

The effects of banking regulation in the South African economy using a computable general equilibrium model

by

Kojo Amonkwandoh Essel-Mensah

under supervision of

Prof Conrad Beyers, Dr Allan De Freitas, Dr Reyno Seymore and Prof Dimitrios Tsomocos

Submitted in partial fulfilment of the requirements for the degree

PhD Actuarial Science

In the Faculty of Natural and Agricultural Sciences

University of Pretoria

Pretoria



UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Denkleiers • Leading Minds • Dikgopolo tša Dihalefi

ACKNOWLEDGEMENT

First of all, let me give thanks to the Almighty God for giving me the wisdom, knowledge, strength, patience and perseverance to enable me complete the studies.

I want to thank my supervisors, Prof Conrad Beyers, Dr Allan De Freitas, Dr Reyno Seymore and Prof Dimitrios Tsomocos for dedicating their time and effort and for providing me with all the necessary guidance and assistance. Prof Dimitrios Tsomocos, a Professor in Financial Economics at the University of Oxford, UK, needs special mention. Even though he is not a faculty member of the University of Pretoria, agreed to be a co-supervisor and also co-authored the two papers from the study and in doing so made important and valuable contributions. I also want to thank Dr Nadine Walters for her assistance in the data manipulation with the balance sheet information used for the calibration exercise and the training in Latex I received from her.

I am grateful to my mother, Madam Mary Mensah and all my brothers and sisters for their constant prayers and support throughout the period of my studies. Finally, I appreciate the friendship and support of all my colleagues and friends, especially Ms Pascaline Kabego and Mrs Zingisa Gqoloqa. I dedicate this thesis to the following:

- my late father, Kobina Essel-Mensah, whose wish was to witness my graduation with a PhD but which couldn't materialize in his lifetime,
- my beautiful wife, Francisca Essel-Mensah, who had to bear with my endurance to obtain the PhD and as a result being neglected at times, and
- my two strong boys (or should I say men), Kwame Tawia Essel-Mensah and Kofi Nyamekye Essel-Mensah, whose enthusiasm made me committed to the research.

I hereby acknowledge the financial assistance of the National Research Foundation (NRF) and the ABSA chair in Actuarial Science towards this research. Opinions expressed and conclusions arrived at, are mine and are not necessarily to be attributed to the NRF or ABSA.

Abstract — The importance of regulation for the banking sector cannot be over emphasised as failure to adequately regulate the banking sector usually leads to financial crisis including collapse of major financial institutions. As such any method used for regulating the sector must ensure that almost all possible risks are detected. The Computable General Equilibrium (CGE) model considers interactions amongst various entities of the economy and so when used for regulation could detect potential risks.

The CGE model has been used widely as a powerful technique for quantitative analysis to answer many “what if” questions about the economy including the South African economy. However, not much of its use is applied to the banking sector especially in South Africa. In particular, the effect of regulatory policy intervention in the banking sector is little known when it comes to modelling with the CGE model in South Africa.

In this study, a CGE model is developed to cover the banking sector in South Africa. Emphasis is placed on modelling the possible effect of regulatory policy on the economy. The CGE model performed well as a tool for regulation and risk assessment for the banking sector in South Africa. It was established that default penalty has a higher effect on the banks’ profits and interest rates than capital requirement infringement penalty. The results also suggest that interest rate targeting has more controlled effects than monetary base targeting since pecuniary externalities are reduced. Default penalty and capital adequacy requirement (CAR) violation penalty have opposing effect on banks profits and that default penalty dominates CAR violation penalty. During periods of adverse economic conditions, tightening capital requirement regulation further reduces banks profits. This study should therefore be a source of providing methodology for regulators of the banking sector and policymakers in South Africa to apply the CGE model for risk assessment and for future regulatory planning.

Keywords – Computable general equilibrium model; Banking regulation; Financial fragility; Systemic risk; Capital adequacy requirements.

Publications

A version of Chapters 4, 5 and 6 has been published in the Annals of Finance journal titled “A Computable General Equilibrium Model for Banking Sector Risk Assessment in South Africa” [22].

A portion of Chapter 7 is forthcoming and titled “A Computable General Equilibrium Model as a Banking Sector Regulatory Tool in South Africa” [21].

I, KOJO AMONKWANDOH ESSEL-MENSAH
declare that the thesis/dissertation, which I hereby submit for the degree
PHD ACTUARIAL SCIENCE at the University of Pretoria, is my
own work and has not previously been submitted by me for a degree at this or
any other tertiary institution.

SIGNATURE: EMensah DATE: 14 JULY 2021

List of Acronyms

ABSA – Amalgamated Banks of South Africa
AIDS – Acquired Immune Deficiency Syndrome
BCBS – Basel Committee on Banking Supervision
BIS – Bank for International Settlement
BSI – Banking Stability Index
CAR – Capital Adequacy Requirement
CCP – Central Counterparties
CDS – Credit Default Swap
CGE – Computable General Equilibrium
CoVAR – Conditional Value at Risk
CR – Capital Ratio
DSGE – Dynamic Stochastic General Equilibrium
ES – Expected Shortfall
FHGE – Finite horizon general equilibrium models
FSA – Financial Services Authority
FSB – Financial Service Board
FS_tB – Financial Stability Board
FSCA – Financial Sector Conduct Authority
FSCF – Financial Sector Contingency Forum
FSOC – Financial Stability Oversight Committee
GDP – Gross Domestic Product
GE – General Equilibrium
GEA – General Equilibrium Analysis
HIV – Human Immunodeficiency Virus
IFPRI – International Food Policy Research Institute
IMF – International Monetary Fund
JPoD – joint Probability of Distress
JSE – Johannesburg Stock Exchange
KTC – Kuhn-Tucker Conditions
LCR – Liquidity Coverage Ratio
MBS – Mortgage Backed Security
MEBD – Monetary Equilibrium with Banks and Default
MES – Marginal Expected Shortfall
NCA – National Credit Act

NCR – National Credit Regulator
NSFR - Net Stable Financial Ratio
PA – Prudential Authority
PoD – Probability of Default
SA – South Africa
SAM – Social Accounting Matrix
SARB – South African Reserve Bank
SIFI – Systemically Important Financial Institution
TBTF – Too-big-to fall
TERM – The Enormous Regional Model
TITF – Too-interconnected-to fall
TMTF – Too-many-to fall
UK – United Kingdom
USA – United State of America
VaR – Value at risk
VAR – Vector Autoregression
VAT – Value Added Tax
VBS – Venda Building Society

Contents

1	Introduction	9
1.1	Background	9
1.1.1	Reform in the financial sector	10
1.1.2	The research	10
1.1.3	Uniqueness of the study	11
1.1.4	Wider field application	11
1.2	Objectives of the Study and Research Problem	12
1.2.1	Objectives of the Study	12
1.2.2	Research problem	13
1.3	Structure of the thesis	16
2	Literature Review	18
2.1	Introduction	18
2.2	Financial Regulation	18
2.2.1	Types of regulation	19
2.2.2	The “Twin Peaks” Model for South Africa	21
2.2.3	The Basel Accords	23
2.2.4	Capital adequacy and regulation	26
2.2.5	The 2008 financial crisis	27
2.3	Systemic Risk	29
2.3.1	Modelling or measuring systemic risk	30
2.3.2	Systemic risk and banking regulation	34
2.3.3	Dealing with systemic risk	35
2.4	Conclusion	37
3	General Equilibrium Analysis and Optimisation	38
3.1	Introduction	38
3.2	Financial regulation in general equilibrium	39

3.2.1	Loan to value ratios	40
3.2.2	Margin requirements for repurchase agreements	40
3.2.3	Capital requirements	40
3.2.4	Liquidity coverage ratios	41
3.2.5	Dynamic provisioning	41
3.3	Modelling in general equilibrium	43
3.4	Computable General Equilibrium Model	45
3.4.1	CGE model applications in South Africa	48
3.4.2	Other financial sector applications of CGE models	51
3.5	Optimisation	53
3.6	Conclusion	54
4	The Banking Sector CGE Model	56
4.1	Introduction	56
4.2	The Banking Sector	60
4.2.1	Banks optimisation problem	61
4.3	Private agent sector	63
4.3.1	Household borrowers demand for loans	63
4.3.2	Supply of deposits	63
4.3.3	Households loans repayment rates	64
4.4	Central Bank and/or Regulator	64
4.5	Gross Domestic Product	65
4.6	Equilibrium	65
4.6.1	Market clearing conditions	65
4.6.2	Equilibrium conditions	66
4.7	Conclusion	66
5	Calibration for the South African Banking Sector	68
5.1	Introduction	68
5.2	Calibration Methodology	68
5.2.1	Balance sheet items	69
5.2.2	Loan repayment rates	69
5.2.3	Other exogenous variables/parameters	70
5.2.4	Elasticities for the reduced form equations	72
5.2.5	Initial equilibrium position	72
5.3	Conclusion	74

6	The Model as a Risk Assessment Tool	75
6.1	Introduction	75
6.2	An expansionary monetary policy	76
6.3	A positive deposit supply shock to bank δ in the initial period	77
6.4	A positive bank capital shock to bank δ in the initial period	78
6.5	Restrictive regulatory policy	79
6.5.1	The capital infringement penalties in the bad state is increased	79
6.5.2	The default penalties in the bad state is increased	80
6.6	A positive shock in GDP in the bad state	81
6.7	Summary of results	82
7	The Model for Banking Regulation	84
7.1	Introduction	84
7.2	Justification of the CGE model as a Regulatory Tool	85
7.3	Equilibrium Characterization	86
7.3.1	Liquidity Structure of Interest Rate Proposition	86
7.3.2	Quantity Theory of Money Proposition	87
7.3.3	Fisher Effect Proposition	87
7.3.4	Default trade-off	87
7.3.5	CAR Violation trade-off	87
7.4	Default and Capital Violation Penalties	87
7.4.1	Default penalty effects	88
7.4.2	Capital violation penalty effects	90
7.4.3	Combined effects of default and capital violation penalties	92
7.5	Capital adequacy requirement	93
7.6	Monetary policy instrument	94
7.6.1	Profits	95
7.6.2	Gross Domestic Product	100
7.7	Policy Rate - Repo Rate	100
7.8	Summary of Results	104
8	Conclusion	106
8.1	Introduction	106
8.2	The CGE model as a risk assessment tool	107
8.2.1	An expansionary monetary policy	107
8.2.2	A positive deposit supply shock to a bank	108
8.2.3	A positive capital shock to a bank	108

8.2.4	Restrictive regulatory policy	108
8.2.5	A positive shock in Gross Domestic Product	109
8.3	The CGE model as a regulatory tool	109
8.3.1	The effect of the penalties on the banks and the economy	109
8.3.2	The effect of CAR on banks	110
8.3.3	Monetary policy instrument	110
8.3.4	The impact of changes in the policy rate	111
8.4	Limitations and suggestions for further research	111
8.5	Final conclusions	113
Appendices		115
A Optimisation Problems		115
A.1	General Optimisation	115
A.2	The Lagrangean multiplier method	117
A.2.1	The case of two variables	117
A.2.2	The case of n variables and m constraints	120
A.3	The Kuhn-Tucker conditions	122
A.4	Application to the Banking Sector CGE Model	123
A.4.1	Optimisation problem of the banks	124
A.4.2	Reduced form equations	125
A.4.3	Market clearing conditions	126
A.4.4	Expectations about interbank repayment rate	127
B Parameters/variables of the model		128
C Graphs		130

Chapter 1

Introduction

1.1 Background

Banking regulation is very important for every country as failure to adequately regulate the banking sector could plunge the country into financial crisis. As a result, banking regulation tends to be more extensive [17] than the regulation of other sectors. Hence the regulation cost may be higher for the banking sector than for other sectors. Any model used as part of the process to regulate the banking sector should be such that it is able to detect most of the risks inherent in the sector in order for necessary steps to be taken to ensure that the benefit outweighs the cost. The banking industry is usually the largest component of the financial sector of any economy [52]. Its functioning affects all aspects of the economy and hence the performance of the economy of that particular country. South Africa is not an exception. The share of the financial assets of the banking industry, excluding the South African Reserve Bank (SARB), is 30% of the total financial assets of the financial sector as at the end of 2018¹. The financial sector comprises of banks, insurance companies, pension funds, public financial institutions, other financial intermediaries and the SARB. Prior to the 2008 global financial crisis (GFC), the banking sector share of the assets of the financial sector was about 40% and has been decreasing gradually². It is therefore necessary to find the reason for the reduction and put a stop to this gradual reduction of the banking sector financial asset.

¹Financial Stability Review First edition 2019: SARB

²Financial Stability Review First edition 2019: SARB

1.1.1 Reform in the financial sector

The financial sector (in particular the banking industry) has undergone massive structural changes internationally and regulators have been challenged to keep up with these changes [51]. South Africa has not been any different. Prior to 1987, the National Treasury (formerly Department of Finance) was responsible for regulating the banking sector. South Africa has gone through almost all the different financial regulations. This includes both the functional and the institutional methods. Since 2017, it has embraced the global change towards the “Twin Peaks” approach of regulating the financial sector. Such approach separates regulation into two main areas; prudential regulation and market conduct and each area is assigned to one regulator [59]. In other words, there is a regulator for prudential regulation and another regulator for market conduct. On implementing the “Twin Peaks” regulation, the responsibility of the banks now lies with two main bodies. For the banking sector, the SARB is responsible for prudential regulation through an established separate entity, called the Prudential Authority (PA). The Financial Services Board (FSB) which was in charge of regulating the non-banking financial services industry is replaced with a new broader market conduct regulator called the Financial Sector Conduct Authority (FSCA). FSCA takes responsibility for market conduct. An advantage of this approach is to ensure none of the areas of regulation is ignored. It is a better model to handle the increasing complexities of financial products [59]. This is because it introduces a holistic approach for supervising financial conglomerates and also allows focused regulators to deal with regulatory arbitrage properly. In addition, conflicts of interest are avoided when compared with regulation by a single regulator, and each regulator is dedicated to its mandate. However, the “Twin Peaks” model puts a higher burden on the regulatory authorities, as well as the regulated institutions, as they are accountable to two regulators. Therefore, coordination and cooperation are warranted between these entities. As a result, different committees have been set up from members of these two bodies to assist in regulating the financial sector. One such committee is the financial stability oversight committee (FSOC), which assists with the implementation of financial stability policy and needs comprehensive models for stress testing and economic forecasting. Developing the CGE model could potentially be of great use to them.

1.1.2 The research

This research analyses the impact of banking regulations on banks and the general economy and applies it as a risk assessment tool. Many models for assessing risk, including stress testing and scenario analysis models, concentrate mostly on individual institutions or banks and thus fail to recognize that the actual risks that these institutions encounter depend

not only on themselves but also on their exposure to other institutions or banks as well as the private sector agents. Using such models may not allow an institution to capture properly adverse effects of other institutions. These effects are more pronounced during periods of financial crisis. On the other hand, CGE models may be better models for assessing risk especially in times of financial crisis. These models by their very nature, consider the interactions among all possible entities and so take the exposure to other institutions into account and so if used as part of the regulatory tool could assist in the assessment of risk in the banking industry.

1.1.3 Uniqueness of the study

CGE models have been applied widely as a method for quantitative studies to answer many “what if” questions on the economy and this includes the South African economy. However, it has not been widely applied for the banking industry in many countries, including South Africa. In particular, the effect of regulatory policy intervention in the banking sector is a grey area when one considers modelling with the CGE model in South Africa. The focus of this study is to develop the CGE model to cover the banking sector for the country. The emphasis is on the effects of regulatory policies. The CGE model is also used as a tool for risk assessment to determine how regulatory changes affect the economy. A CGE model for the banking industry has been used elsewhere (eg UK, Jamaica, Colombia and Brazil) but it is the first time it is being applied to the South African banking industry. Even in the countries where the model was applied in the banking industry, the application was not for modelling the effect of banking regulation on an economy but mainly for evaluating financial fragility. The study is therefore novel in using the CGE model in the South African banking sector.

1.1.4 Wider field application

The study spans many disciplines. These include actuarial science, financial economics and banking. Economists are currently the main users of the CGE models. By developing the model to cover the banking sector, economists, bankers and actuaries can combine ideas, knowledge and skills to ensure that the model is widely applied. Actuaries and bankers will have the opportunities to apply the CGE models in their respective areas. For some time now actuaries have been looking for areas besides the traditional areas of life insurance, general insurance, health insurance, pension and investment to apply their expertise and this study makes a contribution in this respect.

1.2 Objectives of the Study and Research Problem

1.2.1 Objectives of the Study

Few South African banks have failed since the advent of the 21st century. The most prominent cases are Saambou bank in 2002, African Bank in 2014 and VBS bank as recently as 2018. Apart from Saambou bank's failure which resulted in a few other small bank runs, the failures did not generate systemic risk. Interestingly, no bank failures were reported in the aftermath of the 2008 GFC. This is partly attributed to the SARB increasing CAR before the crisis [72]. This indicates that prudent pre-emptive implementation of banking sector regulation could prevent the occurrence of a financial crisis.

South Africa is pursuing a financial inclusion policy agenda [56] of which financial stability is a vital element. Financial inclusion may make it possible for credit to be extended to previously "unbanked" individuals who may not have appropriate credit records. In addition there may be new financial inclusion institutions and instruments which are likely to arise from unregulated parts of the financial system. This rapid growth in credit will pose risk to the financial sector. However, greater access to deposits would result in a significant improvement of the overall financial system resilience and thus financial stability. A balance is therefore required.

The linkages with the international economy exposes the financial sector in South Africa to systemic risk increases. Fiscal, monetary and financial regulatory interventions should therefore address the threat of systemic risk [67]. In order to do so, there is a gradual shift from micro to macro-prudential regulatory intervention mechanisms. At the same time, the economy of South Africa has performed poorly in recent times. The quarterly economic growth rates between January 2018 and December 2019 has been negative³, and the rates continue to decline. The IMF and the SARB have taken a downward view of the economic growth prospects for South Africa in 2020 and 2021. Moreover, in April 2017, S&P and Fitch rating agencies have revised their credit ratings on South Africa's long term debt downwards to the sub-investment level⁴. Further concerns are raised in October 2019, which has realised the Rand's depreciation and an increase in the fiscal deficit after the mid-term budget statement. Moody's and SP's latest revision of South Africa's rating outlook from stable to negative has not allayed the fears of further downgrades in future credit ratings.⁵. It was therefore expected that the country could be downgraded further and indeed during the first quarter of 2020, Moody's also downgraded South Africa's sovereignty to sub-investment grade. Thus

³<https://tradingeconomics.com/south-africa/gdp-growth>

⁴South African Reserve Bank Quarterly Bulletin, June 2017, No. 284

⁵South African Reserve Bank Quarterly Bulletin, December 2019, No. 294.

as at the end of March 2020, all three of the major rating agencies have downgraded South Africa to sub-investment grade and as a result South African Rand bonds have been excluded from the FTSE World Government Bond Index. This led to a sell-off of South African bonds leading to the further depreciation of the South African Rand. The Rand is also impacted by the current measures being taken by the Government, in particular, the lockdown to combat the effects of the coronavirus pandemic.

Households in South Africa are highly indebted from high level borrowing. Thus an increase in deposits can lead to more significant credit extension and hence the need to investigate the impact on banks' profitability and the broader economy. SARB's inflation targets maintain rates between 3% and 6%, subject to key influences from restrictive and expansionary monetary interventions. South Africa belongs to the G20 group of countries and so needs to comply and participate in the Basel Accords. The regulators implement noncompliance charges to the capital requirements to force banks to abide by the minimum capital adequacy requirements. Like any other emerging country, South Africa is exposed to capital volatility from investments and disinvestments borne from perceived risks and uncertainties in the marketplace. These uncertainties lead to irregular injections and flight of capital, hence the need to examine their impact on the economy.

As at the end of July 2020, the whole world is grappling with the negative consequences of the coronavirus pandemic. the Government has provided some bailout packages for the very poor and the SARB has reduced the policy rate by a total of 300 basis point since the beginning of the year. It is important therefore for one to assess the impact of these actions on the banks and the general economy and the CGE model could assist in this area. With that in mind, this study develops the banking sector CGE model to determine the impact of banking regulation in the South African economy. The modelling consists of two parts. For the first part, the model is used as a risk assessment tool for the South African banking sector. In the second part the model is used as a tool to regulate the South African banking sector in terms of the appropriateness of capital requirement and monetary policy instruments and for determining the impact of changes in the policy rate on banks profits and the GDP of South Africa.

1.2.2 Research problem

In this study the CGE model is developed to cover the banking sector for South Africa. The model is used as a risk assessment tool. An analysis of the impact of banking regulations on consumers using the CGE model is considered. The model is then used for determining the impact on profits of the banks, and the economy as a whole, of appropriate real-time inputs such as default penalties and capital violation penalties for policy-makers. Banking

regulation in South Africa is currently in flux. This study will assist in risk assessment and banking regulation.

Risk assessment

The main research question for the risk assessment part is “how do banks and their customers react to shocks in the banking sector?” We first calibrate the model against South African banking sector data and establish the initial equilibrium position. Once equilibrium is established, a series of comparative statistics is conducted by changing the exogenous variables in turns and studying how the equilibrium is impacted. The following are analysed:

- an expansionary monetary policy,
- a positive deposit supply shock to a bank,
- a positive bank capital shock to a bank,
- restrictive regulatory policy, and
- a positive shock in Gross Domestic Product (GDP).

The first comparative study is to see how easing monetary policy affects banks, their customers and the GDP. This is done by either increasing the base money (and in the case where the SARB is a net borrower in the interbank market reducing the bonds issued) or reducing the policy rate (repo rate). The results of key variables such as banks profits, capital, the capital adequacy ratio and GDP are compared to their values at the initial equilibrium.

The second is to see how a significant increase to a bank’s deposit supply in the initial period affects the banks’ profits and other key variables. This is done for each of the two scenarios. One where the Central Bank fixes base money and the other where the Central Bank fixes the interbank rate as its monetary policy instrument. A set of each of the results is compared with the results at the initial equilibrium.

The third scenario involves allocating a significant initial amount of capital to one of the banks and determining its effects on the banks and the economy. Next the effects of restrictive regulatory policy on the banks and their customers are determined. Two penalties are considered - the default penalty and the CAR violation penalty. For each scenario the penalty is increased and the results compared with the results at the initial equilibrium.

Finally, the effect of a positive shock in GDP is determined by running the model and comparing the results of the key variables with their values at the initial equilibrium.

Banking regulation

After using the model for risk assessment, attention was turned to using the CGE model for banking regulation. The following is considered:

- the effect of the penalties (both default and capital violation) on the banks and the economy,
- the effect of capital adequacy requirement on banks,
- monetary policy instrument - base money or policy rate, and
- the impact of changes in the policy rate (repo rate in the case of South Africa) on the South African economy.

The main research question for regulating the banking sector is “how much do the default penalty and CAR violation penalty affect the South African banking sector and the economy (consumers of banking sector)?” This is investigated by developing the standard CGE model for the banking sector. Penalties have to be imposed on banks in order to influence banks to act in line with policy objectives. Whatever penalties are imposed on the banks, the banks will react to maximise their profits and the consumers will react to maximise their utility which will impact the GDP. The first step is to calibrate the model for the South African context. In other words, initial equilibrium is obtained by using appropriate South African banking sector data as well as other relevant data such as the elasticities and the asset risk weights needed for the model. Therefore, the penalties are known from the initial equilibrium. The model is run with different penalties (both higher and lower), one at a time. The results at the new equilibrium are observed and their effects determined by comparing the results. A combination of both penalties (default penalty and capital violation penalty) are also considered to determine which one dominates the other. This is done firstly with the base money as the monetary policy instrument and secondly with the policy rate as the monetary policy instrument. The results from the two scenarios are then compared to determine which one offers the optimum result for the SARB and the economy in general. Next, the effect of CAR on banks and the economy is considered. The model assumes CAR is binding. Even though in reality banks will only be allowed to continue operating if they are not violating their CAR, it is assumed that banks will prefer having a cushion above the minimum requirement. So it is this enhanced CAR that is binding in the model. The model is run again this time tightening CAR. CAR is tightened by reducing the capital adequacy ratio for each bank by increasing the risk weights attached to their assets. The set of results produced at the new equilibrium is compared with the earlier results (ie the initial

equilibrium) to determine the effects on the banks' profits and the economy. This allows banking sector regulators to know how banks react to CAR in terms of banks profit and also the impact on GDP. Similarly, different policy rates are applied one at time to determine the changes in the endogenous variables at equilibrium. This ensures that the impact of changes to the repo rate on banks profit and GDP can be determined.

1.3 Structure of the thesis

This chapter (Chapter 1) provides a background of the study where the uniqueness of the study is mentioned. Also the objectives of the study and the research problem are discussed. The next chapter (Chapter 2) gives the literature review of the main areas covered by the study. These are financial regulation and systemic risk. The discussions of the financial regulation considers the different types of regulation and how the South African banking sector has been regulated in the past leading to its current regulation of the "Twin Peaks" model. Then there is the discussion on the Basel Accord starting from Basel I right through to Basel III. The role of capital adequacy requirement in banking regulation and the 2008 GFC are also discussed. The literature review on systemic risk starts with some definitions and then moves on to the modelling and measuring of systemic risk. Discussions on systemic risk and banking regulations are made and finally there is a discussion on how to deal with systemic risk. The model being used for the research is a CGE model and as such Chapter 3 is devoted to general equilibrium analysis of which the CGE model forms part. Financial regulation in general equilibrium is discussed. This is followed by modelling in general equilibrium and then the CGE model itself. Under the CGE model, a simple definition for the CGE model is provided. This is followed with the various applications in the country of CGE models. These applications are mostly in the non-financial sector as virtually no work is done in the financial sector with CGE models in the country. Consideration is then given to the applications of CGE models in the financial sector in other countries where most of the discussions are on financial fragility. As the model makes use of constrained optimisation problem where banks take action to optimise their profitability and customers of the banks take action to optimise their utility impacting on the economy, the last section of the chapter is dedicated to discussing optimisation problem. Chapter 4 gives a detailed description of the CGE model for the banking sector. It describes the CGE model used for this study. The optimisation problem for the banks is described. Due to the fact that individual data for the customers of the banks are not available as only aggregate data are reported by the banks, it is not possible to consider the optimisation problem for the private sector agents and so reduced form equations are used. Discussions on how the reduced form equations are obtained for

each of the private sector agents as well as the future gross domestic product are also given in this chapter. The involvement of the Central Bank and/or the Regulator in the model is discussed. Finally, the equilibrium position is considered by discussing the market clearing constraints and the equilibrium conditions.

Chapter 5 describes how the model is calibrated for South Africa. Three different approaches are used to obtain the exogenous variables for the model. Firstly where there are available data such as balance sheet information for the banks, these are used. Other variables are obtained arbitrarily taking into consideration what is appropriate for South Africa. The rest of the variables are obtained by solving the model. It is important to note that the variables obtained from solving the model may not necessarily be the endogenous variables of the model. The initial equilibrium position resulting from the calibration exercise is given. The model is used as a risk assessment model for the South African banking sector in Chapter 6. Considerations include: an expansionary monetary policy, a positive deposit supply shock, a positive capital shock and a restrictive regulatory policy which are all pertinent to the South African situation.

In Chapter 7, the CGE model is used for banking sector regulation. Firstly, why the model is considered a regulatory tool is discussed. The propositions to be used in explaining the effects of the shocks conducted in the chapter are then provided. After that the effects of imposition of penalties - both default penalty and capital violation penalty on the banks profits as well as GDP are considered. This is followed by how capital adequacy requirement impacts on banks and the economy. Then the two monetary policy instruments used by Central Banks world wide - base money and policy rate are considered. As the SARB uses the repo rate to ensure inflation does not breach its target range of 3% and 6%, consideration is given to the effect of altering the policy rate on banks profit and the economy.

Chapter 8 gives the summary and concluding remarks where limitations of the model and opportunities for further research are mentioned. The chapter is then concluded with recommendations on policy implementation of the CGE model developed for the South African banking sector.

Chapter 2

Literature Review

2.1 Introduction

The study focuses on the banking regulation from the South African economy perspective. Another aspect of the study is to consider how the CGE model is used for risk assessment and in particular how it could give an early warning signal of systemic risk. Hence the first section considers literature on financial regulation with emphasis on banking regulation. This is followed by a discussion on systemic risk.

2.2 Financial Regulation

There has been controversy over whether banks should be regulated at all taking into account the cost of regulation. Neither theory nor empirical evidence supports most of the arguments used to justify extensive regulation [19]. The main argument against extensive regulation is that prudential regulation is only required to minimise negative externalities in the case where deposit insurance is imposed by government. The opinion is that government regulation has rather increased the failure rate of banks and reduced the benefits to the public and that the only justifiable reason for regulating banks is to reduce moral hazard and agency cost in cases where deposit insurance is offered. In a similar view, the extent of banking regulation (where regulation is restricted to competition in the banking industry) did not offer any support of welfare effect anywhere in the world [70]. It concluded that restricting entry to the banking sector increased the cost of credit and reduced access to credit. The only advantage is the reduction of bad loans.

However, unlike non-financial institutions, banks need to provide guarantees for short-term liabilities such as money and hence more stringent regulation is required. Regulation ensures that the financial system is kept stable and individual banks are safe and that banks have

good managers who do not make bad investments and take too much risks. In addition it ensures that banks have adequate capital in the event of investments going bad. Nowadays, the financial service industry is viewed by many as the most powerful political force in the United Kingdom and the United State of America [85]. This applies to other countries including South Africa. As such it is important that regulation of the financial sector is modeled appropriately to assess its macroeconomic consequences. A properly run banking system is important for maintaining economic growth [117] and it will be difficult to achieve that without well designed regulation.

Until the banking crisis of 1930, Central Banks were responsible for ensuring financial stability [8]. They prevented crises by setting the discount rate and conducting open market operations. After the banking crisis of 1930, many of the central banks, in particular the Federal Reserve Bank of the United States of America, came out with other regulations to prevent systemic risks. Some of these are asset restrictions, reserve requirements, ceilings on interest rates, restrictions on services and products and capital adequacy requirements (CAR). With time, most of these regulations have been removed, although CAR still persists. It is therefore relevant that the appropriate level of capital is determined. It is argued in [51] that the financial sector, in particular the banking industry, has undergone major structural changes internationally and regulators have been challenged to keep up with these changes. The South African regulatory structure followed the international trend whereby regulators hardly looked beyond their narrowly defined borders. Capital requirements were based on ratios of capital to total assets [29]. The regulation of the banking sector became the sole responsibility of the South African Reserve Bank (SARB) in 1987.

2.2.1 Types of regulation

There are basically four different approaches to financial regulation [29] across the globe. These are the institutional approach, the functional approach, the single-regulator/integrated approach and the “Twin Peaks” approach.

The institutional approach

The institutional approach regulates according to the legal status of an entity or the sector in which the firm operates. Thus banks, insurance companies and pension funds have different regulators. The Central Bank is usually responsible for regulating the banks. Countries using this approach include China and Mexico. In this case, the firm is usually regulated by one regulator and the applicable regulator supervises all activities undertaken by the firm, regardless of the market or sector in which the activities take place [59]. It is difficult to

use this approach for financial conglomerates as these companies usually have subsidiaries operating in different sectors and are able to classify their business in such a way that most of their business go into the sector which is least regulated. In other words they take advantage of regulatory arbitrage.

The functional approach

Countries using the functional approach include France, Italy and Spain. With this approach, the regulation is done according to the type of business being transacted by the entity irrespective of its legal status. Each type of business will have its own regulator. For example a firm offering both insurance products and banking product will have two separate regulators - the insurance regulator and the banking regulator. Its advantage is that consistent rules of regulation are applied to each business activity even though it is difficult sometimes to distinguish which activities come under a particular regulatory jurisdiction. This may lead to similar activities of different firms being regulated differently.

The integrated approach

Under the single-regulator/integrated approach, a single regulator is used for the whole of the financial sector for both prudential and market conduct regulation. Germany still uses this type of regulation. An advantage of this type of regulation is that there is a streamlined focus on regulation without the conflict over jurisdictional lines that are inherent under either the institutional approach or the functional approach. Regulating all aspects of a firm's activity allows the Regulator to assess the risks properly and also reduce the possibility of regulatory arbitrage. There is however the possibility of either the prudential regulation or market conduct regulation being neglected at the expense of the other. the Regulator may not be able to give the necessary attention to each of the two separate objectives.

The “Twin Peaks” approach

The “Twin Peaks” approach separates regulatory functions between two main regulators: one that performs the prudential supervision function and the other that focuses on business conduct regulation [67]. It is usually referred to as regulation by objective [112] as it has the purpose of achieving particular and concrete outcomes. The idea of the “Twin Peaks” was introduced in 1996 by Michael Taylor, who recommended that financial services should be regulated with two goals in mind - protecting the stability and integrity of the financial system and ensuring that the interests of consumers are protected [120]. Its advantage is that it is able to eliminate the conflict of interest that may arise from the prudential regulation processes

and the market conduct regulation which occurs under the integrated approach. It also has the added benefit of regulatory consistency and jurisdictional clarity which are not possible under the institutional and the functional approaches. Furthermore the approach is able to cope better with the increasing complexities of financial products and financial conglomerates. The problem associated with this approach is the possibility of regulatory overlap from the two regulators which could cause a burden for the regulated firms. In addition, much needed cooperation and coordination between the two regulators is required. Australia was the first country to implement the “Twin Peaks” approach to financial regulation [135] in 1998. Other countries currently operating this regulatory approach include Canada, the Netherlands and New Zealand.

2.2.2 The “Twin Peaks” Model for South Africa

South Africa has gone through almost all of these approaches and is currently implementing the “Twin Peaks” approach. Following the 2008 GFC there was an international shift from the integrated model (single-regulator) towards the “Twin Peaks” model and South Africa adopted the “Twin Peaks” model of regulation. This is in contradiction with the 1993 Melament Commission which recommended the single-regulator model [29]. In a National Treasury Policy Document - “A Safer Financial Sector to serve South Africa better”, it was proposed that the responsibility of the prudential regulation of banking sector will lie with both the SARB and the Financial Service Board(FSB) and that the SARB will be responsible for prudential regulation and the FSB market conduct regulation. Thus instead of the banking sector having its own regulator, different from non-bank financial institutions, all sectors of the financial system are regulated by two main bodies.

Following the commencement of the Financial Sector Regulation Act 19 of 2017, South Africa shifted to the “Twin Peaks” model [135]. The implementation is in two phases [53]. The first phase which involves relevant legislation being developed and tabled in Parliament to enable the regulators to deliver on their revised mandates began in 2013/14. The second phase which consists of harmonising specific legislative, regulatory and supervisory frameworks is expected to be implemented over several years. This makes South Africa the first emerging economy to be adopting the “Twin Peaks” model of regulating the financial services industry [130]. If successfully implemented, it might assist other developing countries to also implement it.

Before the “Twin Peaks” was implemented, South Africa followed the institutional approach with the SARB responsible for the banking sector, FSB for insurance, fund managers and exchanges. The Johannesburg stock exchange (JSE) was responsible for supervising listed companies, the Department of Trade and Industry for the unlisted companies and the Na-

tional Credit Regulator (NCR) for lending. In the South African “Twin Peaks” model, the SARB is responsible for one of the peaks (i.e. an extra peak) with financial stability mandate [130]. In other words, the SARB is now mandated as the guardian of the financial stability in the new framework. The system took away the banking regulation and supervision from the Bank Supervision Department in the SARB and established a separate entity called the Prudential Authority (PA) which is located inside the SARB. The PA is the broader prudential regulator not only for the banking sector but for other financial sectors such as the short-term and long-term insurers and pension funds. It will assist the SARB in maintaining the overall financial stability and overseeing systemic risk in the financial sector. The FSB is to be replaced with a new broader market conduct regulator called the Financial Sector Conduct Authority (FSCA). The FSCA is responsible for providing protection for the consumers of financial products and for maintaining confidence in the financial sector. Thus there are three main regulators (SARB, PA and FSCA) involved in the South African “Twin Peaks” regulatory framework.

The “Twin Peaks” regulatory system requires cooperation and collaboration between the various regulators. In this respect, various committees have been established to assist. Two of the committees pertinent to this study are the Financial Stability Oversight Committee (FSOC) and the Financial Sector Contingency Forum (FSCF).

The FSOC is chaired by the Governor of the SARB and includes members from both the PA and the FSCA [53]. The committee coordinates efforts to maintain financial stability and to limit systemic risk. It is expected from the committee to identify risks and respond to them appropriately and also play an advisory role in crisis management and prevention. The FSCF’s primary objective is to assist the FSOC in identifying the potential risk that systemic events may occur and coordinating appropriate plans to mitigate the risk. In other words, the FSCF is the forum where the actual detection of risk that could threaten financial stability and its mitigation takes place. The work done at the FSCF level will therefore inform the FSOC about risk to financial stability leading to possible actions to be taken by the SARB.

The SARB has also been given powers to control systemically important financial institutions (SIFIs). A company is classified as a SIFI if it is regarded as “too big to fail”. These are usually companies (financial conglomerates) which have grown very large and complex such that their failure leads to instability in the financial markets and as such the Government or the Regulator bails them out whenever they are in trouble. These companies could potentially take too much risk knowing that should they be in trouble the Government will come to their aid. The new regulation gives much attention to such companies. As indicated in [128], the regulatory culture has shifted from bail out to bail in to curb moral hazard and hold

shareholders and creditors of SIFIs accountable. Thus being a SIFI does not guarantee that the institution will receive any credit or support from the state when it is in trouble. Rather being given the designation of a SIFI requires more intrusive regulation. This is because SIFIs are regarded as high risk as far as systemic risk is concerned and as such there should be stricter prudential measures for them.

2.2.3 The Basel Accords

The Basel Committee on Banking Supervision (BCBS) was established in 1974 after the failure of a German Bank, Herstatt, which resulted in some form of systemic crisis [2]. The BCBS is responsible for implementing The Basel Accords. They were set up with the aim of evolving over time so any development which could assist the BCBS in improving its mandate is welcome and this is where this study is most relevant. The Basel Accords are the global standard for regulating financial institutions [54]. The objective of the Basel Accords was to mitigate systemic risk through maintaining adequate capital. Even though this is not evident in Basel I and Basel II, it is evidently clear in Basel III.

Basel I

The regulation of the Basel Accords began with Basel I in 1992. The idea behind Basel I is to ensure banks reduce their desire of taking risks by making capital requirements dependent on risk-weighted assets of the banks. However, it is not clear whether this desired outcome was achieved [80] as banks found ways through regulatory capital arbitrage. In other words banks held more than the required capital but also increased their risks substantially. This was possible because it was only a prerequisite for banks to maintain a fixed percentage of capital (8% of risk-weighted assets) which was dependent on the level of risks taken.

Basel II

Basel I was followed by Basel II in 2004 with the intention of addressing some of the shortcomings of Basel I. However, Basel II focused on micro-prudential regulation which meant that the regulation ensured the wellbeing of individual banks and not the overall financial sector and so could not solve the problem of systemic risk. Basel II has three underlining pillars that permit banks and supervisors to measure the risks faced by banks and which should provide safety and soundness in the financial sector [18]. Pillar I dealt with minimum capital requirements – the rules banks use in calculating their capital ratios. It considered three different risks; credit risk, market risk and operational risk instead of only credit risk which was the focus of the earlier accord. Banks could use any of the following three options

in calculating the required capital: simple calculation using fixed weights for smaller banks which don't have the resources to model their risk, a complex system based on external ratings and an internal rating based (IRB) method for complex banks, and using their own models approved by the Regulator. Banks took advantage of these options and used the approach which suited their own financial needs and in so doing created problems [24, 25] for the banking industry and its regulation. The problems as identified in [25] for pillar I of Basel II included:

- Portfolio invariance - capital charges need to be portfolio-invariant, i.e., the capital charge on any instrument is dependent on only its features, and does not take into account the specification of the entire portfolio it belongs [68]. This led to no penalty for portfolio concentration which did not encourage diversification.
- Single global risk factor - the requirement to have a single global risk factor does not allow for country specific risks which could understate the capital needed to support some regions or banks.
- Different treatment of financial “promises” - which allowed complete markets in credit to weaken capital weighting methods. This was brought about by the development of credit default swaps (CDSs) that allowed banks to transform their risks using derivatives (without trading on the underlying assets) and so reduce the risk-weights attached to those securities.
- Bank capital market activities - banks conducted capital market activities which were not supported by adequate capital. Securitisation and its warehousing on and off balance sheet became the main problem, eventually causing contagion and counterparty risks to occur.
- Procyclicality - the Basel system is pro-cyclical. Risks are underestimated during good times and overestimated during bad times. For example, leverage ratios depend on current market values. This will make them high in good periods and low in bad periods resulting in procyclicality. Also profit recognition and compensation schemes encourage short-term risk taking. These are not usually adjusted for risk over the entire business cycle. The capital regulation had nothing which could counteract these problems.
- Subjective inputs - risk inputs are subjective in that some prices are of the over-the-counter variety and so are not observable. Others do not have the necessary records for modelling purposes. These allowed banks to manipulate them to lower the required capital.

- Unclear and inconsistent definitions of capital - the definition of capital is neither clear nor consistent. For example the regulatory adjustments are not applied consistently over jurisdictions which allowed regulatory arbitrage resulting in banks not being able to absorb losses during crisis.

Pillar II dealt with the supervisory review of a bank's capital adequacy and internal assessment procedure. The aim is to ensure banks follow rigorous processes, measure their risk exposures properly and have sufficient capital to support their risks. Banks are supposed to hold capital for risks which are not covered under Pillar I under the guidance of supervisors. This required that supervisors needed to be ahead of time in their thinking and consider possible future innovations and complexities. This was difficult as supervisors had less resources and expertise than the private bankers themselves which led to some problems including the Financial Services Authority (FSA) in the UK, one of the most sophisticated supervisors signing off Northern Rock to use the internal rating based approach, knowing very well that it would reduce its capital. This problem is also evident in the US banking supervisors allowing Lehman to use repo 105 in its accounts prior to 2008 GFC, implying that the supervisors did not fully understand its complications [115].

Pillar III dealt with market discipline which encourages safe and sound banking practices through effective disclosure. It requires banks to disclose information which could affect their risk and capital. The aim of this framework was to improve how regulatory capital requirements take account of the fundamental risks and to address the financial innovation that had occurred post the implementation of Basel I [13]. This should reward and encourage continued improvements in risk assessment under the notion of efficient markets. However, this was not the case as the root cause of the sub-prime crisis indicates systematic absence of informational efficiency. Supervisors worldwide faced a major challenge under Basel II in dealing with risk assessment in multiple jurisdictions. Even though this concept was already known to the regulators, Basel II demanded much more cooperation between home and host supervisors [13]. The drawbacks of Basel II is summarised as follows [113]: necessity for a macroprudential view in regulation and supervision, necessity for international coordination, treatment of systemic (liquidity) risk, treatment of procyclicality, reduction of the too-big-to-fall (TBTF), too-many-to-fall (TMTF) and too-interconnected-to-fall (TITF) problems, improvements in transparency, and incentives for sustainability/long-term orientation.

Basel III

Basel III was introduced as an amendment to Basel II to help resolve some of these problems [131]. Some of the changes pertinent to this study included the introduction of capital buffers and changes to regulatory capital composition. Unlike Basel I and II which focused

on solvency risk, Basel III's focus was on liquidity risk. This was clearly stated as Basel III recognizing that the three types of risks which could result in the failure of a financial institution are solvency risk, liquidity risk and funding liquidity risk [2]. In actual fact Basel III was a regulatory reaction to systemic risk. Basel III makes an attempt to deal with the shortcomings of Basel II listed above with the exception of the TBTF, TMTF and TITF problems [113]. For instance macroprudential regulation is handled by the requirement of conservation and countercyclical buffers and all 27 member countries of the Basel committee will implement the framework which should address the necessity of the international coordination issue. The issue of treating systemic (liquidity) risk is countered by the new liquidity standards and in particular the net stable financial ratio (NSFR). Also the main aim of Basel III is the achievement of financial stability and so all proposals provide solutions to the reduction of systemic risk. In general they lead to overall stability of the financial sector instead of stability of each institution. The procyclicality issue is dealt with by the following: build-up of additional capital buffer, avoidance of excessive credit growth and usage of stressed data for the calculation of counterparty credit risk. Improvement in transparency is countered with intensified disclosure of capital and liquidity requirements, disclosure of the leverage ratio and national countercyclical buffer and implementation of central counterparties (CCP). Finally sustainability is resolved by an enhanced capital base, widened risk coverage and liquidity standards (esp. the NSFR).

The procyclical effects of bank capital requirements have been a major consideration for regulators following the 2008 GFC. During recessions, banks' capital gets eroded as a result of losses from their investments. Although risk-based capital requirements, such as those in Basel II become higher, if banks are not able to swiftly raise enough new capital, they are not able to lend sufficiently and could lead to a credit crunch [106]. Hitherto, relaxing capital requirements in downturns to correct the possible contractionary effect on credit supply may increase bank failure probabilities and these failure probabilities are largest in downturn due to high loan defaults. These contradictions explains why microprudential regulators consider procyclicality a necessary evil and macroprudential regulators think that it should be explicitly corrected. Basel III is a compromise in that it requires reinforcing the quality and quantity of the minimum capital and also the establishment of mandatory buffers for the banks. The intention is to build up these buffers in boom times and release them in bust times.

2.2.4 Capital adequacy and regulation

Banking regulations have pros and cons. In particular, theories on regulation relating to capital have conflicting results as to whether capital requirements have positive features [69, 110].

Although CAR limits the moral hazard of banks that arises from deposit insurance schemes, it is costly [76] as it reduces the opportunity for banks to manage liquidity. If that was not the case then regulators could raise CAR as much as they want and force banks to be only financed through equity. Thus other considerations must be taken into account such as the effect on the economy whilst deciding on the optimal CAR. There is a trade-off between ensuring that CAR is as low as possible and thus not making it cost too high and ensuring that bank failures are kept as low as possible by ensuring that banks make adequate profits. CGE models could be used to assist regulators to achieve the necessary trade-off. According to [46], regulations relating to capital have positive features. With sufficient capital, losses often do not lead to failures. However, excessive direct government regulation and supervision tend not to give the best results. Instead regimes that depend on guidelines [16] but require accurate information disclosure, do well in promoting bank development, performance and stability. This is because it offers the private sector opportunity to control the banks and foster incentives for them to exert control.

Banking regulations, especially those related to capital requirements, can have positive effects. Capital cushions losses and therefore a good implementation of CAR may prevent bank failures. In addition, with limited liability in place, the tendency for banks to take higher risk is reduced when there is more skin in the game [16]. CAR also helps to align the incentives of the shareholders of the bank with those of the depositors and the creditors of the bank. CAR may also have negative effects. For instance, it may increase the risk-taking behavior of the banks as they may want to increase their profits. Increasing profit allows them to retain funds to further increase their capital in order not to violate the minimum capital required. Also, higher capital requirements in a general equilibrium context may induce banks demanding lower deposits which could lead to liquidity problems [69].

2.2.5 The 2008 financial crisis

South African banks were not significantly affected during the 2008 GFC. Due to restrictions on foreign exchange [109] and associated capital controls, South African banks did not invest significantly in sub-prime securities, which was one of the main causes of the crisis. The National Treasury Policy Document of South Africa gave the following reasons for South Africa's resilience to the financial crisis [67]:

- A sound framework for financial regulation and well-regulated institutions - effective legislation ensured that potential risks were anticipated and appropriate actions taken to mitigate the risks. The National Credit Act (NCA), for example, ensured that credit extension by the banks was not over board. This confirms that implementation of good

regulatory practices usually minimise financial risks.

- Appropriate and conservative risk management practices at domestic banks. The failure of Saambou bank which brought about a small banking crisis in 2002 made banks put appropriate risk management systems in place. This was followed by the adoption and implementation of the Basel II Capital Accord in 2008. These conservative practices at banks ensured that there was not any significant securitisation and derivatives trading that took place compared with developed countries.
- Limited exposure to foreign assets. The prudential regulation imposed limits on foreign assets banks could have and this reduced the exposure to foreign risks.
- Subsidiary structure and listing requirements. A registered bank was required to be a subsidiary of the parent company. As a result the banks were isolated from the financial problems of their foreign parent companies. The listing requirement also forced banks to adhere to good corporate governance.
- A robust monetary policy framework. Two policies assisted in absorbing the massive impact from the external shocks. These are the inflation targeting framework and the flexible exchange rate regime. Compared to countries that operated on fixed exchange rates, South Africa was able to lessen the impact of disruptive capital flows.
- Countercyclical monetary policy. Prior to the crisis, there was a very large demand for credit and as a result, the SARB gradually raised the repo rate by 5% in the period between 2005 and mid-2008 to ensure that the consumer price inflation stayed in its target range. This assisted in halting the excessive credit growth and mitigated the risks of the global surge in financial activity. Then during the period of the financial crisis, the SARB reduced rates rapidly and that cushioned the domestic economy from adverse global conditions.
- Countercyclical fiscal policy. South Africa had a strong fiscal position so the reduced tax revenue associated with the crisis did not pose a problem. It also allowed the increased spending required to deal with the crisis to be managed successfully.
- A proactive approach to dealing with bank credit risks. The Registrar of Banks sensing danger from the credit extension boom took proactive action to reduce potential risks by raising the capital adequacy requirements and setting conservative leverage ratios. This limited the credit extension.

- A focus on reducing household vulnerability. The National Credit Act was in place and protected households and consumers from any reckless lending practices.

Banking activities may be regulated in order to reduce conflict of interest, ensure that banks do not become too complex since monitoring then becomes difficult, reduce the risks banks may take, not to reduce competition and efficiency and to avoid banks becoming too economically powerful to make them “too big to discipline” [16].

2.3 Systemic Risk

Systemic risk occurs in both financial and non-financial sectors. Systemic risk in these two areas have similar features. An example of systemic risk occurring in non-financial sector is the spread of a disease such as COVID-19 which surfaced in China in November 2019. In the financial system a significant amount of assets lost value (eg all the major stock indices across the globe fell) as a result of systemic risk during the initial phase of the pandemic. In this study, one is interested in the systemic risk in the financial sector and so will concentrate on financial sector systemic risk. Many definitions have been given for systemic risk but in general, three different concepts of systemic risk can be found in the literature [84]. These are macroshocks, failure chains and common-shock or reassessment failures. The first concept involves a macroshock that produces nearly simultaneous, large, adverse effects on most or all of the domestic economy or system. Here one is looking at one sudden and unexpected event which affects the entire financial system.

The second concept termed failure chains involves a spillover from one institution or bank affecting other institutions in the entire financial sector. In other words, it can be considered as a chain reaction. That is, one bank’s failure may lead to other bank’s failure due to the fact that the first bank could not honour its obligations to the second and as a result the second bank could also not honour its obligations to another and it continues until the whole system is affected. This results from correlation or interconnection existing between institutions.

The third concept of systemic risk also involves spillover but does not arise because of direct causation or interconnectedness between institutions. This is brought about by uncertainties created when one institution, especially a very big financial institution, experiences adverse effects from a shock. This uncertainty may arise from the fact that market participants may consider the possibility of other institutions experiencing the same adverse effect especially if these institutions have similar risk exposures to the original institution that suffered the shock. The market participants then take actions such as withdrawing funds and thus cause liquidity and even solvency problems in the financial system. This form is referred to as a “common shock” or “reassessment shock” effect and represents correlation but not direct

causation.

Some definitions combine two or all three of the concepts. For example, in [1] which states that systemic risk occurs if many banks fail together or if one bank's failure brings about the failure of other banks combines all three concepts. Systemic risk is also defined as the likelihood of experiencing a systemic failure, a broad-based breakdown of the financial system that is triggered by a strong systemic event (e.g., a financial institution failure), which severely and negatively impacts the financial markets and the economy in general [102]. The International Monetary Fund (IMF) defines systemic risk as the risk of widespread disruption to the provision of financial services that is caused by an impairment of all or parts of the financial system, which can cause serious negative consequences for the real economy [79]. This definition is also in line with that of other International bodies such as the Bank for International Settlement (BIS), the World Bank and the Financial Stability Board (FS_tB). All these definitions have one issue in common. It is not only a failure of one institution but that of the entire financial system.

The 2008 GFC illustrated that systemic risk takes many forms [57]. One of the forms is interbank contagion which occurs as a result of the linkages between banks from interbank lending leading to a default from a bank causing losses and further defaults from other banks. Another form is a common shock to the banking sector in general as a results of banks having similar asset holdings. Systemic risk could also be considered to exist in two dimensions - cross sectional dimension and time dimension [32]. The cross sectional dimension relates to how a specific shock to the financial system propagates itself to become systemic. The focus is on how the risk is spread at a given point in time. Many companies are affected concurrently leading to the derailing of the financial system. With the time dimension, there is a build up of the risk that caused the crisis over a period of time and the 2008 global financial crises could be considered as an example. There is usually a period of booms and then busts. During the boom period, a lot of financial innovations occur. Individuals and firms take on a lot of risks creating products which are hard to understand and value. Credit grows quickly inflating asset prices. The bust occurs when the unseen risk materializes.

2.3.1 Modelling or measuring systemic risk

Systemic risk is a major factor in financial stability and very little is known about how to model it [9]. Attempts to model or measure systemic risk may be grouped into two classes. These are direct methods using analytical tools and indirect methods whereby indicators considered to have a relationship with systemic risks are used.

Direct methods of measuring systemic risk

A few of the direct methods can be found in [4, 66, 88, 136]. In [4], Conditional Value at Risk (CoVaR) which is defined as the Value at Risk (VaR) of the whole financial sector conditional on an institution being under distress, is used to determine systemic risk. Financial institutions used VaR as a measure of risk. However, VaR concentrates on a single institution and so is not able to capture systemic risk [4]. CoVaR allows spillover from other institutions to be studied. CoVaR is a bottom-up method in that a bank's individual contribution to systemic risk is measured separately from the entire financial system's systemic risk rather than measuring the overall systemic risk and then determining an individual bank's contribution. By using CoVaR, one is able to assess how the impact of insolvency of an individual financial institution on systemic risk can be assessed. This allows the individual's systemic importance to be quantified. Using CoVaR also allows the individual institution's exposure to systemic risk between specified institutions to be assessed.

In [66], a joint probability of distress (JPoD) and a banking stability index (BSI) are estimated to analyse common distress in the banks. The JPoD signifies the probability of all the banks being distressed, i.e., the tail risk of the system. It entrenches alterations in the individual banks' probability of defaults (PoDs) and captures these alterations between the banks, which increases in times of financial crisis. Thus, in such periods, the banking system's JPoD may see larger and nonlinear increases than those seen by the average PoDs of individual banks. The BSI is a reflection of the expected number of banks becoming distressed on condition that at least one bank is distressed. A higher number indicates increased instability. It can also be regarded as representing a probability measure that conditions on any bank being distressed, without specifying the particular bank. In an attempt to monitor systemic risk of European banks, [136] considered forward looking distance to default series. The theory behind the method is grounded on contingent claims analysis. The aggregated distance to default series are generated using option prices information from systemically important banks and the DJ STOXX Banks Index. This method has some advantages over other market based methods. The analysis of systemic risk is superior if the average of portfolio distance to default series and their gap are applied together to monitor exposure in the banking system over time. The forward-looking feature allows for early indication of distress and they incorporate market expectations through option prices which do not misrepresent the risk outlook in the financial system as a whole.

CoVaR and Marginal Expected Shortfall (MES) were used to determine the contributions of individual Korean banks to systemic risk [88]. MES is a top-down method as it determines the entire systemic risk before evaluating an individual bank's contribution towards it. MES refers to an individual bank's loss in the tail of the aggregate sector's loss distribution. Thus

it detects the individual bank’s marginal contribution to the systemic risk through expected losses that is experienced during periods of meaningful slowdown in the overall financial system. Therefore, unlike CoVaR which is based on VaR, it is based on the expected shortfall (ES). On adding the individual institution’s MES, one obtains a single value for the entire systemic risk. With CoVaR being a bottom-up measure and MES a top-down measure, applying the two methods together allows systemic risk to be assessed from many positions. Many approaches using network theory to model systemic risk also fall under the direct method. A dynamic approach merging network theory and credit risk detection procedures was used in assessing systemic risk in financial networks [105]. A PoD model was built to measure systemic risk. The model makes use of a combination of credit risk detection procedures and a contagion mechanism on the network of exposures between banks. A potential loss distribution is attained by considering the PoD of the banks and their propensity to default over the same time period. A contagion process increases the PoD of banks exposed toward distressed counterparties. Their result was at variance with the usual diversification benefit which could underestimate regulatory capital required as for some banks, it revealed the emergence of a strong contagion regime where lower default correlation between banks corresponds to higher losses.

How network structures influence the way shocks spread through financial networks was investigated [133] using South African banks’ balance sheet data. The results obtained indicate that network models can be useful for monitoring systemic risk levels. One of the suggestions made from the results is that the resilience of network structures is dependent on network characteristics such as interconnectivity, distribution of assets and the level of capital. It is possible to determine drivers of systemic risks from the methodology used and so this should assist regulators in deciding the kind of information banks should provide in order to determine their possible contribution to systemic risk.

An investigation into how various financial network structures respond to the default of a single bank is conducted [86]. It analyses the fragility of the structures and the characteristics of the institutions with larger effects on the overall system should they fail. The aim is to identify institutions that are possibly systemically relevant because of the implications of their bankruptcy on other financial institutions. Considering the fact that modern financial systems have an extremely complicated structure, network illustration provides an important view of the whole system. Therefore, mapping financial systems to networks, taking financial institutions as nodes, network theory offers a possible framework for analysing the inner working of interbank money flows. They analysed the performance of many network centrality methods of identifying SIFIs using Turkish Interbank market data and concluded that the measures are useful in determining SIFIs. This is an important result for the “Twin

Peaks” approach to regulating the financial sector currently being implemented in South Africa since SIFIs need to be given special attention.

Indirect methods of measuring systemic risk

Some indirect methods can be found in [26, 102, 113, 121]. Some of the indicators used by the indirect methods includes size, interconnectedness, contagion, concentration, correlation and conditions. Central banks of the G20 countries were asked to rank the factors that contribute to systemic risk or systemically important banks [26] and almost all of them ranked size as the most important factor when it comes to systemic importance both before and after the 2008 GFC. Interconnectedness came a close second and others which were high on the list included concentration risk, leverage and correlation of exposures.

In particular, a stock return correlation is used as a pointer of systemic risk [102]. The opinion is that measuring continuously the stock return correlation will not only give an indication of systemic risk at the time the event happens but also on an ongoing basis. High correlation among banks causes systemic risk because it is unlikely to have a great disruption of the banking sector from a single event in a short period of time if correlations between banks are low. Hence they analysed the trends and fluctuations of daily stock return correlations and default correlations among the 22 largest bank holding companies and investment banks in the US from 1988 to 2008. The result indicated that the method is a simple, robust, forward-looking, and timely systemic risk indicator. There was an increasing trend in stock return correlation among banks but not among non-banks. When the stock returns were split into systematic and idiosyncratic components it was noted that correlation increases are largely driven by the increases in correlations between banks’ idiosyncratic risks, which give rise to increasing systemic risk. They also showed that stock return correlations give another perspective to the level of systemic risk not detected by default correlations and recommended that financial regulators consider monitoring stock return correlations among large financial institutions as part of detecting systemic risk.

Special factors which may be used in assessing systemic risks such as size, interconnectedness, idiosyncratic risk, leverage, common risk exposure, maturity mismatch and procyclicality are listed and presented [113] in the form of a diagram as shown in Fig. 2.1. SIFIs have been considered as major source of contribution to systemic risks. Identifying such institutions and putting in place mechanisms for regulating them could therefore reduce systemic risk. According to [121], size alone is not enough for determining SIFIs and that other factors such as contagion, correlation, concentration, and conditions (context) which, individually or collectively, can make a financial institution systemically important.

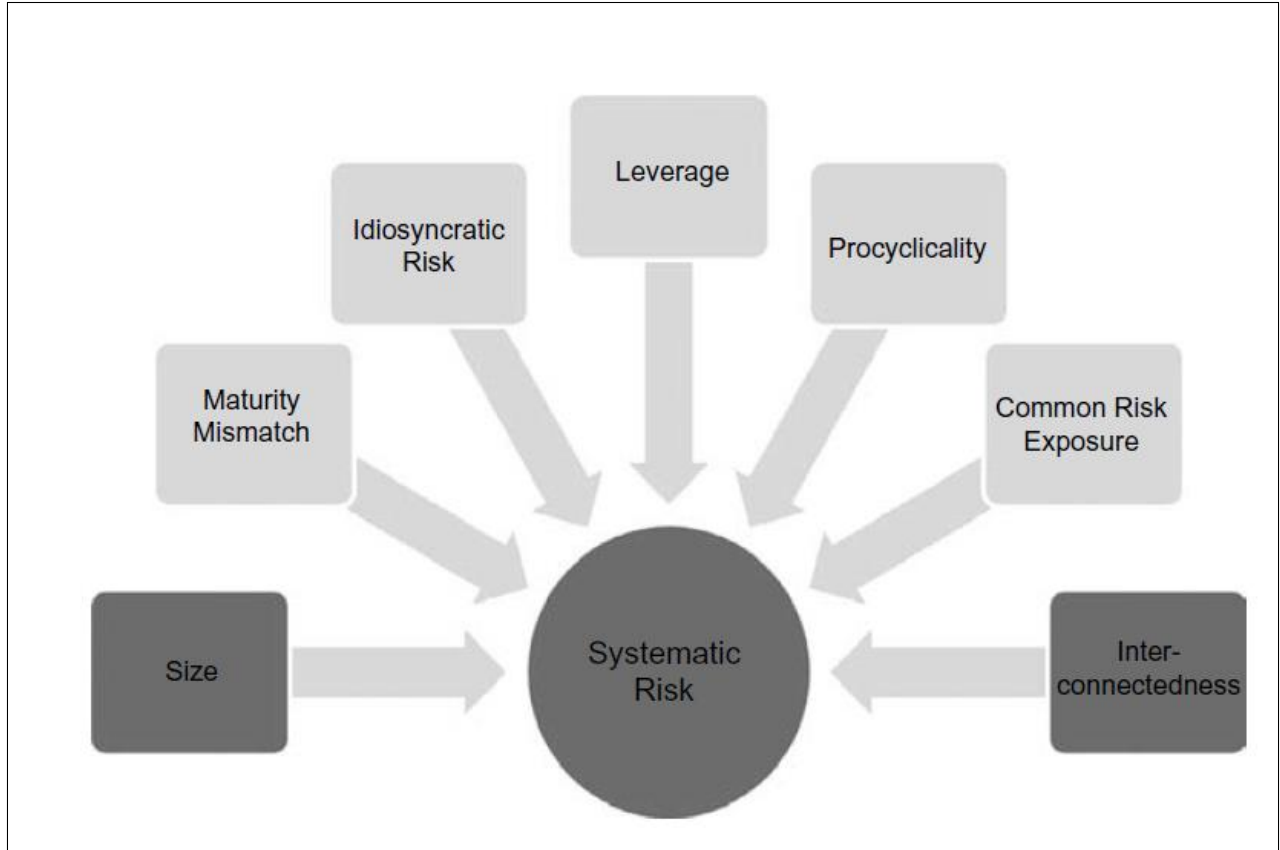


Figure 2.1: The factors causing systemic risk (See [113])

2.3.2 Systemic risk and banking regulation

Before the 2008 GFC, prudential regulation concentrated on single institutions [5, 6] and failed to deal with systemic risk. In the aftermath of the crisis, systemic risk is taken into consideration when looking at regulation. This is emphasised in [1] by showing that regulatory tools that consider only an institution's own risk fail to alleviate aggregate risk-shifting incentives and rather heighten systemic risk. Prudential regulation must therefore function at a collective level, regulating each institution taking into account its joint risk with other institutions together with its individual risk.

A small shock which affects one bank or institution may spread by contagion to the rest of the financial sector and ultimately to the economy as a whole [7]. Properly implemented capital regulation may lower systemic risk. However, it is difficult to say whether regulation currently being implemented is indeed working due to concerns raised about credit risk transfer. In practice, banks transfer their credit risk to insurers [8]. The transfer of risk diversifies the credit risk across the financial sector. However, this practise increases banks' counterparty risks [73, 75, 74]. Even though the transfer leads to efficient capital distribution and risks, the threat of systemic risk increases if not structured properly [8].

Systemic risk is one of the worst risks of the banking system. Central Banks' intervention can reduce this risk [57]. However, regulators are sometimes accused of contributing to it [84], even though it may not be intentional, rather than alleviating it. Regulators need to avoid monetary and regulatory policies that produce macroshocks. The provision of deposit insurance and other guarantees from government does not give the necessary incentives for banks to protect themselves against these macroshocks. Although, deposit insurance can stop bank runs, it comes at a cost. When underpriced, it encourages bank management to take more risks than usual. Regulators sometimes also delay the recognition and payment for the losses. Such delays lead to rapid growth in the losses. The liquidators from the Government lack the expertise and the necessary incentives to increase profitability for the banks [84]. Regulators have a mandate to intervene in market crises irrespective of the cause of the financial turmoil [55]. As such, regulators require robust intervention mechanisms that are informed by adequate methods and model solutions. Therefore, central banks and regulators focus on monetary and regulatory strategies to prevent and solve such market disruptions. The CGE models provide the tools to avoid and curb systemic risk infringements and to implement efficient CAR provisions in the marketplace. Other measures to mitigate systemic risk include providing adequate liquidity to the market and ensuring that banks are solvent with healthy balance sheets [78]. Without adequate liquidity in the market it will not be possible for distressed banks to sell assets when the need arises without moving prices or the market falling drastically. Solvent banks will have high capital requirements, adequate liquid assets and not have excess leverage. Central Banks or regulators could levy banks during period of no crisis in order to set up funds to provide emergency liquidity. Risk is considered in the context of the entire banking system instead of individual banks [49]. Such an approach allows banking regulators to uncover exposures to aggregate risk which may not be visible to those who only rely on the assessment of single institutions. One major problem of dealing with systemic risk is the fact that a bank causing systemic risk for the financial system will only attempt to resolve its own problem without taking into account the problem created for the other banks in the financial sector. Due to the fact that CGE models take into account interactions with other banks and the private sector agents, it could potentially provide an early warning for systemic risk.

2.3.3 Dealing with systemic risk

In dealing with systemic risk, it is best to treat it separately under the three concepts and also the two dimensional forms described above.

Macroshocks

Regulators need to avoid monetary and fiscal policies that have the potential of producing systemic risk and instead introduce policies that moderate them. There is evidence indicating that macrofailures, rather than individual bank failures, more often come from government monetary, fiscal, or regulatory policy shortcomings than from the weakness in bank management. Banks employ various risk management techniques such as maintenance of higher capital ratios to absorb unexpected losses. Government or the Regulator should therefore understand that private market incentives do limit systemic risk and so should encourage it rather than imposing measures which instead of retarding systemic risk rather contributes to it. Clearly financial regulatory policies are important but they cannot solve the problem of systemic risk alone. Monetary and fiscal policy is also needed to address issues of systemic risk. Then there is the need for coordination among all these policies not only nationally but internationally as well.

Failure chains

The application of prompt closure rules should be applied to reduce the amount of losses. Many times regulators take time before action is taken especially if the institution that started the chain reaction is regarded as too big to fail. The institutions could also monitor their exposures ceilings to other institutions so as to reduce the effect of defaults and also take prompt actions whenever they deem necessary. Again it is important that regulation does not prevent the institutions from doing so. There should be no deposit insurance cover for interbank transactions [84].

Common-shock or reassessment failures

Most times, depositors are aware of solvent and insolvent banks and usually shut down the latter through bank runs quicker than the Regulator might do [84]. Regulators must rather ensure than banks disclose adequate information to allow customers or shareholders to take their own decision. This disclosure could include information on asset and liabilities of individual banks. Therefore market discipline, transparency, governance, incentives, market integrity, consumer protection and so on are important to curb excesses in risk-taking [32].

Cross-sectional dimension

How the financial system is structured provides guidance on how to deal with the shocks. The spillover may arise from common exposures across institutions or from network interconnections. The issue is how to address such problems among financial institutions. The

main idea is to limit the destructions arising from such interlinkages and common exposures. In addition capital and liquidity buffers must be increased across the board to enhance the banking sector's resistance to shocks arising from financial and economic stress from whatever sources [32]. This would move part of the risk of spillover from the financial sector into the real economy. There is a trade-off between higher requirements and profitability.

Time dimension

In this case, the build-up of risk over time interacts with the macroeconomic cycle and so the issue involves addressing the procyclicality of the financial system. Capital and liquidity margins of safety must be built up over time [32]. This build up must be done especially during the upswing when it is easier and cheaper to do so. This also reduces the possibility of taking too much risk when there is so much funds available. In the downturn, the margins could be run down allowing the strain to be taken more easily. Individual banks can achieve appropriate buffers through retaining much of the profits by limiting excessive dividend payments, share buybacks and compensation and releasing them during periods of stress.

2.4 Conclusion

This chapter provides the literature review of the main areas covered by the study, namely financial regulation and systemic risk. Four approaches to financial regulation are discussed. They are institutional approach, the functional approach, the single-regulator/integrated approach and the “Twin Peaks” approach. The “Twin Peaks” approach is discussed in more detail as it is currently being implemented in South Africa. Subsequently the Basel I, II and III Accords are dealt with to serve as a basis for a discussion on capital adequacy requirement and regulation. The 2008 GFC is also discussed, mentioning how prudent regulation assisted in minimising its impact on the South African financial sector. The literature also provides insight into systemic risk and the methods to measure and/or monitor it. The CGE model could provide an early warning signal to potential systemic risk if applied as part of the tools for banking regulation. The next chapter is devoted to general equilibrium analysis which comprises the CGE model and optimisation which is the technique the CGE model uses.

Chapter 3

General Equilibrium Analysis and Optimisation

3.1 Introduction

Leon Walras' work in 1854 on the function of some complicated economic system dealing with a number of interdependent economic units firmed the idea of general equilibrium modelling which began two centuries ago [43]. Some of the problems encountered in his formulation were subsequently addressed in the 20th century following a series of activities relating to general equilibrium by mathematical economists such as Arrow and Debreu. What then is a general equilibrium analysis (GEA)? A general equilibrium analysis considers all markets together such that a shock in a particular market affects other markets [90]. It allows the outcomes of significant changes in a given sector in the overall economy to be traced. It can therefore be considered as an input-output analysis as it ensures an adaptable handling of the consumer part of an economy but less stern in the prerequisite of the production side [111]. The consistency of the general equilibrium model is mathematically confirmed.

However, in partial equilibrium, the effects of a shock in a specific market are assessed in this particular market and the effects on other markets are ignored. So it is only relevant when the market in which the effects of the shock are assessed is relatively small compared to the economy as a whole. Both dynamic and static equilibrium problems can be assessed under the principles of a partial or general equilibrium [28]. Static equilibrium problems involve a move from one equilibrium to another as a result of an economic or policy shock. Time is omitted from such analysis and as such it is only appropriate for comparative analysis. In such cases, one equilibrium is compared against some other equilibrium. However, in the majority of economic issues like investment and capital accumulations, time plays an important part and so must be analysed in a dynamic setting with time clearly allowed for

in the analysis. There are two types of dynamic models – recursive and fully dynamic. The recursive settings consider pair-wise periods whilst in the fully dynamic setting periods are considered concurrently [96]. Time dynamics are more relevant if the movement trail from one equilibrium state to another is of interest. The general equilibrium analysis is a much better representation of what happens in the real world, i.e. in reality it is more likely that an action in one market may be translated to other markets. A model, which is used in this study, falls under the classification of a general equilibrium analysis. CGE models are basically the present day equivalent of Walras’ model and for many they are the type of general equilibrium model that ensures all markets clear [114]. A CGE model is, therefore, nothing but a general equilibrium model for quantitative analysis of economic policy problems. A CGE model also needs economic data in addition to the theoretical structure of a general equilibrium model. Putting the data and the general equilibrium model together, a method is needed to solve the equilibrium prices and decision variables in the equilibrium system [103].

3.2 Financial regulation in general equilibrium

One of the reasons why the 2008 GFC was not foreseen is that most of the mainstream economic models assume away financial frictions such as defaults. It is difficult to properly model default, partially because it is a discrete variable. An economic agent either defaults on its obligation or not. The probability of default has always been an important item in finance even though very little attempt has been made to include it in formal macroeconomic models [65]. There are now models where endogenous default and regulation are assessed in general equilibrium analysis. One such model which is presented in [60] delves into how different types of financial regulation in general equilibrium deals with many of the problems encountered in the 2008 GFC. The framework includes a bank and a “shadow bank” (sometimes refer to as an “investor” throughout the section) that each lends to households. Households have the option to default on their borrowings but that prompts forced selling by the shadow bank. Forced selling usually leads to sales below the property value (a fire sale). Five different policy options that could be used to deal with default, credit crunches and fire sales were considered. These are: limits on loan to value ratios, margin requirements on repurchase agreements used by shadow banks, capital requirements for banks, liquidity coverage ratios for banks, and dynamic loan loss provisioning for banks. The section looks at the benefit and cost of each option.

3.2.1 Loan to value ratios

The amount that could be borrowed is restricted taking into account the value of the property. This limitation ensures that the financial loss in the event of default is reduced. However, such an option limits the ability of the purchaser of a property which reduces the value of the property for the seller since demand is lowered. It is observed that during a boom period, existing borrowers benefit from capital gains on their properties, and improve their creditworthiness. So, if the restriction is set higher to constrain the existing home owners, then first time home owners would find it difficult to obtain credit. This regulatory tool forces a higher deposit on mortgages and leads to a reduction in both the issuing of mortgage backed security (MBS) and mortgage extensions which in turn results in higher repayment rates during periods when the house price is down. With fewer mortgages in default and a smaller repo default, the banks are able to payback more on their deposits and have fewer MBS fire sales.

3.2.2 Margin requirements for repurchase agreements

Securitization such as MBS is one of the problems that caused the 2008 GFC. Imposing margin requirements on investors limits their ability to use credit when buying MBS. This forces investors to put in more of their own fund instead of borrowing to purchase the MBS. Using more capital for the purchase of the MBS, ensure that defaults are limited as a results of the margin requirements as the capital takes in more of the losses. Thus, margin requirements partly inhibit risk sharing and ensures mortgage borrowing becomes costly. Increasing the margin requirements leads to less repo loans being granted to the shadow banks and lower securitization. This results in higher interest rate for the mortgages and a reduction in the overall amount of mortgages granted.

3.2.3 Capital requirements

If the capital ratio (CR) is set high enough for it to be a binding constraint, banks would be forced to respond by limiting mortgage offers. According to the Basel rules, risk weights are attached to assets. If the risk weights on mortgages and MBS are different, then banks would take a decision of securitizing more mortgages and benefit from diversification and in doing so shift the risk to the less risk averse investors. So this option has the benefit of ensuring that instead of just reducing intermediation, it does not become part of the banking system at all. Whether the households benefit or not will depend on the decision taken by the bank. Choosing more securitization will result in much less mortgage credit for households than simply reducing the amount of mortgage credit. If the bank reduces

its mortgage lending, purchasers will be unable to have as much properties as they would prefer and sellers will have to keep more of their properties than they would otherwise want to, and this impacts on their consumption. There are competing effects for the banks when the capital requirement is increased. It acts as a cushion against losses but also alters their motivations for securitization.

3.2.4 Liquidity coverage ratios

The liquidity coverage ratio (LCR) gives an indication of the proportion of assets that are liquid (i.e. prices do not move significantly when sold). Riskless assets are considered liquid and the rest illiquid. The LCR is a yardstick the bank uses to reduce fire sale by having liquid funds when needed to pay depositors. By forcing the bank to maintain more liquid assets, the Regulator ensures that fewer mortgages are approved. This is necessary since any effort to have more securitization means more repo lending is required, and consequently will not result in a rise of the LCR for the bank. So regulation via the LCR will have different effects from that of the CR on both the banks and their customers. The imposition of a liquidity requirement during a boom period forces banks to lower their mortgage exposures. This makes a reduction in house price appreciation during the period a possibility. So contrary to capital regulation, liquidity regulation can support the boom. Should the LCR become binding the banks would have to counteract it by having additional securitization which will in turn aggravate the fire sale. Unlike the CR, the calculation of the LCR is not affected by the loss in profits from the forced sale. This crucial difference makes liquidity regulation more procyclical than capital regulation. The central focus of the liquidity regulation is to encourage banks to raise money from their assets without moving prices substantially and so has different effects from that of capital regulation. For instance, stricter capital requirements in boom times will lead to higher levels of securitization but a higher LCR rather lowers the issuance of MBS in that same period. The reason for this is that the repo loans supporting the securitization are themselves illiquid. Therefore, securitization cannot circumvent liquidity rules. A higher LCR rather leads banks to move their portfolio more towards short-term loans and lower their mortgages and repo loans. Thus, the housing bust losses together with their associated fire sales of MBS are reduced, leading to lower defaults on both mortgages and deposits.

3.2.5 Dynamic provisioning

The first four tools described above are all intended to make the fire sale less severe. Thus, they are very effective during times of economic downturn. It is, therefore, important to

have a regulatory tool which changes behavior in the boom times. One such tool is dynamic loan loss provisioning. It forces banks to keep cash on their balance sheets throughout the boom period when the increase in real estate related credit surpasses a particular limit. The importance of dynamic provisioning has been alluded to when it was mentioned in [40] that it could support financial stability in many ways. It encourages banks to price their products taking into account their exposure to risk. It also lowers the procyclicality of bank lending and strengthens the banking systems ahead of an economic downturn. Hence its execution is needed to surmount established accounting and taxation codes. The banking sector is one of the losers from such regulation as their profits reduce during boom periods. Existing home owners are also losers as the value of their properties reduce and their welfare also drops in that same period. So one can conclude that the dynamic provisioning regulation benefits from distributing the problems of regulation quite differently when compared with the other policies.

Three observations were made from the analysis of the five regulatory tools [60]. The first is that entities will respond differently to the different regulatory policies. The second is that capital requirements provide motivations for regulatory arbitrage, by allowing intermediation to be removed from the banks to the shadow bank. Finally, as to whether regulations act as complements or substitutes depends on the particular tools used.

The following conclusions were made:

- There is a considerable benefit from having a formal general equilibrium model that allows the financial system to depend on the shadow banks for funding.
- Combining market incompleteness with higher default costs distort the housing market. The wealthy agents take decisions on their savings taking into account the possibility that there could be default on deposits. With low default penalties for banks, the households assume that risk, and so put less fund into the banking system and rather maintain more funds in the housing market. Thus more houses are supplied in times of boom and so house prices fall which raises welfare for the first time home purchasers.
- Two regulatory policies that can effectively go the opposite way and possibly tame a boom are dynamic provisioning and the LCR tools. The dynamic provisioning tool can slow mortgage credit growth. This may be only effective during a boom and lower the house prices. So the welfare implications differs from the other tools. On the contrary, restricting liquidity restrictions to counteract the effects of the boom takes into account also the lending behaviour of the banks during busts. Banks normally have more liquid funds in the boom period than the bust period. For the LCR to be binding during a

boom, it must be extremely binding during a bust, and so the LCR is potentially very procyclical.

- Considering the complicated interrelationship amid the different agents of the model, none of the regulatory tools will be sufficient alone to overcome the distortions that arise from defaults. The actual combination of tools that does the work well depends on the precise details of the model, but the proposition that different sources of inefficiency require numerous tools, covers all models [82].

3.3 Modelling in general equilibrium

Recently, there has been a variety of general equilibrium (GE) papers that try to address how to model financial stability and financial frictions. Research on these models with incomplete markets have illuminated the complex and important relationship between banks, their customers and the regulators. This interrelationship impacts upon financial stability. In most of the existing literature, dynamic stochastic general equilibrium (DSGE) modelling is used. This class of models makes an effort to justify economic phenomena, including economic growth and business cycles, and the impacts of policies, using econometric models based on applied general equilibrium theory and microeconomic principles. Financial frictions were introduced into the DSGE framework [42, 87, 132]. However, they did not take into account the simultaneous effects of liquidity, agent heterogeneity, money, and default risk. Many of these models consider default modelling as an out-of-equilibrium phenomenon. Put differently, defaults do not occur in equilibrium. Nevertheless, these models have played an important part towards reasonable explanation for development during and after the 2008 GFC. A paper that had originally made some headway in this regard is [93](later published as [94]).

An important element still lacking in mainstream DSGE models is the absence of liquidity constraints faced by agents, as goods are not fully exchangeable. Introducing liquidity constraints to a dynamic framework is critical to gauge the effect of the financial and real shocks. This allows assessing the impact of a liquidity shock in both the short and the medium term. In addition, a dynamic setting enables the parametarization of possible liquidity settings and analyse how shocks affect the economic variables in each situation. This idea has been introduced in models exploring financial stability. In this regard, a GE model that included heterogeneous banks and capital requirements with incomplete markets, money, and default was introduced [125]. This was followed by [63] which included possible capital requirements infringement and its associated penalties. A simplified solution was proposed in [61], where a minimal market structure was introduced. This minimal system initially had three house-

holds, two banks, a central bank and a regulator. They concluded that the framework had the capacity to characterise the UK's financial stability.

The next step was an introduction of an additional (third) bank for the model [62]. This bank could have represented all of the remaining UK banks but only the seven largest banks were covered. Hence, the third bank comprises of the five remaining banks. In all this analysis, two time periods were used. An attempt was made to extend the analysis to an infinite time period [64] but only succeeded with a finite period. It was pointed out that standard dynamic models, with active bank participation, assume that banks maximise their expected discounted profits over an infinite period. In other words, bank managers' behavior may be considered similar to that of shareholders and so may only be interested in banks' expected profits within the expected lifetime of the banks. However, bank managers may only be interested in the expected profits of their banks up to a finite horizon in line with how long they expect to be with the banks. It was then shown that this is the same as the values of the discount factors applicable to the bank managers over a certain finite horizon approach zero. For simplicity, they assume that such a horizon is equal to one period. So, at the end of period t , banks make their optimal decisions on their portfolios to maximise their expected level of profits in the next time period $t + 1$. Such a framework allows GE models with incomplete markets to match time series data of a given country or region. Apart from the the model being used successfully to analyse financial fragility in the UK, it has also been applied in a few emerging countries such as Jamaica, [89], Colombia, [108] and Brazil, [118]. Therefore the model could be applied successfully in both developed and developing nations. However, there is other pioneering literature on bank CGE Models (augmented with asset markets) such as [3, 30, 92] and [119] which provide important insights. A model that puts together microeconomics characteristics of a CGE model and the usual components of a macroeconomic model was built [30] for the economies of Côte d'Ivoire and Morocco. This allowed the social impact of adjustment (which involves macroeconomic measures and the effects on income and poverty which are microeconomics factors) to be estimated. Many studies on how structuralists formulate and apply CGE models in economies in the developing world are covered in [119]. Most relevant to our work is the implementation of a CGE model for Mexico which includes portfolio balances. It allowed capital flight, capital gains or losses on assets and liabilities, the banking system and the public sector accounts to be considered together. Also covered in this book is a model designed for Thailand which is one of the first CGE models to incorporate financial variables, which discussed how monetary policy affects macroeconomic equilibrium in a relatively open economy. The integration of asset markets into standard trade-focused CGE models is discussed in [3]. Starting from a core specification of the real economy, calibrated to data for Zambia (a low-income, commodity-

dependent economy), the full asset market model was built from a simple flow model in the mid-1990s. There are three main differences between the full asset market model and the simple flow model. First, the model includes a detailed specification of the banking sector and the Central Bank that intermediate between households, the public and private sectors. Second, it combines the flow equilibrium constraints of the real model with fully articulated stock constraints, defined by the portfolio choices of all the agents and the monetary authorities. Finally, it introduces an explicit set of policy rules governing the nominal exchange rate and the financing of the government's domestic budget balance. In [92], a small general equilibrium model that has several financial instruments and institutions to study the impacts of capital flow reversal shocks in the South African economy is developed. This model is different from the DSGE models and is more microfounded, consistent, with stock and flow models.

As compared to the work on general equilibrium models, the model used in this study is the classical general equilibrium model modified with additional default and liquidity constraints that also includes the possibility of capital requirements.

3.4 Computable General Equilibrium Model

The CGE model illustrates the actions of all model entities, including consumers and producers, and their interactions within the economy [31]. Model equations are formulated that describe these linkages between the entities and the economy at large. The formulations are composed of endogenous and exogenous sets of variables that estimate the market's general outlook. The model estimates and provides market equilibrium results at prices that equate market demand to supply. Users provide a set of exogenous inputs, and the model outputs the estimates of the equations' endogenous variables. Furthermore, the CGE model's computable reputation is derived from its ability to conduct and evaluate model shocks that affect the economy. For a given change in the exogenous variable, the changes in size are quantified and direction of the endogenous variables are provided. Thus the GCE model estimates the change in endogenous variables while the exogenous variables are varied. The GCE model is general because it references all general aspects of the economy. The model contemporaneously includes and quantifies economic activities such as consumption, investments, taxation and employment statistics.

The GCE model comprises three key entities [77] made up of consumers, markets and producers. Households, individuals and firms are the key consumers of the banking sector CGE model. The banks and other financial institutions make up the producers, and markets are duly represented by the credit, deposit, and interbank markets. Consumers aim to maximise

their utilities whilst the producers aim to maximise their profits. The CGE models are usually used to perform comparative statistics - what will occur if a certain policy is carried out. Some examples include:

- macro-economy – effects of public expenditure cuts,
- agriculture – the impact of trade barriers in agricultural products to a country’s economy,
- tax – the effect of the move from sales tax to value added tax on South Africans and
- financial sector – the impact of banking regulation on the consumers and the economy.

CGE models can be classified according to the way the parameters of the models are derived. The two main methods are ‘calibration’ and “econometric estimation”. With calibration, the parameters of the model are chosen in such a manner that the model can reproduce the data set as an equilibrium solution. The parameters thus generated can then be used to solve the alternative equilibrium associated with any change in the exogenous variables [28]. This practice is known as “counterfactual” or “policy replacement equilibrium”. The parameters are generated given the functional form of the CGE equations to replicate the benchmark data. With the econometric estimation, the parameters are estimated by using a regression technique. The most common estimation techniques are the simultaneous equation method and the single-equation method.

CGE models have been applied in developing countries to assist in formulation of policies in four different ways in [45]. These are measurement, directions of change, evidence to nourish the public debate and for comparative analysis across countries. An evaluation of many macroeconomic models was done [15]. According to the authors, there are some features which make a model desirable for analysing financial stability. These desirable features were presented in a diagram in [108] and is shown in Fig. 3.1. One of the models evaluated was the CGE model used in the financial sector. The model falls under the finite horizon general equilibrium (FHGE) models and it satisfied all the desirable features. According to the authors, the main contribution of the CGE model for the banking sector is that financial fragility occurs naturally in equilibrium, and so can be used to manage and prevent crisis from active policies. Also, as the monetary sector is integrated, the effects from monetary and regulatory policies can be measured together. Its flexibility makes it convenient to respond to precise policy issues and conduct scenario analysis for different risks in the banking industry. Financial stability used for the model is defined as high probability of default and low profitability of a financial institution. Other observations made about the model are as follows:

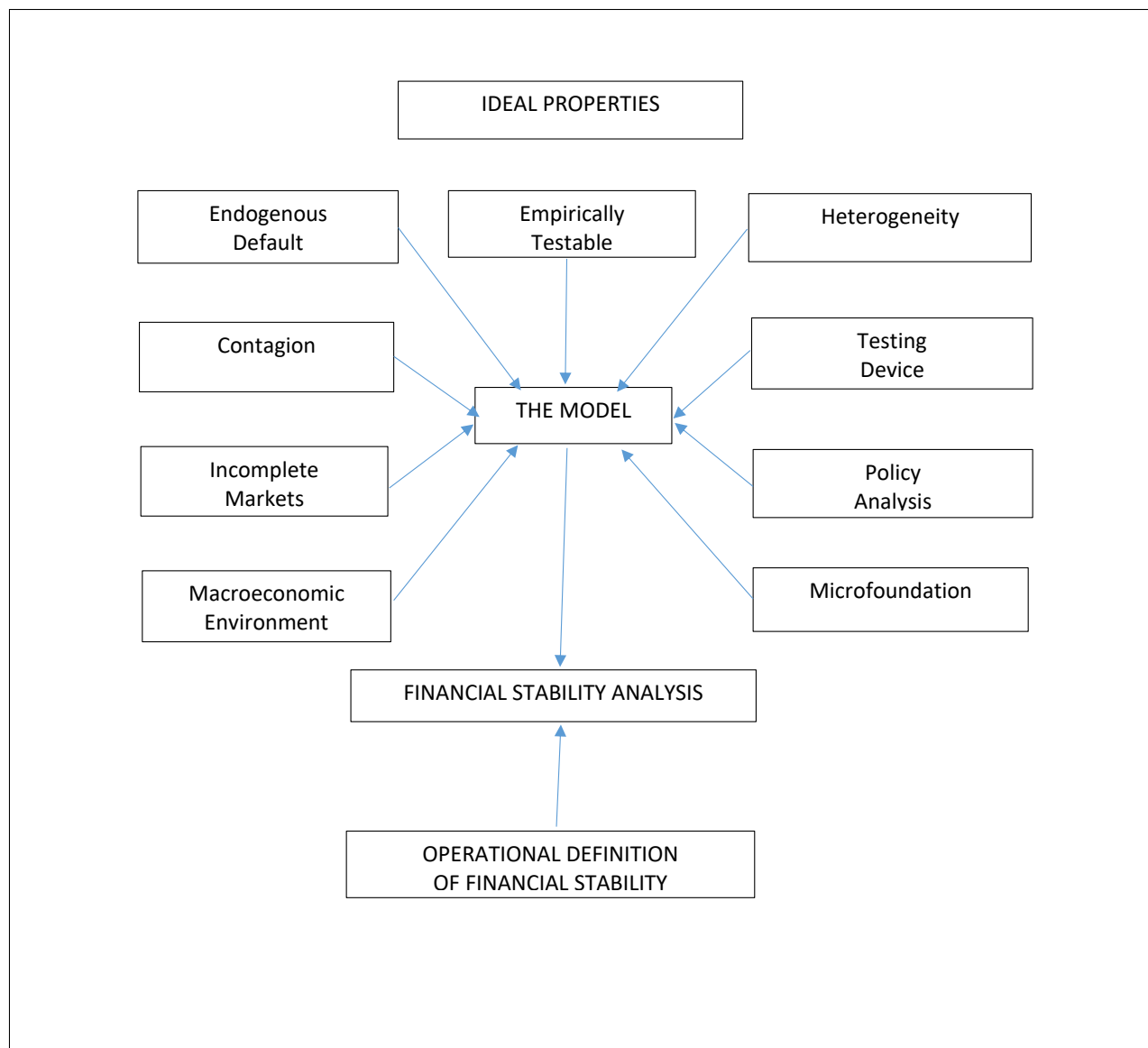


Figure 3.1: The desirable features of a model for analysing financial stability (See [108])

- It is a GE model with no production. It has endogenous default and active heterogeneous banks that must satisfy balance sheet regulatory requirements.
- The model is dynamic and thus allows the assessment of the impact of capital constraints on the intertemporal decision taking by banks.
- The model clearly specifies the definition of financial instability, and makes it possible for a continuum of contingencies. One can therefore analyse the impact of policy measures undertaken prior to the occurrence of financial crisis.
- A change in monetary policy affects both prices and quantities. This breaks the classical

dichotomy. The Modigliani-Miller theorem does not hold in the model.

- The model allows comparative static exercises to analyse the effect of economic policy shocks.
- It is a model of an exchange economy. It is impossible to analyse the relationship between financial instability and economic growth.
- The flexibility of the model allows other aspects related to the relationship between credit markets and the real economy, such as borrowers' collateral or banks' provisioning policy to be investigated.
- Its computational difficulty and calibration in a way limits its usefulness.

These properties make the computable general equilibrium model a powerful tool for managing crisis prevention which could be very useful for regulators in the banking sector. Thus CGE models may be applied to assess the effect of changes in banking regulation on systemic risk and financial fragility.

3.4.1 CGE model applications in South Africa

In South Africa, even though CGE modelling has not been used extensively (if at all) in the financial sector, they have been used in several applications in other areas. These include health policies, social security and public finance, and labour and trade policies [123]. This section concentrates on the areas where the CGE model has been applied in South Africa. In [11], a CGE model is used to determine the effect of HIV/AIDS on the South African economy. An economy-wide simulation model which allows features of the economy and key impact channels of the HIV/AIDS epidemic was built. Two scenarios were considered. One has no AIDS (i.e. the economy will continue to grow as has been in the past assuming there was no AIDS) and the other with the AIDS features. Comparing the two scenarios, they concluded that the effect of HIV/AIDS could be substantial. Using a CGE model allowed relations between the effects of the AIDS epidemic and the economic structure together with the policy situation to be captured.

A standard International Food Policy Research Institute (IFPRI) CGE model is constructed and tested for South Africa [124]. The social accounting matrix (SAM) which was used in previous models was updated with the the supply-use tables produced by Statistics South Africa. SAM is an all-inclusive and economy-wide database recording data about all transactions between economic agents in a particular economy for a specified period of time [34].

It is a matrix of national accounts with the rows representing receipts and the columns expenditure. The CGE model was applied to stimulate economy-wide effect of a range of issues which included the impact of increased government spending and expansionary fiscal policy. One of the results was that an expansionary fiscal policy appears to boost growth.

The CGE model was used to determine the effect of the implementation of the basic income grant on the economy [122]. The model allowed not only for the effect of the microeconomic benefit of the grant to addressing the prevailing poverty but also for the impact that such a grant has on the macroeconomy of the country and the government's budget by considering different financing scenarios. It suggested that consideration should be given to "targeted" grant instead of universal coverage. It concluded that the decision for South Africa to become the first African welfare state might not necessarily depend on the possibility of the grant alleviating poverty but also the financial and macroeconomic impact on the country. In [39], the CGE model was used to determine how different labour policies could affect employment in future. It investigated the economy-wide connections between formal and the informal sectors of the economy. Three different policies were considered and the conclusions were as follows: trade liberalization reduces national employment, wage subsidies on low-skilled formal workers reduce unemployment and finally unrestricted cash transfers encourage demand for informally produced products.

After the 2008 GFC, South Africa experienced some economic hardships including a fall in its exports and prices of key commodities to the economy which made the country enter into a recession. A CGE model was used to assess the impact of the 2008 GFC on South Africa in [35]. It analysed three scenarios which are a fall in export demand, a decline in world prices and a reduction in foreign investment. The CGE model allowed the impact of the three scenarios to be modeled together as well as individually. The result indicated that in each of the scenarios, GDP, investments and government deficit would worsen in both the short term and the long term and that the decline to the world prices had the most significant effect in making South Africa enter into recession.

Generally, there is a positive link between infrastructure development and economic growth. The South African government has embarked on massive infrastructure development in Limpopo, one of the poorest province in South Africa, to create employment for the residents of the province and boost economic growth. An infrastructural project in the province is to build a railway line from the province to the Richards Bay harbour. In [98], a CGE model was applied to determine the effect of the proposed railway line on economic growth in the province. The model used is the South African TERM (SA-TERM) model. TERM (The Enormous Regional Model) is a "bottom-up" CGE model which considers each region as an economy on its own. The key feature of TERM is its ability to deal with many of regions and

sectors. The South African model is a regional CGE model of all the nine provinces in South Africa. Each province is modeled individually. However, the model also allows provinces to be modeled collectively as a group so that the interactions between different provinces could be determined. Two sets of simulations were done. The first looked at the short term where large funds were invested in the construction of the railway line thereby creating employment for the people of the province. The second was the long term benefits of the railway line being operational in which case firms and individuals benefit from lower cost of transportation and improving their productivity in the province. It concluded that the construction of the railway line will have greater economic growth in the province through increased GDP and creation of employment.

South Africa has a problem with illegal immigrants, usually unskilled workers, entering the country with skilled workers leaving the country in large numbers. This is negative for the economy. A dynamic CGE model was used to determine the effect of skilled emigration and the consequent loss in primary factor productivity on the South African economy [27]. Even though many econometric and statistical models can be used to determine the effect of the immigration/emigration, the use of an economy wide CGE model allows the full impact of migration to be measured. This is because with CGE models, full details of how the different sectors of the economy operate are incorporated and linked together in the model. The result indicated that with the prevailing skilled emigration, the South African GDP would reduce by about 3% over an eight-year period. This supported the idea that skilled emigration, especially in the case where it is permanent, reduces economic growth and welfare in the long term. CGE models could also be applied to isolate the effect of immigration or emigration on the economy.

A CGE model was used to determine how tax policies could be used to reduce carbon emissions in a distorted economy [44]. South Africa being the largest economy in Africa was used for the purpose. Alternative taxes, such as those on energy commodities, or on pollution-intensive commodities, to a pure carbon tax were compared to capture the administrative and technical constraints facing many developing countries. An extensive CGE model on the South African economy allowed some of the distortions to be incorporated. The result was that the carbon taxation cost could be insignificant if distortions from the labour market could be removed and concluded that the welfare costs of taxing carbon emissions in developing nations is rather dependent on other distortions than the country's own carbon emissions.

A dynamic CGE model was used to determine the effect of an increase in Value Added Tax (VAT) on the South African economy [50]. Five different simulations were considered starting from 1% (with 1% increments) to 5%. The National Treasury's model (t-SAGE) was

used. The parameters were calibrated using observed data from the SAM for the year 2010. The model is built such that evaluation of structural changes of trade on macroeconomic variables, the effect of contractionary fiscal policy on the economy, and the outline of growth strategy for the long term can be considered. It also allows both corporate and personal income taxes to be characterised and captures three indirect taxes namely an activity tax, customs duties and a general sales tax. The result showed that if lower income households benefited from the higher revenue received by government, possibly through higher social grants, then they would not be negatively affected by the increase in VAT. In addition GDP increased, indicating that the economy benefited from consumption and investment which resulted from the higher revenue received from the increase in VAT. An article similar to [50] is [91]. In [91], the CGE model was used to determine the impact of fiscal policy on the South African economy. The results indicated that an expansionary fiscal policy would have a positive impact on GDP in the short term but the debt to GDP ratio would be greater. This gives a valuable lesson for South Africa and other developing countries which are focusing on using expansionary fiscal policy for economic growth and job creation. Other areas where the CGE model has been used in South Africa include examining the economy-wide effects of selected macro and water-related policy reforms on the economy [71] and modelling the possible effect of carbon tax on the South African economy [129].

3.4.2 Other financial sector applications of CGE models

Consideration is now given to the applications of the CGE model in the financial sector of the rest of the world. In [63, 89, 108], the model is used to analyse financial fragility. In [63] the CGE model is used to analyse financial fragility by considering three households, two banks and two time periods with three possible states in each period. It concluded that monetary policy has ambiguous welfare and profit effects depending on the state of the economic cycle and that even though the effect on borrowers is normally positive, with investors, their portfolio and the applicable regulatory regimes determine the effects.

A CGE model was used to evaluate financial stability of the banking sector in Jamaica [89]. The model could be used to evaluate financial fragility because it is very flexible and allows multiple contagion channels. It performed satisfactorily in predicting medium-term trends which are very important in accessing financial stability. It also confirmed that the existence of monetary equilibrium with banks and default (MEBD) has two significant implications for evaluating financial stability. One is that agents may choose in equilibrium an acceptable level of default and the other is financially fragile regimes are not incompatible with the existence of orderly markets under certain conditions. The model was used as a tool to assess the financial stability of the Colombian [108] banking system. Two distinct periods

were considered. One was during a recession and the other during the recovery period. It performed satisfactory in predicting short-run trends (up to two years). It was also able to represent some of the unique situation of the Colombian financial system at various stages of the business cycle.

A CGE model [12] was used to show that whenever a shock to the economy induces financial fragility, GDP decreases. Financial fragility is defined as an increase in aggregate default and a decrease in banks' profitability. By considering two simulations of a tightening of monetary policy where in one, banks are subject to CAR and another where banks are not subject to CAR, they showed that in both scenarios, banks profitability improves. However, the change in bank profitability was smaller for the case where the banks were not constrained by CAR. This is due to the fact that banks are now less concerned in violating CAR and so have less motivation to increase capital, and therefore profits. Also GDP falls slightly more as a result of the lower bank equity. They then concluded that an adverse shock to money supply triggers an increase in the level of default in the economy but at least when CARs are in place, banks' profitability increases and therefore the economy is not more financially fragile. In [107], a 2-country CGE model was used to determine the effect of monetary and fiscal expansion on the economy of the two countries. One country called the home country was subjected to monetary and fiscal expansion shocks but no shocks to the other one called the foreign country. The currency of the home country depreciated against the foreign country's currency in response to each of the shocks. With the case of the monetary expansion, there was an increase in consumption of the home country relative to the foreign country. The shock also led to a sharp increase in the output of the home country relative to the foreign one in the short run, while in the long run output increases in the foreign country and decreases in the home country. For the fiscal expansion, there was a fall of private consumption in the home country relative to the foreign country and an increase in the output of the home country relative to the foreign one in the short run as well as in the long run. Finally in response to both shocks real interest rate fell quite substantially.

The CGE model was used for forecasting real-time inputs such as output growth and inflation for policymakers [10]. The model performed well in predicting the output growth and the result was comparable to that of the Greenbook even though both of them performed worse than the atheoretic Vector Autoregression (VAR) forecast. With regard to inflation, adjustments were needed to be made in order to make it comparable to that of both the Greenbook and atheoretic VAR forecasts. This adjustment even though it is not part of the theoretical structure of the CGE model was necessary as there was quite a substantial variation in interest rate in the period that the forecasting was done. Therefore a moving-average interest rate adjustment improved the forecast. It is therefore important to add that the

model on its own does not empirically generate consistent real interest rates and inflation. A standard general equilibrium model is extended to cover defaults and punishment [48]. The punishment for default needs to be optimal. It must be low enough for some agents to default even though they have the means to honour their obligations but not too low for everyone to default. This then reduces adverse selection and/or moral hazards. A model was built [126] that combined the properties of models with contagion occurring among banks, with those in which individual banks take risks which could be diversified and observed that even when banks' portfolio are such that their returns are uncorrelated, contagion comes through the interbank market. This confirms that the risks faced by an institution are not only the risks internal to that institution but also risks from other institutions. Another important result from the model is that sequential contagion is caused via the interbank market channel even when banks specialize in their portfolio composition and their returns are uncorrelated. Finally, whenever banks incorporate a relative performance criterion in their maximization problem then limited participation emerges naturally as an equilibrium phenomenon within the model. Limited participation is the situation where banks specialize in lending to specific consumers. This result justifies an assumption (private sector agents are constrained to deal with specific banks) used in the main model for the study. A CGE economy that models explicitly the banking sector [47] is developed. The banks act as intermediaries between households and between the household sector and the government sector. In other words households borrow from the banks for purchase of their homes and saves with the banks for future uncertainties and retirement. The banks use part of the savings from the households to purchase government bonds. The findings indicate that a policy that results in a procyclical real rate of return on government bonds does not stabilize the economy. Neither does it affect welfare significantly. Also the welfare benefits of policies that increases after tax real return on household savings are very large.

3.5 Optimisation

The CGE model involves optimisation problems. For the banking sector model, it maximises the profits of the banks subject to some constraints. So this section discusses the optimisation problem and how it applies to the model.

In economics, decision makers may be considered “rational”. In other words, each decision-maker is believed, chooses an outcome most preferred among all possible outcomes. The decision-maker's preference is usually represented by a payoff function or a utility function. This makes it possible to express the problem as choosing an action, among those feasible, that maximises or minimises the value of this function. This is equivalent to optimizing an

objective function subject to some constraints in constrained optimisation problems. Normal optimisation techniques may be difficult to apply in the case of constrained optimisation involving many variables.

One method which is used in such cases is the Lagrangean multiplier method. The Lagrangean multiplier is a method used in optimisation problems to find maximum and minimum values of a function subject to equality constraints. The principle behind it is to convert a constrained problem into a form where derivatives can be applied just as in the unconstrained case. The relationship between the derivatives of the function and the constraints leads to a new formulation of the original problem, known as the Lagrangian function. Its advantage is that it allows the optimisation to be solved without explicit parameterisation in terms of the constraints. The Lagrangean multiplier method unfortunately is only able to handle optimisation problems where the constraints are in the form of equality. With the banking sector CGE model some of the constraints are in the form of inequalities. This type of constraint is handled by the application of the Kuhn-Tucker conditions (KTC). The KTC is therefore an extension of the Lagrangean multiplier method and can be used to solve optimisation problems with some or all of the constraints being in the form of inequalities. Thus the KTC is applicable to the banking sector CGE model.

The discussion of the optimisation problem and how it is applied to obtain equations necessary to solve for the endogenous variables of the model are discussed in Appendix A.

3.6 Conclusion

The chapter deals with a general equilibrium analysis which considers all markets together such that a shock in a particular market affects other markets. Starting from the function of some complicated economic system dealing with a number of independent economic units that firmed the idea of general equilibrium modelling, a detailed discussion leads to a decision on the model being used for the study. This model is the classical general equilibrium model modified with additional default and liquidity constraints that also includes the possibility of capital requirements. Financial regulation in general equilibrium is discussed. This is followed by modelling in general equilibrium and then the CGE model itself. The applications of the CGE model in South Africa and elsewhere are discussed. The South African applications are mostly in the non-financial sector as not much work is done in the financial sector with CGE models in the country. CGE applications in the financial sector in other countries were mostly on financial fragility. The last section of the chapter is dedicated to discussing optimisation problem, the technique used by the CGE model. The next chapter deals with the specific CGE model used for this study.

Chapter 4

The Banking Sector CGE Model

4.1 Introduction

The model used in this thesis is an extension of the Goodhart, Sunirand and Tsomocos model [61]. The model, as illustrated in [12, 62, 63, 64, 89, 118] consists of three heterogeneous banks, four private sector agents, a central bank and a regulator. The banks are denoted by γ , δ , and τ and the agents by α , β , θ , and ϕ . The three banks can represent many groupings of banks. In [62, 63, 64], the chosen banks are the seven largest banks in the UK. Two of the banks were taken as γ and δ and the rest were combined as τ . In Jamaica [89], the banks were categorized into three main groupings - commercial banks, merchant banks and building societies. They were grouped as public, private and foreign banks in Brazil [118]. Hence in principle, the banks can refer to any banking system of any country or region. In the case of South Africa, all the major banks are represented in the model. In a case where a particular bank needs to be analysed, that bank should be taken as one of the three heterogeneous banks. Banks can be strategically grouped to assist in focusing the analysis. For example, in Colombia [108], banks were grouped into mortgage banks, domestic banks and foreign banks. Such grouping is essential if one is interested in analysing the crisis in the real estate sector. However, in South Africa, the effect of the 2008 financial crisis was muted due to the aforementioned reasons and so it is not deemed necessary to have mortgage banks as a separate group. Nonetheless, almost all the banks in South Africa have mortgage loans in their balance sheet and there are no banks that exclusively specialize in mortgage lending. In this study, consideration is given to the largest six banks by assets which is in line with the analysis done in the UK. Two of the banks are taken as heterogeneous banks and the rest of the banks (four in total) are combined as the last of the three heterogeneous banks. The private sector agents are individuals/households or firms who deposit funds or borrow from the banks. For simplicity, each of the first three agents are constrained to deal with a

particular bank and the fourth agent deals with any of the banks. This means agent α can only borrow from bank γ , agent β from bank δ , and agent θ from banks τ . Individuals/firms being attached to a particular bank may be unrealistic as individuals or firms can borrow from any bank. However, a provision of microfoundations to this limited participation assumption is achieved by showing that whenever banks incorporate a relative performance criterion in their maximization problem, limited participation emerges naturally as an equilibrium phenomenon within the model [23]. Limited participation is the specialization of banks lending to specific consumer classes. The remaining agent, ϕ supplies funds to any of the banks.

There is also the interbank market where the Central Bank conducts open market operations (OMOs). Individual banks can borrow from each other, where a bank in deficit can borrow from a bank with a surplus or from the Central Bank. The model is presented in Fig. 4.1 This

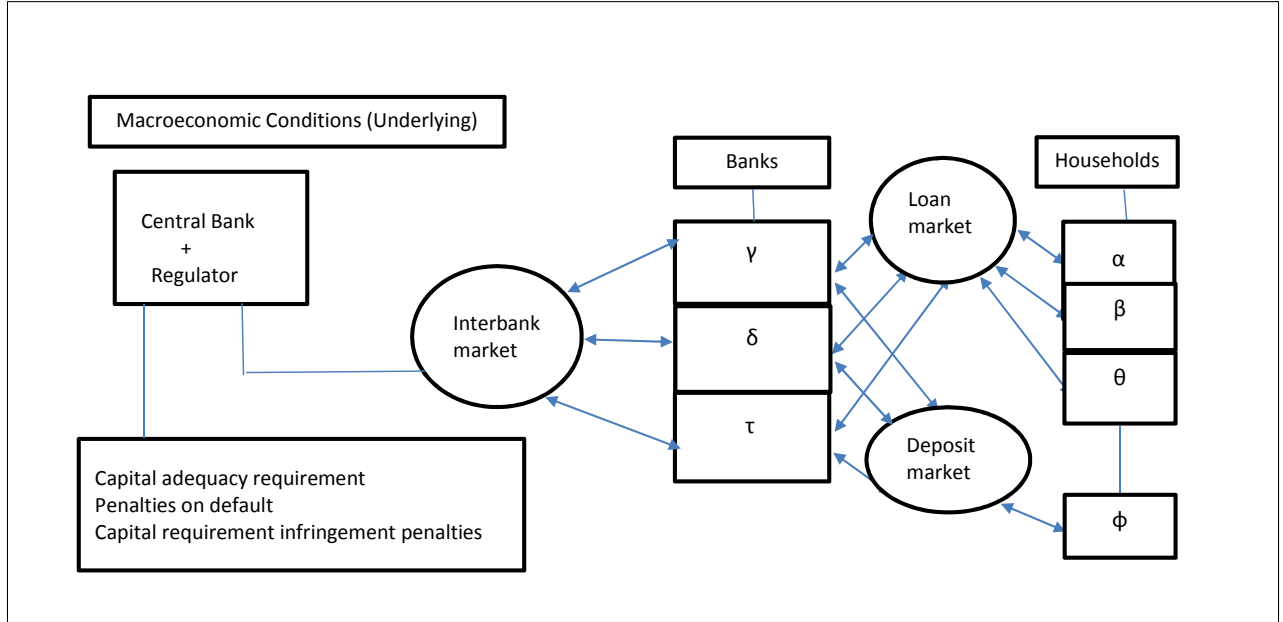


Figure 4.1: The structure of the model (See [89])

representation of the structure of the model [89] indicates that the actions of the Central Bank and/or the Regulator affect the bank indirectly through the interbank markets. It needs to be noted that the actions of the Central Bank affect the banks directly as well, for example, through the imposition of the penalties. In addition ϕ represents the aggregate of all the depositors. Hence, the deposits from the private sector agents to their nature-selected banks are included in ϕ . A structure of the model that takes into account the direct interactions between the entities as outlined in [125] is shown in Fig 4.2.

The time horizon can be infinite, with $t \in T = \{1, \dots, \infty\}$ as in [12, 64, 89] or finite, e.g. two time periods, $t \in T = \{1, 2\}$ as in [33, 62]. In the case of two time periods, it may only

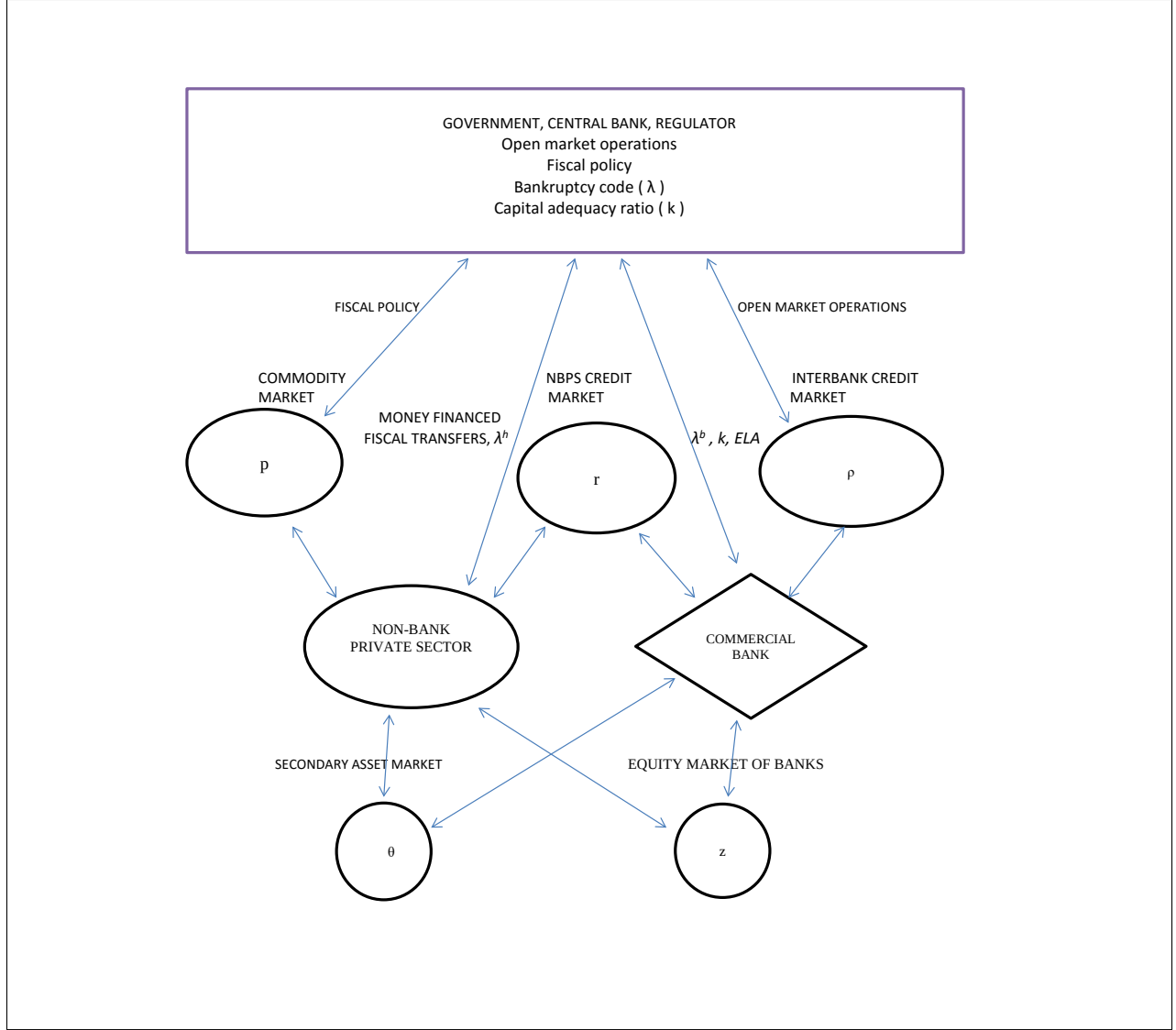


Figure 4.2: The structure of the model that considers Central Bank's action affecting banks directly (see [125])

be used to calibrate features of the country's banking sector at a particular point in time and offer policy insight via sensitivity analysis with respect to exogenous parameters. However, an infinite horizon model may be used to calibrate time series of certain variables and consequently be employed by forecasters. One hastens to add that the computational complexity of the period increases considerably. Hence the modeler needs to simplify the banking sector and, therefore, may potentially miss important contagious effects among heterogeneous banks. It is assumed there exist two possible future states. One state is the good/normal state and the other is the bad/crisis state of nature. The good state is denoted by i and its corresponding probability p and the bad state by ii and its probability $1 - p$. These probabilities are assumed to be time invariant and common knowledge by the economic agents.

They possess Von Neumann-Morgenstern preferences and the time structure of the model is presented in Fig. 4.3.

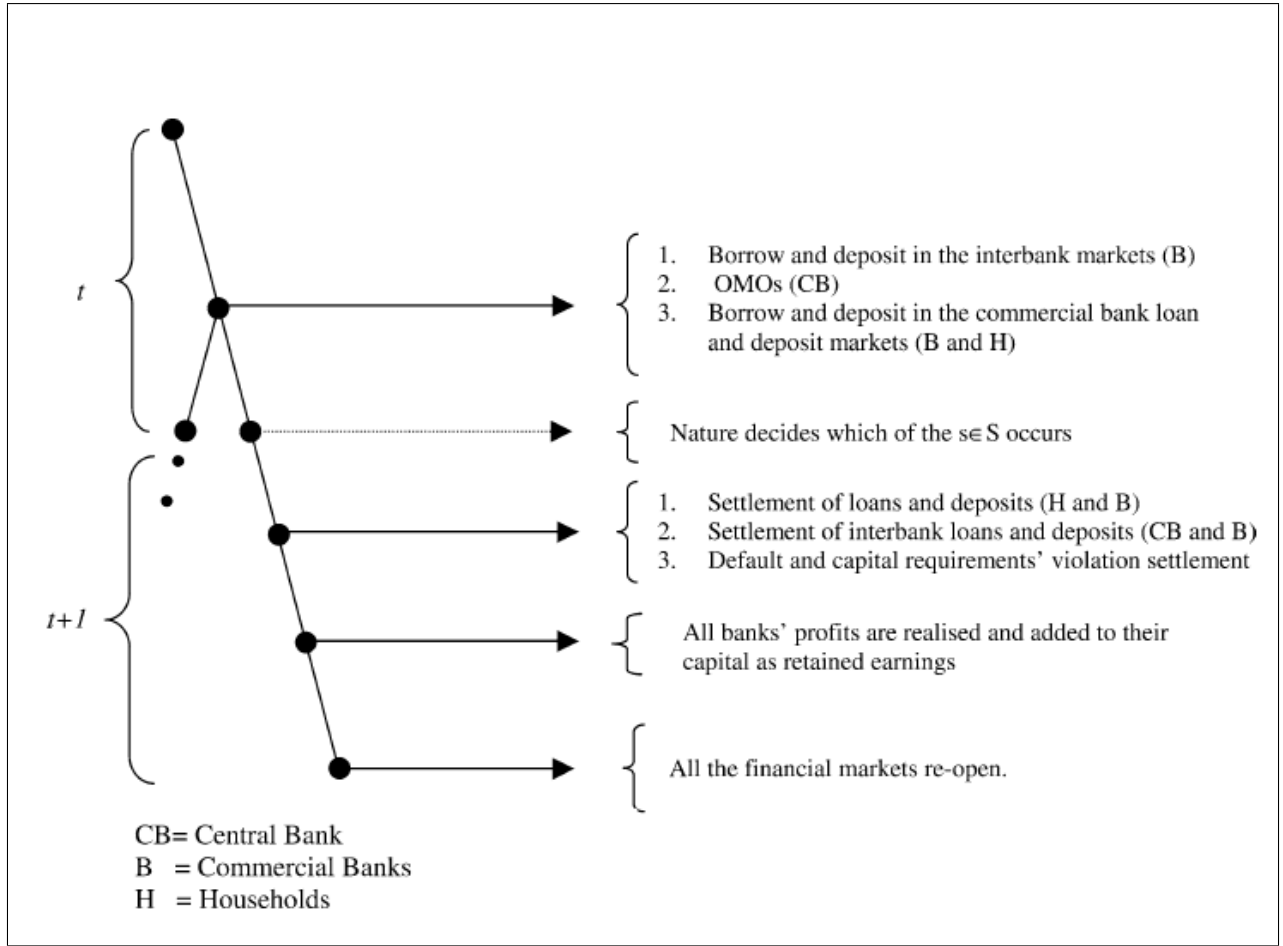


Figure 4.3: Time structure of the model

Once the markets open at the end of period t or beginning of period $t + 1$, each bank decides how much to borrow or lend taking into account the fact that each of the two states could occur during period $t + 1$. The Central Bank also conducts OMOs in the interbank market during this period. All contracts are settled allowing for penalties for any defaults or capital infringements.

The balance sheet structure for a bank is given in Table 4.1. Capital is carried over, i.e. for each period, capital is calculated as capital from the previous period plus retained earnings, except for the initial period where the bank is given some initial capital to start operations. This process is repeated indefinitely for the case where the period is infinite. Capital is thus one of the variables that is both exogenous and endogenous in the model. The initial capital is exogenous as banks are given initial capital to start their operations. However, subsequent capital becomes endogenous as its value is determined by the model.

Table 4.1: Balance sheet structure of the bank

Assets	Liabilities
Loans to agent	Deposit from ϕ
Interbank deposits	Interbank borrowing
Market book	Equity
	Others

4.2 The Banking Sector

Each bank is unique in terms of the size of their capital and business portfolio. The level of risk taken by each bank is also different and as such they expect different returns. The business environment is assumed to be highly competitive and so each bank chooses its interest rate when making portfolio decisions in order to maximise its profits. As mentioned earlier, the six largest South African banks by assets are used for the analysis. Two of the banks are taken individually and the rest are combined as the third homogenous bank in the model.

Banks are allowed to default on their deposits and interbank borrowings but with the provision that they will be subjected to the default penalties set by the Regulator. Default is defined as the inability of the institution to honour its financial contractual obligations. However, default could be strategic or due to ill fortune and lenders are assumed to be unable to distinguish between the two. Strategic default occurs when institutions choose not to honour their obligations even though they have the means to do so, while ill fortune default occurs when a bank is genuinely unable to honour its obligations as a result of not having adequate funds.

The default rate is akin to the probability of the bank shutting down¹. If banks are not able to repay their loans fully when due, they are forced to shut down. The default rate for deposits and that for the interbank market for each bank are assumed to be the same. In other words, banks pay their creditors *pro rata*. Hence, banks cannot choose to pay their depositors and decide not to pay their fellow banks and/or the Central Bank. In the model, banks are allowed to infringe on their capital adequacy requirements. However, banks are punished for each infringement by the regulator imposing a capital requirements infringement penalty on them. In reality, most banks capital is above the minimum regulatory capital requirements. This is the case because banks maintain excess capital in accordance to their risk management models, and for signalling purposes in the capital markets. Therefore, the banks are subjected to reputation costs (i.e. capital requirements penalties) whenever they fall below the “market determined capital requirements threshold”. The size of the penalty is

¹See, Tsomocos and Zicchino [127] where the isomorphism between repayment rates and probability of default is discussed.

proportional to the deviations from the “market determined capital requirements threshold”. With this assumption, corner equilibria is ruled out and therefore one could focus the analysis entirely on well-defined interior solutions whereby banks violate their enhanced capital requirements. It also assumes that penalties are linear as capital declines from its ideal level. The time horizon over which banks maximise their expected profit is taken as one year. There are only two states (the good state and the bad state) and so the expectation is taken over only these two states. The private sector agents optimisation of their utility is not explicitly modeled as it is extremely difficult to obtain data such as amounts borrowed by individual households. As a result, reduced form equations are used.

4.2.1 Banks optimisation problem

Each bank maximises its expected payoff at the end of period t or beginning of period $t + 1$. The expected payoff of the bank is a quadratic function of its expected profitability in the next period less the unbudgeted penalties it may suffer for defaulting on the deposit and interbank markets. Then there is also the capital infringement penalty which is a linear function of the capital requirements infringement. The expectation is taken over the two possible states in $t + 1$. The optimisation problem of bank b in period t is

$$\begin{aligned} \bar{m}_t^b, d_t^b, \mu_t^b, \mu_{d,t}^b, v_{t+1,s} E_t(\Pi_{t+1}^b) = & \text{Max} \left[\sum_{s \in S} p_s [\pi_{t+1,s}^b - c_s^b (\pi_{t+1,s}^b)^2] \right. \\ & \left. - \sum_{s \in S} p_s [\lambda_{ks}^b \max(0, \bar{k}_{t+1,s}^b - k_{t+1,s}^b) + \lambda_s^b (\mu_t^b - v_{t+1,s}^b \mu_t^b) + \lambda_s^b (\mu_{d,t}^b - v_{t+1,s}^b \mu_{d,t}^b)] \right], \quad (4.1) \end{aligned}$$

(i.e. maximum expected payoff = expected profitability — capital infringement penalty — penalty on default of interbank obligations — penalty on default on deposits). Equation (4.1) is subject to the following two conditions:

$$\bar{m}_t^b + d_t^b + A_t^b = \frac{\mu_t^b}{(1 + \rho_t)} + \frac{\mu_{d,t}^b}{(1 + r_{d,t}^b)} + e_t^b + O_t^b, \quad (4.2)$$

(i.e. Assets of the bank (loans to agents, interbank lending, and investments) should be the same as the liabilities of the bank (interbank borrowing, deposit, equity and residual). This is the usual balance sheet constraint for the bank), and

$$\begin{aligned} (1 + \rho_t) v_{t+1,s}^b \mu_t^b + (1 + r_{d,t}^b) v_{t+1,s}^b \mu_{d,t}^b + e_t^b + O_t^b \\ \leq v_{t+1,s}^b (1 + r_t^b) \bar{m}_t^b + (1 + r_t^A) A_t^b + \check{R}_{t+1,s} d_t^b (1 + \rho_t), s \in S, \quad (4.3) \end{aligned}$$

(i.e. money paid on liabilities must be less or equal to money received from assets. Banks will only continue to do business if they expect to make profit in the future or in the next time period). Profit is defined as

$$\pi_{t+1,s}^b = v_{t+1,s}^{h^b}(1 + r_t^b)\bar{m}_t^b + (1 + r_t^A)A_t^b + \check{R}_{t+1,s}d_t^b(1 + \rho_t) - ((1 + \rho_t)v_{t+1,s}^b\mu_t^b + (1 + r_{d,t}^b)v_{t+1,s}^b\mu_{d,t}^b + e_t^b + O_t^b), \quad (4.4)$$

(i.e. profit = money received from assets - money paid on liabilities).

The capital at period $t + 1$ is given by

$$e_{t+1,s}^b = e_t^b + \pi_{t+1,s}^b, \quad (4.5)$$

(i.e. capital at period $t + 1$ = capital at period t + profit earned).

The capital adequacy ratio is

$$k_{t+1,s}^b = \frac{e_{t+1,s}^b}{\hat{\omega}v_{t+1,s}^{h^b}(1 + r_t^b)\bar{m}_t^b + \omega\check{R}_{t+1,s}d_t^b(1 + \rho_t) + \check{\omega}(1 + r_t^A)A_t^b}, \quad (4.6)$$

(i.e. capital adequacy ratio equals the ratio of capital to the risk-weighted assets), and

p_s = probability that state $s \in S$ will occur,

c_s^b = coefficient of risk aversion in the utility function of bank $b \in B$,

λ_{ks}^b = capital requirements violation penalty imposed on bank $b \in B$ in state $s \in S$,

$\bar{k}_{t+1,s}^b$ = capital adequacy requirements for bank $b \in B$ in state $s \in S$,

λ_s^b = default penalties on bank $b \in B$ in state $s \in S$,

μ_t^b = amount of money that bank b owes in the interbank market at time t ,

$\mu_{d,t}^b$ = amount of money that bank b owes in the deposit market at time t ,

$v_{t+1,s}^b$ = repayment rate of bank b to all its creditors in state s in the period $t + 1$,

$\bar{m}_t^b$ = amount of credit that bank b offers in the loan market at time t ,

d_t^b = bank b 's interbank lending at time t ,

A_t^b = the value of market book held by bank $b \in B$ at time t ,

e_t^b = capital held by bank b in state s at time t ,

O_t^b = the other items in the balance sheet of bank $b \in B$ at time t ,

r_t^b = lending rate offered by bank $b \in B$ at time t ,

$r_{d,t}^b$ = deposit rate offered by bank $b \in B$ at time t ,

ρ_t = interbank rate at time t ,

r_t^A = rate of return on market book, A , at time t ,

$v_{t+1,s}^{h^b}$ = repayment rate of agent h to his nature-selected bank b in the consumer loan

market at time $t + 1$,

$\tilde{R}_{t+1,s}$ = repayment rate by banks from their interbank lending,

$\hat{\omega}$ = risk weight on consumer loans,

$\tilde{\omega}$ = risk weight on market book, and

ω = risk weight on the interbank lending.

4.3 Private agent sector

In each period, each of the three households that are assigned to a specific bank demands loans from that particular bank. Each household chooses their default rates on their loans. The other agent, ϕ , who is allowed to deal with all the banks, supplies deposits to the various banks. The actual individual information for the agents such as the size of the loans and deposits for each household are not readily available. As a result, the optimisation problem of households is not explicitly modeled. The maximization problems are expressed in reduced form equations.

4.3.1 Household borrowers demand for loans

As the agents are restricted to particular banks in which they could borrow from, each agent's demand for loan will be negatively correlated to the lending rate being offered by its nature-selected bank. In addition, as GDP improves the demand for loan increases. Therefore the demand for loan will also depend on the GDP of the next time period. A linear trend is included to take into account of the fact that each household's demand for loan also depends on the time period. So in this case the trend value is 0 in the initial period (2016), 1 in 2017, 2 in 2018 and so on. Thus the reduced form equation is of the form

$$\ln(\mu_t^{h^b}) = a_{h^b,1} + a_{h^b,2}trend + a_{h^b,3} \ln[p(GDP)_{t+1,i} + (1-p)(GDP)_{t+1,ii}] + a_{h^b,4}r_t^b, \quad (4.7)$$

where $\mu_t^{h^b}$ = amount of money that agent $h^b \in H^b$ chooses to owe in the loan market of bank $b \in B$ in period t , $GDP_{t+1,s}$ = Gross Domestic Product in period $t + 1$ of state $s \in S$, r_t^b = lending rate offered by bank b , $a_{h^b,1}$, $a_{h^b,2}$, $a_{h^b,3}$, and $a_{h^b,4}$ are the coefficients or the elasticities of the model.

4.3.2 Supply of deposits

Unlike the loan markets, the limited participation assumption does not apply in the deposit markets. Thus, the fourth agent θ is not restricted on which bank to supply the deposits.

Therefore the supply of deposit for bank b depends on the deposit rate that the bank is offering as well as the deposit rate of the other banks. Banks are allowed to default on their obligations in the model. Therefore the expected rate of return on the deposit needs to be adjusted for the corresponding default rate of the banks. Again, as GDP improves it is expected that agent θ will supply more deposits. Thus the deposit supply is positively correlated with future GDP. Hence the reduced form equation for deposit supply is of the form

$$\ln(d_{b,t}^\theta) = z_{b,1} + z_{b,2} \ln[p(GDP)_{t+1,i} + (1-p)(GDP)_{t+1,ii}] + z_{b,3} [r_{d,t}^b(pv_{t+1,i}^b + (1-p)v_{t+1,ii}^b)] + z_{b,4} \sum_{\hat{b} \neq b \in B} [r_{d,t}^{\hat{b}}(pv_{t+1,i}^{\hat{b}} + (1-p)v_{t+1,ii}^{\hat{b}})], \quad (4.8)$$

where $d_{b,t}^\theta$ = amount of money that agent θ chooses to deposit with bank $b \in B$ in period t , $r_{d,t}^b$ = interest rate offered on deposit by bank b in the period t and $r_{d,t}^{\hat{b}}$ = competitor interest rate on deposits, $v_{t+1,i}^b$ = repayment rate of bank b in $t+1, s$ and $v_{t+1,ii}^{\hat{b}}$ is the repayment rate of bank $\hat{b}$'s competitors, $z_{b,1}$, $z_{b,2}$, $z_{b,3}$, and $z_{b,4}$ are the coefficients or elasticities of the model.

4.3.3 Households loans repayment rates

The repayment rates of each household to the nature-selected bank at period $t+1$ for each possible state is positively correlated to the corresponding GDP. The default rate for every household increases with a fall in the overall credit supply. Therefore the repayment rate of the households also depend on the combined credit supply in the previous period. Hence the reduced form equation of the repayment rates of each household is of the form

$$\ln(v_{t+1,s}^{h^b}) = g_{h^b,s,1} + g_{h^b,s,2} \ln(GDP_{t+1,s}) + g_{h^b,s,3} [\ln(\bar{m}_t^\gamma) + \ln(\bar{m}_t^\delta) + \ln(\bar{m}_t^\tau)], \quad (4.9)$$

where $v_{t+1,s}^{h^b}$ is the repayment rate of household h^b at $t+1$ to the bank b if state s occurs and $\bar{m}_t^b$ is the amount of credit that bank b develops in period t , and $g_{h^b,s,1}$, $g_{h^b,s,2}$, and $g_{h^b,s,3}$ are the coefficients or the elasticities of the model.

4.4 Central Bank and/or Regulator

The Central Bank and the Regulator could be two different entities. However, in some cases the Central Bank is also the Regulator [89]. This is the case in South Africa where the Central Bank is the SARB and also the Regulator for the banking sector. In such a case, the Central Bank is responsible for both regulatory and monetary policies. The Central

Bank manages monetary policy by conducting OMOs in the interbank market. It sets the interbank rate as its monetary policy instrument in each period by supplying base money or issuing government bonds to clear the interbank market. It does not do both at the same time. The overall liquidity of the economy is also controlled by the Central Bank.

the Regulator is responsible for setting the capital adequacy requirements for the banks. It determines and imposes penalties when they fail to meet their capital requirements and/or default on their deposits and interbank borrowings. Its other responsibility is to set the risk weights on consumer loan, interbank market and market book investment.

4.5 Gross Domestic Product

From equations (4.7) - (4.9), the households' actions are assumed to depend on their expected GDP in the second period. So, in this section, consideration is giving to endogenising GDP in both states of the second period. Also in the model, the Modigliani–Miller proposition does not hold. Therefore higher credit extension as a result of loosening monetary policy, or any other shocks, generates a positive real balance effect that raises consumption demand and ultimately GDP. Hence the future GDP at each possible state is positively correlated to the overall credit supply and so GDP at time $t + 1$ is a positive function of the aggregate credit supply of the previous period. A linear trend is included to improve the empirical fit. Hence the reduced form equation is of the form

$$\ln(GDP_{t+1,s}) = \mu_{s,1} + \mu_{s,2}trend + \mu_{s,3}[\ln(\bar{m}_t^\gamma) + \ln(\bar{m}_t^\delta) + \ln(\bar{m}_t^\tau)], \quad (4.10)$$

where $\mu_{s,1}$, $\mu_{s,2}$ and $\mu_{s,3}$ are the coefficients or the elasticities of the model.

4.6 Equilibrium

4.6.1 Market clearing conditions

There are seven markets in the model, i.e. three consumer loans, three deposits, and one interbank. Interest rates are determined for the respective markets ensuring there is a balance in demand and supply. The interest rates are adjusted to take account of the permissible defaults allowed in each market. Each of the three different markets (consumer loans, deposits and interbank) determines interest rate that ensures equilibrium.

Loan market clears, i.e.

$$1 + r_t^b = \frac{\mu_t^{h^b}}{\bar{m}_t^b}, h^b \in H^b, \forall b \in B, \quad (4.11)$$

Deposits market clears, i.e.

$$1 + r_{d,t}^b = \frac{\mu_{d,t}^b}{d_{b,t}^\Theta}, \forall b \in B, \quad (4.12)$$

Interbank market clears, i.e.

$$1 + \rho_t = \frac{\bar{B}_t + \sum_{b \in B} \mu_t^b}{M_t + \sum_{b \in B} d_t^b}, \quad (4.13)$$

where $\bar{B}_t$ = government bonds, and M_t = money issued by the Central Bank.

4.6.2 Equilibrium conditions

The equilibrium in the economy in each period is described by a vector of all choice variables of active agents such that banks maximise their payoffs subject to the following conditions: all markets (loan, deposit, and interbank) clear, banks expectations about repayment rates in the interbank market are accurate, and for each household and state the reduced form equations are satisfied.

Formally, let $\sigma^b = \{\bar{m}_t^b, \mu_t^b, d_t^b, \mu_{d,t}^b, v_{t+1,s}^b, \pi_{t+1,s}^b, e_{t+1,s}^b, k_{t+1,s}^b\} \in R_+^4 \times R^4$

for $b \in B$; $\sigma^{h^b} = (\mu_t^{h^b}, v_{t+1,s}^{h^b}) \in R_+ \times R$ for $h^b \in H^b$ and; $\sigma^\phi = (d_b^\phi) \in R_+$ for $b \in B$; and $GDP_{t+1,s} \in R$.

Also, let $\eta = \{r_t^\gamma, r_t^\tau, r_t^\delta, r_{d,t}^\tau, r_{d,t}^\delta, M_t, \bar{B}_t\}$, $B^b(\eta) = \{\sigma^2 : (4.7) - (4.10) \text{ hold}\}$. We say that the vector $((\sigma^b)_{b \in B}, \eta, (\sigma^{h^b})_{h^b \in H^b}, \sigma^\phi, (GDP_{t+1,s})_{s \in S})$ is a *monetary equilibrium with banks and default* for the economy $E = \{(e_t^b, O^b, A^b)_{b \in B}; p; (\bar{k}_{t+1,s}^b, \lambda_s^b, \lambda_{ks}^b, \hat{\omega}, \omega, \check{\omega})_{b \in B, s \in S}; r_t^A; \rho\}$ only if,

- (i) $\sigma^b \in \arg \max E_t(\Pi_{t+1}^b(\pi_{t+1}^b)), b \in B$ so all banks optimise their payoff function,
- (ii) all markets clear according to equations (4.11) - (4.13),
- (iii) $\check{R}_s = \frac{\sum_{b \in B} v_{t+1,s}^b \mu_t^b}{\sum_{b \in B} \mu_t^b}, s \in S$, (i.e. all banks are correct about their expectations of repayment rates in the interbank market), and
- (iv) $\sigma^{h^b}, \sigma^\phi$, and $GDP_{t+1,s}$, for $h \in H$ and $s \in S$ satisfy the reduced form equations (4.7) - (4.10).

4.7 Conclusion

The chapter discusses the CGE model used for the study, which is based on an extension of the Goodhart, Sunirand and Tsomocos model. The model consists of three heterogeneous banks, four private sector agents, a central bank and a regulator. It details the optimisation

problem for the banking sector and uses reduced-form equations for the private sector agents as a consequence of limited data availability. The optimisation problem of the banks is specified together with its constraints. This is followed by a discussion on how the reduced form equations are obtained for each of the private sector agents and the future gross domestic product. Then there is a discussion on the involvement of the Central Bank and/or the Regulator in the model. Finally, the equilibrium position is considered by discussing the market clearing constraints and the equilibrium conditions. The next chapter deals with the calibration of the CGE model for South Africa.

Chapter 5

Calibration for the South African Banking Sector

5.1 Introduction

In this chapter the CGE model is calibrated for South Africa. As mentioned before, there are exogenous and endogenous variables in the model. The exogenous variables must be obtained somehow so that it can be inputted into the model to obtain the numerical solutions for the model which are the endogenous variables. The exogenous variables need to be set appropriately or calibrated against real South African data. It is important to mention that the exogenous variables used to obtain solutions to the model may not necessarily have to be the exogenous variables in the model. For example in obtaining the initial values at equilibrium, the balance sheet data such as the credit extension, interbank lending and borrowing are used as exogenous variables because their values are available at a particular point in time. However, one may be interested in how these values change if a particular action is taken by the Regulator/user of the model. In such a case they would now have to be treated as endogenous variables. In obtaining the initial equilibrium a combination of approaches used in other countries such as the UK [62, 63, 64], Jamaica [89], Brazil [118], and Colombia [108] are used. The modelling system/package used is Mathematica.

5.2 Calibration Methodology

If one excludes Lagrange multipliers then from conditions (i) - (iv) of the “Equilibrium conditions” of section 4.6.2, one has a system of 56 equations with 143 unknown variables.

In order to obtain a unique solution for the model, 87 of the 143 parameters/variables which are exogenous need to be chosen. The parameters/variables of the model are obtained in one of three ways. These are calibrated against South African banking sector data, arbitrarily chosen inputs (compatible with the South African economy) or endogenously solved from the model.

5.2.1 Balance sheet items

The items for the initial period were calibrated against annual account data for the banking sector as at the end of December 2016. The data is publicly available as standardized monthly balance sheet data (BA900) are provided by individual South African banks. The extraction of the data is described in [134] which made use of the monthly data from April 2015 to March 2017. The assets were grouped into short term, medium term, long term and interbank lending. The long term assets include mortgage loans. The credit extension is extracted from total asset as the difference between the total amount of loans and the interbank lending. The market book (i.e. investments) is the difference between the total assets of the bank and the total amount of loans. On the liability side, the term ‘other liability’ is the difference between the total liabilities and the sum of the deposit, interbank borrowing and equity. The latest available full calendar year data was therefore 2016. The values are normalised by dividing by 10^9 and are given in Table 5.1.

Table 5.1: Normalized balance sheet data for the South African markets

b	γ	δ	τ
$\bar{m}_t^b$	9.6189	19.1436	7.5744
A_t^b	7.1411	3.4910	2.0913
d_t^b	2.3066	1.5006	0.4392
μ_t^b	1.4591	0.6713	0.4966
$d_{b,t}^\phi$	20.6960	9.2916	7.6206
e_t^b	1.9830	0.8118	0.5587
O_t^b	4.4531	3.8358	1.4328

5.2.2 Loan repayment rates

The loan repayment rates of the private sector agents to their nature-selected banks in the good state are calibrated using actual non-performing loans to total loans data for each banking sector at the end of December 2016 from the same source as the balance sheet data. Since the period did not experience any bad or crisis state, no data is available for calibrating the default rate for the bad state so they are arbitrarily chosen to be 0.1. This implies that

the repayment rates for each of the private sector agents in the bad state is 0.9.

The repayment rates for the banks in the good state are set to be higher than that of the corresponding private sector agents since banks hardly default on their obligations in that state. For that reason, The repayment rates for the banks in the bad state are set to be relatively higher than the corresponding rates for the private sector agents. Tables 5.2 and 5.3 show the repayments for households and banks respectively.

Table 5.2: Household repayment to nature-selected bank

b	α^γ	β^δ	θ^τ
$v_{t+1,i}^{h^b}$	0.9790	0.9862	0.9824
$v_{t+1,ii}^{h^b}$	0.9000	0.9000	0.9000

Table 5.3: Repayment rate of banks

b	γ	δ	τ
$v_{t+1,i}^b$	0.999	0.999	0.999
$v_{t+1,ii}^b$	0.950	0.950	0.950

5.2.3 Other exogenous variables/parameters

Probability of a state occurring

The probability that the bad state occurs, $1 - p$, is taken to be 0.05 to reflect a one-in-twenty year event [62, 64]. Thus, $p_i = 0.95$ and $p_{ii} = 0.05$.

Interbank rate

The interbank rate is set to match the actual repurchase rate of the SARB at the end of December 2016. The repurchase rate is the rate at which the South African banks borrow money from the SARB and the value was $\rho_t = 0.07$ [116].

Risk weights

The values of the risk weights were set taking into account risks attached to various asset classes from Basel I requirements. These are 1 for loans and 0.2 for interbank lending and market book. Hence they are $\hat{\omega} = 1$ and $\omega = \tilde{\omega} = 0.2$ [14]. The higher value attached to the risk weight of the loans compared to the other assets is an indication that loans are defaultable and therefore riskier than the other two types of assets.

Capital adequacy ratio and penalties

In reality, the capital of most banks is above the minimum regulatory capital requirements. As already mentioned in section 3.2, one subjects the banks to reputation costs (i.e. capital requirements penalties), if they fall below the “market determined capital requirements threshold”. The size of the penalty is proportional to the deviations from the market determined capital requirements threshold. Thus $\bar{k}^b > k_s^b$. The values of default and capital violation penalties (λ_s^b and λ_{ks}^b , $b \in B$, $s \in S$) reflect both the tightness of the Regulator’s policy and the (subjective) risk aversion of banks managements to putting themselves at risk of default and/or regulatory violations, and can, in principle, be treated as inputs given by the users of the model. Their values are, however, unobservable, and, therefore, have to be chosen. They have been chosen to be consistent with the following economic conjunction. First, the resulting endogenously solved banks lending rates are such that all banks earn high profit in the good state and lower in the bad state. This in turn implies that bank’s capital at $t = 2$ decreases, whenever the bad state occurs. Second, all banks coefficients of risk aversion (c^b ’s, $b \in B$, $s \in S$) are positive, reflecting prudent risk management or the limited liability clause of the bank and the associated option like payoff strike. The values together with the penalties are given in Table 5.4.

Table 5.4: Capital requirements data and penalties

b	γ	δ	τ
k_i^b	0.1164	0.1083	0.0879
k_{ii}^b	0.0958	0.0685	0.0600
$\bar{k}_{t+1,i}^b$	0.1300	0.1200	0.1000
$\bar{k}_{t+1,ii}^b$	0.1300	0.1200	0.1000
λ_i^b	0.9000	0.9000	0.9000
λ_{ii}^b	1.0200	1.0200	1.0200
λ_{ki}^b	0.1000	0.1000	0.1000
λ_{kii}^b	0.1000	0.1000	0.1000

Rate of return on market book and GDP

The rate of return on the market book is arbitrarily chosen to be 30 basis point above the repurchase rate as at the end of December 2016 as it is naturally expected that return on the bank’s investments will be higher than the repurchase rate. In addition, the repurchase rate which is the interbank rate is assumed to be default free and so does not include a default premium whilst the return on asset must include some margin. The value is set equal to 0.073.

The nominal GDP in the good state is set to equal the actual GDP as at the end of December 2017. As South Africa did not experience any crisis state in the period of investigation and one generally expects the GDP in the bad state to be lower than in the good state, it is set to be 4% lower than GDP in the good state. Thus $GDP_{(t+1,i)} = 4.700^1$ and $GDP_{(t+1,ii)} = 4.512$

5.2.4 Elasticities for the reduced form equations

The elasticities or the coefficients of the reduced form equation for future GDP equation (4.10) were estimated using multiple regression analysis. The trend component was found to be statistically insignificant. Hence, it was set to be zero. The other trend component of the household borrowers demand for loans was also set to be equal to zero. This reduced the multi-period model to the two time period model. This is consistent with [33] where a finite time horizon is used in a CGE model. So the finite horizon approach as in [62] whereby there exist two possible future states is adopted. The rest of the elasticities other than the intercepts of the reduced form equations were arbitrarily chosen in such a way that the deviations from the predicted values and the realized values were minimised akin to the Brazilian case [118].

It is important to mention that as the endogenous variables of the model are not necessarily the endogenous variables of the system of equations, one is able to impose exogenously (from real data), the value of the endogenous variables of the model in the initial period of the simulation. These estimated variables are then used as exogenous variables in the model. This strategy was used for the intercepts of the reduced form equations as well as the risk aversion coefficients (similar to the approach used in [118])

5.2.5 Initial equilibrium position

The exogenous variables and the resulting initial equilibrium position are as shown in Table 5.5 below:

¹<http://www.statssa.gov.za/publications/P0441/P04414thQuarter2017.pdf>

Table 5.5: Initial equilibrium position

	Initial Equilibrium	Exogenous variables in the model
E	$r^\gamma = 0.0943$	$O^\gamma = 4.4531$
	$r^\delta = 0.0872$	$O^\delta = 3.8358$
	$r^\tau = 0.0956$	$O^\tau = 1.4328$
	$r_d^\gamma = 0.0659$	$g\alpha_{i,1}^\gamma = -0.4405$
	$r_d^\delta = 0.0658$	$g\alpha_{ii,1}^\gamma = -0.6679$
	$r_d^\tau = 0.0700$	$g\beta_{i,1}^\delta = -0.4332$
	$\mu_d^\gamma = 22.0590$	$g\beta_{ii,1}^\delta = -0.6679$
	$\mu_d^\delta = 10.4572$	$g\theta_{i,1}^\tau = -0.4370$
	$\mu_d^\tau = 8.1540$	$g\theta_{ii,1}^\tau = -0.6679$
	$k_i^\gamma = 0.1164$	$\mu_{i,1} = 0.4154$
	$k_{ii}^\gamma = 0.0958$	$\mu_{ii,1} = 0.3745$
		$B = 1.7367$
C	$\mu^\tau = 0.0574$	$r^A = 0.0730$
	$\rho = 0.0700$	$A^\gamma = 7.1411$
	$\bar{m}_t^\gamma = 19.1436$	$A^\delta = 3.4910$
	$\bar{m}_t^\delta = 9.6189$	$A^\tau = 2.0913$
	$\bar{m}_t^\tau = 7.5744$	$e_0^\gamma = 1.9830$
		$e_0^\delta = 0.8118$
		$g_{h,s,2} = 0.0370, \forall h \in H^b, \forall s \in S$
		$g_{h,i,3} = 0.0500, \forall h \in H^b$
		$g_{h,ii,3} = 0.0700, \forall h \in H^b$
		$\lambda_{ii}^b = 1.0200 \forall b \in B$
		$k_s^\delta = 0.1200, \forall s \in S$
		$k_s^\tau = 0.1000, \forall s \in S$
A		$k_s^\gamma = 0.1300, \forall s \in S$
	$v_{ii}^{\alpha\gamma} = 0.0900$	$\lambda_{ks}^b = 0.1000, \forall b \in B, \forall s \in S$
	$v_{ii}^{\beta\delta} = 0.9000$	
	$v_{ii}^{\theta\tau} = 0.9000$	
		$p = 0.95$

E = endogenously solved, C = calibrated against South African data and A = arbitrarily chosen

5.3 Conclusion

The chapter describes how the model is calibrated for South Africa, using three approaches to obtain the values of the variables for the model and hence determines the initial equilibrium position. These three different approaches are: making use of available data such as balance sheet information for the banks, choosing inputs arbitrarily (taking into consideration what is appropriate for South Africa) and endogenously solving the model for the rest of the variables. One needs to emphasise that the variables obtained from solving the model may not necessarily be the endogenous variables of the model. The initial equilibrium position resulting from the calibration exercise is given. This is based on the annual account data for the banking sector as at the end of December 2016. The data is publicly available as standardised and provided by individual South African banks.

The next two chapters are the core areas of the study. The first considers the CGE model as a risk assessment tool and the second as a regulatory tool for the banking sector in South Africa. Together they demonstrate how the CGE model can be used to model the effects in the South African economy and hence provide a tool for the banking sector regulators and policymakers.

Chapter 6

The Model as a Risk Assessment Tool

6.1 Introduction

In this chapter, the model is used as a risk assessment tool for South African banks. Once equilibrium is established, a series of comparative statistics is conducted by changing the exogenous variables in turns and studying how the equilibrium is affected. The analysis can be done in two different ways. One is where the SARB sets the base money as its monetary policy instrument and the other is where it sets the interbank rate (repo rate) as its monetary policy instrument. At the starting point (year 2016) of the analysis, the SARB was a net borrower in the interbank market. In other words instead of supplying base money in the interbank market it was rather issuing bonds, that is borrowing from the interbank market. In this case an expansionary monetary policy will mean either reducing the amount of bonds issued or reducing the repo rate. At the same time, banks δ and γ had surplus funds (net lenders) whilst bank τ was in deficit (net borrower) in the interbank market.

As alluded to earlier on, South Africa did not suffer much from the 2008 financial crisis. However, the SARB is vigilant and is committed to ensuring a similar financial crisis does not occur in future. In this respect, in the G20 leaders summit of November 2010, the then South African president committed the country to a global financial regulatory reform agenda aimed at strengthening financial stability [67]. Moreover, the SARB adopted an expansionary monetary stance to stimulate economic activities in the aftermath of the Global Financial Crisis of 2008. Against this background, we followed the work done in the UK [62] and examined the impacts of the following shocks for risk assessment purposes of the South African economy: an expansionary monetary policy; a positive deposit supply shock to a bank; a positive bank capital shock to a bank; a restrictive regulatory policy; and a positive shock in Gross Domestic Product (GDP).

6.2 An expansionary monetary policy

As mentioned before, there are two ways that the analysis can be done. The first is to reduce the amount of bond issued by the Central Bank (reduce borrowing in the interbank market). The other is to reduce the interbank rate. In reducing the amount of bonds issued, the interbank rate is solved endogenously in the model and in reducing the interbank rate, the amount of bonds issued is solved endogenously. Therefore, the two analyses produce the same results, provided the induced interbank rate is the same in both cases. The case where the SARB sets its base money as its monetary instrument is considered. Here the amount of open market operations by the Central Bank was decreased from 1.72 trillion to 1.67 trillion of South African Rand (approximately 3%). Recall, in equilibrium, the SARB was a net borrower so this produced a decrease in the interbank rate of 0.09%. The results for some key variables are shown in Table 6.1. The main effects are as follows:

As the interbank market is less attractive for lending because of the reduction in the repo rate, both banks δ and γ , the net lenders in the interbank market, invest less in that market. Thus given credit availability increased, they decide to take fewer deposits and lend more to their customers. Hence, both their lending and deposit rates are reduced. Inversely, the other bank τ , the net borrower in the interbank market, lowers its deposits demand and increases borrowing from the interbank market. Moreover, it lends more to its customers. Therefore, both its lending and deposit rates decrease. Households liquidity as well as income improve, due to the greater credit supply, which in turn increases GDP in both states by 0.07%.

Finally, agent ϕ , because of increased GDP deposits more funds in all three banks. This contributes to the decrease in deposit rates for all banks. Consequently, the banks expect that the credit extension in the economy would increase, and so the household probability of default decreases as a result of higher household liquidity and income. In the model, banks choose their optimal expected level of profitability by equating the marginal benefit with the corresponding marginal cost. Higher profitability increases banks utility as well as their capital to asset ratios which in general should make them suffer less capital infringement penalty. However, in pursuit of higher profitability, the banks take more risk and consequently suffer higher cost from higher expected default penalties. There is therefore a trade-off between the marginal benefits and cost of default and the banks choose a slightly lower profitability in order to reduce the default cost. In our case, GDP dominates default cost. Thus, even with lower default penalties, the greater GDP results into lower households default probability and the repayment rate of agents to their nature-selected banks in the consumer loan market increase, resulting in higher value for the risk-weighted assets for banks. Therefore all banks capital adequacy ratios reduce causing all banks to suffer higher capital infringement

penalties. Therefore there exist another trade-off between penalties due to high expected default probabilities and reputation penalty due to lower capital. In our case, the effect of default penalty dominates the capital requirements penalty. The banks prefer to default less and suffer the capital requirements penalty rather than default more and suffer less of capital penalty.

Table 6.1: Positive shock to base money (reduction of B by 3%) - Central Bank sets its base money

b	r_d^b	r^b	ρ	π_i^b	π_{ii}^b	e_i^b	e_{ii}^b	k_i^b	k_{ii}^b	v_i^b	v_{ii}^b	GDP_i	GDP_{ii}
δ	-0.08	-0.37		-0.01	-0.10	$\frac{-3}{10^3}$	-0.02	-0.10	-0.12	$\frac{-1}{10^3}$	$\frac{3}{10^3}$		
γ	-0.08	-0.34	-0.09	$\frac{-4}{10^3}$	-0.03	$\frac{-1}{10^3}$	0	-0.10	-0.11	0	$\frac{4}{10^3}$	0.07	0.07
τ	-0.09	-0.35		-0.01	-0.23	$\frac{-4}{10^3}$	-0.04	-0.13	-0.18	$\frac{1}{10^3}$	0.01		

6.3 A positive deposit supply shock to bank δ in the initial period

The deposit supply is increased by increasing $z_{b,1}$ of equation (8) by 0.8%. The increase in the deposit supply to bank δ has almost the same (directional) impact as that of an expansionary monetary policy if the base money is used by the SARB as its monetary policy instrument. This is because in both scenario, the overall broad money supply available becomes higher except that in this scenario (deposit supply shock), the concentration is specifically in bank δ . So in effect the interbank rate decreases. As a result, the other two banks also benefits from the liquidity improvement in the interbank market from bank δ 's supplies. The % changes in the key variables are shown in Table 6.2.

Table 6.2: A positive deposit supply shock to bank δ in the initial period - Central Bank sets its base money

b	r_d^b	r^b	ρ	π_i^b	π_{ii}^b	e_i^b	e_{ii}^b	k_i^b	k_{ii}^b	v_i^b	v_{ii}^b	GDP_i	GDP_{ii}
δ	-0.24	-1.13		-0.05	-0.58	-0.02	-0.09	-0.60	-0.70	0.01	0.01		
γ	-0.25	-1.04	-0.28	-0.01	-0.11	$\frac{-3}{10^3}$	$\frac{-1}{10^3}$	-0.31	-0.33	0	0.01	0.20	0.20
τ	-0.28	-1.07		-0.04	-0.72	-0.01	-0.12	-0.41	-0.54	$\frac{2}{10^3}$	0.02		

Major differences occur, however, where the interbank rate is used as the monetary instrument by the Central Bank to conduct monetary policy. In this case, there is no change to the interbank rate and so that channel is closed which means the banks cannot benefit

from the increased liquidity through their interactions in the interbank market. As a result the changes only come through in the probability of default in the loan market. As bank δ supplies more credit, the overall credit supply increases and every household benefits from improved liquidity and higher income from improved GDP. Every household's default probability reduces. This in turn causes the expected rate of return to increase for all three banks leading to their lending rates falling. Bearing in mind that the interbank rate is fixed, the cost of borrowing in the interbank market is fixed no matter the amount demanded in that market. So bank τ , the net borrower in the interbank market, finance its credit extension by borrowing more from that market instead of requiring more deposits. This contributes to the reduction in its lending rate by 0.01% and ensures no change in its deposit rate. Table 6.3 has the % changes in the key variables.

Comparing Tables 6.2 and 6.3, it is clear that the contagion effects is much weaker for the banks when the SARB sets its monetary policy instrument as the interbank rate than when the monetary policy instrument is the base money. This is because apart from the fact that the contagion effect in the interbank market is shut down, the contagion effect in the loan market is also weakened when the interbank rate is fixed. This suggests that interest rate targeting has more controlled effects than monetary base targeting.

Table 6.3: A positive deposit supply shock to bank δ in the initial period - Central Bank sets the interbank rate

b	r_d^b	r^b	ρ	π_i^b	π_{ii}^b	e_i^b	e_{ii}^b	k_i^b	k_{ii}^b	v_i^b	v_{ii}^b	GDP_i	GDP_{ii}
δ	$\frac{2}{10^3}$	-0.01		-0.02	-0.28	-0.01	-0.04	-0.29	-0.34	0.01	0		
γ	0	-0.01	0	0	$\frac{-1}{10^3}$	0	0	$\frac{-3}{10^3}$	$\frac{-3}{10^3}$	0	0	$\frac{2}{10^3}$	$\frac{2}{10^3}$
τ	0	-0.01		0	-0.01	0	$\frac{-1}{10^3}$	$\frac{-4}{10^3}$	-0.01	0	0		

6.4 A positive bank capital shock to bank δ in the initial period

The initial capital of bank δ is increased by 5.6%. Considering the case where the monetary instrument is the base money, the result for most of the variables are in the same direction as that of a positive deposit supply shock as in both cases more funds become available for the bank. The only difference is with respect to capital to asset ratio of the bank. The increase in capital reduces the banks capital requirements infringement penalty. As a result, bank δ 's capital and capital adequacy ratio improve in both states. Table 6.4 has the % changes in the key variables.

Where the Central Bank uses the interbank rate as its monetary policy instrument, the consumer loan default channel becomes the main contagion effect. Bank δ switches part of the massive investment away from the loan market due to the large size of the investment which results in a negative contagion effects on the other banks. There is therefore pressure on the overall credit supply which increases the default probability. This higher default probability causes the other banks risk-weighted assets to reduce resulting in less infringement of capital adequacy requirements and hence less capital infringement penalty. Hence, in this case the capital adequacy ratio for the other two banks γ and τ also improves. Table 6.5 has the % changes in the key variables.

So far it is not clear from the results which of the two monetary policy instruments offers better financial stability. All one can say is that the contagion effect through the interbank market is shut down completely when the SARB sets its monetary policy using the interbank rate and this may negatively or positively affect the contagion effect through the other channels.

Table 6.4: A positive bank capital shock to bank δ in the initial period - Central Bank sets its base money

b	r_d^b	r^b	ρ	π_i^b	π_{ii}^b	e_i^b	e_{ii}^b	k_i^b	k_{ii}^b	v_i^b	v_{ii}^b	GDP_i	GDP_{ii}
δ	-0.10	-0.32		-0.02	-0.18	3.73	6.40	3.55	6.20	0.04	0.02		
γ	-0.09	-0.33	-0.10	$\frac{-4}{10^3}$	-0.03	$\frac{-1}{10^3}$	0	-0.10	-0.10	0	$\frac{3}{10^3}$	0.06	0.06
τ	-0.10	-0.34		-0.01	-0.22	$\frac{-3}{10^3}$	-0.03	-0.12	-0.16	$\frac{1}{10^3}$	0.01		

Table 6.5: A positive bank capital shock to bank δ in the initial period - Central Bank sets the interbank rate

b	r_d^b	r^b	ρ	π_i^b	π_{ii}^b	e_i^b	e_{ii}^b	k_i^b	k_{ii}^b	v_i^b	v_{ii}^b	GDP_i	GDP_{ii}
δ	-0.02	0.09		-0.01	-0.07	3.73	6.42	3.66	6.34	0.04	0.01		
γ	$\frac{-2}{10^3}$	0.05	0	$\frac{1}{10^3}$	0.01	0	0	0.02	0.02	0	$\frac{-1}{10^3}$	-0.01	-0.01
τ	0	0.05		$\frac{2}{10^3}$	0.04	$\frac{1}{10^3}$	0.01	0.02	0.03	0	$\frac{-1}{10^3}$		

6.5 Restrictive regulatory policy

6.5.1 The capital infringement penalties in the bad state is increased

The capital adequacy requirements penalty is increased from 0.1 to 0.12 (by 20%) for all banks in the bad state. The infringement of capital requirements is now costly for the banks

in the bad state so in order to increase their capital to asset ratio, they respond as follows: They adopt a more risky strategy in order to optimise their profitability. Their profits in the bad state increase. This then enhances their capital situation in that state and make them suffer less capital infringement penalties. To reduce the capital infringement penalty, banks δ and γ reduce the level of risk-weighted asset in the bad state. The deposit rates for them reduce as they demand fewer funds. They lend less in the interbank market and more in the consumer loan market making the interbank rate to increase and their lending rate to reduce. The lending rate and deposit rate for bank τ increase by 0.16% and 0.18% respectively. The reason is that it borrows less from the interbank market as the interbank market is now expensive, takes more deposit and lend less in the consumer loan market. The extent of the reduction in the credit extension of bank τ outweighs the increase in the credit supply of banks δ and γ . As a result the overall credit supply in the economy decreases causing the GDP in both states to decline by 0.003% and consequently the probability of default for every household increases. Table 6.6 has the % changes in the key variables.

Table 6.6: A rise in CAR penalty of 20% for all banks in the bad state - Central Bank sets its base money

b	r_d^b	r^b	ρ	π_i^b	π_{ii}^b	e_i^b	e_{ii}^b	k_i^b	k_{ii}^b	v_i^b	v_{ii}^b	GDP_i	GDP_{ii}
δ	-0.11	-0.06		0	18.77	0	2.77	$\frac{3}{10^3}$	2.78	$\frac{2}{10^3}$	-0.23		
γ	-0,11	-0,06	0.18	0	6.43	0	0.05	$\frac{3}{10^3}$	0.05	$\frac{1}{10^3}$	-0.02	$\frac{-3}{10^3}$	$\frac{-3}{10^3}$
τ	0.18	0.16		$\frac{1}{10^3}$	34.31	0	5.73	0.01	5.74	$\frac{1}{10^3}$	-0.35		

6.5.2 The default penalties in the bad state is increased

The default penalty in the bad state is increased from 1.02 to 1.023 (approximately 0.3%). In order to reduce the default penalty they face in the bad state, the banks adopt a conservative strategy of choosing lower profitability in this state. The interbank market is now slightly safer compared to the other markets and so bank δ and bank γ , being net lenders in the interbank market, increase their investment there. They do this by taking more deposits and reducing their lending in the consumer loan market. The resultant effect is that the interbank rate reduces and the lending and deposit rates for the two banks increase. The other bank τ , the net borrower in the interbank market, takes advantage of the reduced interbank rate and borrows more in that market. It also reduces the intake of deposit so its deposit rate reduces. As the good state is not affected by the increase in default penalty, it lends more in an attempt to improve its profit in that state so that its overall payoff is not affected so much. This reduces its lending rate by 0.19%.

It is interesting to note that results show that the effect of a rise in the default penalty is higher than that of the capital requirements infringement penalty even in the case where the percentage increase in the default penalty (0.3%) was much lower than the percentage increase in the capital adequacy requirements penalty(20%) . This may be due to the fact that banks view the possibility of being penalized for defaulting more serious than infringing their capital requirements and thus act accordingly. Table 6.7 has the % changes in the key variables.

Table 6.7: A rise in default penalty of 0.3% for all banks in the bad state - Central Bank sets its base money

b	r_d^b	r^b	ρ	π_i^b	π_{ii}^b	e_i^b	e_{ii}^b	k_i^b	k_{ii}^b	v_i^b	v_{ii}^b	GDP_i	GDP_{ii}
δ	0.10	0.08		0	-29.08	0	-4.29	$\frac{-2}{10^3}$	-4.29	0	0.36		
γ	0.10	0.08	-0.26	0	-19.82	0	-0.14	$\frac{-2}{10^3}$	-0.15	0	0.03	$\frac{3}{10^3}$	$\frac{3}{10^3}$
τ	-0.26	-0.19		$\frac{-2}{10^3}$	-40.74	0	-6.80	-0.02	-6.82	$\frac{1}{10^3}$	0.42		

6.6 A positive shock in GDP in the bad state

GDP in the bad state is increased by approximately 0.23% by increasing $\mu_{ii,1}$ by 0.6%. The shock raises the expected aggregate output. It also increases the demand for loans as well as the probability of repaying the loans. The lending rates of the banks increase. A lower default probability increases the expected rates of return on the loans. Consequently, the banks invest heavily in the markets. The effect of the individual borrowers borrowing more from the banks is weaker than that of the banks' greater demand for deposit and so the interbank and deposit rates increase. The two net lenders in the interbank market, bank δ and bank γ take advantage of the higher interbank rate to invest more there. They do this by demanding more deposits. Their deposit rates end up being higher than the other bank. The banks risk-weighted assets rise as a result of higher probability of individuals paying their loans in full. This lowers capital infringement penalties for all banks. The rise in the banks risk-weighted assets makes the benefit of higher profitability from capital infringement penalty lower. The banks therefore revise their optimal profits downwards in order not to suffer much default penalty which in turn worsen their capital position. Table 6.8 has the % changes in the key variables.

Table 6.8: A positive shock in GDP in the bad state - Central Bank sets its base money

b	r_d^b	r^b	ρ	π_i^b	π_{ii}^b	e_i^b	e_{ii}^b	k_i^b	k_{ii}^b	v_i^b	v_{ii}^b	GDP_i	GDP_{ii}
δ	0.14	0.09		$\frac{-1}{10^3}$	-0.02	0	$\frac{-3}{10^3}$	-0.01	-0.02	$\frac{1}{10^3}$	0.01		
γ	0.14	0.09	0.13	$\frac{-1}{10^3}$	-0.01	0	0	-0.01	-0.02	$\frac{-1}{10^3}$	0.01	$\frac{2}{10^3}$	0.23
τ	0.13	0.08		$\frac{-1}{10^3}$	-0.04	0	-0.01	-0.01	-0.03	0	0.01		

6.7 Summary of results

As mentioned earlier, we followed the work done for the UK banking sector. The aim was to determine whether the CGE model will be appropriate in assessing risks for the South African banking sector and also determine if the banks in the two countries will behave in a similar manner if they were exposed to the same risks. It is interesting to note that the results obtained from the shocks are similar to that obtained for the same analyses of the UK banks [62] especially in terms of the directional changes. However, the magnitude of the changes are much lower for the South African case than the UK ones for all the rates - deposit, lending and interbank rates. The reason for this is mainly that at the time of the various analyses, the corresponding rates were much lower for the UK than South Africa and hence the impact of the same shocks are lower for South Africa. This supports the assertion that the CGE model works well for the South African banking sector, although the impact depends on the features of the particular economy at the time the analysis is done. These results are consistent with other studies using different methodologies such as [101] and [81]. Whilst [101] showed that consumption and loans from households decreased during periods of monetary tightening but increased during periods of expansionary monetary policy in South Africa, [81] confirmed that effective regulation is associated with economic growth in developing countries .

It was also observed that the effect of a rise in the default penalty is higher than that of the capital requirements infringement penalty on almost all the key variables. This could be attributed to the fact that banks view the possibility of being penalized for defaulting more seriously than infringing their capital requirements and thus act accordingly. Banks are exposed to different risks and react differently depending on whether the SARB sets its base money or the interbank rate as its monetary policy instrument. Where the bank sets the interbank rate as its monetary instrument, the banks are unable to manipulate their activities in order to maximise their profits through the interbank market and concentrate on the loan and deposit markets. This suggests that interest rate targeting has more controlled effects than monetary base targeting due to the elimination of pecuniary second order effects. However, all one can say at this stage is that the contagion effect through the interbank market

is shut down completely when the SARB sets its monetary policy using the interbank rate and this may negatively or positively affect the contagion effect through the other channels. Section 7.5 of the next chapter looks at which of these two approaches offer optimal solutions for the banks, the private sector agents and the economy as a whole.

Chapter 7

The Model for Banking Regulation

7.1 Introduction

In Chapter 6, the CGE model is used as a tool for risk assessment for the South African banking sector and it performed well. In this chapter, the model is now used as a regulatory tool. One of the SARB's main responsibilities is inflation targeting. It serves to discipline monetary policy and increases the SARB's accountability [97]. The aim of the inflation targeting regime is to keep inflation, defined in the case of South Africa as the consumer price index (CPI), in a fixed range. The SARB's inflation target range is 3% to 6%. This target is achieved through periodic adjustment of the repurchase (or repo) rate. The repo rate is the rate at which the South African banks borrow money from the SARB. The SARB sets the repo rate to achieve its inflation target. A CGE model may potentially assist in determining the appropriate repo rate. In addition, CGE models could assist in estimating the impact of actions taken by the SARB, for example the effects of changes in the policy rate on the banks and the economy as a whole. This is crucial especially during periods of global uncertainty and systemic risk, such as the Covid-19 pandemic, which has induced the SARB to reduce the policy rate by 3.0% from January to July 2020 in order to ensure inflation remains within its target range and also contain its negative impact on GDP. The CGE model is applied to determine the effects of the inflation targeting policy on banks profit and the economy and also how the capital adequacy requirement regulation affects banks and the economy in general. Consideration is also given to the two monetary policy instruments generally used world-wide by Central Banks to determine their effects on the South African banking sector and the economy as a whole. The following are therefore considered: the effect of the penalties (both default and capital violation) on the banks and the economy, the effect of capital adequacy requirement (CAR) on banks, monetary policy instrument - base money and policy rate and the impact of changes in the policy rate (repo rate in the case of

South Africa) on the South African economy.

7.2 Justification of the CGE model as a Regulatory Tool

The features of the model used in the study are presented in Fig. 7.1. As discussed in

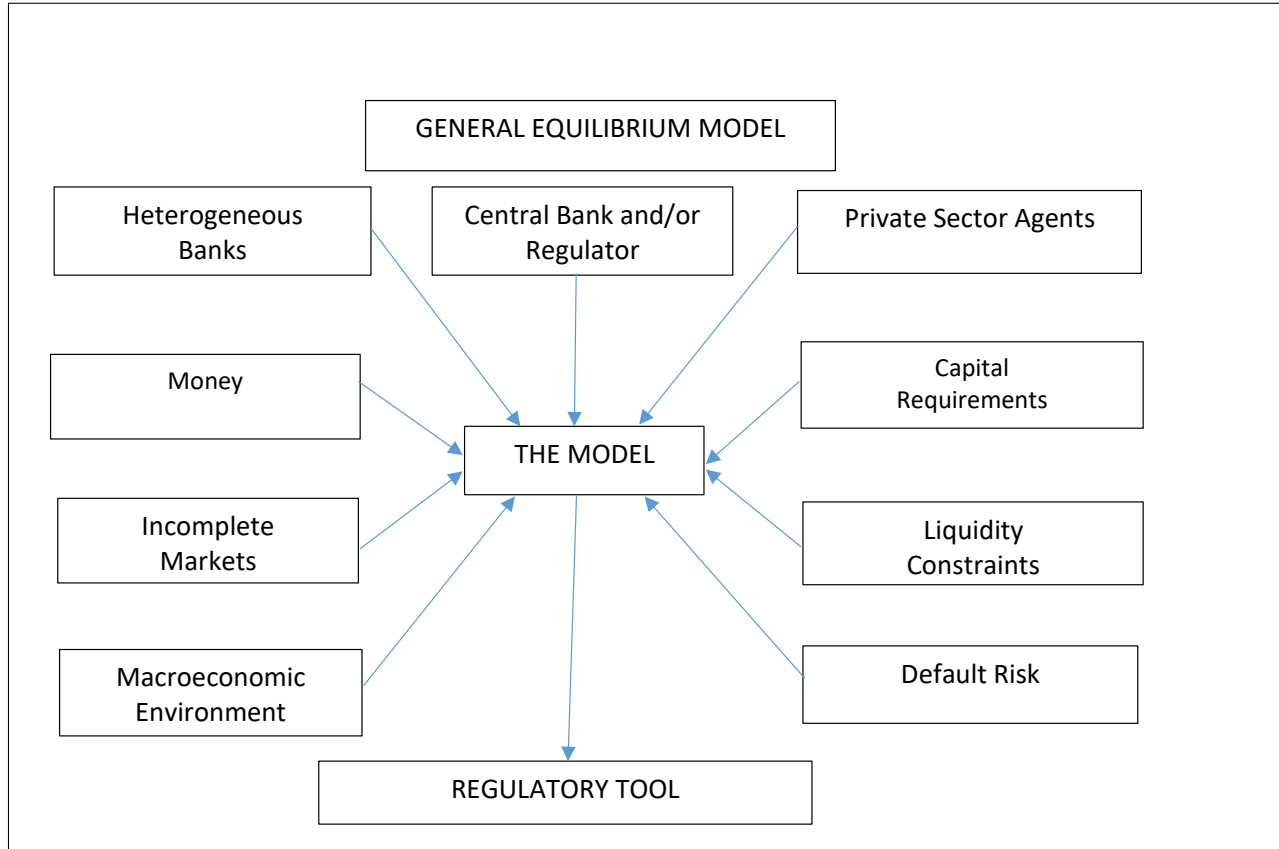


Figure 7.1: Features of the model

recent work which incorporates the banking sector as a financial intermediary with a CGE model [20, 58, 83, 99], there are three main conditions that a model must satisfy to possess a distinct lending channel. First, the liabilities of agents such as financial capital raised by loans from banks or other sources, including the foreign sector, must be viewed as imperfect substitutes because of the differing default rates and credit risks. Similarly, banks must view financing of deposit and other sources as imperfect substitutes. Last, but not the least, there must be a nominal rigidity that prevents monetary shocks from having no impact on the real economy. The work goes beyond that by incorporating other financial frictions such as default and liquidity constraints. The implicit assumptions in the model, such as

different sources of finance having different default rates (i.e. the fact that money borrowed from interbank market have different repayment rates from that of the loan market), the cash advance constraint and incomplete markets satisfy the first two conditions. The final condition is satisfied by the model due to the presence of capital buffers (or enhanced CAR). The private sector agents are considered to be the investors and so investments are reflected in the reduced form equations of Appendix A. The emphasis of the work was not on the role that foreign investors play in South Africa so the exchange rate channel was not included. Nevertheless, the model can in theory be extended to include the foreign sector in line with what was done in [104]. Moreover, in [107], a 2-country CGE model was used to establish the effect of monetary and fiscal expansion on the economy of two countries. Also [58, 99], argued that bank regulation changes impact offshore activity by domestic banks (changing foreign capital outflows), and the supply of foreign finance (via changes in the current account balance and the nominal exchange rate). Some of these issues may be covered in future work. The model also allows users to study how other domestic forms of finance provision influence the results of regulatory reform. It all depends on the scenario considered by the policy maker and some of these scenarios, such as capital shocks and deposit supply shocks to a particular bank, were considered in Chapter 6.

7.3 Equilibrium Characterization

The results of all the shocks are explained using the propositions and the associated trade-offs given below. The three propositions (in sections 7.3.1 to 7.3.3 below) were established in [61] and [63].

7.3.1 Liquidity Structure of Interest Rate Proposition

Since base money is fiat and the horizon is finite, in the end no household will be left with fiat money. Thus, all households will finance their loan repayments to commercial banks via their private monetary endowment and the initial capital endowments of banks. However, since one allows for defaults, the total amount of interest rate repayments is adjusted by the corresponding anticipated default rates. In sum, aggregate ex post interest rate payments adjusted for default to commercial banks is equal to the total amount of outside money. In this way, the overall liquidity of the economy and endogenous default co-determine the structure of interest rates.

7.3.2 Quantity Theory of Money Proposition

The model possesses a non-trivial quantity theory of money. Velocity will always be less than or equal to one. However, since quantities supplied in the markets are chosen by agents, the real velocity of money, that is how many real transactions can be moved by money per unit of time, is endogenous. The upshot of the analysis is that nominal changes affect both prices and quantities.

7.3.3 Fisher Effect Proposition

The nominal interest rate is equal to the real interest rate plus the expected rate of inflation. That is the nominal interest rate charged by the bank is equal to the real rate of interest which is the marginal depreciation rate of consumption tomorrow plus the expected rate of inflation.

7.3.4 Default trade-off

There is a trade-off between the marginal benefit and the marginal cost of defaulting payment on deposit and interbank obligations. Thus banks choose their optimal expected level of profitability by equating the derived marginal benefit with the corresponding marginal cost. In other words, there is a marginal benefit derived from defaulting and consequently as a result we have the marginal cost which depends on the regulatory penalty.

7.3.5 CAR Violation trade-off

There is a trade-off between the marginal benefit from violating capital adequacy requirement and the marginal cost of violating capital adequacy requirement. Put differently, there is a trade-off between the profit from the extra interest obtained by the banks extending their credit extension and the cost of the regulatory penalty for the capital falling below the associated CAR.

7.4 Default and Capital Violation Penalties

Penalties have to be applied for the banks to act in accordance with certain regulatory objectives. For instance if no penalties are used, the banks will have the freedom to act arbitrarily. They could charge very low interest just to get business and when in trouble default their repayment without any repercussions. In reality, any bank defaulting on its deposits will be forced to close down. However, it is shown that endogenous default provides

microfoundations to exogenous probabilities of default [127]. So in the model, a bank's default rate is interpreted as a probability that such a bank goes bankrupt and closes down, and hence defaults completely on its financial obligations in the short run. In other words, a bank's decision to increase its default rates is equivalent to its decision to adopt a riskier strategy in pursuit of higher expected profitability. A default penalty also ensures that the banks take responsibility for their repayments either in the interbank market or for deposits they receive from the private sector agents. Just as banks can default on their deposits, the model also allows banks to violate their CAR. Again, in reality, each bank's capital to asset ratio may be above the Regulator's requirement and so will not be subjected to any CAR violation penalty. However, it is assumed that each bank wants to have a buffer above the Regulator's requirement and so the ratio is always binding. What that means is that each bank's self-imposed enhanced capital requirement is always above the actual value of that regulatory capital to asset ratio. The level of enhanced capital is signaling to the market either potential problems or financial health of the bank. Hence there is a non-pecuniary cost. The section starts with the penalties used at the initial equilibrium. The penalties are then altered to see how the banks react and the impact on their profits as well as the economy.

7.4.1 Default penalty effects

The model is run with the capital violation penalties fixed at their initial level (i.e. maintained at their values at the initial equilibrium position) and the default penalty set one percentage point below and above their initial level at equilibrium to determine their effects. The main effects of reducing the default penalty by 1% are shown in Table 7.1 and are as follows:

Table 7.1: Default Penalty Reduced by 1%

bank	r_d^b	r^b	ρ	π_i^b	π_{ii}^b	k_i^b	k_{ii}^b	v_i^b	v_{ii}^b	GDP_i	GDP_{ii}
δ	-1.441	-0.873		8.268	98.910	2.793	14.467	-0.340	-1.204		
γ	-1.430	-0.837	2.687	8.614	67.407	2.053	0.537	-0.230	-0.091	-0.040	-0.040
τ	2.687	2.236		9.654	135.611	2.728	24.170	-0.198	-1.421		

As expected, the profits for all the three banks increase in both states. There is a reduction in both the deposit and the lending rates for the banks which are net lenders in the interbank market and an increase in both the deposit and the lending rates for the bank which is a net borrower in the interbank market. The capital adequacy ratios for all the banks increase in both states. The interbank rate increases and the GDP drops. The reason for this is that the banks adopt an aggressive strategy of choosing higher profits as they are now relaxed

about the default penalty they could face. Since a lower default penalty will decrease the marginal cost of defaulting, it will also increase liquidity demand since the Central Bank will increase the interest rate charge to incorporate the increased default risk premium. In general, the interbank rate is higher than the deposit rate but lower than the lending rate, so the net lenders adjust their portfolios by lending less in the interbank market, more in the customer loan market and taking less deposits. This adjustment of their portfolios increases the interbank rate and puts pressure on both their lending and the deposit rates, making them reduce accordingly. Bank τ , the net borrower, on the other hand takes more deposits and borrows less in the interbank market, as this market is now more expensive. It also lends less in the customer loan market. These actions increase both its deposit and lending rates. The strength of the pressure caused by the banks and the household portfolio adjustments in general depends on the relative elasticities of demand and supply of such a market.

With more credits for banks δ and γ , given the liquidity structure of interest rate proposition, it is expected that their interest rates would be lower and consequently it is observed that their rates decrease. Similarly, the interest rate for bank τ increases given that its credit supply reduces. Although the profits of the banks increase, it is observed that the extent of the increase in the combined credit extension of banks δ and γ was lower than the decrease in bank τ 's credit supply. This leads to a reduction in the cumulative credit supply and negatively affects household liquidity and income. With lower income and liquidity, it is expected from the quantity theory of money proposition, that economic activities (prices of goods) will fall. Hence chances of both the banks and household defaulting on their debt increases and their repayment rates fall in both states. This is expected since, given that the default penalty is lower, by the default trade-off, the marginal benefit of default increases more than the marginal cost and consequently banks default more, hence leading to a reduction in their repayments. This results in a decrease in economic activities leading to a reduction in GDP. Lower economic activities (lower prices of goods) imply higher real rates and so according to the Fisher effect proposition should lead to higher interest rates. However, only bank τ 's interest rate increases. With the other two banks, their credit extension in the consumer loan market and the demand for low deposits overshadow the effects of the lower economic activities, so that their rates reduce. It is also observed that all the banks violate less their capital adequacy requirements and so suffer less capital adequacy violation penalties. This is because the overall credit extension is lower and the higher default probability causes the repayment rate of households to decrease, consequently the risk weighted assets of the banks decrease.

The opposite effect is observed when the default penalty is increased. In other words the following effects are observed when the default penalty is increased by 1%. There is a

reduction in profits for all the three banks. Both the deposit and the lending rates for the net lending banks in the interbank market, increase whilst both the deposit and the lending rates for the net borrowing bank in the interbank market, decrease. The capital adequacy ratios for all the banks decrease in both states. The interbank rate reduces and the GDP increases in both states. These effects are more pronounced as the default penalty is increased.

The percentage changes in key variables of a 1% increase in the default penalty are shown in Tables 7.2.

Table 7.2: Default Penalty Increased by 1%

bank	r_d^b	r^b	ρ	π_i^b	π_{ii}^b	k_i^b	k_{ii}^b	v_i^b	v_{ii}^b	GDP_i	GDP_{ii}
δ	1.430	0.868		-8.268	-98.910	-2.790	-14.628	0.339	1.203		
γ	1.420	0.832	-2.666	-8.614	-67.407	-2.051	-0.536	0.229	0.094	0.039	0.039
τ	-2.666	-2.217		-9.574	-135.501	-2.695	-24.050	0.197	1.415		

7.4.2 Capital violation penalty effects

The default penalty is fixed at the initial level (maintained at its level at the initial equilibrium) and the capital violation penalty is set a percentage point below and above their initial levels to determine their effects. The main effects of reducing the capital violation penalty by 1% are shown in Table 7.3 and are as follows: There is a reduction in profit for each of

Table 7.3: Capital Violation Penalty decreased by 1%

bank	r_d^b	r^b	ρ	π_i^b	π_{ii}^b	k_i^b	k_{ii}^b	v_i^b	v_{ii}^b	GDP_i	GDP_{ii}
δ	0.028	0.006		-0.082	-0.939	-0.028	-0.139	0.002	0.011		
γ	0.027	0.010	-0.011	-0.043	-0.322	-0.011	-0.003	0.001	0.000	0.001	0.001
τ	-0.011	-0.024		-0.121	-1.673	-0.034	-0.297	0.001	0.016		

the three banks in both states. Both the deposit and the lending rates for banks δ and γ , the net lenders in the interbank market, increase. However, there is a reduction in both the deposit and the lending rates for bank τ which is the net borrower in the interbank market. The capital adequacy ratios for all the banks decrease in both states. The interbank rate decreases and the GDP increases in both states.

These effects are in the opposite direction to that of the change in the default penalty and the magnitude of the changes are much smaller. The banks adopt a conservative strategy of choosing lower profitability since they are now less concerned about infringing on the capital

adequacy requirements as it is less costly. The net lenders in the interbank market increase their investment there. In other words they lend more in the interbank market. They do this by lending less in the loan market and taking more deposit in the deposit market. Their actions increase both their lending and deposit rates. The interbank rate decreases as a result of an increased investment from the net lenders.

The other bank τ , takes advantage of the reduced interbank rate and borrows more in that market and reduces the intake of deposits, so its deposit rate reduces. It also lends more in an attempt to improve its profit. This puts pressure on its lending rate thereby reducing it. Given reduced credit supply for bank δ and bank γ , their rates increase, as expected from the liquidity structure of interest rates proposition. By this same proposition, bank τ 's interest rates reduce as a result of higher credit extension. The combined profit of the banks reduces but there is an increase in the cumulative credit supply which overshadows the reduction in profits. This improves household liquidity and income. Hence chances of both the banks and household defaulting on their debt reduces, improving on their repayment rates. The result is an increase in the GDP as a result of an increased economic activities. From the quantity theory of money, the higher liquidity and income ensure that economic activities improve. Higher economic activities (higher prices) imply lower real rate of interest and so by the Fisher effect proposition nominal interest rates must rise, which it did for bank τ .

Given that the CAR violation penalty is lower, by the CAR violation trade-off, the marginal benefit of violating CAR increases more than the reputational cost of violating the CAR, consequently the banks violates their CAR even more leading to their capital adequacy ratio decreasing in both states.

On increasing the capital violation penalties, the following are observed which are in the opposite direction to the effects of reducing the capital violation penalty, as expected. Profits for all three banks increase. There is a reduction in both the deposit and the lending rates for the banks which are the net lenders in the interbank market and an increase in both the deposit and the lending rates for the bank which is a net borrower in the interbank market. The banks capital adequacy ratios increase in both states. The interbank rate increases and the GDP decreases in both states. These observations result from the fact that banks try to increase the values of their capital to asset ratios since violating capital requirement is now costly for all of them. The banks also adopt a riskier strategy of choosing higher expected profitability since they are now more concerned about infringing on the capital adequacy requirements because it is costly. This allows them to suffer fewer capital violation penalties. The banks also adjust their portfolios so that the size of the risk-weighted assets decrease, which helps in further reducing the capital violation penalties.

Again, the effects are more pronounced as one increases the magnitude of the changes in

the penalties. The percentage changes in key variables of a 1% increase in capital violation penalty are shown in Table 7.4.

Table 7.4: Capital Violation Penalty Increased by 1%

bank	r_d^b	r^b	ρ	π_i^b	π_{ii}^b	k_i^b	k_{ii}^b	v_i^b	v_{ii}^b	GDP_i	GDP_{ii}
δ	-0.028	-0.006		0.082	0.939	0.028	0.140	-0.002	-0.011		
γ	-0.027	-0.010	0.011	0.043	0.322	0.011	0.003	-0.001	-0.000	-0.001	-0.001
τ	0.011	0.024		0.121	1.673	0.034	0.297	-0.001	-0.016		

7.4.3 Combined effects of default and capital violation penalties

The default penalty and the capital violation penalty are both reduced by 1%. The effects are in the same direction to the effects when the default penalty alone was reduced by 1%. This is due to the fact that the magnitude of the changes for a change in the default rate far exceeded that of a change in the capital violation penalty. This is possible due to the fact that banks regard defaulting on their deposits more seriously than infringing on their capital adequacy requirements. There is therefore a trade-off between the banks defaulting on their deposits and the interbank obligations, and the reputation cost of violating their capital adequacy requirement. In this case, the effect of the cost of the defaults dominates that of the capital adequacy requirement. Due to the fact that, the effects of the two penalties oppose each other, the magnitude of the changes were slightly lower than that of just reducing the default penalty by 1%. As mentioned in chapter six, the banks prefer to default less and suffer the CAR penalty rather than default more and suffer less of CAR penalty. The percentage changes in key variables of a combination of a 1% reduction in capital infringement penalty and 1% reduction in default penalty are shown in Table 7.5. A similar result was obtained

Table 7.5: Both Default and Capital Infringement Penalties Reduced by 1%

bank	r_d^b	r^b	ρ	π_i^b	π_{ii}^b	k_i^b	k_{ii}^b	v_i^b	v_{ii}^b	GDP_i	GDP_{ii}
δ	-1.412	-0.868		8.186	97.970	2.765	14.508	-0.338	-1.194		
γ	-1.403	-0.827	2.677	8.571	67.085	2.042	0.534	-0.229	-0.091	-0.039	-0.039
τ	2.677	2.212		9.532	133.934	2.694	23.871	-0.196	-1.404		

when both the default penalty and the capital violation penalty were increased together by 1% each. That is the results were in the same direction as just increasing the default penalty by 1% with the magnitude being slightly lower. The percentage increases in the key variables with an increase in both penalties of 1% are shown in Table 7.6.

Table 7.6: Both Default and Capital Infringement Penalties Increased by 1%

bank	r_d^b	r^b	ρ	π_i^b	π_{ii}^b	k_i^b	k_{ii}^b	v_i^b	v_{ii}^b	GDP_i	GDP_{ii}
δ	1.403	0.862		-8.186	-97.972	-2.762	-14.489	0.336	1.192		
γ	1.393	0.822	-2.655	-8.571	-67.085	-2.040	-0.533	0.228	0.093	0.039	0.039
τ	-2.655	-2.193		-9.453	-133.832	-2.661	-23.755	0.195	1.398		

7.5 Capital adequacy requirement

As CAR for each bank is enhanced so that each bank violates its CAR, to tighten the capital requirement, one can reduce the capital adequacy ratio for each bank. This is done by increasing the risk weights on loans akin to what was done in [61]. Thus the risk weights on loans are increased by 10%. As expected the profits for all three banks decrease in both states. The deposit rates for all three banks as well as the interbank rate increase. By the CAR violation trade-off, the banks capital adequacy ratios reduce in each of the two states. There is a reduction in bank δ 's lending rate whilst the other two bank's lending rates increase. Repayment rates for the banks in general increase and GDP increases slightly. The percentage changes in key variables as a result of the change are shown in Table 7.7:

Table 7.7: Risk weights on Loans Increased by 10%

bank	r_d^b	r^b	ρ	π_i^b	π_{ii}^b	k_i^b	k_{ii}^b	v_i^b	v_{ii}^b	GDP_i	GDP_{ii}
δ	0.010	-0.016		-0.067	-0.827	-0.841	-1.003	0.001	0.008		
γ	0.022	0.004	0.027	-0.033	-0.264	-0.773	-0.825	0.0001	-0.0003	0.0003	0.0003
τ	0.027	0.005		-0.053	-0.918	-0.533	-0.725	0.0001	0.009		

As far as the effects on the banks are concerned, tightening of the capital requirement regulatory policy is similar to a contractionary monetary policy. Therefore this leads to an increase in the interbank rate. All the banks adjust their portfolios to take advantage of the increase in the interbank rate. The two net lenders, bank γ and bank δ increase their lending in the interbank market whilst the net borrower, bank τ , reduces its borrowing as it is no more attractive to do so. As part of bank δ 's portfolio adjustment, it takes more deposit in order to increase its credit extension in the consumer loan market. These adjustments increase its deposit rates and reduces its lending rates. It also ensures that its profitability is maintained.

Bank γ , on the other hand is more concerned about avoiding capital requirements' violation penalties, so it further reduces its credit extension in the consumer loan market and take on more deposits leading to an increase in both its lending and deposit rates. In order not to be unduly affected in terms of profitability, it also lowers its repayment in the bad state. It

could do all this because it is not limited in terms of the size of its portfolio. This suggests that banks with many investment opportunities and sufficient capital are able to turn things around in terms of adverse shocks and which in the end negatively affects private sector agents and banks with limited opportunities and funds. Bank τ , the net borrower, have not reduced its borrowing in the interbank market, it offers a higher deposit rate in order to attract more deposits instead and reduces its credits in the consumer loan market to avoid excess capital requirements violation penalties. Its action increases its lending rate as well. The increase in the deposit rates of the banks is reinforced by the fact that agent ϕ lowers its deposits to the banks in anticipation of higher defaults. As the shock is equivalent to tightening monetary policy, less credit becomes available and by the liquidity structure of interest rates, the interest rates should increase and indeed they increase except for bank γ , whose lending rate declines. This exception from bank γ is possible because it reduces its lending in both the consumer loan market and the interbank market because it is not constrained by funds and so could transfer the negative shock to the other two banks and the private sector agents. As bank τ , the net borrower in the interbank market, increases its deposit demand and reduces its interbank borrowing, it is able to increase its repayment of deposits and reduces its repayment of interbank borrowing.

More funds become available to agents ϕ and β as agent ϕ benefits from the increased deposit rates and agent β benefits from the reduction in the lending rate of its nature selected bank δ . This increase in funds outweighs the reduction in funds from the other two agents who suffer as a result of their nature selected banks increasing their lending rates. Therefore, by the quantity theory of money proposition, economic activities (prices of goods) increase from the improved income and liquidity which leads to a slight improvement in GDP. Finally, the profits of the banks reduce as a result of higher payments on CAR violation penalties, higher interest payments on deposits to agent ϕ and in the case of bank δ , reduced interest receipt to its nature selected customer as well. As the banks violate their CAR in the initial condition, it may be regarded as an adverse economic condition. Therefore one may conclude that as CAR is tightened during periods of economic downturn, banks profits further reduce.

7.6 Monetary policy instrument

So far the base money have been used as the monetary policy instrument. In this section, the policy rate is considered as the monetary policy instrument. In other words, the policy rate is fixed and the base money is allowed to be solved endogenously in the model. This is different from using the base money as the monetary policy instrument since in that case the base money is fixed and the policy rate is solved endogenously in the model. The differences

in results are then examined with a focus on the effects on the banks profits and the GDP. It needs to be mentioned that the equilibria where agents will not be on both sides of the market will be investigated. Put differently, banks will either be in a position of a lender or a borrower but not both. This simplification does not alter the result since it can be established that:

Proposition 1

Given any equilibrium, when an agent is on both sides of the market (both supply and demand), there exists another equilibrium where the agent is on one side of the market and support the same allocation.

Proof

Suppose that $d^b, \mu^b \geq 0$. We have three banks. We will prove this for bank γ and the same argument applies for banks δ and τ too.

Since a bank cannot be a net lender and at the same time a net borrower, then for bank γ , either $d^\gamma = 0$ or $\mu^\gamma = 0$. If $d^\gamma - \mu^\gamma > 0$ then set $\hat{\mu}^\gamma = 0$ and $\hat{d}^\gamma = d^\gamma - \mu^\gamma$ (ie a net lender). If $d^\gamma - \mu^\gamma < 0$ then set $\hat{d}^\gamma = 0$ and $\hat{\mu}^\gamma = \mu^\gamma - d^\gamma$ (ie a net borrower).

The same argument applies for d^δ and μ^τ too,

where, d^b = bank b 's interbank lending, and μ^b = bank b 's interbank borrowings.

7.6.1 Profits

There is a linear relationship between the changes in profits and the changes in the default penalties for all banks in both the good and the bad states when the Central Bank sets the base money as its monetary policy instrument. As the default penalty is increased, the profits reduce. This is also the case when the policy rate is the monetary policy instrument except for the net borrower, bank τ , whose profit increases with an increase in the default penalty. With the policy rate as the monetary policy instrument, the policy rate is fixed so the banks are not able to improve their profits through the interbank market. They can only do so through the consumer loan and deposit markets. As the default penalty is increased, the profits reduce. The graphs of the percentage changes in profits (Good state and Bad state) against percentage changes in the the default penalty with the base money as monetary instrument are shown in Fig C.1 of the Appendix. The graphs of the percentage changes in profits (Good state and Bad state) against percentage changes in the the default penalty with the policy rate as monetary instrument are shown in Fig C.2 of the Appendix.

It is observed that as the default penalty is reduced, net lenders reduce their lending in the interbank market and eventually become net borrowers. Bank γ is the first to become a net borrower and that happens when the default penalty is reduced by 2%. Bank δ becomes a net borrower when the default penalty is reduced by 3%. In the same way, when the default

penalty is increased the net borrower reduces its borrowing in the interbank market and eventually becomes a net lender in the interbank market. This happens when the default penalty is increased by 0.2%. To illustrate the point that the net lenders could become net borrowers and vice versa, before the model is run (i.e. at the initial equilibrium), one determines whether a bank is a net borrower or a net lender in the interbank market. This is done by subtracting the banks borrowing from its lending in the interbank market. If it is positive, it is said that the bank is a net lender and it is allocated the value as d . If it is negative, it is said that the bank is a net borrower and the absolute value is allocated as μ . So for the initial run, the two banks which were net lenders (δ and γ) had their values allocated as d . The other bank, the net borrower (τ) had its value allocated as μ . The exogenous variable (in this case the default penalty) that one wants to shock is altered and the model is run and depending on the size of the default penalty, d or μ may become negative. If d for a particular bank becomes negative after the run then that bank has moved from a net lender to become a net borrower and vice versa. The values used for the initial run are in table 7.8.

The split of the profits when the monetary policy instrument is the policy rate at equilibrium,

Table 7.8: Net lender/Borrower Position at Initial Equilibrium

Bank	Delta	Gamma	Tau
Lending	1.5006	2.3066	0.4392
Borrowing	0.6713	1.4591	0.4966
Difference	0.8293	0.8474	(0.0574)
So	$d = 0.8293$	$d = 0.8474$	$\mu = 0.0574$

for the cases where the default penalty is reduced by 3%, and when it is increased by 3% are shown in Tables 7.9, 7.10 and 7.11 respectively.

In the case of a capital infringement penalty, the profits increase as the capital infringement penalties increase under both monetary policy instruments. However, the increases are slightly higher for the case where the monetary policy instrument is the base money. The graphs are similar under the two cases. They are shown in Fig C.3 and Fig C.4 respectively of the Appendix. The profits increase because the banks take action to increase their profits and hence capital in order to reduce the magnitude of the cost incurred from infringing on their CAR. With the dominant effect of the default penalty over capital violation penalty, when both penalties are changed the effects are similar to when only the default penalty is changed under both monetary policy instruments.

¹Negative value in the income section indicates net lender has become net borrower

²Negative value in the outgo section indicates net borrower has become net lender

Table 7.9: Breakdown of Profit: Equilibrium Position - Policy Rate as Monetary Policy Instrument

BANK	GOOD STATE		
	Delta	Gamma	Tau
Total income	14.94520	29.07745	10.39616
Loan market	10.31290	20.50923	8.15220
Investment	3.74584	7.66240	2.24396
Interbank market	0.88646	0.90581	-
Total Outgo	14.54027	28.47300	10.19870
Interbank market	-	-	0.06136
Deposit market	9.89267	22.03690	8.14589
Capital	0.81180	1.98300	0.55870
Others	3.83580	4.45310	1.43276
Profit	0.40493	0.60445	0.19746

BANK	BAD STATE		
	Delta	Gamma	Tau
Total income	14.00031	27.37803	9.71239
Loan market	9.41148	18.85425	7.46842
Investment	3.74584	7.66240	2.24396
Interbank market	0.84298	0.86138	-
Total Outgo	14.10456	27.39211	9.79614
Interbank market	-	-	0.05835
Deposit market	9.45696	20.95601	7.74634
Capital	0.81180	1.98300	0.55870
Others	3.83580	4.45310	1.43276
Profit	(0.10425)	(0.01408)	(0.08376)

Table 7.10: Breakdown of Profit: Default Penalty Reduced by 3% - Policy Rate as Monetary Policy Instrument

BANK	GOOD STATE		
	Delta	Gamma	Tau
Total income	14.91311	29.02995	11.27187
Loan market	11.47279	22.81871	9.02790
Investment	3.74584	7.66240	2.24396
Interbank market	(0.30552)	(1.45117) ¹	-
Total Outgo	14.41029	28.27131	11.08361
Interbank market	-	-	0.91739
Deposit market	9.76269	21.83521	8.17477
Capital	0.81180	1.98300	0.55870
Others	3.83580	4.45310	1.43276
Profit	0.50282	0.75863	0.18825

BANK	BAD STATE		
	Delta	Gamma	Tau
Total income	14.00298	27.43862	10.56932
Loan market	10.53922	21.11607	8.32536
Investment	3.74584	7.66240	2.24396
Interbank market	(0.28209)	(1.33984)	-
Total Outgo	13.80595	27.42461	10.38612
Interbank market	-	-	0.84702
Deposit market	9.15835	20.98851	7.54765
Capital	0.81180	1.98300	0.55870
Others	3.83580	4.45310	1.43276
Profit	0.19703	0.01401	0.18320

Table 7.11: Breakdown of Profit: Default Penalty Increased by 3% - Policy Rate as Monetary Policy Instrument

BANK	GOOD STATE		
	Delta	Gamma	Tau
Total income	14.97333	29.11139	9.37526
Loan market	8.96907	17.83401	7.13130
Investment	3.74584	7.66240	2.24396
Interbank market	2.25842	3.61498	-
Total Outgo	14.66531	28.66035	9.15829
Interbank market	-	-	(0.93860) ²
Deposit market	10.01771	22.22425	8.10543
Capital	0.81180	1.98300	0.55870
Others	3.83580	4.45310	1.43276
Profit	0.30801	0.45104	0.21697

BANK	BAD STATE		
	Delta	Gamma	Tau
Total income	14.08595	27.47848	8.72108
Loan market	8.11491	16.25429	6.47712
Investment	3.74584	7.66240	2.24396
Interbank market	2.22519	3.56180	-
Total Outgo	14.48861	27.52051	9.05284
Interbank market	-	-	(0.92479)
Deposit market	9.84101	21.08441	7.98618
Capital	0.81180	1.98300	0.55870
Others	3.83580	4.45310	1.43276
Profit	(0.40266)	(0.04203)	(0.33176)

7.6.2 Gross Domestic Product

With the base money as the monetary policy instrument, as the default penalty is increased, GDP decreases. When the policy rate is used as the monetary policy instrument, there is a linear relationship between the changes in default penalty and the GDP. GDP increases as the default penalty is increased at a very slow pace. This effect is in the opposite direction to the case where the monetary policy instrument is the base money. The graphs of percentage change in GDP against the percentage change in the default penalties under the two monetary policy instruments are shown in Fig C.5 of the Appendix. There is a linear relationship between GDP and capital violation penalties no matter which of the monetary policy instruments is used by the Central Bank. However, whilst the GDP increases with capital violation penalties in the case where the monetary policy instrument is the base money, the GDP decreases at a much faster pace when the policy rate is used as the monetary policy instrument. The graphs of percentage change in GDP against the percentage change in the capital violation penalties under the two monetary policy instruments are shown in Fig C.6 of the Appendix.

7.7 Policy Rate - Repo Rate

The SARB uses the repo rate to ensure that inflation in future remains in its target range of 3% and 6%. This actually assisted South Africa from being significantly impacted by the 2008 GFC. Prior to the crisis, there was a massive demand for credit and as a result, between 2005 and mid-2008 the SARB gradually increased the policy rate, from 7% to 12% to ensure that the consumer price inflation stayed in its target range [67]. This assisted in halting the excessive credit extension and mitigated the risks from financial activities. Then in period of the GFC, to ensure that inflation does not breach the lower target, the SARB reduced rates rapidly and that lowered the impact on the domestic economy. The SARB probably have a model that assist them in deciding what the repo rate should be in order to ensure they meet that target. The CGE model could be taken as one such model. Even though the intention is to ensure that inflation remains in its target range, one may also be interested in the effects on banks and the economy on altering the repo rate.

Inflation itself is not a variable in the model but there are many variables that can be used as proxies to inflation. Some of these variables are the interest rates for both deposit and lending, probability of default and hence the repayment rates of customers to their nature-selected banks, profits of the banks and the GDP. Consideration is given to these variables emphasising on profits of the banks and the GDP. The starting point is to look at the effects on these key variables when the repo rate is altered by 1% on both sides of the rate at

equilibrium. The impact on the key variables of 1% reduction in the repo rate is as follows: a reduction in both the deposit and lending rates for all banks, a reduction of profits in both states for all banks, a reduction in the repayment rate for bank δ in the good state, a rise in the repayment rate for the rest and an rise in GDP in both states. The percentage changes in key variables are shown in Table 7.12.

With a reduction in the interbank rate, the interbank market is more attractive to the net

Table 7.12: Repo rate reduced by 1%

bank	r_d^b	r^b	ρ	π_i^b	π_{ii}^b	k_i^b	k_{ii}^b	v_i^b	v_{ii}^b	GDP_i	GDP_{ii}
δ	-0.896	-4.039		-0.090	-1.092	-1.127	-1.323	-0.006	0.038		
γ	-0.898	-3.747	-1.000	-0.048	-0.378	-1.117	-1.179	0.001	0.040	0.737	0.737
τ	-1.000	-3.838		-4.419	-12.027	-2.554	-3.587	0.007	0.064		

borrower and less attractive to the net lenders. Therefore bank τ , readjusts its portfolio by borrowing more from the interbank market and lending more to its customer θ in the customer loan market. It also demands less deposit from agent ϕ . Its actions put a downward pressure on its lending as well as deposit rates ensuring that both of them reduce. The net lenders, banks γ and δ , on the other hand, reduce their lending in the interbank market and rather lend more to their private sector agents in the loan market. With increased credit availability, they are able to take less deposit. Such portfolio readjustments of the banks ensure that both their deposit and lending rates also reduce. Lower interest rates result in lower default for households from increased liquidity. The three banks expect the overall supply of credit to rise because of their greater credit extension. This causes the probability of household default to decline as a result of greater aggregate credit supply increasing household liquidity as well as income. All these lead to greater economic activities from not only the private sector agents but the banks as well which ensures GDP increases in both states. Thus, the private sector agents and the banks with the exception of bank δ (in the good state) increase their repayments. With improved GDP, more funds become available to agent ϕ and so supplies more deposits to all the banks. This adds to the reason why the deposit rates of all banks reduce. With greater GDP, the expected rate of return from credit extension rises for all banks. This entices them to even supply more credit. The private sector agents demand more loan and this should in general put positive pressure on lending rates of the banks. However, the greater credit supply from the banks dominates this positive pressure on banks lending rate from the agents demand ensuring that the lending rates still decline. Higher credit extension effects together with higher households repayment rate overshadow the impact of lower lending rates allowing the banks risk-weighted assets to increase.

For a given capital, the banks infringe on their capital requirements as a result of the risk

weighted assets increasing due to the effects of higher credit extension and repayment rates offsetting the effects of the reduction in interest rates. This is exacerbated by the fact that the benefit from the increased profits is higher than the cost from violating the capital requirements. Therefore in a situation where capital is initially compromised, the profit effect from expansionary monetary policy overshadows the capital requirement violation cost, thus worsening the capital adequacy condition of the banks. Also the marginal costs from default and capital requirements' violation differ. Therefore, as was stated in [61], to achieve the optimal banks' asset composition, interactions between the capital adequacy ratio and credit extension should be analysed contemporaneously. Also, as banks want to maximise their profit all the time, they respond to lower defaults on consumer borrowing by increasing their lending.

As far as welfare is concerned, the three private agents who are allowed to borrow from their nature selected banks, improve their utility or payoffs as a result of lower borrowing cost and lower default penalties since they increase their repayment. The expected income of the other private sector agent who is allowed to deposit funds in any of the banks falls because of reduced deposit rates. His consumption therefore reduces. Similarly, the payoffs of all the banks reduce. This is because the benefit resulting from higher repayment rates from their customers is dwarfed by the negative effects of lower lending rates. Clearly, more money chases the same amount of goods, so by the quantity theory of money proposition, prices in both states increase. Put differently, inflation increases. As income improves from economic activities as a result of higher prices, this contributes to the higher repayment rates. To summarize, the improvement from the default rates of the private sector agents on easing monetary policy may not lead to less financial fragility. The improved liquidity resulting from it may rather give incentives to banks whose aim is to make profits to expand and this may not improve their capital requirements condition.

Raising the policy rate has the opposite effect. Therefore the impact on the key variables of 1% increase in the repo rate is as follows: a rise in both the deposit and lending rates for all banks, an increase of profits in both states for all banks, a rise in the repayment rate for bank δ in the good state, a reduction in the repayment rate for the rest and a decline in GDP in both states. The percentage changes in key variables are shown in Table 7.13.

The effects are more pronounced as one increases the magnitude of the change in repo rate. Fig 7.2 shows the graph of percentage change in GDP (GDP growth) against the percentage change in the repo rate. From the graph, as the repo rate is reduced, GDP rises.

Since the year (2020), the SARB has been reducing the repo rate to ensure that the lower band of the inflation target range is not breached and also to support the GDP from the effect of both the sovereign downgrade and COVID-19. Up till now (October 2020) the

Table 7.13: Repo rate increased by 1%

bank	r_d^b	r^b	ρ	π_i^b	π_{ii}^b	k_i^b	k_{ii}^b	v_i^b	v_{ii}^b	GDP_i	GDP_{ii}
δ	0.891	4.063		0.091	1.106	1.141	1.343	0.006	-0.038		
γ	0.893	3.770	1.000	0.048	0.383	1.131	1.194	-0.001	-0.040	-0.734	-0.734
τ	1.000	3.866		4.461	12.152	2.625	3.702	-0.007	-0.065		

cumulative reduction in the repo rate is 2.75%. If one should use this graph to estimate the GDP growth, then GDP should grow by 2.3%. In other words GDP should have increased by 2.3%. However, we are not in normal times, taking into account the lockdowns, industries have collapsed, the fact that unemployment rate has risen quickly and most bank customers are not able to repay their loans, the results in reality is different from what the model estimates. For example, even though the reduction of the repo rate led to GDP increasing, the actual GDP would reduce because of the above mentioned issues. In actual fact the GDP for the first quarter of 2020 declined by 2%. What one can say, is that without the intervention by the SARB, the decline in GDP would have been greater. So in the end, GDP is expected to reduce but it will be offset by the increase the model suggested which is 2.3%. It is important to mention though that the CGE models (especially those with finite time periods) are not for forecasting GDP growth rates. Rather they analyse the impact of a specific shock or scenario.

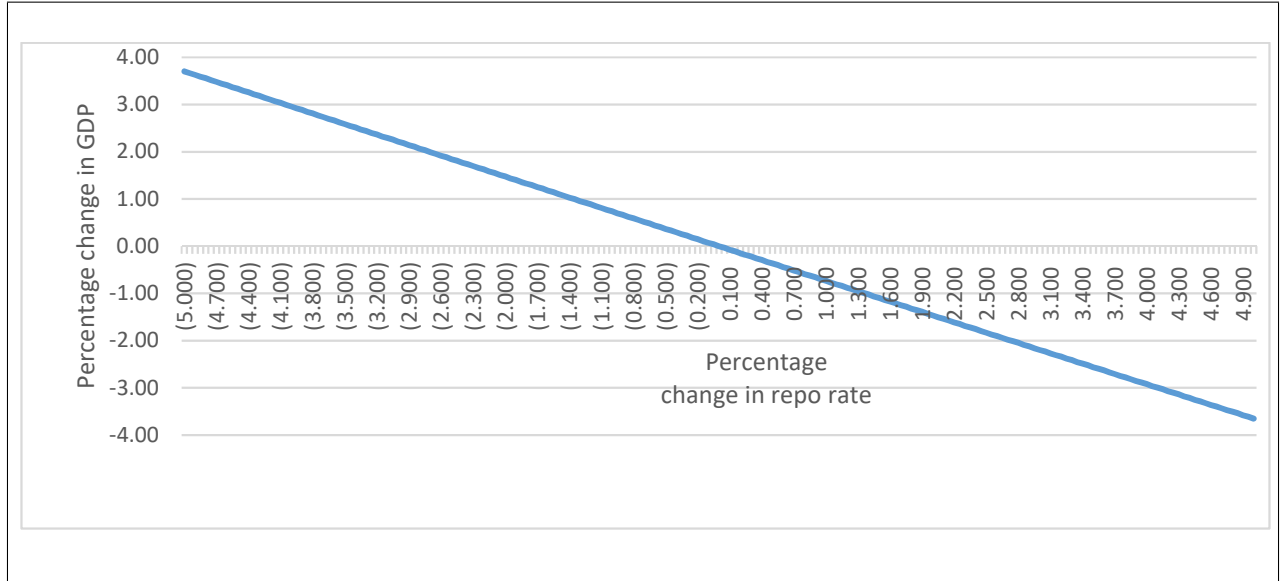


Figure 7.2: The graph of percentage change in GDP against policy rate

7.8 Summary of Results

In this chapter, a CGE model is applied to the South African economy as a regulatory tool for the banking sector. As one increases the default penalty, the profits of the banks decrease. However, as one increases the CAR violation penalty the profits of the banks increase. Hence, there is a trade-off in profit changes as one tightens both the default and the CAR violation penalties. The change in default penalty dominates that of the CAR penalty. Moreover, there is almost a negative linear relationship between the changes in profits and the changes in the default penalties (within a narrow range) for all banks when the Central Bank sets the money supply. However, this is not the case when the Central Bank sets the policy rate. In this case, it depends on whether a bank is a net lender or a net borrower. For net lenders, as the default penalty is increased, profits decrease and for net borrowers, profits increase.

With the capital infringement penalty, profits behave in a similar manner under the two monetary policy instruments. In both cases profits increase as the capital infringement penalties increase even though the increase is slightly higher for the case where the monetary policy instrument is the base money. Since the default penalty dominates the capital violation penalty, profits “increase somewhat” when both penalties are reduced. Profits increase because the banks take action to increase profits and hence capital in order to reduce the magnitude of the cost incurred from infringing on their capital requirements.

It is observed that the net lenders in the interbank market reduce their lending in the interbank market when the default penalty is reduced, and eventually become net borrowers when the Central Bank sets interest rates. The first order effects are more powerful than the case when the Central Bank controls the money supply. Similarly, net borrowers in the interbank market reduces their borrowing in the interbank market when the default penalty is increased, and eventually become net lenders. Banks with many investment opportunities and adequate capital react quite well to adverse shocks compared to those with less diversified portfolios, as they are able to readjust their portfolios to counteract the negative effects of exogenous shocks eventualities and in doing so worsen the predicament of the private sector agents and smaller banks. Finally, during periods of adverse economic conditions, tightening regulatory requirements further worsens the banks profitability.

These results are in line with most literature on capital requirement. In particular, higher capital requirements have been shown to reduce risk in the banking sector but also lead to lower amount of lending by the banks which result in a lower GDP [36, 37, 38, 41, 95]. It is also shown that banks take action to increase their profit and hence their capital in order not to violate their CAR in a regime where CAR is in place compared with a regime where there is no CAR in place [12].

Given an initial compromising capital position, expansionary monetary policy worsens the capital adequacy condition of banks as the banks desire to make additional profit overshadows the cost incurred from violating capital requirements. There is a trade-off between earning a greater excess return through interest payments and the cost of capital requirement violation. Expansionary monetary policy may not necessarily lead to less financial fragility even though it improves aggregate consumer default rates. The higher liquidity resulting from expansionary monetary policy may induce banks to expand which may not improve their capital requirement position. Expansionary monetary policy indeed leads to higher expected inflation so the SARB in order to ensure that inflation does not breach the lower band of its target could reduce the repo rate. A restrictive monetary policy (increasing the repo rate) has the opposite effect. So the SARB could increase the repo rate if it is concerned that expected inflation may breach the upper limit of its target range. Finally, even though the actions of the SARB aggressively reducing the repo rate may not lead to positive GDP growth it will help cushion the effects of the sovereign downgrade and the covid-19 pandemic.

Chapter 8

Conclusion

8.1 Introduction

This study contributes to how the banking sector in South Africa could be regulated to ensure that problems encountered in the banking sector are minimised. There have been some suggestions that the banking sector regulation could not be entirely exonerated from the 2008 GFC even though it appears that decisions by the SARB before the crisis minimised its impact in South Africa. The study uses a CGE model to analyse some probable risks and conduct shocks to determine the impact of those shocks on banks' profitability and the general economy. In effect, CGE models can be used by banking regulators to determine early warning signals of possible systemic risk. The research also considered the importance of capital adequacy requirements, penalties imposed on banks for breaching CAR and other obligations in the interbank market, and the deposit market.

Chapter 1 outlines the aims and objectives of the study and gives some background to the study. Chapter 2 considers the various literature relevant to the study. Financial sector regulation is discussed and a brief history of the banking sector regulation in South Africa is given. In addition, some definitions for systemic risk and its impact on the financial sector are provided. General equilibrium analysis and optimisation are considered in Chapter 3, where financial regulation in general equilibrium and modelling in general equilibrium are discussed. Also, some of the work done in South Africa with CGE models are elaborated. As the banking sector CGE model has not been applied in South Africa, consideration was given to some of the work done in the banking sector in other countries where the CGE model was applied in the context of financial fragility. The chapter concludes with a discussion of the relevant optimisation problem and how the Lagrangean multiplier is applied in the banking sector's CGE model.

The CGE model used for the banking sector is described in Chapter 4. This covers the

banks' optimisation problem, the reduced form equations for the private sector agents and the equilibrium conditions. Calibration of the model is done in Chapter 5 leading to the initial equilibrium position.

Chapter 6 presents the CGE model as a risk assessment tool and Chapter 7 as a regulatory tool. The findings for these two chapters are summarised in the following two sections. The limitations of the research, as well as suggestions for future research, are discussed. Finally, conclusions are made which contains recommendations and applications for the South African banking sector.

8.2 The CGE model as a risk assessment tool

The CGE model performed well as a risk assessment tool for the South African banking sector. The results are in line with similar shocks [62] done in the UK especially when considering the direction of the impacts. However, the magnitude of the impacts differed as the economic conditions were different for the two countries at the time of the investigation. This suggests that a particular economy or country's features influence the impact of the model's results. The result for each of the sensitivity analyses of section 1.2.2 of the research problem when the model is used as a risk assessment tool is summarised.

8.2.1 An expansionary monetary policy

An expansionary monetary policy is achieved by either reducing the bond issued by the SARB or reducing the interbank rate. For the case where the SARB is a net lender in the interbank market, a similar result is achieved by the SARB increasing the base money (or money supply). The main result is that the profits of all the banks decrease and GDP increases. Once the interbank rate decreases, the interbank market becomes less attractive to net lenders and more attractive to net borrowers. The banks then adjust (e.g. net lenders reduce lending in the interbank market and increase lending in the loan market) their portfolio in the three markets (deposit, loan and interbank) to benefit from a reduction of the interbank rate. In doing so, pressure is put on both their lending and deposit rates resulting in both decreasing. As the margin on lending is higher than borrowing (deposits) for the banks, the decrease in rates leads to a reduction in profits for all banks.

With the bank customers, both individuals and firms, credit availability lead to household liquidity and income improvement. This increases economic activities that lead to improvement in GDP.

8.2.2 A positive deposit supply shock to a bank

In the case where the monetary policy instrument is the base money, the result obtained is similar to that of expansionary monetary policy. In both scenarios, the overall broad money supply increases even though the increase is concentrated in a particular bank. However, when the interbank rate is the monetary policy instrument, the interbank rate is fixed and so the banks cannot benefit from the increased availability of funds through their interactions in the interbank market. They therefore focus on the loan and deposit markets. As the overall credit supply increases, household liquidity and income improve resulting in increased GDP from greater economic activities. This ensures that household default probability reduces causing the expected rate of return for the banks to increase, resulting in their lending rates falling. Profits for all banks reduces with the impact more pronounced for the bank with the increased deposit supply.

The impact on both the profit and the GDP is weaker when the SARB sets the interbank rate as its monetary policy instrument. This is due to the contagion effect being shut down in the interbank market and being weakened in the loan market when the interbank rate is fixed.

8.2.3 A positive capital shock to a bank

Again when the base money is the monetary policy instrument, the result is similar to both the expansionary monetary policy and deposit supply shock to a bank as the overall broad money supply increases. The only difference is that the possibility of the bank with the increase in capital infringing on its CAR reduces as its capital adequacy ratio improves. The main contagion effect is the default channel when the policy rate is set as the monetary policy instrument. The bank with the positive capital shock switches part of the funds from the loan market which puts pressure on the overall credit supply for the other banks which increases their default probability. This eventually leads to their capital adequacy ratio improving. The impact on the banks supports the fact that the contagion effect is completely shut down in the interbank market which affects the contagion effects in the other markets when the interbank rate is fixed. In conclusion, the liquidity assistance from injecting capital into a bank when implemented under an interest rate targeting regime may worsen financial fragility.

8.2.4 Restrictive regulatory policy

The model allows two central restrictive regulatory policies. One possible policy is to increase the CAR violation penalty and the other is to increase the default penalty. On increasing

the CAR violation penalty, infringing on CAR becomes costly. Therefore the banks adopt a riskier strategy to increase their profits to boost their capital from the retained profit. On the other hand, when the default penalty is increased, the banks adopt a conservative strategy to not default on their obligations. This leads to lower profits. Interestingly the impact on critical variables when the default penalty is increased is much higher than when the CAR violation penalty is increased. One therefore concludes that banks take violating their default more seriously than infringing on CAR. This is as expected since, in reality, banks defaulting on their deposits payments and interbank obligations lead to them being shut down. GDP declined in the case of tightening the CAR violation penalty because the overall supply of credit in the economy decreases. The opposite happens when the default penalty is tightened and so GDP increases in such a scenario.

8.2.5 A positive shock in Gross Domestic Product

A positive shock to GDP increases the expected aggregate output, demand for loans and the probability of repaying the loans. These lead to the expected rates of return on loans increasing which entices the banks to invest heavily in the markets. There is also a rise in the banks' risk-weighted assets due to individuals paying their loans in full which lowers the capital infringement penalty for all the banks. Therefore, the marginal benefit of higher profitability from suffering less capital violation penalties for all banks is lower. Thus the banks revise their optimal profitability downwards not to suffer much default penalty which worsens their capital position.

8.3 The CGE model as a regulatory tool

The CGE model performed well as a regulatory tool for the South African banking sector. Some economic propositions such as the liquidity structure of interest rate, quantity theory of money, Fisher effects, the default trade-off, CAR violation trade-off and Proposition 1 are used to explain the results. The result for each of the sensitivity analyses of section 1.2.2 of the research problem when the model is used as a regulatory tool is summarised.

8.3.1 The effect of the penalties on the banks and the economy

Two different penalties are considered. These are the default penalty and the CAR violation penalty. As one tightens the default penalty, the following effects are observed: the profits for all three banks decrease, and there is a rise in both the deposit and lending rates for the banks which are net lenders in the interbank market. Other effects are a decrease in

both deposit and lending rate for the bank which is a net borrower in the interbank market, the interbank rate decreases and GDP increases. These effects are reversed when the CAR violation penalty is tightened. In other words, there is a trade-off between the two penalties. The default penalty dominates the CAR penalty. So in the case when both penalties are tightened, the effects are similar to only tightening the default penalty. This confirms that there exists a trade-off in profits between banks defaulting on their deposit and violating their capital adequacy requirement and that banks consider defaulting on deposits more critical than violating the CAR. Indeed, defaulting on deposits leads to bank closure.

8.3.2 The effect of CAR on banks

The imposition of CAR on banks ensures that banks take action to increase their profits to retain funds to improve their capital position so as not to violate CAR. However, CAR also has some effects on banks profits and the economy. CAR is tightened by reducing the capital adequacy ratios of the banks by increasing their risk weights on their assets. Such a shock is similar to tightening monetary policy. Therefore the interbank rate increases. Banks profits reduce and the GDP improves slightly. More affluent banks can soften the blow of the shock by readjusting their portfolios and transferring the problem to the more deficient banks and their customers. This confirms that regulatory policies which are selectively targeted at different banks may produce different consequences since larger banks have the flexibility to adjust their portfolios swiftly. Therefore, they can handle shocks better and in so doing, transfer the problem to banks with constrained portfolios. Finally, during periods of adverse economic conditions, tightening regulatory requirement negatively affects banks profitability.

8.3.3 Monetary policy instrument

With the policy rate as the monetary policy instrument, the policy rate which is the interbank rate, is fixed when one varies the default penalty. When the default penalty is increased, the net borrower reduces its borrowing in the interbank market as it is less attractive to borrow from there than the loan market. As the magnitude of the penalty becomes bigger the net borrower eventually becomes a net lender as it borrows more from the loan market and lends it out in the interbank market. The reverse happens when the default penalty is reduced. The net lenders eventually become net borrowers because the consumer loan market becomes more attractive than the interbank market. This issue does not arise when the monetary policy instrument is the base money, as in this case, the interbank rate is endogenously solved. In addition, the first-order effects are more potent than the case when the Central Bank controls the money supply. In the case of the CAR violation penalty there

is not much difference between the two monetary policy instruments. In both cases, the banks' profits increase as one increases the CAR violation penalty.

8.3.4 The impact of changes in the policy rate

The SARB uses the policy rate to ensure that inflation remains within its targeted range. Even though inflation is not one of the variables specified in the model, there are proxies for inflation. These proxies change when the repo rate is altered such that the model could be used to control inflation. When the repo rate is reduced, the effects are as follows: a reduction in both the deposit and lending rates for all banks, a reduction of profits in both states for all banks, a reduction in the repayment rate for bank δ in the good state, an increase in the repayment rate for the rest and an increase in GDP in both states. These changes lead to an increase in inflation. Thus if the regulators are interested in reducing inflation they could increase the repo rate and alternatively when they are interested in increasing inflation they could reduce the repo rate under normal circumstances. The result also suggest that if a bank is in a compromising capital position then expansionary monetary policy rather worsens the capital adequacy condition of that particular bank as extra profit effect dominates the capital requirement violation cost. Also the higher liquidity resulting from expansionary monetary policy may induce banks to expand rather than improving their capital requirement position.

8.4 Limitations and suggestions for further research

The model only works properly when the capital adequacy requirement is binding. In the modelling, CAR is enhanced for each bank and an appropriate argument is given to support it so that the model could work. It will be better if the model could be altered to work when the capital adequacy requirement is also not binding. In such a case, one will analyse the situation where some banks' capital adequacy ratios are below, and others are above CAR. Put differently, it will allow the situation where some banks violate their CAR and others do not violate their modelled CAR. It will also allow the same CAR for all banks as this is what happens in practice in a country or region. The model could potentially be modified to allow for such cases in future research.

Some of the assumptions underlying the model may not be what happens in practice. Examples include: Individuals or firms being constrained to a particular bank could be an issue as in practice, individuals or firms can borrow from any bank. Banks maximise their expected profits over one year. Again this assumption may not be what happens in practice as banks may have a longer horizon than one year for their profit expectation. Banks are allowed to

default on their deposit and interbank borrowings but with the provision that they will be subjected to the default penalties set by the Regulator. Default is defined as the inability of the institution to honour its financial obligation. The default rate for deposit and that for the interbank market for each bank are the same. In other words, banks are forced to pay their creditors in the same way. They cannot choose to pay their depositors and decide not to pay their fellow banks or the Central Bank. Again, in reality, banks may not default on their deposits. There is the freedom for each bank to infringe on their capital adequacy requirements. However, each infringement is punished by the Regulator imposing a capital requirement infringement penalty. The penalty's size is proportional to how far the level of capital is from the minimum level set by the Regulator. In practice, the further the banks deviate from their minimum capital requirement, the more severe the penalty, so the capital infringement penalty cannot be linear. Future research could consider modelling the non-linearity of capital falling below the required minimum.

In the modelling, three approaches are used for the calibration exercise. These are: calibration against South African banking sector data, arbitrarily chosen inputs and endogenously solved variables. Even though care was taken to ensure that the arbitrarily chosen variables took the South African context into account, the lesser these chosen variables are, the better the model's results will be. Therefore, in future research, emphasis should be put on ensuring that only a bare minimum of the variables are chosen arbitrarily if they cannot be eliminated. In particular, all the elasticities of the reduced form equations may be calibrated against South African data. As a result of lack of data (only aggregated data and not individual data are available), reduced form equations are used for the private sector agents instead of the private sector agents maximising their utility functions. This could affect the accuracy of the result.

The model uses a quadratic profitability function in which a risk aversion coefficient is multiplied by the square of the profit and then deducted from the profit for each bank. This places a restriction on the coefficient of risk aversion to lie between zero and one for the model to work correctly. Since the model already allows for risk by imposing a reputational cost each time the banks violate their CAR and a default penalty each time they default on their deposits or interbank obligations, such an adjustment may not be necessary. In other words, the possibility of risk-neutral banks merits further consideration. In such a case, instead of using a quadratic expected profitability function, one could use a linear one. This should pose no problem as the model punishes banks that take an extreme risk by deducting the penalties from the profit in the objective function. Thus in effect risk is already taken into account in the model. Other appropriate utility risk functions (such as a log function) could be explored in future work. Such an adjustment will eliminate the restriction imposed on the

coefficient of risk aversion having to be in the range from zero to one.

In sum, the CGE model performed satisfactorily as a regulatory tool for South Africa. However, further research is warranted to provide an integrated CGE model to assess regulatory and monetary policy contemporaneously. Hence, one may potentially assess the substitutability and complementarities of various regulatory tools and monetary policy.

8.5 Final conclusions

This research is novel because it is the first time that a CGE model has been applied as a tool for risk assessment and regulation in the banking sector in South Africa. The study covered many disciplines such as financial economics, banking and actuarial science. Economists are the primary users of CGE models, but going forward, actuaries and other practitioners may consider using the model as well. It is believed that even though in this study it is applied in the banking area, there is scope for it to be applied in other actuarial traditional areas such as insurance (life, health and general), pension funds and investments.

The financial sector and, in particular, the banking industry is vital for every country as it has been the main driver of economic growth in many countries. This makes financial sector regulation essential. Hence, models or methods used to regulate the sector need to be efficient. Banking activities keep on changing with many innovations and products. Hence banking regulation must keep up with such changes. The CGE model is flexible and considers individual banks and the entire banking sector, and the economy as a whole. The banking sector model consists of three heterogeneous banks, four private sector agents, a Central Bank, a regulator and three markets (loans, deposit and interbank). Thus it allows feedback and contagion channels to function in equilibrium and is appropriate for macro-prudential regulation. Hence it can assist banking regulators in South Africa to detect problems before they arise.

In an economic environment where capital constraints are binding, an expansionary monetary policy can aggravate financial fragility. This is the case because certain banks may use the extra liquidity injected by the Central Bank to expand and, in so doing, worsen their capital position, and therefore the overall financial stability of the economy. Put differently, in adverse economic conditions, tightening regulatory requirements, especially those of capital adequacy requirements further worsens banks profitability. Thus, a trade-off between efficiency and financial stability exists for both regulatory and monetary policies. When the monetary policy instrument being used is the policy rate, net lenders in the interbank market reduce their lending in the interbank market when the default penalty is reduced and eventually become net borrowers. Similarly, the net borrower in the interbank market reduces

its borrowing in the interbank market when the default penalty is increased and eventually becomes a net lender.

There is a trade-off between the default and the CAR penalties and that the default penalty dominates the CAR violation penalty. Also, regulatory policies which are selectively targeted at different groups of banks can produce higher asymmetric results as banks with richer portfolios and more capital can readjust their balance sheets and transfer the problem to the more constrained banks and the private sector agents. Interest rate targeting has more controlled effects than monetary base targeting since pecuniary externalities are reduced. Both regulatory and monetary policies affect credit extension. Also, default and capital requirements violation have different marginal costs. So, there is a trade-off between earning a greater excess return through interest receipts and the cost of violating capital requirements. Lower defaults on consumer borrowing do not necessarily improve capital assets' ratios since profit-maximising banks will respond by lending even more.

Finally, the banking sector CGE model performed well as a regulatory and risk assessment tool for South Africa. Therefore, it is proposed that the model be one of the models considered for banking regulation and monetary policy decisions.

Appendix A

Optimisation Problems

A.1 General Optimisation

Let f be a differentiable function and I be an interval of numbers. We know that if $\max_x f(x)$ subject to $x \in I$ exists, it may be either at the stationary points of f that are in the constraint set S or at the end points of the interval I . For examples $\max_x x^2$ subject to $x \in [-1, 2]$ exists and $\max_x (-x^2)$ subject to $x \in (-\infty, \infty)$ also exists. However, $\max_x x^2$ subject to $x \in (-\infty, \infty)$ does not exist, seeing that x^2 does not have a global maximum but $\min_x x^2$ subject to $x \in (-\infty, \infty)$ does exist.

Similarly, let f be a differentiable function of n variables and S be a set of n -vectors of numbers. We know that if $\max_x f(x)$ subject to $x \in S$ exists, it may be either at the stationary points of f in the constraint set S or at the boundary of f . This can be illustrated by the following examples taken from [100]:

- $\max_{x,y} [(x-1)^2 + (y-1)^2]$ subject to $0 \leq x \leq 2$ and $-1 \leq y \leq 3$ and
- $\max_{x,y} (x^2 + y^2 + y - 1)$ subject to $x^2 + y^2 \leq 1$ and $\min_{x,y} (x^2 + y^2 + y - 1)$ subject to $x^2 + y^2 \leq 1$

We begin with: $\max_{x,y} [(x-1)^2 + (y-1)^2]$ subject to $0 \leq x \leq 2$ and $-1 \leq y \leq 3$. Differentiating partially with respect to x and y respectively and equating to 0 gives: $-2(x-1) = 0$ and $-2(y-1) = 0$. This has a unique solution $(x, y) = (1, 1)$ which is in the constraint set. The value of the objective function is 0 at this point.

Next we consider what happens to the objective function on the boundary of the constraint set.

If $x = 0$ and $-1 \leq y \leq 3$, the value of the objective function is $1 + (y-1)^2$. On differentiating and equating to 0 gives $2(y-1) = 0$, which has a unique solution $y = 1$,

which is in the constraint set. The value of the objective function at this point is 1. On the boundary of the set $\{(0,y): -1 \leq y \leq 3\}$ - namely at the points (0,1) and (0,3) - the value of the objective function is 5. Thus on this part of the boundary, the points (0,1) and (0,3) are the only candidates for a solution of the original problem.

A similar analysis leads to the conclusion that the points (2, 1) and (2, 3) are the only candidates for a solution on the part of the boundary for which $x = 2$ and $-1 \leq y \leq 3$, the points (0, 1) and (2, 1) are the only candidates for a solution on the part of the boundary for which $0 \leq x \leq 2$ and $y = 1$, and the points (0, 3) and (2, 3) are the only candidates for a solution on the part of the boundary for which $0 \leq x \leq 2$ and $y = 3$.

The value of the objective function at all these candidates for a solution on the boundary of the constraint set is 5. Finally, comparing the values of the objective function at the candidates for a solution that are interior to the constraint set (namely (1, 1)) and on the boundary of the constraint set, we conclude that the problem has four solutions, (0, 1), (0, 3), (2, 1), and (2, 3).

For the second one, $\max_{x,y}(x^2 + y^2 + y - 1)$ subject to $x^2 + y^2 \leq 1$ and $\min_{x,y}(x^2 + y^2 + y - 1)$ subject to $x^2 + y^2 \leq 1$, differentiating partially the objective function with respect to x and y respectively and equating to 0 gives: $2x = 0$ and $2y + 1 = 0$. This has a solution $(x, y) = (0, -1/2)$ which is in the constraint set. The value of the objective function is $-5/4$ at this point.

The boundary of the constraint set is the set of points (x, y) such that $x^2 + y^2 = 1$ which is a circle with radius 1. Thus for a point (x, y) on the boundary we have $f(x, y) = x^2 + (1 - x^2) + y = y$. We have $-1 \leq y \leq 1$ on the boundary, so the maximum of the function on the boundary is 1, which is achieved at $(x, y) = (0, 1)$, and the minimum is -1 , achieved at $(x, y) = (0, -1)$. Combining with the value we have found at the turning point, we see that the global maximum of f is 1, achieved at (0, 1), and the global minimum is $-5/4$, achieved at (0, $-1/2$).

This method for many variables is much less useful than the single variable case, seeing that for many variables, finding the largest or smallest at the boundary is difficult. In both of the examples above, one could solve it easily because the value of the function on the boundary could be expressed in terms of a single variable (y). This may not be the case for many other problems. Hence there is the need for other methods of finding maximum or minimum values of a function subject to a constraint. The Lagrangean multiplier is one such method.

A.2 The Lagrangean multiplier method

A.2.1 The case of two variables

Consider the two-variable problem: $\max_{x,y} f(x, y)$ subject to $g(x, y) = c$. The constraint set, is a set of points in (x,y) space. Suppose that it is a curve. Assume also that the level curves (or contour lines) of f are one dimensional, as shown in Fig. A.1.

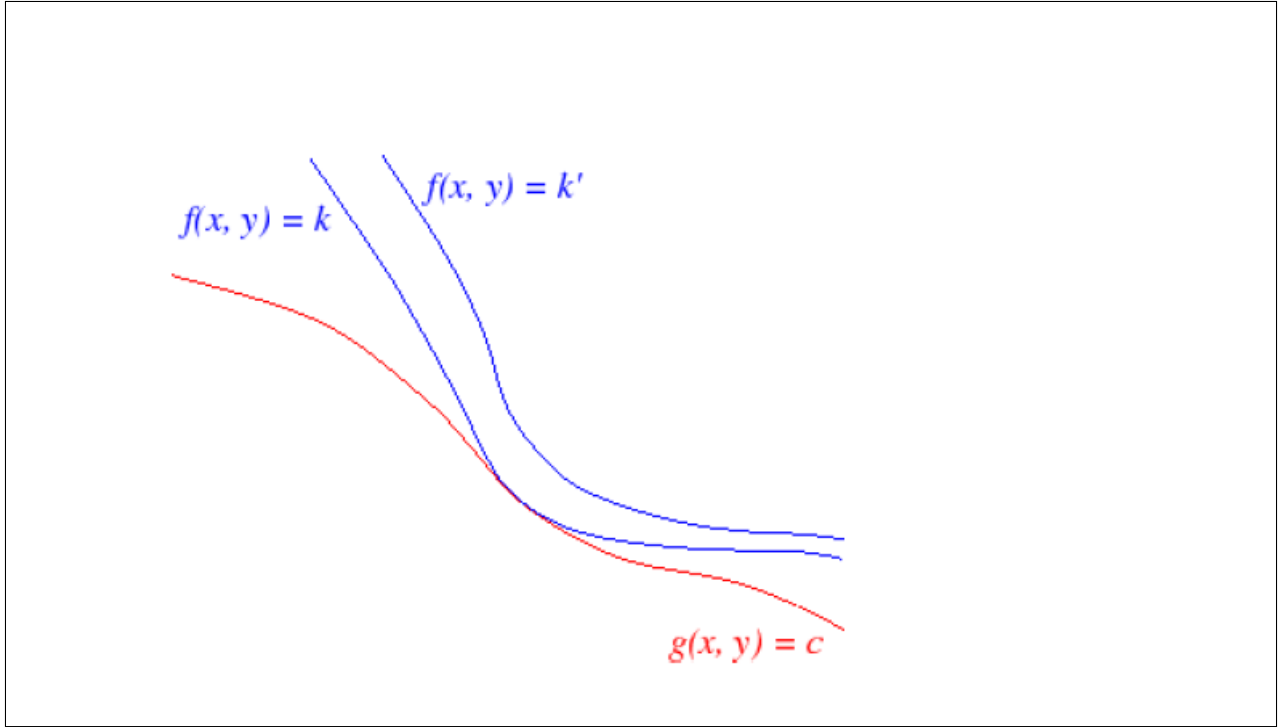


Figure A.1: Graph (From [100])

Assuming that f and g are differentiable, then at the solution (x_0, y_0) of the problem, the constraint curve is tangent to a level curve of f , so that using the equation for a tangent, we have:

$$\frac{y - y_0}{x - x_0} = -\frac{f'_1(x_0, y_0)}{f'_2(x_0, y_0)}, \quad (\text{A.1})$$

and

$$\frac{y - y_0}{x - x_0} = -\frac{g'_1(x_0, y_0)}{g'_2(x_0, y_0)}. \quad (\text{A.2})$$

So from equations (A.1) and (A.2), we get:

$$-\frac{f'_1(x_0, y_0)}{f'_2(x_0, y_0)} = -\frac{g'_1(x_0, y_0)}{g'_2(x_0, y_0)}, \quad (\text{A.3})$$

or

$$\frac{f'_1(x_0, y_0)}{g'_1(x_0, y_0)} = \frac{f'_2(x_0, y_0)}{g'_2(x_0, y_0)}, \quad (\text{A.4})$$

assuming that neither $g'_1(x_0, y_0)$ nor $g'_2(x_0, y_0)$ is zero.

Now let λ , be a new variable such that:

$$\lambda = \frac{f'_1(x_0, y_0)}{g'_1(x_0, y_0)} = \frac{f'_2(x_0, y_0)}{g'_2(x_0, y_0)}, \quad (\text{A.5})$$

then the condition for (x_0, y_0) , to solve the maximization problem, can be written as the two equations:

$$f'_1(x_0, y_0) - \lambda g'_1(x_0, y_0) = 0,$$

and

$$f'_2(x_0, y_0) - \lambda g'_2(x_0, y_0) = 0.$$

At the solution of the problem, we also need the constraint $g(x_0, y_0) = c$, to be satisfied.

Thus the following must be satisfied at a solution (x_0, y_0) :

$$f'_1(x_0, y_0) - \lambda g'_1(x_0, y_0) = 0, \quad (\text{A.6})$$

and

$$f'_2(x_0, y_0) - \lambda g'_2(x_0, y_0) = 0, \quad (\text{A.7})$$

and

$$c - g(x_0, y_0) = 0. \quad (\text{A.8})$$

The first two of these equations ((A.6) and (A.7)) can be viewed as the conditions of the derivatives of the Lagrangean:

$$L(x, y) = f(x, y) - \lambda(g(x, y) - c), \text{ with respect to } x \text{ and } y \text{ to be zero.}$$

In summary, if (x_0, y_0) solves the problem: $\max_{x,y} f(x, y)$ subject to $g(x, y) = c$, and if neither $g'_x(x_0, y_0) \neq 0$ nor $g'_y(x_0, y_0) \neq 0$, then (x_0, y_0) is a stationary point of the Lagrangean.

Similar results holds for $\min_{x,y} f(x, y)$ subject to $g(x, y) = c$.

Necessary conditions for an optimum of a function of two variable

Let f and g be continously differntiable functions of two variables, defined in the set S and let c be a number. Suppose that (x_0, y_0) , is an interior point of S , that solves the problem:

$$\max_{x,y} f(x, y) \text{ subject to } g(x, y) = c,$$

or

$$\min_{x,y} f(x, y) \text{ subject to } g(x, y) = c,$$

or a local maximiser or minimiser of $f(x, y)$. Suppose also that either $g'_x(x_0, y_0) \neq 0$ or $g'_y(x_0, y_0) \neq 0$.

then there is a unique number λ , such that (x_0, y_0) , is a stationary point of the Lagrangean:

$$L(x, y) = f(x, y) - \lambda(g(x, y) - c).$$

In other words, (x_0, y_0) satisfies the first order conditions:

$$L(x_0, y_0) = f'_x(x_0, y_0) - \lambda g'_x(x_0, y_0) = 0,$$

and

$$L(x_0, y_0) = f'_y(x_0, y_0) - \lambda g'_y(x_0, y_0) = 0,$$

where $f'_x(x, y)$ and $g'_y(x, y)$ are the partial derivatives of $f(x, y)$ with respect to x and of $g(x, y)$ with respect to y respectively.

In addition, $g(x_0, y_0) = c$.

If we take the following example:

$$\max_{x,y} xy \text{ subject to } x + y = 6,$$

we see that its solution is as follows:

$$L(x, y) = xy - \lambda(x + y - 6),$$

$$L'_x(x, y) = y - \lambda = 0,$$

$$L'_y(x, y) = x - \lambda = 0,$$

and

$$x + y - 6 = 0.$$

These equations have unique solution: $(x, y, \lambda) = (3, 3, 3)$ and $g'_x(x, y) = 1 \neq 0$ and $g'_y(x, y) = 1 \neq 0$ for all (x, y) .

So we conclude, if the problem has a solution, it is $(x, y) = (3, 3)$.

Conditions under which a stationary point is a global optimum

We have shown that if (x_0, y_0) solves the problem:

$\max_{x,y} f(x, y)$ subject to $g(x, y) = c$,

then there is a number λ_0 , such that (x_0, y_0) , is a stationary point of the Lagrangean:

$L(x, y) = f(x, y) - \lambda_0(g(x, y) - c)$. given λ_0 .

Suppose that (x_0, y_0) maximises $L(x, y)$, given λ_0 . Then

$$L(x_0, y_0) \geq L(x, y) \text{ for all } (x, y),$$

or

$$f(x_0, y_0) - \lambda(g(x_0, y_0) - c) \geq f(x, y) - \lambda(g(x, y) - c) \text{ for all } (x, y).$$

Now since (x_0, y_0) , satisfies the constraint: $g(x_0, y_0) = c$, the above is equivalent to:

$$f(x_0, y_0) \geq f(x, y) - \lambda(g(x, y) - c) \text{ for all } (x, y).$$

So

$$f(x_0, y_0) \geq f(x, y) \text{ for all } (x, y) \text{ with } g(x, y) = c.$$

Thus we conclude that if (x_0, y_0) maximises the Lagrangean, given λ_0 , and satisfies the constraint, then it solves the problem.

The method can readily be generalized to functions with n variables.

A.2.2 The case of n variables and m constraints

The Lagrangean method can be easily generalized to the problem of the form:

$\max_{\bar{x}} f(\bar{x})$ subject to $g_j(\bar{x}) = c_j, j = 1, \dots, m$,

where $\bar{x} = (x_1, \dots, x_n)$.

The Lagrangean for the problem is

$$L(\bar{x}) = f(\bar{x}) - \sum_{j=1}^m \lambda_j(g_j(\bar{x}) - c_j).$$

That is, there is one Lagrangean multiplier for each constraint.

Necessary conditions for an extremum

Let f and $g_1, \dots, g_m$ be continuously differentiable functions of n variables, defined on the set S . Let also c_j for $j = 1, \dots, m$ be numbers and suppose that $\bar{x}^0$ is an interior point of S that solves the problem

$$\max_{\bar{x}} f(\bar{x}) \text{ subject to } g_j(\bar{x}) = c_j, j = 1, \dots, m,$$

or the problem

$\min_{\bar{x}} f(\bar{x})$ subject to $g_j(\bar{x}) = c_j, j = 1, \dots, m$,

or a local maximiser or minimiser of $f(\bar{x})$ subject to $g_j(\bar{x}) = c_j, j = 1, \dots, m$. Suppose also that the rank of the matrix in which the (i,j)th component is $g'_{x_i}(\bar{x}^0)$ is m ,

then there are unique numbers $\lambda_1, \dots, \lambda_m$ such that, $\bar{x}^0$ is a stationary point of the Lagrangean function, defined by

$$L(\bar{x}) = f(\bar{x}) - \sum_{j=1}^m \lambda_j (g_j(\bar{x}) - c_j).$$

That is, $\bar{x}^0$ satisfies the first-order conditions:

$$L'(\bar{x}^0) = f'(\bar{x}^0) - \sum_{j=1}^m \lambda_j (g'_j(\bar{x}^0)).$$

In addition,

$$g_j(\bar{x}^0) = c_j, j = 1, \dots, m.$$

The sufficient conditions also hold. That is if there are unique numbers $\lambda_1, \dots, \lambda_m$ such that, $\bar{x}^0$ is a stationary point of the Lagrangean function, defined by:

$$L(\bar{x}) = f(\bar{x}) - \sum_{j=1}^m \lambda_j (g_j(\bar{x}) - c_j),$$

and in addition,

$$g_j(\bar{x}^0) = c_j, j = 1, \dots, m,$$

then $\bar{x}^0$ solves the constraint optimisation problem:

$$\max_{\bar{x}} f(\bar{x}) \text{ subject to } g_j(\bar{x}) = c_j, j = 1, \dots, m,$$

or the problem:

$$\min_{\bar{x}} f(\bar{x}) \text{ subject to } g_j(\bar{x}) = c_j, j = 1, \dots, m.$$

For example, for the the problem:

$$\min_{x,y,z} x^2 + y^2 + z^2 \text{ subject to } x + 2y + z = 1 \text{ and } 2x - y - 3z = 4,$$

it can be shown that the solution is: $(x, y, z) = (\frac{16}{15}, \frac{1}{3}, \frac{-11}{15})$.

Since the Lagrangean is

$$L(x, y, z) = x^2 + y^2 + z^2 - \lambda_1(x + 2y + z - 1) - \lambda_2(2x - y - 3z - 4),$$

and differentiating partially with respect to x, y , and z respectively, and equating each to 0 we get:

$$L'_x(x, y, z) = 2x - \lambda_1 - 2\lambda_2 = 0,$$

$$L'_y(x, y, z) = 2y - 2\lambda_1 + \lambda_2 = 0,$$

$$L'_z(x, y, z) = 2z - \lambda_1 + 3\lambda_2 = 0.$$

Combining with the two constraints:

$$x + 2y + z = 1$$

and

$$2x - y - 3z = 4$$

and solving, we get $(x, y, z) = (\frac{16}{15}, \frac{1}{3}, \frac{-11}{15})$.

A.3 The Kuhn-Tucker conditions

The Lagrangean multiplier method only works with equality constraints. An extension of the Lagrangean multiplier method is the Kuhn-Tucker method. The Kuhn-Tucker conditions (KTC) can be used to solve optimisation problems with some or all of the constraints being in the form of inequalities. In the banking sector CGE model, some of the constraint are in equality form and others in inequality form. Thus the KTC is applicable and it is applied in deriving the equations of the CGE model in the next section.

The KTC for the problem:

$$\max_{\bar{x}} f(\bar{x}) \text{ subject to } g_j(\bar{x}) \leq c_j, j = 1, \dots, m$$

are

$$L'_{x_i}(\bar{x}) = 0 \text{ for } i = 1, \dots, n,$$

$$\lambda_j \geq 0, g_j(\bar{x}) \leq c_j, \text{ and } \lambda_j[g_j(\bar{x}) - c_j] = 0 \text{ for } j = 1, \dots, m,$$

where

$$L(\bar{x}) = f(\bar{x}) - \sum_{j=1}^m \lambda_j(g_j(\bar{x}) - c_j).$$

Let's consider the example taken from [100]:

$$\max_{x_1, x_2} [-(x_1 - 4)^2 - (x_2 - 4)^2] \text{ subject to } x_1 + x_2 \leq 4 \text{ and } x_1 + 3x_2 \leq 9$$

The Lagrangean is:

$$L(x_1, x_2) = -(x_1 - 4)^2 - (x_2 - 4)^2 - \lambda_1(x_1 + x_2 - 4) - \lambda_2(x_1 + 3x_2 - 9), \quad (\text{A.9})$$

and the Kuhn-Tucker conditions are:

$$-2(x_1 - 4) - \lambda_1 - \lambda_2 = 0, \quad (\text{A.10})$$

$$-2(x_2 - 4) - \lambda_1 - 3\lambda_2 = 0, \quad (\text{A.11})$$

$$x_1 + x_2 \leq 4, \lambda_1 \geq 0, \lambda_1(x_1 + x_2 - 4) = 0, \quad (\text{A.12})$$

and

$$x_1 + 3x_2 \leq 9, \lambda_2 \geq 0, \lambda_2(x_1 + 3x_2 - 9) = 0. \quad (\text{A.13})$$

With the two constraints: $\lambda_1(x_1 + x_2 - 4) = 0$ and $\lambda_2(x_1 + 3x_2 - 9) = 0$, the following are the possibilities:

First case: $x_1 + x_2 = 4$ and $x_1 + 3x_2 = 9$. In this case $x_1 = 3/2$ and $x_2 = 5/2$. Substituting them into equations (A.10) and (A.11) and solving leads to $\lambda_1 = 6$ and $\lambda_2 = -1$, but λ_2 cannot be negative so we discard it.

Second case: $x_1 + x_2 = 4$ and $x_1 + 3x_2 < 9$, so that $\lambda_2 = 0$. So from equations (A.10) and (A.11), we get $x_1 = x_2 = 2$ and $\lambda_1 = 4$. All the conditions are met so $(x_1, x_2, \lambda_1, \lambda_2) = (2, 2, 4, 0)$ is a solution..

Third case: $x_1 + x_2 < 4$ and $x_1 + 3x_2 = 9$, so that $\lambda_1 = 0$. So from equations (A.10) and (A.11), we get $x_1 = 12/5$ and $x_2 = 11/5$. This violates $x_1 + x_2 < 4$ and so we discard it.

Fourth case: $x_1 + x_2 < 4$ and $x_1 + 3x_2 < 9$, so that $\lambda_1 = \lambda_2 = 0$. So from equations (A.10) and (A.11), we get $x_1 = x_2 = 4$. This violates $x_1 + x_2 < 4$ and so we discard it.

Therefore $(x_1, x_2, \lambda_1, \lambda_2) = (2, 2, 4, 0)$ is the only solution of the Kuhn-Tucker conditions. Thus the solution to the problem is $(x_1, x_2) = (2, 2)$.

A.4 Application to the Banking Sector CGE Model

The banking sector model was described in the main body of the thesis. Here we explain how it is implemented using the Lagrangean multiplier method. Clearly if one excludes Lagrange multipliers then from conditions (i) - (iv) of the "Equilibrium conditions" section of the previous chapter, we would have a system of 56 equations with 143 unknown variables.

Therefore if we are able to obtain 87 of the variables/parameters, then we will be able to obtain unique solution for the remaining 56 variable. The 87 variables/parameters that we input into the model are what we call the exogenous variables. Their values must be chosen before a solution to the model can be obtained. The 56 variables which are obtained as a solution to the model are the endogenous variables. These endogenous variables are obtained by applying the Lagrangean multiplier method and the Kuhn-Tucker conditions.

A.4.1 Optimisation problem of the banks

For bank b , let

$$x^b = (\bar{m}_t^b, d_t^b, \mu_t^b, \mu_{d,t}^b, v_{t+1,s=i}, v_{t+1,s=ii}). \quad (\text{A.14})$$

Then from the optimisation problem of Section 4.2.1 we need to maximise:

$$\begin{aligned} f^b(x^b) = & \sum_{s \in S} p_s [\pi_{t+1,s}^b - c_s^b (\Pi_{t+1,s}^b)^2] \\ & - \sum_{s \in S} p_s [\lambda_{ks}^b \max(0, \bar{k}_{t+1,s}^b - k_{t+1,s}^b) + \lambda_s^b (\mu_t^b - v_{t+1,s}^b \mu_t^b) + \lambda_s^b (\mu_{d,t}^b - v_{t+1,s}^b \mu_{d,t}^b)] \end{aligned} \quad (\text{A.15})$$

such that:

$$g_1^b(x^b) = \bar{m}_t^b + d_t^b + A_t^b - \left(\frac{\mu_t^b}{(1 + \rho_t)} + \frac{\mu_{d,t}^b}{(1 + r_{d,t}^b)} + e_t^b + O_t^b \right) = 0, \quad (\text{A.16})$$

and

$$\begin{aligned} g_2^b(x^b) = & (1 + \rho_t) v_{t+1,i}^b \mu_t^b + (1 + r_{d,t}^b) v_{t+1,i}^b \mu_{d,t}^b + e_t^b + O_t^b \\ & - (v_{t+1,i}^{h^b} (1 + r_t^b) \bar{m}_t^b + (1 + r_t^A) A_t^b + \check{R}_{t+1,i} d_t^b (1 + \rho_t)) \leq 0, \end{aligned} \quad (\text{A.17})$$

and

$$\begin{aligned} g_3^b(x^b) = & (1 + \rho_t) v_{t+1,ii}^b \mu_t^b + (1 + r_{d,t}^b) v_{t+1,ii}^b \mu_{d,t}^b + e_t^b + O_t^b \\ & - (v_{t+1,ii}^{h^b} (1 + r_t^b) \bar{m}_t^b + (1 + r_t^A) A_t^b + \check{R}_{t+1,ii} d_t^b (1 + \rho_t)) \leq 0. \end{aligned} \quad (\text{A.18})$$

Applying the Lagrangian multiplier method, and making use of the Kuhn–Tucker conditions, we get for each bank the following equations:

$$\nabla f^b(x^b) - (\lambda_1^b \nabla g_1^b(x^b) + \lambda_2^b \nabla g_2^b(x^b) + \lambda_3^b \nabla g_3^b(x^b)) = 0, \quad (\text{A.19})$$

for each variable in x^b , and

$$g_1^b(x^b) = 0, \quad (\text{A.20})$$

and

$$\lambda_2^b g_2^b(x^b) = 0, \quad (\text{A.21})$$

with $\lambda_2^b \geq 0$, and

$$\lambda_3^b g_3^b(x^b) = 0, \quad (\text{A.22})$$

with $\lambda_3^b \geq 0$. Where,

$\nabla f^b(x^b) = \frac{\partial f^b(x^b)}{\partial(x^b)}$ and $\nabla g_i^b(x^b) = \frac{\partial g_i^b(x^b)}{\partial(x^b)}$ are the respective gradients and λ_i^b 's are constants called Lagrangian multipliers.

With 6 variables and 3 banks, equation (A.19) provides 18 equations. Equation (A.20) gives 3 equations - one for each bank and equation (A.21) gives 3 equations one for each of the three banks in the good state. Equation (A.22) also gives 3 equations one for each of the three banks in the bad state. Together with 6 equations from (4.6) we get a total of 33 equations for the bank optimisation problem.

A.4.2 Reduced form equations

The number of equations are 3 for credit demand, 3 for supply of deposits, 6 for household repayment rates and 2 for GDP. - This gives a total of 14 equations.

Private sector agents

For $b = 1, 2, 3$,

we have from equation (4.7) for household borrowers demand for loans:

$$\ln(v_{t+1,s}^{h^b}) = g_{h^b,s,1} + g_{h^b,s,2} \ln(GDP_{t+1,s}) + g_{h^b,s,3} [\ln(\bar{m}_t^\gamma) + \ln(\bar{m}_t^\delta) + \ln(\bar{m}_t^\tau)],$$

and from equation (4.8) for supply of deposits:

$$\begin{aligned} \ln(d_{b,t}^\Theta) = & z_{b,1} + z_{b,2} \ln[p(GDP)_{t+1,i} + (1-p)(GDP)_{t+1,ii}] + \\ & z_{b,3} [r_{d,t}^b (pv_{t+1,i}^b + (1-p)v_{t+1,ii}^b)] + z_{b,4} \sum_{\acute{b} \neq b \in B} [r_{d,t}^{\acute{b}} (pv_{t+1,i}^{\acute{b}} + (1-p)v_{t+1,ii}^{\acute{b}})], \end{aligned}$$

and from equation (4.9) for household loan repayment rate for the good state:

$$\ln(v_{t+1,i}^{h^b}) = g_{h^b,i,1} + g_{h^b,i,2} \ln(GDP_{t+1,i}) + g_{h^b,i,3} [\ln(\bar{m}_t^\gamma) + \ln(\bar{m}_t^\delta) + \ln(\bar{m}_t^\tau)],$$

and from equation (4.9) for household loan repayment rate for the bad state:

$$\ln(v_{t+1,ii}^{h^b}) = g_{h^b,ii,1} + g_{h^b,ii,2} \ln(GDP_{t+1,ii}) + g_{h^b,ii,3} [\ln(\bar{m}_t^\gamma) + \ln(\bar{m}_t^\delta) + \ln(\bar{m}_t^\tau)].$$

Gross Domestic Product

The two equations for the GDP are from equation (4.10) for the good state:

$$\ln(GDP_{t+1,i}) = \mu_{i,1} + \mu_{i,2} trend + \mu_{i,3} [\ln(\bar{m}_t^\gamma) + \ln(\bar{m}_t^\delta) + \ln(\bar{m}_t^\tau)],$$

and for the bad state:

$$\ln(GDP_{t+1,ii}) = \mu_{ii,1} + \mu_{ii,2} trend + \mu_{ii,3} [\ln(\bar{m}_t^\gamma) + \ln(\bar{m}_t^\delta) + \ln(\bar{m}_t^\tau)].$$

A.4.3 Market clearing conditions

The number of equations are 3 each for deposit and credit markets and 1 for interbank market making a total of 7 equations.

Credit market

For $b = 1, 2, 3$, we have from equation (4.11) which ensures equilibrium in the loan market:

$$1 + r_t^b = \frac{\mu_t^{h^b}}{\bar{m}_t^b}.$$

Deposit market

For $b = 1, 2, 3$, we have from equation (4.12) which ensures equilibrium in the deposit market:

$$1 + r_{d,t}^b = \frac{\mu_{d,t}^b}{d_{b,t}^\Theta}.$$

Interbank market

The equation from equation (4.13) which ensures equilibrium in the interbank market is:

$$1 + \rho_t = \frac{\bar{B}_t + \sum_{b \in B} \mu_t^b}{M_t + \sum_{b \in B} d_t^b}$$

A.4.4 Expectations about interbank repayment rate

There are two equations for the interbank repayment rates - one for the good state and the other for the bad state. These are

$$\check{R}_i = \frac{\sum_{b \in B} v_{t+1,i}^b \mu_t^b}{\sum_{b \in B} \mu_t^b},$$

and

$$\check{R}_{ii} = \frac{\sum_{b \in B} v_{t+1,ii}^b \mu_t^b}{\sum_{b \in B} \mu_t^b}.$$

So in total we get the 56 equations. These are the 33 equations from the optimisation problem of the banks, 14 from the reduced form equations of the private sector agents and GDP, 7 for the market clearing constraints and 2 for the expectations about the interbank repayment rate.

See Appendix B for the parameters of the model.

Appendix B

Parameters/variables of the model

The 143 parameters/variables are: (number of parameter/variables in bracket)

- (1) p_s = probability that state $s \in S$ will occur
- (6) c_s^b = coefficient of risk aversion in the utility function of bank $b \in B$ in state $s \in S$
- (6) $\lambda_{k,s}^b$ = capital requirement violation penalty imposed on bank $b \in B$ in state $s \in S$
- (6) $\bar{k}_{t+1,s}^b$ = capital adequacy requirement for bank $b \in B$ in state $s \in S$
- (6) λ_s^b = default penalties on bank $b \in B$ in state $s \in S$
- (3) μ_t^b = amount of money that bank b owes in the interbank market
- (3) $\mu_{d,t}^b$ = amount of money that bank b owes in the deposit market
- (6) $v_{t+1,s}^b$ = repayment rate of bank b to all its creditors in state $s \in S$ in the period $t+1$
- (3) $\bar{m}_t^b$ = amount of credit that bank b offers in the loan market
- (3) d_t^b = bank b 's interbank lending
- (3) A_t^b = the value of market book held by bank $b \in B$
- (6) $e_{t,s}^b$ = capital held by bank $b \in B$ in state $s \in S$ in the period t
- (3) O_t^b = the other items in the balance sheet of bank $b \in B$
- (3) r_t^b = lending rate offered by bank $b \in B$
- (3) $r_{d,t}^b$ = deposit rate offered by bank $b \in B$
- (1) ρ_t = interbank rate
- (3) r_t^A = rate of return on market book
- (6) $v_{t+1,s}^{h,b}$ = repayment rate of agent h to his nature-selected bank b in the consumer loan market
- (2) $\check{R}_{t+1,s}$ = repayment rate by banks from their interbank lending in state $s \in S$
- (1) $\hat{\omega}$ = risk weight on consumer loans
- (1) $\check{\omega}$ = risk weight on market book
- (1) ω = risk weight on the interbank lending
- (6) $\pi_{t,s}^b$ = profit of bank $b \in B$ in state $s \in S$ in the period t

- (6) $k_{t+1,s}^b$ = capital adequacy ratio for bank $b \in B$ in state $s \in S$
- (3) $\mu_t^{h^b}$ = amount of money that agent $h^b \in H^b$ chooses to owe in the loan market of bank $b \in B$ in period t
- (3) $d_{b,t}^\theta$ = amount of money that agent θ chooses to deposit with bank $b \in B$ in period t
- (2) $r_{d,t}^b$ = competitors deposit interest rates
- Elasticities for the household borrowers' demand for loans (reduced form equations)
- (3) $a_{h^b,2}$
- (3) $a_{h^b,3}$
- (3) $a_{h^b,4}$
- Elasticities for supply of deposits (reduced form equations)
- (3) $z_{b,1}$
- (3) $z_{b,2}$
- (3) $z_{b,3}$
- (3) $z_{b,4}$
- Elasticities for household's loans repayment rates (reduced form equations)
- (6) $g_{h^b,s,1}$
- (6) $g_{h^b,s,2}$
- (6) $g_{h^b,s,3}$
- Elasticities for Gross domestic product (reduced form equations)
- (2) $\mu_{s,1}$
- (2) $\mu_{s,2}$
- (2) $\mu_{s,3}$
- Other parameters/variables
- (1) $\bar{B}_t$ = government bond
- (1) M_t = money issued by the Central Bank
- (2) $GDP_{t,s}$ = Gross Domestic Product at time t in state $s \in S$

Appendix C

Graphs

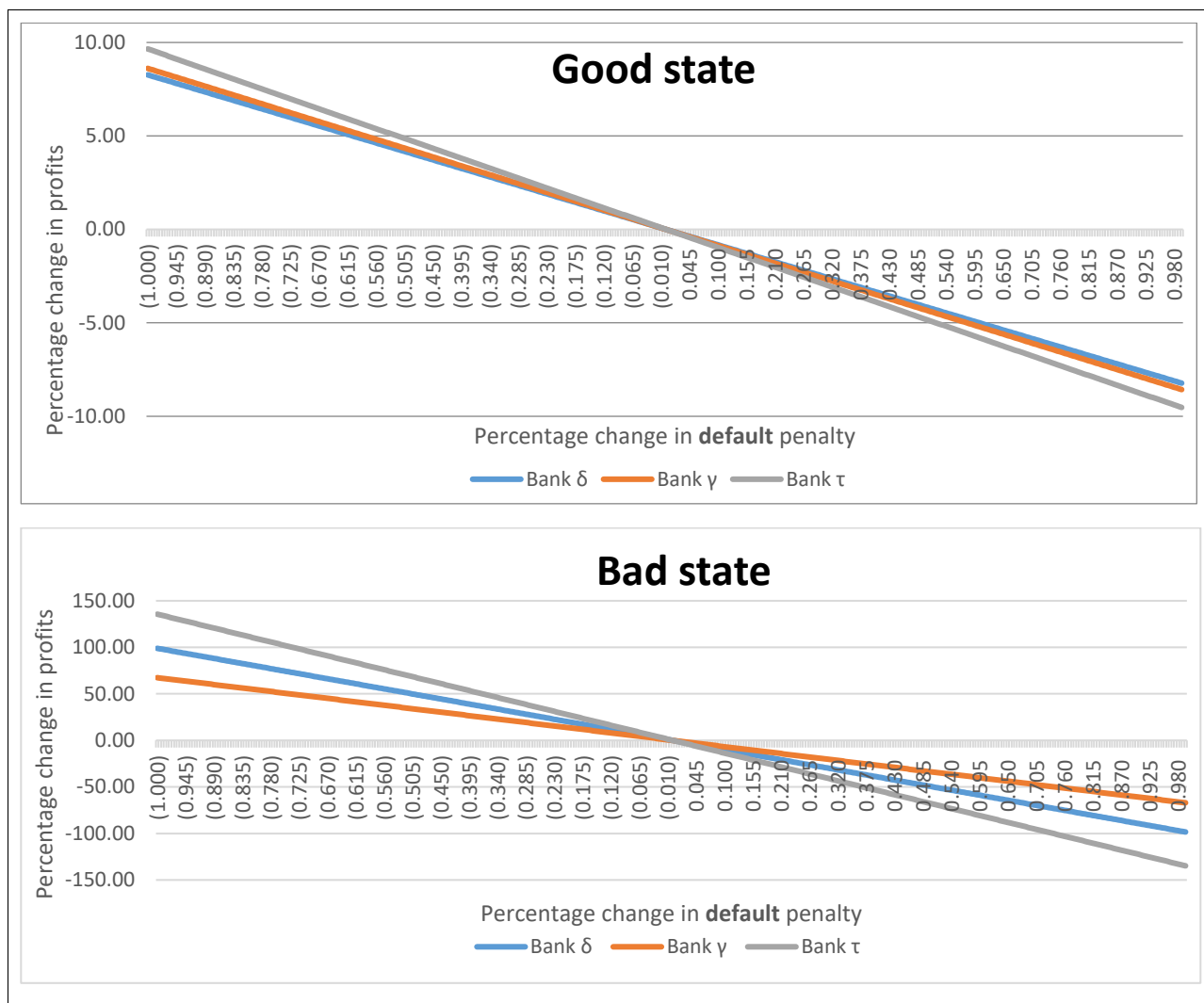


Figure C.1: The graph of percentage change in profit against percentage change in default penalty when the base money is set as the monetary policy instrument

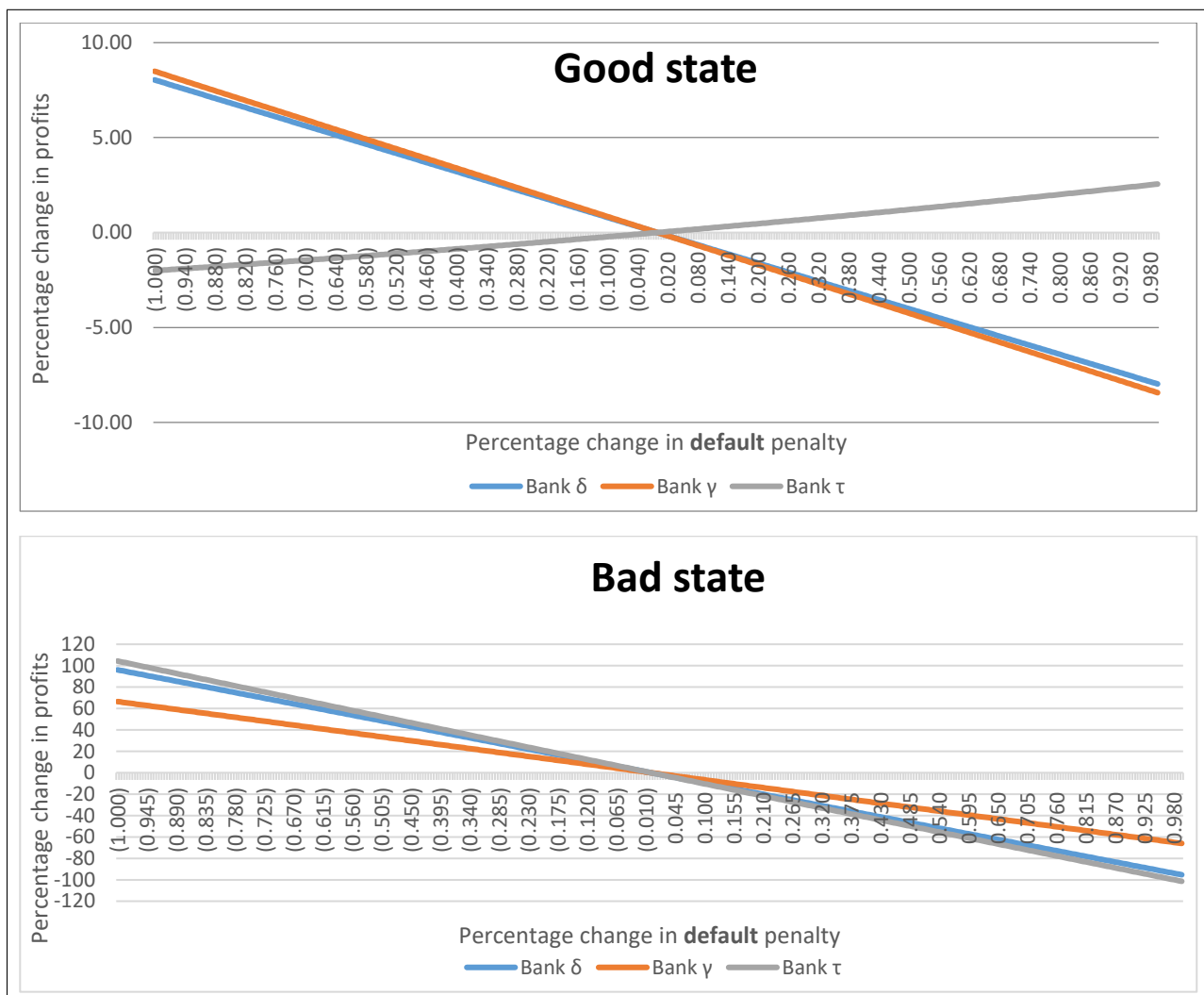


Figure C.2: The graph of percentage change in profit against percentage change in default penalty when the policy rate is set as the monetary policy instrument

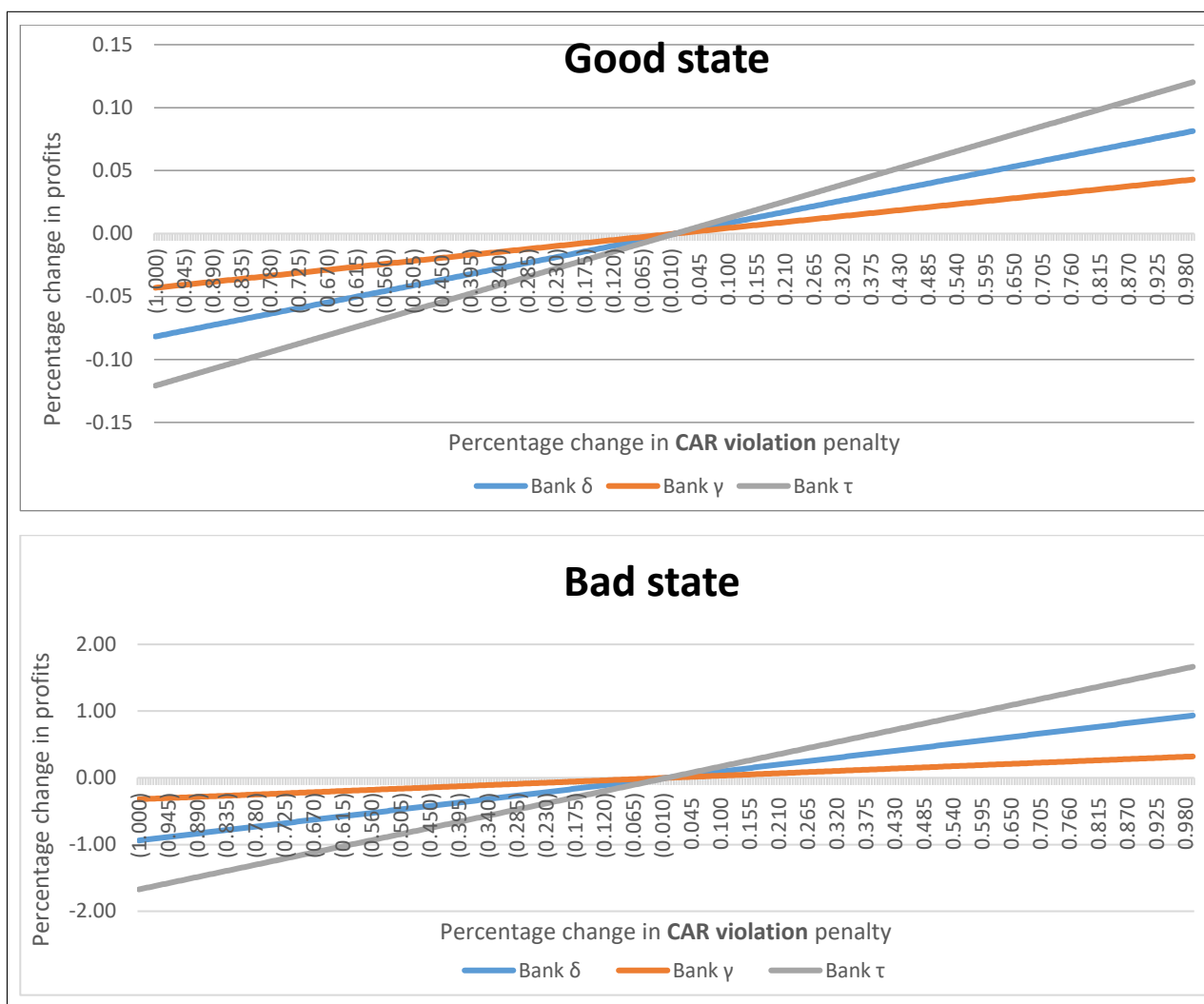


Figure C.3: The graph of percentage change in profit against percentage change in capital infringement penalty when the base money is set as the monetary policy instrument

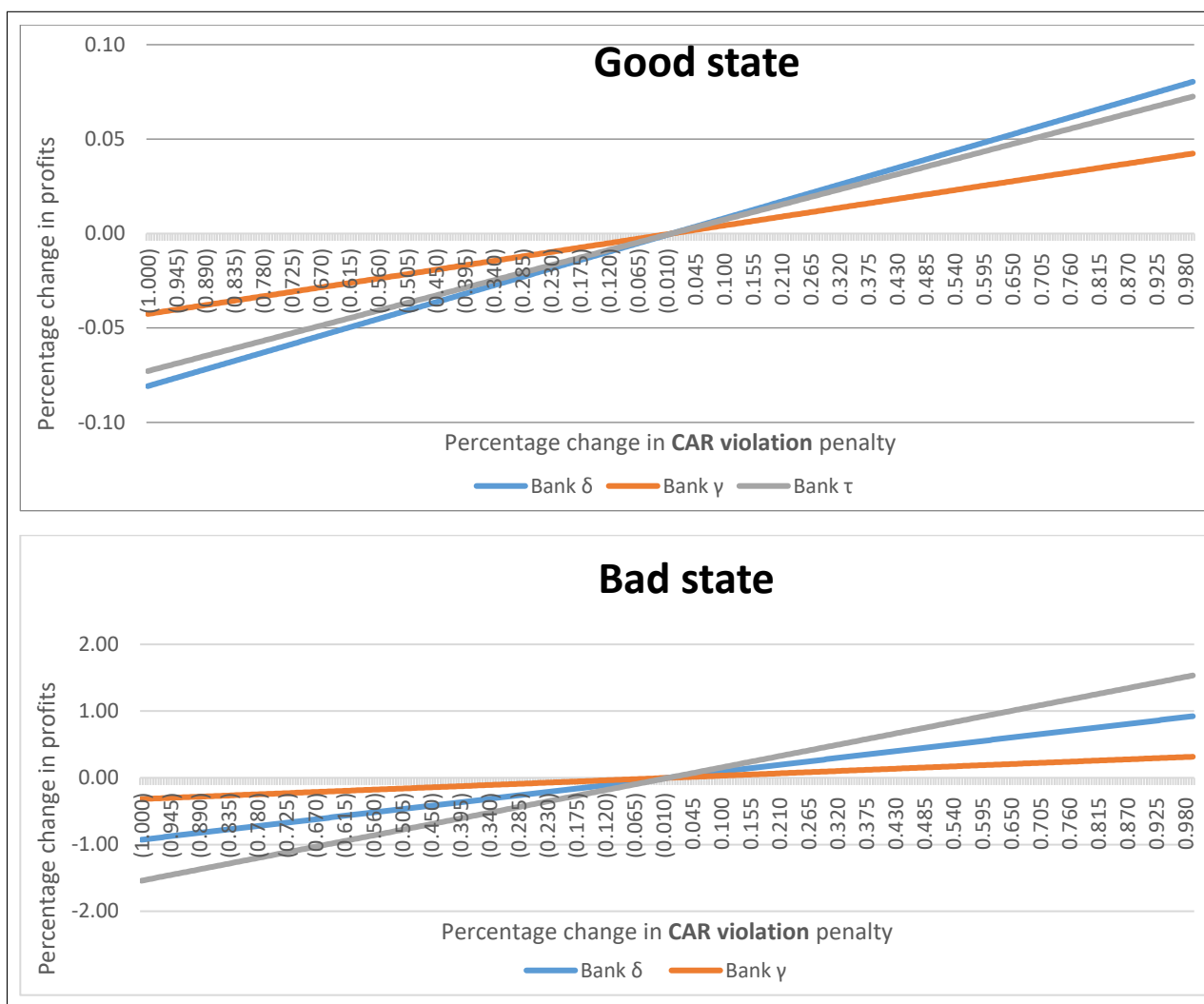


Figure C.4: The graph of percentage change in profit against percentage change in capital infringement penalty when the policy rate is set as the monetary policy instrument

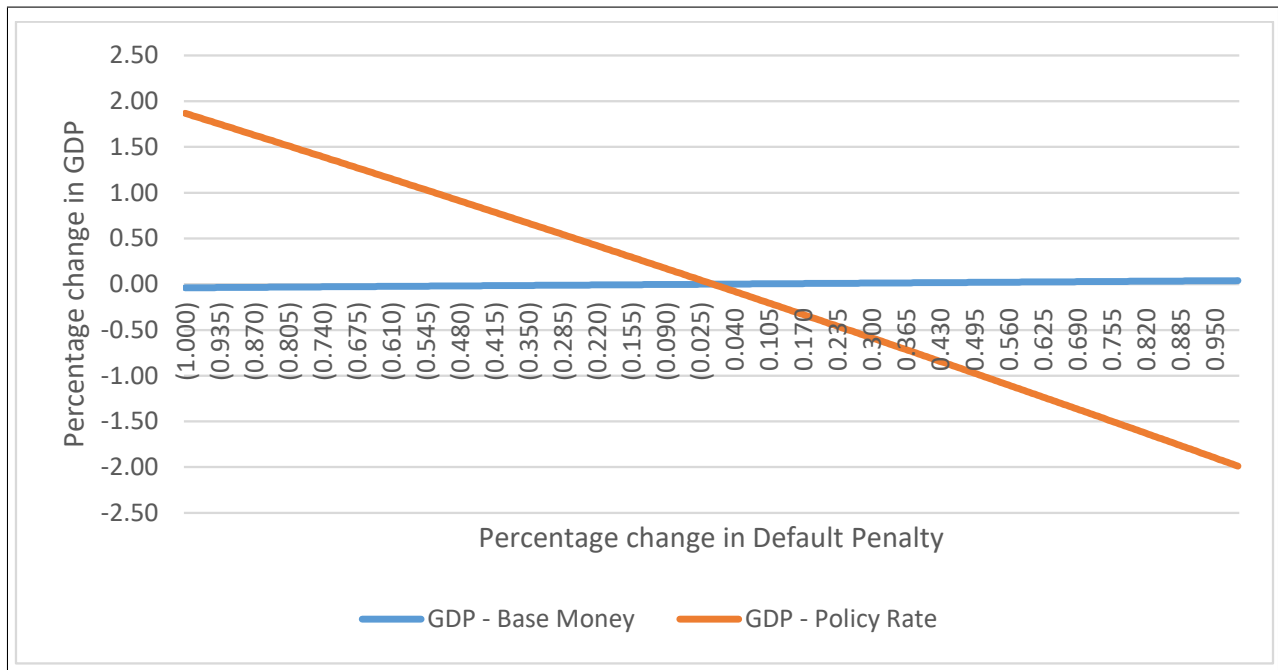


Figure C.5: The graph of percentage change in GDP against percentage change in default penalty with the two monetary policy instruments

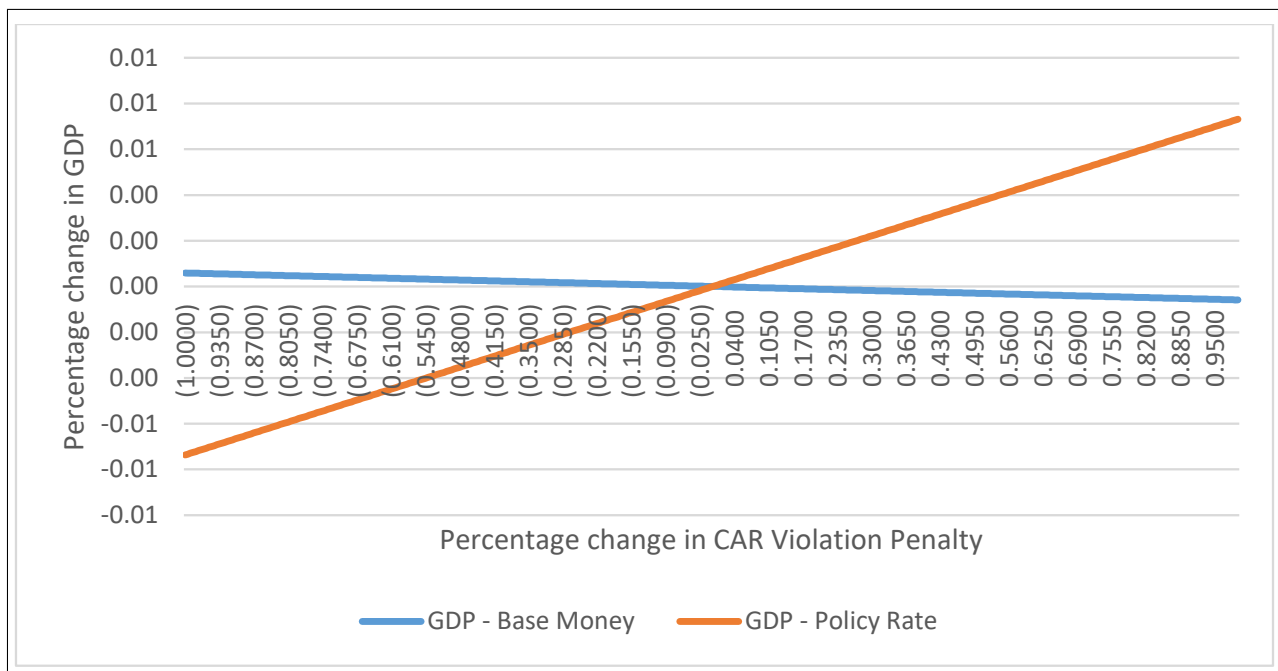


Figure C.6: The graph of percentage change in GDP against percentage change in capital violation penalty with the two monetary policy instruments

Bibliography

- [1] Acharya, V.V.: A theory of systemic risk and design of prudential bank regulation. *Journal of financial stability* **5**(3), 224–255 (2009)
- [2] Acharya, V.V.: The dodd-frank act and basel III: Intentions, unintended consequences, and lessons for emerging markets. Tech. rep., Asian Development Bank Institute (2012)
- [3] Adam, C.S., Bevan, D.L.: Costs and benefits of incorporating asset markets into CGE models: Evidence and design issues. Institute of Economics and Statistics, University of Oxford (1998)
- [4] Adrian, T., Brunnermeier, M.K.: Covar. Tech. rep., National Bureau of Economic Research (2011)
- [5] Allen, F., Carletti, E.: Systemic risk and macroprudential regulation. In: *The Global Macro Economy and Finance*, pp. 191–210. Springer (2012)
- [6] Allen, F., Carletti, E.: Systemic risk and macroprudential regulation. In: *Risk and EU law*. Edward Elgar Publishing (2015)
- [7] Allen, F., Gale, D.: Financial contagion. *Journal of political economy* **108**(1), 1–33 (2000)
- [8] Allen, F., Gale, D.: Systemic risk and regulation. In: *The risks of financial institutions*, pp. 341–376. University of Chicago Press (2007)
- [9] Allen, F., Goldstein, I., Jagtiani, J., Lang, W.W.: Enhancing prudential standards in financial regulations. *Journal of Financial Services Research* pp. 1–17 (2014)
- [10] Altig, D.E., Carlstrom, C.T., Lansing, K.J.: Computable general equilibrium models and monetary policy advice. *Journal of Money, Credit and Banking* **27**(4), 1472–1493 (1995)

- [11] Arndt, C., Lewis, J.D.: The macro implications of hiv/aids in South Africa: a preliminary assessment. *South African Journal of Economics* **68**(5), 380–392 (2000)
- [12] Aspachs, O., Goodhart, C.A., Tsomocos, D.P., Zicchino, L.: Towards a measure of financial fragility. *Annals of finance* **3**(1), 37–74 (2007)
- [13] Bank for International Settlements: History of the basel committee. <https://www.bis.org/bcbs/history.htm>. Accessed: 2019-12-24
- [14] Bank for International Settlements. Committee on Banking Regulations and Supervisory Practices: International convergence of capital measurement and capital standards. Bank for International Settlements (1988)
- [15] Bårdsen, G., Lindquist, K.G., Tsomocos, D.P.: Evaluation of macroeconomic models for financial stability analysis. Institutt for samfunnsøkonomi (2006)
- [16] Barth, J.R., Caprio, G., Levine, R.: Bank regulation and supervision: what works best? *Journal of Financial intermediation* **13**(2), 205–248 (2004)
- [17] Barth, J.R., Caprio, G., Levine, R.: Rethinking bank regulation: Till angels govern. Cambridge University Press (2008)
- [18] Basel, I.I.: The new basel capital accord. Switzerland: Bank for International Settlements (2004)
- [19] Benston, G.J., Kaufman, G.G.: The appropriate role of bank regulation. *The Economic Journal* **106**(436), 688–697 (1996)
- [20] Bernanke, B.S., Blinder, A.S.: Credit, money, and aggregate demand. *American Economic Review* **78**(2), 435–439 (1988)
- [21] Beyers, C., De Freitas, A., Essel-Mensah, K., Seymore, R., Tsomocos, D.P.: A computable general equilibrium model as a banking sector regulatory tool in South Africa. Available at SSRN 3646263 (2020)
- [22] Beyers, C.F., De Freitas, A., Essel-Mensah, K.A., Seymore, R., Tsomocos, D.P.: A computable general equilibrium model for banking sector risk assessment in South Africa. *Annals of Finance* pp. 1–24 (2020)
- [23] Bhattacharya, S., Goodhart, C., Sunirand, P., Tsomocos, D.: Relative performance, banks and sequential contagion, university of oxford. Tech. rep., mimeo (2003)

- [24] Blundell-Wignall, A., Atkinson, P.: Origins of the financial crisis and requirements for reform. *Journal of Asian Economics* **20**(5), 536–548 (2009)
- [25] Blundell-Wignall, A., Atkinson, P.: Thinking beyond Basel III. *OECD Journal: Financial Market Trends* **2010**(1), 9–33 (2010)
- [26] Board, F.S.: Guidance to assess the systemic importance of financial institutions, markets and instruments: initial considerations. Report to G20 finance ministers and governors (2009)
- [27] Bohlman, H.R.: The macroeconomic impact of skilled emigration from South Africa: a CGE analysis. Melbourne: Centre of Policy Studies, Monash University (2010)
- [28] Bonga-Bonga, L.: Computerised general equilibrium (CGE) modelling of the impact of fiscal policy on economic growth, income redistribution and poverty alleviation in South Africa. Ph.D. thesis, University of Johannesburg (2007)
- [29] Botha, E., Makina, D.: Financial regulation and supervision: Theory and practice in South Africa. *International Business & Economics Research Journal (IBER)* **10**(11), 27–36 (2011)
- [30] Bourguignon, F., Branson, W., de Melo, J.: Macroeconomic adjustment and income distribution: A macro-micro simulation model. Tech. rep., OECD Publishing (1989)
- [31] Burfisher, M.E.: Introduction to computable general equilibrium models. Cambridge University Press (2011)
- [32] Caruana, J.: Systemic risk: How to deal with it? *Bankarstvo* **39**(7-8), 80–99 (2010)
- [33] Catarineu-Rabell, E., Jackson, P., Tsomocos, D.P.: Procyclicality and the new basel accord-banks’ choice of loan rating system. *Economic Theory* **26**(3), 537–557 (2005)
- [34] Causape, A.J.M., Ferrari, E., McDonald, S.: Social accounting matrices: basic aspects and main steps for estimation. Tech. rep., Joint Research Centre (Seville site) (2018)
- [35] Chitiga, M., Mabugu, R., Maisonnave, H.: The impact of the economic crisis in South Africa: A computable general equilibrium model. *Poverty and Economic Policy Research Network*, June pp. 5–20 (2010)
- [36] Christiano, L., Ikeda, D.: Leverage restrictions in a business cycle model. Tech. rep., National Bureau of Economic Research (2013)

- [37] Clerc, L., Derviz, A., Mendicino, C., Moyen, S., Nikolov, K., Stracca, L., Suarez, J., Vardoulakis, A.P.: Capital regulation in a macroeconomic model with three layers of default. 40th issue (June 2015) of the International Journal of Central Banking (2018)
- [38] Corbae, D., D’Erasmus, P.: Capital requirements in a quantitative model of banking industry dynamics. Tech. rep., National Bureau of Economic Research (2019)
- [39] Davies, R., Thurlow, J.: Formal–informal economy linkages and unemployment in South Africa. *South African Journal of Economics* **78**(4), 437–459 (2010)
- [40] De Lis, F., Pagés, J.M., Saurina, J.: Credit growth, problem loans and credit risk provisioning in Spain. *BIS papers* **1**, 331–353 (2001)
- [41] De Nìcolo, G., Gamba, A., Lucchetta, M.: Microprudential regulation in a dynamic model of banking. *The Review of Financial Studies* **27**(7), 2097–2138 (2014)
- [42] De Walque, G., Pierrard, O., Rouabah, A.: Financial (in) stability, supervision and liquidity injections: a dynamic general equilibrium approach. *The Economic Journal* **120**(549), 1234–1261 (2010)
- [43] De Wet, T.J.: The effect of a tax on coal in South Africa: A CGE analysis. Ph.D. thesis, University of Pretoria (2005)
- [44] Devarajan, S., Go, D.S., Robinson, S., Thierfelder, K.: Tax policy to reduce carbon emissions in a distorted economy: Illustrations from a South Africa CGE model. *The BE Journal of Economic Analysis & Policy* **11**(1) (2011)
- [45] Devarajan, S., Robinson, S.: Contribution of computable general equilibrium modeling to policy formulation in developing countries. In: *Handbook of Computable General Equilibrium Modeling*, vol. 1, pp. 277–301. Elsevier (2013)
- [46] Dewatripont, M., Tirole, J.: The prudential regulation of banks. Tech. rep., ULB–Université Libre de Bruxelles (1994)
- [47] Diaz-Gimenez, J., Prescott, E.C., Fitzgerald, T., Alvarez, F.: Banking in computable general equilibrium economies. *Journal of Economic dynamics and Control* **16**(3-4), 533–559 (1992)
- [48] Dubey, P., Geanakoplos, J., Shubik, M.: Default and punishment in general equilibrium¹. *Econometrica* **73**(1), 1–37 (2005)

- [49] Elsinger, H., Lehar, A., Summer, M.: Risk assessment for banking systems. *Management science* **52**(9), 1301–1314 (2006)
- [50] Erero, J.L.: Effects of increases in value-added tax: a dynamic CGE approach. Tech. rep., ERS Working Paper 558. <https://econrsa.org/publications/working-papers> . . . (2017)
- [51] Falkena, H., Bamber, R., Llewellyn, D., Store, T.: Financial regulation in South Africa. In: *South Africa: SA Financial Sector Forum* (2001)
- [52] Falkena, H., Davel, G., Hawkins, P., Llewellyn, D., Luus, C., Masilela, E., Parr, G., Pienaar, J., Shaw, H.: Competition in South African banking. Task Group Report for the National Treasury and the South African Reserve Bank (2004)
- [53] Financial Regulatory Reform Steering Committee: Implementing a twin peaks model of financial regulation in South Africa. the Financial Services Board, in *Twin Peaks*, Financial Services Board, published by the Financial Regulatory Reform Steering Committee, Pretoria, RSA **1**, 1–77 (2013)
- [54] Foggitt, G.M.: Measuring the systemic risk in the South African and United States banking sectors. Ph.D. thesis, North-West University (South Africa), Potchefstroom Campus (2016)
- [55] Freixas, X., Parigi, B.M., Rochet, J.C.: Systemic risk, interbank relations, and liquidity provision by the central bank. *Journal of money, credit and banking* pp. 611–638 (2000)
- [56] García, M.J.R., José, M.: Can financial inclusion and financial stability go hand in hand. *Economic Issues* **21**(2), 81–103 (2016)
- [57] Georg, C.P.: The effect of the interbank network structure on contagion and common shocks. *Journal of Banking & Finance* **37**(7), 2216–2228 (2013)
- [58] Giesecke, J.A., Dixon, P.B., Rimmer, M.T.: The economy-wide impacts of a rise in the capital adequacy ratios of Australian banks. *Economic Record* **93**, 16–37 (2017)
- [59] Godwin, A.: Introduction to special issue—the twin peaks model of financial regulation and reform in South Africa (2017)
- [60] Goodhart, C.A., Kashyap, A.K., Tsomocos, D.P., Vardoulakis, A.P.: Financial regulation in general equilibrium. Tech. rep., National Bureau of Economic Research (2012)

- [61] Goodhart, C.A., Sunirand, P., Tsomocos, D.P.: A model to analyse financial fragility: applications. *Journal of Financial Stability* **1**(1), 1–30 (2004)
- [62] Goodhart, C.A., Sunirand, P., Tsomocos, D.P.: A risk assessment model for banks. *Annals of Finance* **1**(2), 197–224 (2005)
- [63] Goodhart, C.A., Sunirand, P., Tsomocos, D.P.: A model to analyse financial fragility. *Economic Theory* **27**(1), 107–142 (2006)
- [64] Goodhart, C.A., Sunirand, P., Tsomocos, D.P.: A time series analysis of financial fragility in the UK banking system. *Annals of Finance* **2**(1), 1–21 (2006)
- [65] Goodhart, C.A., Tsomocos, D.: The mayekawa lecture: the role of default in macroeconomics. *Monetary and Economic Studies* **29**, 49–72 (2011)
- [66] Goodhart, M.C., Basurto, M.A.S.: Banking stability measures. International Monetary Fund (2009)
- [67] Gordhan, P.: A safer financial sector to serve South Africa better. National Treasury Policy Document (2011)
- [68] Gordy, M.B.: A risk-factor model foundation for ratings-based bank capital rules. *Journal of financial intermediation* **12**(3), 199–232 (2003)
- [69] Gorton, G., Winton, A.: Liquidity provision, bank capital, and the macroeconomy. *Journal of Money, Credit and Banking* **49**(1), 5–37 (2017)
- [70] Guiso, L., Sapienza, P., Zingales, L.: The cost of banking regulation. Tech. rep., National Bureau of Economic Research (2006)
- [71] Hassan, R., Thurlow, J.: Macro–micro feedback links of water management in South Africa: CGE analyses of selected policy regimes. *Agricultural Economics* **42**(2), 235–247 (2011)
- [72] Havemann, R.C.: Lessons from South African bank failures 2002 to 2014. Ph.D. thesis, Stellenbosch: Stellenbosch University (2019)
- [73] Hellwig, M.: Liquidity provision, banking, and the allocation of interest rate risk. *European Economic Review* **38**(7), 1363–1389 (1994)
- [74] Hellwig, M.: Systemic aspects of risk management in banking and finance. *Revue Suisse d Economie Politique et de Statistique* **131**, 723–738 (1995)

- [75] Hellwig, M.: Banks, markets, and the allocation of risks in an economy. *Journal of Institutional and Theoretical Economics (JITE)/Zeitschrift für die gesamte Staatswissenschaft* pp. 328–345 (1998)
- [76] Van den Heuvel, S.J.: The welfare cost of bank capital requirements. *Journal of Monetary Economics* **55**(2), 298–320 (2008)
- [77] Hosoe, N.: Computable general equilibrium modeling with GAMS. Tokyo: National Graduate Institute for Policy Studies (2004)
- [78] Huang, X., Vodenska, I., Havlin, S., Stanley, H.E.: Cascading failures in bi-partite graphs: model for systemic risk propagation. *arXiv preprint arXiv:1210.4973* (2012)
- [79] IMF: Key aspects of macroprudential policy—background paper (2013)
- [80] Jackson, P., Furfine, C., Groeneveld, H., Hancock, D., Jones, D., Perraudin, W., Radecki, L., Yoneyama, M.: Capital requirements and bank behaviour: the impact of the Basle Accord. 1. Bank for International Settlements Basle (1999)
- [81] Jalilian, H., Kirkpatrick, C., Parker, D.: The impact of regulation on economic growth in developing countries: A cross-country analysis. *World development* **35**(1), 87–103 (2007)
- [82] Kashyap, A.K., Berner, R., Goodhart, C.A.: The macroprudential toolkit. *IMF Economic Review* **59**(2), 145–161 (2011)
- [83] Kashyap, A.K., Stein, J.C.: The impact of monetary policy on bank balance sheets. In: *Carnegie-rochester conference series on public policy*, vol. 42, pp. 151–195. Elsevier (1995)
- [84] Kaufman, G.G., Scott, K.E.: What is systemic risk, and do bank regulators retard or contribute to it? *The Independent Review* pp. 371–391 (2003)
- [85] Kay, J.A.: Narrow banking: The reform of banking regulation. CSFI publication (2009)
- [86] Kuzubaş, T.U., Ömercikoğlu, I., Saltoğlu, B.: Network centrality measures and systemic risk: An application to the turkish financial crisis. *Physica A: Statistical Mechanics and its Applications* **405**, 203–215 (2014)
- [87] Leao, E.R., Leao, P.R.: Modelling the central bank repo rate in a dynamic general equilibrium framework. *Economic Modelling* **24**(4), 571–610 (2007)

- [88] Lee, J.H., Ryu, J., Tsomocos, D.P.: Measures of systemic risk and financial fragility in Korea. *Annals of Finance* **9**(4), 757–786 (2013)
- [89] Lewis, J.: A computable general equilibrium (CGE) model of banking system stability: Case of Jamaica. *Journal of Business, Finance and Economics in Emerging Economies* **5**, 81–120 (2010)
- [90] Luenberger, D.G.: *Microeconomic theory mcgraw-hill. Inc.*, New York (1995)
- [91] Mabugu, R., Robichaud, V., Maisonnave, H., Chitiga, M.: Impact of fiscal policy in an intertemporal CGE model for South Africa. *Economic Modelling* **31**, 775–782 (2013)
- [92] Makrelov, K., Davies, R.H., Harris, L.: The impact of capital flow reversal shocks in South Africa: a stock-and flow-consistent analysis. *Economic Research and Statistics Department, South African Reserve Bank* (2019)
- [93] Martinez, J., Tsomocos, D.: Liquidity effects on asset prices, financial stability and economic resilience. Unpublished manuscript (2011)
- [94] Martínez, J.F., Tsomocos, D.P.: Liquidity and default in an exchange economy. *Journal of Financial Stability* **35**(C), 192–214 (2018)
- [95] Martinez-Miera, D., Suarez, J.: Banks’ endogenous systemic risk taking. manuscript, CEMFI (2014)
- [96] Menezes, A.G.D., Fortuna, M., Silva, F., Vieira, J.C.: Computable general equilibrium models: A literature review (2006)
- [97] Van der Merwe, E.: *Inflation Targeting in South Africa*. Citeseer (2004)
- [98] Mostert, J., Van Heerden, J.: A computable general equilibrium (CGE) analysis of the expenditure on infrastructure in the limpopo economy in South Africa. *International Advances in Economic Research* **21**(2), 227–236 (2015)
- [99] Nassios, J., Giesecke, J.A., Dixon, P.B., Rimmer, M.T.: What impact do differences in financial structure have on the macro effects of bank capital requirements in the United States and Australia? *Economic Modelling* **87**, 429–446 (2020)
- [100] Osborne, M.J.: *Mathematical methods for economic theory: a tutorial*. University of Toronto, Toronto (2007)

- [101] Owusu-Sekyere, E.: The impact of monetary policy on household consumption in South Africa: Evidence from vector autoregressive techniques. *South African Journal of Economic and Management Sciences* **20**(1), 1–14 (2017)
- [102] Patro, D.K., Qi, M., Sun, X.: A simple indicator of systemic risk. *Journal of Financial Stability* **9**(1), 105–116 (2013)
- [103] Pearson, K., Parmenter, B.R., Powell, A.A., Wilcoxon, P.J., Dixon, P.: Notes and problems in applied general equilibrium economics. Elsevier (2014)
- [104] Peiris, M.U., Tsomocos, D.P.: International monetary equilibrium with default. *Journal of Mathematical Economics* **56**, 47–57 (2015)
- [105] Petrone, D., Latora, V.: A dynamic approach merging network theory and credit risk techniques to assess systemic risk in financial networks. *Scientific reports* **8**(1), 1–14 (2018)
- [106] Repullo, R., Suarez, J.: The procyclical effects of bank capital regulation. *The Review of financial studies* **26**(2), 452–490 (2013)
- [107] Rumler, F.: Computable general equilibrium modeling. numerical simulations in a 2-country monetary general equilibrium model. Inst. für Volkswirtschaftstheorie und-politik, WU Vienna University of Economics and Business (1999)
- [108] Saade, A., Osorio, D., Estrada, D.: An equilibrium approach to financial stability analysis: the Colombian case. *Annals of Finance* **3**(1), 75–105 (2007)
- [109] Saayman, A.: Why money matters: the financial crisis and the South African economy. Potchefstroom: Noordwes-Universiteit, Potchefstroomkampus (Suid-Afrika) (2010)
- [110] Santos, J.A.: Bank capital regulation in contemporary banking theory: A review of the literature. *Financial Markets, Institutions & Instruments* **10**(2), 41–84 (2001)
- [111] Scarf, H.E., Shoven, J.B.: Applied general equilibrium analysis. Cambridge Books (2008)
- [112] Schmulow, A.: Twin peaks: a theoretical analysis. CIFR Paper No. WP064/2015 (2015)
- [113] Schwerter, S.: Basel III’s ability to mitigate systemic risk. *Journal of financial regulation and compliance* (2011)

- [114] Shoven, J.B., Whalley, J.: Applied general-equilibrium models of taxation and international trade: An introduction and survey. *Journal of Economic literature* **22**(3), 1007–1051 (1984)
- [115] Sorkin, A.: At lehman, watchdogs saw it all. *New York Times* (2010)
- [116] South African Reserve Bank: South African Reserve Bank repurchase rate. <https://www.global-rates.com/interest-rates/central-banks/central-bank-south-africa/sarb-interest-rate.aspx>. Accessed: 2019-05-27
- [117] Swamy, V.: Testing the interrelatedness of banking stability measures. *Journal of Financial Economic Policy* **6**(1), 25–45 (2014)
- [118] Tabak, B.M., Cajueiro, D.O., Fazio, D.M.: Financial fragility in a general equilibrium model: the Brazilian case. *Annals of Finance* **9**(3), 519–541 (2013)
- [119] Taylor, L.: Socially relevant policy analysis: Structuralist computable general equilibrium models for the developing world. MIT press (1990)
- [120] Taylor, M.W.: “twin peaks”: A regulatory structure for the new century”, series edited by the centre for the study of financial innovation, no. 20. Centre for the Study of Financial Innovation, published by the Centre for the Study of Financial Innovation pp. 1–18 (1995)
- [121] Thomson, J.B.: On systemically important financial institutions and progressive systemic mitigation. *DePaul Bus. & Comm. LJ* **8**, 135 (2009)
- [122] Thurlow, J.: Can South Africa afford to become Africa’s first welfare state? Tech. rep., International Food Policy Research Institute (IFPRI) (2002)
- [123] Thurlow, J.: A dynamic computable general equilibrium (CGE) model for South Africa: Extending the static IFPRI model. *Trade and Industrial Policy Strategies*, Johannesburg (2004)
- [124] Thurlow, J., van Seventer, D.E.: A standard computable general equilibrium model for South Africa. Tech. rep., International Food Policy Research Institute (IFPRI) (2002)
- [125] Tsomocos, D.P.: Equilibrium analysis, banking, contagion and financial fragility. Bank of England Working Paper (2003)
- [126] Tsomocos, D.P., Bhattacharya, S., Goodhart, C.A., Sunirand, P.: Banks, relative performance, and sequential contagion. *Economic Theory* **32**(2), 381–398 (2007)

- [127] Tsomocos, D.P., Zicchino, L.: On modelling endogenous default. LSE FMG Discussion paper 548 (2005). In: C.A.E. Goodheart, D.P. Tsomocos (eds.) *The Challenge of Financial Stability*, chap. 6, pp. 134–52. Edward Elgar (2012)
- [128] Van Heerden, C., Van Niekerk, G.: Twin peaks in South Africa: a new role for the central bank. *Law and Financial Markets Review* **11**(4), 154–162 (2017)
- [129] Van Heerden, J., Blignaut, J., Bohlmann, H., Cartwright, A., Diederichs, N., Mander, M.: The economic and environmental effects of a carbon tax in South Africa: A dynamic CGE modelling approach. *South African Journal of Economic and Management Sciences* **19**(5), 714–732 (2016)
- [130] Van Niekerk, G., van Heerden, C.: Twin peaks: The role of the South African central bank in promoting and maintaining financial stability. *THRHR* **80**, 636 (2017)
- [131] Van Vuuren, G.: Basel III countercyclical capital rules: Implications for South Africa. *South African Journal of Economic and Management Sciences* **15**(3), 309–324 (2012)
- [132] Vasco, C., Woodford, M.: *Credit Spreads and Monetary Policy*. National Bureau of Economic Research (2009)
- [133] Walters, N.M.: Network structure indirect losses and financial contagion in inhomogeneous stochastic interbank networks. Ph.D. thesis, University of Pretoria (2019)
- [134] Walters, N.M., Beyers, F., van Zyl, A., van den Heever, R.: A framework for simulating systemic risk and its application to the South African banking sector. *South African Actuarial Journal* **18**(1), 99–133 (2018)
- [135] Xuba, A.: The role of the prudential authority in the South African twin peaks model. Ph.D. thesis, University of Pretoria (2019)
- [136] Zambrana, M.S.: Systemic risk analysis using forward-looking distance-to-default series. Tech. rep., Federal Reserve Bank of Cleveland (2010)