to other financial institutions in period t
7) LFV_t : Liabilities at FVTPL in period t
8) Db_t : Debt issues in period t
9) cDb_t : Carrying value of debt issues in period t, as result of full fair value accounting adjustment
10) LC_t : Loan capital in period t
11) REx_t : Remuneration paid for executives in period t

II. Parameters provided by management

A. Accounting parameters

1) NI_t : Net income in period t
2) $IntInc_t$: Interest income in period t
3) $IntEx_t$: Interest expense in period t
4) $OInc_t$: Other operating income in period t
5) $ImpEx_t$: Impairment expense in period t
6) $OpEx_t$: Operating expense in period t
7) $CTax_t$: Corporate tax in period t
8) $PTax_t$: Policyholder tax in period t
9) $NonIA_t$: Total non-interest earnings assets in period t
10) $NonIL_t$: Total non-interest bearing liabilities in period t
11) SC_t : Share capital in period t
12) Res_t : Reserves in period t
13) RP_t : Retained profit in period t
14) ΔRP_t : The change of retained profit in year t
15) NCI_t : Net cash inflows in period t
16) CFO_t : Net cash flow from operating activities in period t
17) CFI_t : Net cash flow from investing activities in period t
18) CFF_t : Net cash flow from financing activities in period t
19) PPE_t : Property, plant and equipment in period t
20) $IntAs_t$: Intangible assets in period t
21) CAD_t : Cash available for dividend in period t
22) ROE_t : Return on equity in period t
23) NIM_t : Net interest margin in period t
24) ER_t : Efficiency ratio in period t
25) NII_t : Net interest income in period t
26) LR_t : Loans ratio in period t
27) $LTDR_t$: Loans to deposits ratio in period t
28) TA_t : The total assets in period t
29) $fvDb_t$: Fair value of debt in period t
30) NCF_{SW} : The future net payment expected under swap contract
31) $CF^*_{VR,t}$: The anticipated cash flows to be paid for the floating rate
32) $CF^*_{FX,t}$: The expected cash flows to be received for the fixed rate
33) $AccOCI_t$: Accumulated other comprehensive income in period t

B. Financial parameters and definition

1) k_e : Cost of equity capital
2) g : The constant growth rate in perpetuity expected for the dividends
3) δ_t : The dividend payout ratio in period t

4) a_t : Fixed component of remuneration paid in period t
5) χ_t : Variable-compensation payout ratio in period t
6) $\underline{REx_{\min(t)}}$: Lower limit for executives incentives in period t
7) $\overline{REx_{\max(t)}}$: Upper limit for executives incentives in period t
8) φdiv_t : Minimum dividend growth in period t over period t-1
9) φNII_t : Minimum revenue growth rate in period t over period t-1
10) $\underline{LR_{min}}$: Lower limit for loans ratio
11) $\overline{LR_{max}}$: Upper limit for loans ratio
12) $\overline{LTDR_t}$: Permitted/required value of loans to deposits ratio in period t
13) $\varphi Assets_t$: Minimum assets growth rate in period t
14) $i_{db} fvDb_t$: The interest expense of adjusted value of debt at period t
15) $\Delta fvDb_t$: The changes in fair value of debt in period t from its carrying value in period t-1
16) $\Delta fvSW_t$: The change in fair value of swap in period t from its carrying value in period t-1
17) Db_0 : The notional (principal) amount of debt issues
18) $fvSW_t$: The fair value of swap in period t
19) DOR_0 : The ratio of the changes in fair values of the hedge instrument and the hedged item at the inception date
20) $\Delta fvSW_0^*$: The changes in fair value of the swap at the inception date under specific scenario
21) $\Delta fvDb_0^*$: The changes in fair value of the debt issues at the inception date under specific scenario
22) DOR_T : The ratio of the changes in fair values of the hedge instrument and the hedged item at observation period T
23) $\Delta fvSW_T$: The changes in fair value of the swap at observation period T
24) $\Delta fvDb_T$: The changes in fair value of the debt issues at observation period T
25) $\sigma^2[NI_t(H)]$: The variance of net income of hedged position at period t
26) $\sigma^2[NI_t(U)]$: The variance of net income of unhedged position at period t
27) $s[NI_t(H)]$: The standard deviation of net income of hedged position at period t
28) $s[NI_t(U)]$: The standard deviation of net income of unhedged position at period t
29) $CET.Adj$: Common Equity Tier 1 capital adjustments
30) $CET1_{hist}$: Historical Common Equity Tier 1 capital ratio of the company
31) $Add\ Tier\ 1$: Additional Tier 1 capital in period t
32) $TT1_{hist}$: Historical Total Tier 1 capital ratio of the company
33) $Tier\ 2$: Tier 2 capital in period t
34) TC_{hist} : Historical total capital ratio of the company

C. Economic parameters

1) R_f : Risk free rate
2) β : Market risk
3) R_m : Market return
4) y_i : The yield on the i^{th} asset
5) i_j : The interest rate on the j^{th} liability
6) τ_t : The corporate tax rate in the period t
7) $ROE_{ind(t)}$: Return on equity of industry average in period t
8) $NIM_{ind(t)}$: Net interest margin of industry average in period t
9) $ER_{ind(t)}$: Efficiency ratio of industry average in period t
10) R_w : The weighted-average market interest rate
11) R_b : Market yield for similar type of debt
12) $Rfw_{t\to t+1}^*$: The benchmark (forward) rate for t+1, for any period of t
13) R_x : The fixed-coupon rate of debt issues
14) Rz_t : The zero-coupon bond rate at period t

Appendix 2. Summary of the Numerical Mechanism Design Model

Maximise:

$$0.000538d_1 + 0.000422d_2 + 0.000459d_3 + 0.000368d_4 + 0.010519d_5 \quad (1)$$

Subject to:

A. Accounting definitional constraints

1) Income statement identity constraints

$$0.0490L_0 + 0.0244CL_0 + 0.0190R_0 + 0.0352Sec_0 - 0.0324D_0 - 0.0194AP_0 - 0.0421LFV_0 - 0.0374Db_0 - 0.0389LC_0 - REx_1 \geq 3{,}244.30 \quad (2)$$

$$0.0433L_1 + 0.0120CL_1 + 0.0071R_1 + 0.0277Sec_1 - 0.0271D_1 - 0.0078AP_1 - 0.0273LFV_1 - 0.0367cDb_1 - 0.0004Db_0 - 0.0312LC_1 - REx_2 \geq 2{,}687.22 \quad (3)$$

$$0.0496L_2 + 0.0173CL_2 + 0.0046R_2 + 0.0324Sec_2 - 0.0324D_2 - 0.0109AP_2 - 0.0321LFV_2 - 0.0376cDb_2 + 0.0132Db_0 - 0.0381LC_2 - REx_3 \geq 2{,}654.55 \quad (4)$$

$$0.0474L_3 + 0.0125CL_3 + 0.0082R_3 + 0.0310Sec_3 - 0.0305D_3 - 0.0071AP_3 - 0.0243LFV_3 - 0.0376cDb_3 - 0.0001Db_0 - 0.0334LC_3 - REx_4 \geq 2{,}347.08 \quad (5)$$

$$0.0422L_4 + 0.0074CL_4 + 0.0050R_4 + 0.0235Sec_4 - 0.0247D_4 - 0.0079AP_4 - 0.0210LFV_4 - 0.0378cDb_4 - 0.0000Db_0 - 0.0323LC_4 - REx_5 \geq 2{,}386.35 \quad (6)$$

2) Balance sheet identity constraints

$$L_1 - 0.0490L_0 + CL_1 - 0.0244CL_0 + R_1 - 0.0190R_0 + Sec_1 - 0.0352Sec_0 - D_1 + 0.0324D_0 - AP_1 + 0.0194AP_0 - LFV_1 + 0.0421LFV_0 - cDb_1 + 0.0374Db_0 - LC_1 + 0.0389LC_0 + REx_1 + d_1 = 37{,}759.70 \quad (7)$$

$$L_2 - 0.0433L_1 + CL_2 - 0.0120CL_1 + R_2 - 0.0071R_1 + Sec_2 - 0.0277Sec_1 - D_2 + 0.0271D_1 - AP_2 + 0.0078AP_1 - LFV_2 + 0.0273LFV_1 - cDb_2 + 0.0370Db_0 - LC_2 + 0.0312LC_1 + REx_2 + d_2 = 24{,}916.78 \quad (8)$$

$$L_3 - 0.0496L_2 + CL_3 - 0.0173CL_2 + R_3 - 0.0046R_2 + Sec_3 - 0.0324Sec_2 - D_3 + 0.0324D_2 - AP_3 + 0.0109AP_2 - LFV_3 + 0.0321LFV_2 - cDb_3 + 0.0282Db_0 - LC_3 + 0.0381LC_2 + REx_3 + d_3 = 40{,}809.45 \quad (9)$$

$$L_4 - 0.0474L_3 + CL_4 - 0.0125CL_3 + R_4 - 0.0082R_3 + Sec_4 - 0.0310Sec_3 - D_4 + 0.0305D_3 - AP_4 + 0.0071AP_3 - LFV_4 + 0.0243LFV_3 - cDb_4 + 0.0378Db_0 - LC_4 + 0.0334LC_3 + REx_4 + d_4 = 36{,}475.92 \quad (10)$$

$$L_5 - 0.0422L_4 + CL_5 - 0.0074CL_4 + R_5 - 0.0050R_4 + Sec_5 - 0.0235Sec_4 - D_5 + 0.0247D_4 - AP_5 + 0.0079AP_4 - LFV_5 + 0.0210LFV_4 - cDb_5 + 0.0378Db_0 - LC_5 + 0.0323LC_4 + REx_5 + d_5 = 27{,}855.65 \quad (11)$$

3) Cash flow identity constraints

$$1.0490L_0 - L_1 + 0.0244CL_0 + 1.0190R_0 - R_1 + 1.0352Sec_0 - Sec_1 - 1.0324D_0 + D_1 - 1.0194AP_0 + AP_1 - 1.0421LFV_0 + LFV_1 - 1.0374Db_0 + cDb_1 - 1.0389LC_0 + LC_1 - REx_1 - d_1 \geq -1{,}571.21 \quad (12)$$

$$1.0433L_1 - L_2 + 0.0120CL_1 + 1.0071R_1 - R_2 + 1.0277Sec_1 - Sec_2 - 1.0271D_1 + D_2 - 1.0078AP_1 + AP_2 - 1.0273LFV_1 + LFV_2 - 1.0370Db_0 + cDb_2 - 1.0312LC_1 + LC_2 - REx_2 - d_2 \geq -169.60 \quad (13)$$

$$1.0496L_2 - L_3 + 0.0173CL_2 + 1.0046R_2 - R_3 + 1.0324Sec_2 - Sec_3 - 1.0324D_2 + D_3 - 1.0109AP_2 + AP_3 - 1.0321LFV_2 + LFV_3 - 1.0282Db_0 + cDb_3 - 1.0381LC_2 + LC_3 - REx_3 - d_3 \geq 2{,}251.67 \quad (14)$$

$$1.0474L_3 - L_4 + 0.0125CL_3 + 1.0082R_3 - R_4 + 1.0310Sec_3 - Sec_4 - 1.0305D_3 + D_4 - 1.0071AP_3 + AP_4 - 1.0243LFV_3 + LFV_4 - 1.0378Db_0 + cDb_4 - 1.0334LC_3 + LC_4 - REx_4 - d_4 \geq 1{,}268.82 \quad (15)$$

$$1.0422L_4 - L_5 + 0.0074CL_4 + 1.0050R_4 - R_5 + 1.0235Sec_4 - Sec_5 - 1.0247D_4 + D_5 - 1.0079AP_4 + AP_5 - 1.0210LFV_4 + LFV_5 - 1.0378Db_0 + cDb_5 - 1.0323LC_4 + LC_5 - REx_5 - d_5 \geq 1{,}663.50 \quad (16)$$

B. Corporate governance policy: Incentive-compatible contract and corporate control constraints

1) Incentive compatibility constraints

Remuneration definitional constraints

$$0.9937REx_1 - 0.00031L_0 - 0.00015CL_0 - 0.00012R_0 - 0.00022Sec_0 + 0.00020D_0 + 0.00012AP_0 + 0.00027LFV_0 + 0.00024Db_0 + 0.00025LC_0 = -41.64 \quad (17)$$

$$0.9920REx_2 - 0.00035L_1 - 0.00010CL_1 - 0.00006R_1 - 0.00022Sec_1 + 0.00022D_1 + 0.00006AP_1 + 0.00022LFV_1 + 0.00030Db_0 + 0.00025LC_1 = -43.70 \quad (18)$$

$$0.9937REx_3 - 0.00031L_2 - 0.00011CL_2 - 0.00003R_2 - 0.00020Sec_2 + 0.00020D_2 + 0.00007AP_2 + 0.00020LFV_2 + 0.00018Db_0 + 0.00024LC_2 = 8.80 \quad (19)$$

$$0.9938REx_4 - 0.00029L_3 - 0.00008CL_3 - 0.00005R_3 - 0.00019Sec_3 + 0.00019D_3 + 0.00004AP_3 + 0.00015LFV_3 + 0.00023Db_0 + 0.00021LC_3 = -19.49 \quad (20)$$

$$0.9953REx_5 - 0.00020L_4 - 0.00003CL_4 - 0.00002R_4 - 0.00011Sec_4 + 0.00012D_4 + 0.00004AP_4 + 0.00010LFV_4 + 0.00018Db_0 + 0.00015LC_4 = 2.78 \quad (21)$$

Remuneration bounds for executives: Participative constraints

Lower bounds:

$REx_1 \geq 58$ (22)
$REx_2 \geq 68$ (23)
$REx_3 \geq 71$ (24)
$REx_4 \geq 55$ (25)
$REx_5 \geq 50$ (26)

Upper bounds:

$REx_1 \leq 80$ (27)
$REx_2 \leq 80$ (28)
$REx_3 \leq 80$ (29)
$REx_4 \leq 80$ (30)
$REx_5 \leq 80$ (31)

2) Financing policy constraints

Debt capacity (loan capital ratio)

$$LC_1 - 0.0490L_0 - 0.0244CL_0 - 0.0190R_0 - 0.0352Sec_0 + 0.0324D_0 + 0.0194AP_0 + 0.0421LFV_0 + 0.0374Db_0 + 0.0389LC_0 + d_1 \leq 28{,}061.70 \quad (32)$$

$$LC_2 - 0.0433L_1 - 0.0120CL_1 - 0.0071R_1 - 0.0277Sec_1 + 0.0271D_1 + 0.0078AP_1 + 0.0273LFV_1 + 0.0367cDb_1 + 0.0004Db_0 + 0.0312LC_1 + d_2 \leq 30{,}701.78 \quad (33)$$

$$LC_3 - 0.0496L_2 - 0.0173CL_2 - 0.0046R_2 - 0.0324Sec_2 + 0.0324D_2 + 0.0109AP_2 + 0.0321LFV_2 + 0.0376cDb_2 - 0.0132Db_0 + 0.0381LC_2 + d_3 \leq 32{,}673.45 \quad (34)$$

$$LC_4 - 0.0474L_3 - 0.0125CL_3 - 0.0082R_3 - 0.0310Sec_3 + 0.0305D_3 + 0.0071AP_3 + 0.0243LFV_3 + 0.0376cDb_3 + 0.0001Db_0 + 0.0334LC_3 + d_4 \leq 37{,}639.92 \quad (35)$$

$$LC_5 - 0.0422L_4 - 0.0074CL_4 - 0.0050R_4 - 0.0235Sec_4 + 0.0247D_4 + 0.0079AP_4 + 0.0210LFV_4 + 0.0378cDb_4 + 0.0000Db_0 + 0.0323LC_4 + d_5 \leq 40{,}051.65 \quad (36)$$

Minimum dividend policy

$$1.0107L_0 - L_1 + 0.0053CL_0 + 1.0041R_0 - R_1 + 1.0077Sec_0 - Sec_1 - 1.0071D_0 + D_1 - 1.0042AP_0 + AP_1 - 1.0092LFV_0 + LFV_1 - 1.0082Db_0 + cDb_1 - 1.0085LC_0 + LC_1 - 0.2180REx_1 - d_1 \geq -4{,}161.97 \quad (37)$$

$$1.0113L_1 - L_2 + 0.0031CL_1 + 1.0191R_1 - R_2 + 1.0072Sec_1 - Sec_2 - 1.0071D_1 + D_2 - 1.0020AP_1 + AP_2 - 1.0071LFV_1 + LFV_2 - 1.0097Db_0 + cDb_2 - 1.0081LC_1 + LC_2 - 0.2610REx_2 - d_2 \geq 611.04 \quad (38)$$

$$1.0133L_2 - L_3 + 0.0046CL_2 + 1.0012R_2 - R_3 + 1.0087Sec_2 - Sec_3 - 1.0087D_2 + D_3 - 1.0029AP_2 + AP_3 - 1.0086LFV_2 + LFV_3 - 1.0076Db_0 + cDb_3 - 1.0102LC_2 + LC_3 - 0.2680REx_3 - d_3 \geq 3{,}357.60 \quad (39)$$

$$1.0018L_3 - L_4 + 0.0031CL_3 + 1.0020R_3 - R_4 + 1.0077Sec_3 - Sec_4 - 1.0076D_3 + D_4 - 1.0018AP_3 + AP_4 - 1.0060LFV_3 + LFV_4 - 1.0095Db_0 + cDb_4 - 1.0083LC_3 + LC_4 - 0.2500REx_4 - d_4 \geq -6{,}447.99 \quad (40)$$

$$1.0104L_4 - L_5 + 0.0019CL_4 + 1.0012R_4 - R_5 + 1.0058Sec_4 - Sec_5 - 1.0061D_4 + D_5 - 1.0019AP_4 + AP_5 - 1.0052LFV_4 + LFV_5 - 1.0093Db_0 + cDb_5 - 1.0079LC_4 + LC_5 - 0.2460REx_5 - d_5 \geq -948.21 \quad (41)$$

Maximum dividend policy

$$d_1 - 0.0490L_0 - 0.0244CL_0 - 0.0191R_0 - 0.0352Sec_0 + 0.0324D_0 + 0.0194AP_0 + 0.0421LFV_0 + 0.0374Db_0 + 0.0389LC_0 + REx_1 \leq -3{,}322.30 \quad (42)$$

$$d_2 - 0.0433L_1 - 0.0120CL_1 - 0.0071R_1 - 0.0277Sec_1 + 0.0271D_1 + 0.0078AP_1 + 0.0273LFV_1 + 0.0367cDb_1 + 0.0003Db_0 + 0.0312LC_1 + REx_2 \leq -4{,}800.22 \quad (43)$$

$$d_3 - 0.0496L_2 - 0.0173CL_2 - 0.0046R_2 - 0.0324Sec_2 + 0.0324D_2 + 0.0109AP_2 + 0.0321LFV_2 + 0.0376cDb_2 - 0.0094Db_0 + 0.0381LC_2 + REx_3 \leq -4{,}542.55 \quad (44)$$

$$d_4 - 0.0474L_3 - 0.0125CL_3 - 0.0082R_3 - 0.0310Sec_3 + 0.0305D_3 + 0.0071AP_3 + 0.0243LFV_3 + 0.0376cDb_3 + 0.0002Db_0 + 0.0334LC_3 + REx_4 \leq -3{,}877.08 \quad (45)$$

$$d_5 - 0.0422L_4 - 0.0074CL_4 - 0.0050R_4 - 0.0235Sec_4 + 0.0274D_4 + 0.0079AP_4 + 0.0210LFV_4 + 0.0378cDb_4 + 0.0000Db_0 + 0.0323LC_4 + REx_5 \leq -5{,}390.25 \quad (46)$$

Minimum dividend growth

$$d_1 \geq 1.1475 \quad (47)$$

$$d_2 - 1.48d_1 \geq 0 \quad (48)$$

$$d_3 - 1.11d_2 \geq 0 \quad (49)$$

$$d_4 - 1.05d_3 \geq 0 \quad (50)$$

$$d_5 - 1.09d_4 \geq 0 \quad (51)$$

3) Financial performance constraints

Profitability analysis: Return of equity (ROE)

$$0.0490L_0 + 0.0244CL_0 + 0.0190R_0 + 0.0352Sec_0 - 0.0324D_0 - 0.0194AP_0 - 0.0421LFV_0 - 0.0374Db_0 - 0.0389LC_0 - REx_1 \geq 7{,}304.46 \quad (52)$$

$$0.0433L_1 + 0.0120CL_1 + 0.0071R_1 + 0.0277Sec_1 - 0.0271D_1 - 0.0078AP_1 - 0.0273LFV_1 - 0.0367cDb_1 - 0.0004Db_0 - 0.0312LC_1 - REx_2 \geq 8{,}150.67 \quad (53)$$

$$0.0496L_2 + 0.0173CL_2 + 0.0046R_2 + 0.0324Sec_2 - 0.0324D_2 - 0.0109AP_2 - 0.0321LFV_2 - 0.0376cDb_2 + 0.0132Db_0 - 0.0381LC_2 - REx_3 \geq 8{,}880.11 \quad (54)$$

$$0.0474L_3 + 0.0125CL_3 + 0.0082R_3 + 0.0310Sec_3 - 0.0305D_3 - 0.0071AP_3 - 0.0243LFV_3 - 0.0376cDb_3 - 0.0001Db_0 - 0.0334LC_3 - REx_4 \geq 3{,}922.21 \quad (55)$$

$$0.0422L_4 + 0.0074CL_4 + 0.0050R_4 + 0.0235Sec_4 - 0.0247D_4 - 0.0079AP_4 - 0.0210LFV_4 - 0.0378cDb_4 - 0.0000Db_0 - 0.0323LC_4 - REx_5 \geq 9{,}495 \quad (56)$$

Profitability analysis: Net interest margin (NIM)

$$0.0682L_0 + 0.0339CL_0 + 0.0264R_0 + 0.0489Sec_0 - 0.0450D_0 - 0.0270AP_0 - 0.0586LFV_0 - 0.0521Db_0 - 0.0541LC_0 \geq 17{,}955.56 \quad (57)$$

$$0.0615L_1 + 0.0170CL_1 + 0.0101R_1 + 0.0394Sec_1 - 0.0385D_1 - 0.0111AP_1 - 0.0388LFV_1 - 0.0521cDb_1 - 0.0443LC_1 \geq 19{,}466.21 \quad (58)$$

$$0.0688L_2 + 0.0240CL_2 + 0.0064R_2 + 0.0450Sec_2 - 0.0450D_2 - 0.0151AP_2 - 0.0445LFV_2 - 0.0521cDb_2 - 0.0529LC_2 \geq 20{,}829.04 \quad (59)$$

$$0.0657L_3 + 0.0173CL_3 + 0.0113R_3 + 0.0429Sec_3 - 0.0422D_3 - 0.0099AP_3 - 0.0377LFV_3 - 0.0521cDb_3 - 0.0463LC_3 \geq 21{,}606.74 \quad (60)$$

$$0.0582L_4 + 0.0102CL_4 + 0.0069R_4 + 0.0324Sec_4 - 0.0340D_4 - 0.0109AP_4 - 0.0290LFV_4 - 0.0521cDb_4 - 0.0445LC_4 \geq 23{,}009.47 \quad (61)$$

Operational efficiency analysis: Efficiency ratio

$$0.0400L_0 + 0.0199CL_0 + 0.0155R_0 + 0.0287Sec_0 - 0.0264D_0 - 0.0158AP_0 - 0.0344LFV_0 - 0.0306Db_0 - 0.0317LC_0 - 1.7042REx_1 \geq 8{,}116.35 \quad (62)$$

$$0.0361L_1 + 0.0100CL_1 + 0.0059R_1 + 0.0231Sec_1 - 0.0226D_1 - 0.0065AP_1 - 0.0227LFV_1 - 0.0305Db_0 - 0.0260LC_1 - 1.7056REx_2 \geq 8{,}656.03 \quad (63)$$

$$0.0381L_2 + 0.0133CL_2 + 0.0035R_2 + 0.0249Sec_2 - 0.0249D_2 - 0.0084AP_2 - 0.0247LFV_2 - 0.0289Db_0 - 0.0293LC_2 - 1.8044REx_3 \geq 9{,}411.16 \quad (64)$$

$$0.0377L_3 + 0.0099CL_3 + 0.0065R_3 + 0.0246Sec_3 - 0.0242D_3 - 0.0057AP_3 - 0.0193LFV_3 - 0.0299Db_0 - 0.0266LC_3 - 1.7425REx_4 \geq 9{,}395.73 \quad (65)$$

$$0.0318L_4 + 0.0056CL_4 + 0.0038R_4 + 0.0177Sec_4 - 0.0186D_4 - 0.0059AP_4 - 0.0158LFV_4 - 0.0284Db_0 - 0.0243LC_4 - 1.8328REx_5 \geq 12{,}443.46 \quad (66)$$

4) Financial sustainability constraints: Revenue growth

$$0.0682L_0 + 0.0339CL_0 + 0.0264R_0 + 0.0489Sec_0 - 0.0450D_0 - 0.0270AP_0 - 0.0586LFV_0 - 0.0521Db_0 - 0.0541LC_0 \geq 9{,}567.47 \quad (67)$$

$$0.0615L_1 - 0.0757L_0 + 0.0170CL_1 - 0.0376CL_0 + 0.0101R_1 - 0.0293R_0 + 0.0394Sec_1 - 0.0543Sec_0 - 0.0358D_1 + 0.0500D_0 - 0.0111AP_1 + 0.0300AP_0 - 0.0388LFV_1 + 0.0650LFV_0 - 0.0521cDb_1 + 0.0630Db_0 - 0.0443LC_1 + 0.0601LC_0 \geq 0 \quad (68)$$

$$0.0688L_2 - 0.0658L_1 + 0.0240CL_2 - 0.0182CL_1 + 0.0064R_2 - 0.0108R_1 + 0.0450Sec_2 - 0.0422Sec_1 - 0.0450D_2 + 0.0412D_1 - 0.0151AP_2 + 0.0119AP_1 - 0.0445LFV_2 + 0.0415LFV_1 - 0.0521cDb_2 + 0.0557cDb_1 - 0.0529LC_2 + 0.0474LC_1 \geq 0 \quad (69)$$

$$0.0657L_3 - 0.0716L_2 + 0.0173CL_3 - 0.0250CL_2 + 0.0113R_3 - 0.0062R_2 + 0.0429Sec_3 - 0.0468Sec_2 - 0.0422D_3 + 0.0468D_2 - 0.0099AP_3 + 0.0157AP_2 - 0.0337LFV_3 + 0.0463LFV_2 - 0.0521cDb_3 + 0.0542cDb_2 - 0.0463LC_3 + 0.0550LC_2 \geq 0 \quad (70)$$

$$0.0582L_4 - 0.0696L_3 + 0.0102CL_4 - 0.0183CL_3 + 0.0069R_4 - 0.0120R_3 + 0.0324Sec_4 - 0.0455Sec_3 - 0.0340D_4 + 0.0447D_3 - 0.0109AP_4 + 0.0105AP_3 - 0.0290LFV_4 + 0.0357LFV_3 - 0.0521cDb_4 + 0.0552cDb_3 - 0.0445LC_4 + 0.0491LC_3 \geq 0 \quad (71)$$

C. Corporate Risk Management and Regulatory Environment

1) Liquidity Risk: Assets and liabilities quality

Loans ratio

Lower bounds:

$$0.3746L_1 - 0.6254CL_1 - 0.6254R_1 - 0.6254Sec_1 \geq 49{,}655.51 \quad (72)$$

$$0.3508L_2 - 0.6492CL_2 - 0.6492R_2 - 0.6492Sec_2 \geq 49{,}507.99 \quad (73)$$

$$0.3580L_3 - 0.6420CL_3 - 0.6420R_3 - 0.6420Sec_3 \geq 49{,}911.65 \quad (74)$$

$$0.4206L_4 - 0.5794CL_4 - 0.5794R_4 - 0.5794Sec_4 \geq 50{,}043.94 \quad (75)$$

$$0.3727L_5 - 0.6273CL_5 - 0.6273R_5 - 0.6273Sec_5 \geq 55{,}657.19 \quad (76)$$

Upper bounds:

$$0.3081L_1 - 0.6919CL_1 - 0.6919R_1 - 0.6919Sec_1 \leq 54{,}935.48 \quad (77)$$
$$0.3304L_2 - 0.6696CL_2 - 0.6696R_2 - 0.6696Sec_2 \leq 51{,}063.70 \quad (78)$$
$$0.3485L_3 - 0.6515CL_3 - 0.6515R_3 - 0.6515Sec_3 \leq 50{,}650.22 \quad (79)$$
$$0.3618L_4 - 0.6382CL_4 - 0.6382R_4 - 0.6382Sec_4 \leq 55{,}122.61 \quad (80)$$
$$0.3566L_5 - 0.6434CL_5 - 0.6434R_5 - 0.6434Sec_5 \leq 57{,}085.67 \quad (81)$$

Loans-to-deposits ratio

Lower bounds:

$$L_1 - 1.151D_1 \geq 0 \quad (82)$$
$$L_2 - 1.123D_2 \geq 0 \quad (83)$$
$$L_3 - 1.057D_3 \geq 0 \quad (84)$$
$$L_4 - 1.052D_4 \geq 0 \quad (85)$$
$$L_5 - 1.046D_5 \geq 0 \quad (86)$$

Upper bounds:

$$L_1 - 1.3003D_1 \leq 0 \quad (87)$$
$$L_2 - 1.3003D_2 \leq 0 \quad (88)$$
$$L_3 - 1.3003D_3 \leq 0 \quad (89)$$
$$L_4 - 1.3003D_4 \leq 0 \quad (90)$$
$$L_5 - 1.3003D_5 \leq 0 \quad (91)$$

2) Financial distress and bankruptcy risk

Asset growth constraints

$$L_1 - 1.2724L_0 + CL_1 - 1.2724CL_0 + R_1 - 1.2724R_0 + Sec_1 - 1.2724Sec_0 \geq 16{,}325.92 \quad (92)$$
$$L_2 - 1.0418L_1 + CL_2 - 1.0418CL_1 + R_2 - 1.0418R_1 + Sec_2 - 1.0418Sec_1 \geq 6{,}456.84 \quad (93)$$
$$L_3 - 1.0334L_2 + CL_3 - 1.0334CL_2 + R_3 - 1.0334R_2 + Sec_3 - 1.0334Sec_2 \geq 1{,}063.08 \quad (94)$$
$$L_4 - 1.0753L_3 + CL_4 - 1.0753CL_3 + R_4 - 1.0753R_3 + Sec_4 - 1.0753Sec_3 \geq 2{,}766.10 \quad (95)$$
$$L_5 - 1.0487L_4 + CL_5 - 1.0487CL_4 + R_5 - 1.0487R_4 + Sec_5 - 1.0487Sec_4 \geq 1{,}853.32 \quad (96)$$

3) Capital adequacy requirement

$$0.0490L_0 + 0.0244CL_0 + 0.0190R_0 + 0.0352Sec_0 - 0.0324D_0 - 0.0194AP_0 - 0.0421LFV_0 - 0.0374Db_0 - 0.0389LC_0 - REx_1 - d_1 \geq 10{,}333.11 \quad (97)$$
$$0.0433L_1 + 0.0120CL_1 + 0.0071R_1 + 0.0277Sec_1 - 0.0271D_1 - 0.0078AP_1 - 0.0273LFV_1 - 0.0367cDb_1 - 0.0004Db_0 - 0.0312LC_1 - REx_2 - d_2 \geq 9{,}919.39 \quad (98)$$
$$0.0496L_2 + 0.0173CL_2 + 0.0046R_2 + 0.0324Sec_2 - 0.0324D_2 - 0.0109AP_2 - 0.0321LFV_2 - 0.0376cDb_2 + 0.0132Db_0 - 0.0381LC_2 - REx_3 - d_3 \geq 11{,}651.73 \quad (99)$$
$$0.0474L_3 + 0.0125CL_3 + 0.0082R_3 + 0.0310Sec_3 - 0.0305D_3 - 0.0071AP_3 - 0.0243LFV_3 - 0.0376cDb_3 - 0.0001Db_0 - 0.0334LC_3 - REx_4 - d_4 \geq 11{,}249.29 \quad (100)$$
$$0.0422L_4 + 0.0074CL_4 + 0.0050R_4 + 0.0235Sec_4 - 0.0247D_4 - 0.0079AP_4 - 0.0210LFV_4 - 0.0378cDb_4 - 0.0000Db_0 - 0.0323LC_4 - REx_5 - d_5 \geq 11{,}891.60 \quad (101)$$