Optimal Reserve Holdings, Strategic Asset Allocation and Multiple-Goal Investment Plan for Sovereign Wealth Fund of China

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A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Finance

School of Economics, Finance and Business

Durham University

UK

2014

To My Parents and Wife

ABSTRACT

This thesis expounds China's foreign reserve policy and the investment management of the reserves in a behavioural approach. The research provides a behavioural explanation of China's reserve accumulation, which is based on the optimal decision making under uncertainty. Then the thesis proposes a multiple-goal framework for strategic asset allocation of China's reserve management and for the investment decision of Chinese Sovereign Wealth Fund (SWF).

The research first tackles the reserve accumulation puzzle in China, by incorporating loss aversion and narrow framing into the utility maximisation of the representative agent who makes the decision of wealth allocation between consumption and saving under uncertainty. Due to China's policy maker's subscription to promoting GDP growth as the primary political goal, it is reasonable to assume that the policy maker as a representative agent derives utility not only from consumption but also from fluctuations of the value of GDP/income. This agent evaluates the possible uninsured risk of GDP fluctuation narrowly and tends to exhibit the attribute of loss aversion relative to her growth expectation as the reference point. Under the influence of loss aversion and narrow framing, the more the policy maker cares about GDP growth, the

more she needs reserve assets as a precautionary means that may provide self-insurance against uninsured income risk. Such cognitive biases enhance the agent's precautionary motive for foreign reserves in an uncertain world, which in turn leads her to believing in an optimal level of foreign reserves that is higher than that under conventional models with rational agents. Hence, this heightens the accumulation of foreign reserves in China.

Second, this thesis develops a new construction of strategic asset allocation for central banks' management of foreign reserves by way of embedding the Black-Litterman (B-L) model into the mean variance mental accounting (MVMA) framework. While the MVMA measure suggests a multiple-objective framework that may embrace the traditional objectives of reserve management, i.e. safety, liquidity and profitability, it is based on the mean-variance approach, which suffers from profound deficiencies such as the unrealistic objective function that it relies on and the tendency that the methods are prone to undue influences of outliers. So, the B-L model is applied in this study to form forward-looking return forecasts. This method allows us to overcome the error-maximising influences of the mean-variance optimization. Furthermore, one can combine the implied equilibrium excess returns as investors' investment views to form priors for Bayesian estimation. The optimal asset allocation then can be derived in this framework, which is applied to practical use in the context of China.

The third main Chapter of this thesis concerns the investment of China's sovereign wealth fund (SWF). The establishment of the Chinese SWF can be regarded as an optimal policy response to the changing economic conditions facing China. This fund as a special investment vehicle proves very useful for China to focus on the returns objective of managing the reserve assets, on top of the safety and liquidity objectives. This is especially important in a low yield international environment. To help achieve the yield objective, this Chapter develops further the behavioural portfolio model cum the Black-Litterman method to derive the optimal asset allocation for China's sovereign wealth fund.

ACKNOWLEDGEMENTS

I owe my greatest debt to my primary supervisor Dr Zhichao Zhang. His great encouragement gave me the inspiration and confidence to start pursuing my academic dream. He leads me into the fascinating world of international finance and his unwavering support and intelligent guidance have enabled me to sustain every step of my Ph.D. journey. I am so fortunate and privileged to have the opportunity of studying and conducting research under such a great mentor.

I am also grateful to my second supervisor Dr Frankie Chau for his insightful comments and instruction.

So many people have helped me in my Ph.D. study. I would like to thank them all, particularly those in Durham.

I am tremendously grateful to my wife, and my best friend, Xiangyun. Durham is not only where I started my academic journey, but also the place where I find my better half for my life. From being my classmate to being my soul mate, you do not know how much they mean to me, your love, patience and support. Without your passionate love and sparkling companionship, I would not be what I am now. I owe you so much, my darling.

Finally, my deepest gratitude goes to my parents. Mom and Dad, thank both of you for believing in me, in all times. You have raised me through all those hard years and have done everything possible to ensure that I can receive the best education. Your son does not know how to return fully for all you have done for me, but I do know that your smiles at my living to the highest right are the best reward for my life that you give me. I love you, Mom and Dad.

DECLARATION

The content of this doctoral dissertation is based on the research work completed at Durham University Business School, UK. No material contained in the thesis has previously been submitted for a degree in this or any other university.

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Chapter 1

INTRODUCTION

In recent decades, the accumulation of international reserves by emerging and developing economies has surged to a record level. China in particular has amassed a huge amount of foreign reserves: by the end of 2012 these stood at 3,311.6 billion US dollars, accounting for 30.24% of the world's then total reserves. Yet, the extraordinary momentum of reserve accumulation in China is still ongoing. The situation necessitates profound research into understanding the dynamics of China's reserve accumulation and to shed critical lights on the sound management of such enormous external wealth.

Conventional studies of reserve management have not been fully able to provide us with satisfactory answers to the best approach for China to adopt, whether positive or normative. To fill towards the gap in the literature, this thesis takes a behavioural perspective to better our understanding of the behaviour of China's reserve dynamics, and to inform the current debate on China's reserve policy by offering estimation of the optimal level, structure and investment strategy for China's foreign reserves. The present chapter sets the background and the structure of this research.

1.1 Motivations and Contributions of This Study

At the end of 1978, China initiated its first package of economic reforms, characterising a bold move to set up a market economy. Since then, promotion of GDP growth has been firmly established as the overwhelming goal of China's policy, and the reforms have achieved striking progress. Particularly since its WTO accession in 2001, China has witnessed both remarkable GDP growth and massive reserve accumulation. According to data from the International Monetary Fund (IMF), during the period from 2002 to 2012, China's annual real GDP growth stood at 10.33% on average, and by the end of 2012 China's reserves had reached 3,311.6 billion US dollars, more than 15 times of the amount in 2002.

The rapid growth of China's external wealth raises two noteworthy issues for academic research. The first is the saving puzzle. The fact that rapid income growth in China tends to be associated with current account surplus is contrary to the prediction of benchmark models of the consumption-saving nexus. According to the Permanent Income Hypothesis (PIH), a fast growing country such as China would be a borrower to utilise borrowed resources to finance investment and smooth consumption. This is theoretically underpinned by the rational expectations of future income growth (see for example Carroll and Weil 1994, and Sandri 2010). Thus, from the standard economic viewpoint, the dynamics of recent reserve accumulation in China is puzzling for a fast growing, emerging economy.

To tackle this saving puzzle, recent studies of reserve accumulation have provided diverse interpretations, most of which suggest that hoarding international reserves is likely due to a precautionary motive, reflecting the desire of the representative agent for self-insurance against possible uninsured risks that cause adverse effects on economic growth, e.g., future sudden stops (see Edwards 2004, García and Soto 2006, Jeanne 2007, Durdu et al. 2009, Carroll and Jeanne 2009, Jeanne and Rancière 2011, and Hur and Kondo 2011). Another strand of the literature attributes huge reserve accumulation to the undervaluation of the exchange rate (see Dooley et al. 2003, and Benigno and Fornaro 2012). However, existing research seems not to fully expound why emerging economies like China accumulate such enormous amounts of foreign reserves, with no apparent end in sight to the behaviour of stockpiling reserves.

The second issue relates to how the Chinese central bank may manage such a huge amount of wealth soundly and efficiently in an uncertainty world. With a massive amount of reserves in hand, China's monetary authority has shown some degree of macroprudence and has made efforts to diversify its investable foreign assets by gradually reducing some components of its holdings, such as the US Treasuries. The mission is to meet the traditional multiple objectives of reserve management: 'safety, liquidity and profitability'.

A more recent endeavour by the Chinese central bank in this regard is the establishment of a sovereign wealth fund (SWF) in 2007, formally known as the China Investment Corporation (CIC). This effort is widely regarded as an important step facilitating the efficient management of its huge foreign assets. By investing the funds from foreign reserves in a wide range of assets, including stocks, bonds, and alternative assets, the Chinese SWF allows to pursue higher returns and therefore mitigate to some extent the costs of carrying the massive reserve holdings. At the end of 2012, the external assets under CIC management stood at US$ 482 billion, making it one of the world's largest SWFs (TheCityUK, 2013). The recent literature on SWF management indicates that, for a certain country, its SWF should play more than one role, to be achieved either through the establishment of more than one SWF, or by assigning distinct mandates to one SWF, to accomplish varying macroeconomic policy objectives such as providing liquidity needs in the short run and the transfer of wealth in the long run (Pistor 2009, Kunzel et al. 2011, IMF 2011).

Thus, it is necessary and desirable to underpin a multiple-goal investment framework for exploring optimal ways of strategic asset allocation for China's reserve management including that of China's SWF. Existing research on strategic asset allocation for reserve management and SWF management relies mainly on the mean-variance (MV) framework pioneered by Markowitz (1952), in which the MV investors take their portfolio as a whole and explore optimal portfolio weights based on the overall expected returns and risk. However, this approach does not explicitly tell us how central banks and SWFs manage their external assets according to multiple objectives.

While conventional theories based on rational agents are yet to provide satisfactory answers to these challenging issues, we in an endeavour of better interpreting China's reserve policy take a behavioural approach in this thesis to tackle the issues of savings puzzle and the challenge of efficient investment management of foreign reserves. As shown in the latter chapters of the thesis, behavioural finance proves able to help better our understanding of the property of the challenges and can provide solution to the challenging issues facing China.

Behavioural finance, in response to financial anomalies which traditional finance fails to interpret satisfactorily, relates psychological factor to financial markets developments and financial decision making, and is reported to be able to increase the explanatory and predictive power of financial models in many cases. Surveys on behavioural finance include Hirshleifer (2001), Barberis and Thaler (2003), and Shefrin (2009).

Theoretical studies on behavioural finance focus on the improvement of expected utility theory (EUT) – the cornerstone of standard economics and finance – in two ways: one concerns beliefs captured by probability distributions; the other relates to preferences captured by utility functions (Shefrin 2009). Furthermore, studies on behavioural preferences can be classified into two fundamental types (Shefrin 2009): First, loss aversion in prospect theory (PT), pioneered by Kahneman and Tversky (1979), implies that the representative agent is concerned about changes in wealth rather than the absolute level of wealth and exhibits a higher sensitivity to losses than to gains. Second, framing effects can be further classified into two branches: narrow framing, pioneered by Kahneman and Lovallo (1993), suggests that the agent assesses a specific risk under a narrow, rather than a broad frame; mental accounting, labelled by Thaler (1985), indicates that people separate their current and future assets into different portions and assign different levels of utility to each of them.

The two types of behavioural preferences have been well incorporated into financial research for the improvement of traditional models in both positive and normative ways. For example, from a positive perspective, Barberis, Huang and Santos (2001) incorporate loss aversion and narrow framing to provide a general preference structure where the representative agent derives utility from two sources: (1) consumption and (2) the possible fluctuations in the value of her expected financial wealth. The first source is utility in the conventional sense, while the second is reflected in her utility function with an extra term in which the agent assesses her financial risk narrowly, separates it from consumption, and suffers from loss aversion relative to a certain reference point. This model turns out to be able to help expound the existence of the equity premium puzzle. From a normative perspective, Das, Markowitz, Scheid and Statman (2010) for example explore a mean-variance mental accounting (MVMA) framework by combining Markowitz's mean-variance portfolio theory (MVT) and the behavioural portfolio theory (BPT) by Shefrin and Statman (2000). The appealing feature of their model is that the MVMA investors consider their portfolios as collections of mental account sub-portfolios in which each sub-portfolio is connected with a goal and each goal has a threshold level. As a result, their model can assist investors to construct their multiple-goal investment strategy.

Inspired by the recognised contribution of behavioural finance to modern finance research, this thesis is to apply a behavioural approach to investigate dynamic of China's reserve assets and their efficient management. The intended contributions to the current literature include the following. First, this research is to provide a behavioural perspective to better explain the optimal holdings of China's reserves, drawing upon the work of for example Barberis et al. (2001). Because China's policy-maker views the promotion of GDP growth as the primary policy goal, it is reasonable to assume that the policy-maker as a representative agent derives utility from the fluctuations of the value of GDP or income, on top of utility from consumption, and that this agent assesses the possible risk/uncertainty of GDP growth narrowly and suffers from loss aversion relative to her growth expectation as the reference point. This setting is closely reflective of the reality and intuitively, implying that the more the policy-maker cares about GDP growth, the more she needs reserve assets as a precautionary means of providing self-insurance against negative shocks to income. It is likely that this agent has cognitive biases, thus the precautionary motive for reserve holdings would be strengthened. This delivers a better explanation for the reserve levels that the Chinese monetary authority deems "appropriate", which may be greater than that under the conventional thinking.

The second contribution that this thesis makes is the introduction of a new approach to strategic asset allocation for central banks' management of foreign reserves. In essence, this new approach combines the MVMA framework by Das et al. (2010) and the Black-Litterman model by Black and Litterman (1992) to establish a framework in which a multiple-objective investment strategy is formulated. The two sub-portfolios, i.e. mental accounts, are designed to meet the specific needs of central banks': the 'precautionary sub-portfolio' and the 'investment sub-portfolio' are constructed to achieve the multiple objectives of the reserve management policy. Given the distinct overall risk attitudes of reserve managers, many alternative aggregate portfolios can be constructed by making different allocations of the total investable reserves into combinations of the two sub-portfolios. This is furthermore facilitated by the use of the Black-Litterman model. The B-L model is an approach widely applied by researchers to formulate forward-looking return forecasts to overcome the error-maximising tendency of the mean-variance optimisation (Best and Grauer 1991). Using the implied equilibrium excess returns as the starting point, the B-L approach combines subjective investor views to form the posterior estimates of expected returns on the basis of the Bayesian estimation. We for the first time in the literature apply this approach to the study of foreign reserves, with particular reference to the Chinese case.

The third contribution of this research is the development of a multiple-goal investment framework for China's sovereign wealth fund as the optimal policy response to the overall economic conditions affecting China. In this investment framework, three sub-portfolios are constructed: the ‘liquidity sub-portfolio’, the ‘investment sub-portfolio’, and the ‘bequest sub-portfolio’, which are employed for accomplishing the short-term, the medium-term, and the long-term overall macroeconomic objectives, respectively. This approach is also applied to the empirical analysis to derive optimal asset allocation for China’s sovereign wealth fund.

1.2 Why China and Why Behavioural Approach

Because of its unique institutional environment, China can be regarded as a special case for studying the issues under investigation, which is considered as one of the main reasons why this research concentrates on China. Specifically, as the second largest economy in the world, China has witnessed both remarkable economic growth and rapid reserve accumulation since its openness towards the rest of the world. Such great economic achievement can be attributed to China’s unique institutional environment i.e. China’s economic policy makers, unlike Western ones, always take promoting GDP growth as their primary goal. As a result, various economic policies such as the export-led policy are established to eventually serve the goal of GDP growth. From this perspective, it seems that the mechanism of reserve accumulation in China is also thought of as a by-product of rapid economic growth, other than as a precautionary consideration.

Facing China's unique economic development model, it is suitable for this research to behavioural approach to investigate dynamic of China's reserve assets and their efficient management. For assessing dynamic of China's reserve assets, using behavioural approach enhances the explanatory power for the observed reserve accumulation in China. For example, due to the fact that China's central planner i.e. economic policy maker views the promotion of economic growth as her dominant goal, it is logical for her to derive utility from income (GDP) growth. Furthermore, it seems that GDP growth has become the most important criteria of evaluation of her performance over the last three decades. The literature on behavioural science such as Kahneman and Lovallo (1993) has suggested that for a decision maker i.e. the central planner here facing a series of decisions, whether or not to use a broad frame depends on how her performance will be evaluated and on the frequency of performance. If her performance is assessed narrowly (e.g. when facing a risk, if her performance is estimated on that risk alone), the decision maker frames decisions narrowly. Thus, it is reasonable for the central planner to assess the risk/uncertainty of GDP growth narrowly and to suffer from loss aversion against her economic growth target i.e. her reference point.

For foreign asset management, using behavioural approach can help us to provide a more satisfactory solution to how efficiently manage such enormous foreign assets. For example, my multiple-objective foreign asset management framework not only can meet various macroeconomic goals, but also is in accordance with the different risk-return profile of foreign asset managers. This multiple-objective framework can also applicable to other countries who hold excessive reserve assets and who own sovereign wealth funds.

1.3 Organisation of the Thesis

This thesis consists of six chapters. After the introduction chapter, the rest chapters are structured as follows:

- **Chapter 2: Literature Review**. This chapter provides a comprehensive review of the literature related to the current research, setting out the background for the tackling main research problems in the subsequent chapters.

- **Chapter 3: The Dynamics of China's Reserve Assets**. In this chapter, an analytical model in a behavioural perspective is set up to decode the puzzling development of Chinese reserve stockpiling.

- **Chapter 4: The Multiple-Objective Reserve Management Policy.** Chapter 4 proposes a new approach to strategic asset allocation for central banks' management of foreign reserves. The combination of the behavioural portfolio modeling and the Black-Litterman approach allows to derive optimal portfolio weights and hence provides a novelty way for optimal management of central banks' foreign reserves. The case of China is used to illustrate the optimal strategic asset allocation in this approach.

- **Chapter 5: The Multiple-Goal Investment Policy for China's sovereign wealth fund.** Chapter 5 uses the same approach as in Chapter 4 to establish a multiple-goal investment framework for China's sovereign wealth fund.

- **Chapter 6: Conclusions.** The final chapter comprises a summary of the findings of the thesis, and a discussion on directions of future research.

Chapter 2

LITERATURE REVIEW

This chapter provides a comprehensive review of the literature related to this research. The review serves as a background for a better understanding of the main body of the thesis, including topics on (1) behavioural finance, (2) portfolio choice problems, (3) optimal reserve holdings, (4) reserve management, and (5) sovereign wealth funds.

2.1 Behavioural Finance

Behavioural finance, in response to financial anomalies caused by traditional finance, applies psychologically plausible foundations derived from experimental evidence to financial markets and financial decision making, and thus increases the explanatory and predictive power of financial models. Surveys on behavioural finance include Hirshleifer (2001), Barberis and Thaler (2003), and Shefrin (2009).

Studies on behavioural preferences can be classified into two fundamental types (Shefrin 2009): First, loss aversion in prospect theory (PT), pioneered by Kahneman and Tversky (1979), implies that the representative agent is concerned about changes in wealth rather than the absolute level of wealth, and experiences a higher sensitivity to losses than to gains. Second, framing effects can be further classified into two branches: narrow framing, pioneered by Kahneman and Lovallo (1993), suggests that the agent assesses a specific risk under a narrow, rather than a broad frame; mental accounting, labelled by Thaler (1985), indicates that the agent codes, categorises, and evaluates economic outcomes.

2.1.1 Loss Aversion

Loss aversion is a central proposition of the prospect theory (PT) pioneered by Kahneman and Tversky (1979). They propose a value function (i.e. $U = U(x)$) that is defined over changes in wealth (i.e. x) rather than final asset position as in conventional economics. Agents view outcomes as either gains (i.e. $x > 0$) or losses (i.e. $x < 0$), relative to a certain reference point (i.e. $U(0) = 0$). Based on experiment evidence, Kahneman and Tversky (1979) claim that agents are more sensitive to losses than to completely commensurate gains, i.e. more weight is assigned to losses than to equally sized gains. This is known as loss aversion. In addition, they introduce the probability weighting function and the concavity (convexity) of the value function over gains (losses). They show that U is concave for $x > 0$ and convex for $x < 0$; therefore it is S-shaped.

A variety of definitions of loss aversion have been proposed in the literature on the basis of the utility function, e.g. Neilson (2002) and Bowman et al. (1999). Maggi (2004) summarises the definitions and imposes some parameter restrictions on a typical S-shaped utility function so that it can display loss aversion. Tversky and Kahneman (1992) extend their original prospect theory using the rank-dependent utility theory by Quiggin (1982). This gives the cumulative prospect theory (CPT) under which three functions are deployed to illustrate loss aversion: the value (utility) function U, the weighting function for gain probability w^+, and that for loss probability w^-. Specifically, they propose a piecewise power function for the value function, in the form of the following:

$$U(x) = \begin{cases} x^{\alpha} & if\ x \geq 0 \\ -\lambda(-x)^{\beta} & if\ x < 0 \end{cases}$$

The two weighting functions are expressed as:

$$w^+ = \frac{p^{\gamma}}{(p^{\gamma} + (1-p)^{\gamma})^{1/\gamma}} \quad \text{and} \quad w^- = \frac{p^{\delta}}{(p^{\delta} + (1-p)^{\delta})^{1/\delta}}$$

Using experimental data, they derive $\alpha = \beta = 0.88$, which is in line with diminishing sensitivity, and $\lambda = 2.25$, which indicates the degree of loss aversion. Other parameter values include $\gamma = 0.61$, and $\delta = 0.69$. Al-Nowaihi et al. (2008) formally demonstrate the proof of the power function and two weighting functions proposed in Tversky and Kahneman (1992), and conclude that $\lambda > 1$, $\alpha = \beta$, and $w^+ = w^-$ (i.e. $\delta = \gamma$). Barberis and Huang (2008) suggest that $\delta \in (0.28,1)$ is required to ensure the weighting function w is strictly increasing for $p \in (0,1)$ under $\gamma = \delta$. Kobberling and Wakker (2005) introduce an index of loss aversion.

Loss aversion has been well incorporated into economic and finance research. In economics, typical evidence of loss aversion includes asymmetric demand elasticity of a price increase and decrease (Hardie et al. 1993), downward-sloping labour supply derived from the early quitting of cab drivers in New York City after achieving a daily income target (Camerer et al. 1997), and purchase strategies of hog farmers (Pennings and Smidts, 2003). Loss aversion is also shown to explicate both the status quo bias, i.e. an overstated preference for the status quo, as labelled by Samuelson and Zeckhauser (1988), and the endowment effect, whereby owners always estimate value more highly than potential buyers when facing an economically equivalent good, as suggested by Kahneman et al. (1991).

In the world of finance, financial anomalies, deviations from what the traditional efficient market theory predicts, have been widely reported. In an effort to explain such anomalies, the behavioural approach to finance has arisen to provide a new avenue for better understanding financial activities. One major advance in this regard concerns the anomaly caused by the disposition effect (Shefrin and Statman, 1985), which is closely related to loss aversion. Shefrin and Statman (1985) show that, under the influence of such an effect, investors tend to sell stocks that have gained value (winners) and to hold on to stocks that have lost value (losers), relative to the stock's purchase price or the reference point. Odean (1999) further shows that investors will sell winners soon and hold losers long.

Loss aversion has also been applied to explain reserves accumulation (Aizenman, 1998). This is done mainly through the application of Gul's (1991) disappointment aversion, which is similar to loss aversion in that investors exhibit asymmetric aversion to gains versus losses. Employing this disappointment aversion effect, Aizenman investigates optimal buffer stocks and precautionary savings to show that a stabilisation fund becomes larger than such a fund under expected utility. For the utility of an agent with disappointment aversion, in the face of uncertainty of income that has an equal probability between two states ($Y+\varepsilon$ or $Y-\varepsilon$), more weight will be put on losses ($Y-\varepsilon$) than on gains ($Y+\varepsilon$), relative to the reference point (Y). Aizenman and Marison (2003) further incorporate loss aversion into an inter-temporal consumption model to examine large reserve holdings by Asian emerging markets. They assign the extra weight θ to the so-called 'bad state of nature' when the agents face a productivity shock in the second period with an equal possibility of gains or losses. They indicate that the loss aversion ratio is $\frac{1+\theta}{1-\theta}$ and show that an increase in the degree of loss aversion and/or in volatility shocks will boost reserves holdings.

2.1.2 Narrow Framing

The second important factor influencing individuals' decision-making behaviours is narrow framing, whereby they assess a specific risk under a narrow, rather than a broad frame. Kahneman (2003) argues that, under the rational-agent model, it is unrealistic to assume that individuals make their decisions under a comprehensively inclusive context, where they are able to incorporate all the relevant details for present decisions, as well as expectations about all future decisions and risks. Based on this assumption, the representative agent derives her utility under the consumption-based approach, i.e. she evaluates a specific risk only from consumption or total wealth.

However, some experimental works on decision making under uncertainty (e.g. Kahneman and Lovallo, 1993; Kahneman, 2003) indicate that individuals' views of decisions and outcomes are normally characterised by ''narrow framing', first labelled by Kahneman and Lovallo (1993). They suggest that individuals have a tendency to consider decision problems one at a time, in order to isolate the current problem from other pending decisions, as well as from future similar decisions. Furthermore, they offer a corresponding interpretation for the organisational level. For organisations, whether or not to use a broader frame hinges on two conditions: (1) a capacity to gather together problems that are superficially different; (2) an appropriate procedure for evaluating outcomes and the quality of performance. Thus, on the one hand, a broad frame can be achieved by an abstract language that highlights the important common dimensions of different problems. However, such an abstract language conflicts with describing each problem in its own terms, which can be accomplished more easily. On the other hand, for a decision maker facing a series of decisions, whether or not to use a broad frame also depends on how his performance will be evaluated and on the frequency of performance. If his performance is assessed narrowly (e.g. when facing a risk, if his performance is estimated on that risk alone), the decision maker frames decisions narrowly. In consequence, Kahneman and Lovallo (1993) suggest that, if making decisions under a broad frame, the attitude that 'you win a few and you lose a few' can be accepted, because the outcomes of separate decisions have been aggregated before evaluation; whereas if making decisions under narrow framing, the tolerance for 'losing a few' may not be in line with other managerial imperatives (e.g. the setting of high standards).

The effect works only when narrow framing and loss aversion are combined. Since loss aversion only matters for decisions which trigger gains or losses, it would have little impact on decision making where individuals evaluate the specific risk under a broad frame (Read, Loewenstein and Rabin, 1999). Benartzi and Thaler (1995) attribute the equity premium puzzle to myopic loss aversion, which is the combination of narrow framing and loss aversion. Barberis, Huang and Santos (2001) develop a model that incorporates behavioural factors, prominently loss aversion and narrow framing, into the optimal decision-making process. In explaining the equity premium, they show that investors get utility from consumption while facing volatilities in the value of their financial wealth. Loss aversion over these volatilities and narrow framing of risks only in the stock market may help explain the existence of equity premium. Barberis and Huang (2009) further refine the behavioural model of optimal choice uncertainty.

2.2 Related Literature on Portfolio Choice Problems

2.2.1 Asset Allocation and the Mean-Variance Paradigm

The study of asset allocation has played a crucial role in practical investment management. The pioneering mean-variance (MV) framework of Markowitz (1952) is by far the most common formulation of asset allocation problems, and underpins modern portfolio theory (MPT). The appealing feature of the MV framework is that it captures the two fundamental aspects of asset allocation problems: diversification and the trade-off between expected return and risk. By efficiently allocating wealth among risky assets, the MV framework provides investors with an exact solution to optimal asset allocation of their wealth. The derived efficient frontier represents all efficient portfolios, in that all portfolios below this efficient frontier have more risk for a given level of expected return or lower expected return for a given level of risk (Markowitz 1959).

However, the mean-variance framework has several limitations, in terms of both theory and practice. From the theoretical perspective, for example, Brandt (2009) points out three objections to the MV framework. First, the MV framework use quadratic utility as its expected utility maximisation, causing a problem of preference specification due to the fact that it is not monotonically increasing in wealth. Second, as a second-order approximation of expected utility maximisation, the MV framework does not consider any preferences toward higher-order return moments. Third, the MV framework is inherently a myopic single-period problem, which is inconsistent with most realistic investment problems.

More importantly, some behavioural economists have questioned the simple assumptions of the traditional mean-variance risk preference that investors view their portfolios as a whole and that investors with the same degree of risk aversion should have the same portfolio, which explain why mean-variance analysis fails to illustrate the observed behaviour of investors in actual financial markets (Davies and Servigny 2012). Moreover, they argue that, as a normative theory, mean-variance analysis has not produced results capable of consistently outperforming a naive portfolio in which all risky assets are equally weighted (Weber and Johnson 2009; DeMiguel, Garlappi and Uppal 2009).

From the practical perspective, portfolio managers complain that the MV framework often delivers less satisfactory portfolios, because the tendency of small changes in expected return inputs often derives major swings in portfolio weights. The high sensitivity of the optimal portfolio weights to such inputs often engenders extreme solutions (Michaud 1989). Michaud and Michaud (2008) and Best and Grauer (1991), among others, argue that one possible interpretation of this phenomenon is the error-maximising nature of the MV optimisation. For example, given an asset with very low volatility relative to others in the MV optimisation, a risk-minimising process will have a tendency to rely too much on that asset rather than diversifying to hold a wide range of selected assets (Christodoulakis 2002).

It is worth noting three recent review articles on distinct aspects of standard asset allocation problems. First, Brandt (2009) provides an overview of the broad literature on portfolio selection problems, in which he not only summarises the theoretical formulation of asset allocation in both static and dynamic ways, but also identifies various econometric treatment of such problems. Second, Avramov and Zhou (2010) provide a review of the studies on Bayesian portfolio analysis. They argue that portfolio analysis in a Bayesian manner can resolve the key practical problems facing investors, such as parameter uncertainty and model uncertainty, and they consider useful priors in choosing optimal portfolio weights, including macro conditions, information about events, security-driving forces, and asset pricing theories. The Black-Litterman model is described as one of their Bayesian methods for portfolio analysis. Third, Wachter (2010) depicts both static and dynamic models on asset allocation, concentrating on the implications of return predictability for long-run investors and the bond-stock decision.

2.2.2 Behavioural Studies on Portfolio Optimisation Problems

Behavioural studies on portfolio optimisation problems mainly involve in the application of mental accounting to the standard literature on portfolio choice problems, which have been well documented. For example, Lopes (1987) and Lopes and Oden (1999) develop SP/A theory, a psychologically-based approach to expound choice among risky assets. Specifically, S stands for 'Security', denoting a general concern about avoiding low levels of wealth; P stands for 'Potential', implying the general desire to maximise wealth; and A stands for 'Aspiration', expressing the desire to reach a specific goal, such as achieving no less than the subsistence level S. In Lopes' framework, risk-taking is balanced between fear and hope. Lopes points out that fear is such a strong factor due to the fact that fearful people overweight the probability of the worst outcomes, while they underweight those for the best outcomes. This leads individuals to understate the probability of achieving the highest level of expected wealth. In other words, fearful individuals are pessimistic. Hope has the inverse effect on individuals – optimism causes hopeful investors to overstate the probability of achieving the highest level of expected wealth.

Shefrin and Statman (2000) explore behavioural portfolio theory (BPT), based on the foundation of both Prospect Theory (Kahneman and Tversky 1979) and SP/A theory (Lopes 1987). Unlike the MV investors who choose portfolios by considering mean and variance, the BPT investors choose portfolios by considering expected wealth, desire for security and potential, aspiration levels, and probabilities of achieving aspiration levels. Furthermore, unlike the CAPM investors who combine the market portfolio and the risk-free security, the optimal portfolio weights of the BPT investors resemble combinations of bonds and lottery tickets. Shefrin and Statman (2000) present BPT in two versions: a single mental account BPT version (BPT-SA) and a multiple mental account version (BPT-MA). The BPT-SA investors integrate their portfolios into a single mental account, in which, like the MV investors, they consider co-variance. In contrast, the BPT-MA investors divide their portfolios into various mental accounts and overlook co-variance among mental accounts.

Das, Markowitz, Scheid and Statman (2010) develop a mean-variance mental accounting (MVMA) framework by combining Markowitz's mean-variance portfolio theory (MVT) and Shefrin and Statman's behavioural portfolio theory (BPT). They argue that the BPT investors do not consider their portfolios as a whole, and suggest that the MVMA investors consider their portfolios as collections of mental account sub-portfolios in which each sub-portfolio is connected with a goal and each goal has a threshold level. They also suggest that their MA framework has features containing an MA structure of portfolios, a definition of risk as the probability of not reaching the threshold level in each mental account, and various attitudes toward risk associated with distinct accounts. Once investors specify their sub-portfolio threshold levels and probabilities, the problem will be translated into a standard mean-variance problem with an implied risk-aversion coefficient. Das et al. (2010) demonstrate that their

MVMA framework is mathematically equivalent to the mean-variance solution. In line with Markowitz (1952), optimal portfolios within various accounts are on the mean-variance frontier. Finally, as a combination of sub-portfolios, the aggregate portfolio is also on the efficient frontier without short sale constraint.

Two studies extend the work of Das et al. (2010). First, Alexander and Baptista (2011) extend the Das et al. (2010) framework to the case in which investors allocate their wealth in each account among portfolio managers, based on the fact that investors have a tendency to delegate the job of allocating their wealth among assets to portfolio managers who pursue the goal of beating certain benchmarks. They provide an analytical characterisation of the existence and composition of the optimal portfolios within accounts and the aggregate portfolio. They also derive conditions under which such portfolios are not on the mean-variance frontier, and conditions under which they are. Finally, they improve on the numerical approach of Das et al. (2010). Second, Baptista (2012) extends the Das et al. (2010) framework to the case in which investors also consider background risk, based on the assumption of Das et al. (2010) that individuals only face portfolio risk.

De Giorgi (2011) incorporates the behavioural reward-risk model suggested by De Giorgi, Hens, and Mayer (2007) into Shefrin and Statman’s (2000) BPT with the multiple-account, to provide a behavioural solution to the asset allocation puzzle. In his framework, investors deal with distinct mental accounts associated with distinct reference points, investment goals, or aspiration levels. Those accounts with low aspiration pertain to the need for security, whereas those with high aspiration pertain to the hope for wealth. Risk is positively related with the reference point, based on the fact that the higher the reference point, the higher the probability and the value of losses. For each account, investors decide the portfolio with minimum risk. Eventually, investors allocate their wealth between the distinct accounts and thus maximise their total reward, given the loss constraint suggested by their loss tolerance.

In addition, some studies, such as Ang et al. (2005) and Hong et al. (2007), derive optimal portfolio choice using the disappointment aversion proposed by Gul (1991). Other studies generate optimal portfolio choice under loss aversion, for example Gomes (2005), Berkelaar et al. (2004), and Fortin and Hlouskova (2011). Jin and Zhou (2008) provide a behavioural model of portfolio selection in continuous time.

2.2.3 Improvement on MV Efficiency

The two most popular ways of improving MV efficiency from the practical perspective are the Black-Litterman model and Resampled Efficiency, as labelled by Michaud and Michaud (2008).

First, Black and Litterman (1991, 1992) explore a formal framework to construct a stable MV efficient portfolio, providing a quantitative method for combining subjective investor views with market (equilibrium) views. Like MV portfolio analysis, their model constructs optimal portfolio weights based on a variance-covariance matrix. The intuition behind the Black-Litterman (B-L) model is the assumption that the supply of assets should be equivalent to the demand for assets across the entire capital markets, which generates a basis for deriving a set of equilibrium excess returns for selected asset classes. The B-L model then illustrates how investors can mix their own views about expected returns on the asset classes with their corresponding equilibrium excess returns.

In addition to the original B-L model, a number of extensions have been proposed. Walters (2011) and Meucci (2010) survey the original B-L model and its various extensions. Among these Idzorek (2007) presents a means to calibrate the confidence or variance of the investor views in a simple and straightforward method; Fusai and Meucci (2003) propose a way to measure how consistent a posterior estimate of the mean is with regards to the prior, or some other estimate; Braga and Natale (2007) describe how to use Tracking Error to measure the distance from the equilibrium to the posterior portfolio; Krishnan and Mains (2006) present a method to incorporate additional factors into the model; Qian and Gorman (2001) propose a method to integrate views on the covariance matrix as well as views on the returns.

Amenc et al. (2011) suggest that the main problem with the B-L model is that it considers only a static setting in which hedging considerations are ignored. In particular, they point out that there is no room for dynamic upgrading of the views in response to the flow of continuously incoming information. Cvitanic et al. (2006) address these concerns by deriving in closed form the optimal investment strategy of investors who have priors about the abnormal return of a set of securities, and renew those priors in a Bayesian way. They also suggest that, in a certain portfolio, the degree of correlation among the priors on the distinct securities seems to be a key factor in deciding optimal portfolio weights.

Second, Michaud (1998) proposes the concept of Resampled Efficiency to attempt to overcome the error-maximising problem of the original MV analysis. Michaud (1998) argues that the central problem of the MV paradigm can be attributed to uncertainty in forecasts of optimisation inputs, i.e. expected returns and their standard deviations. Thus, his new procedure introduces statistical inference into the MV analysis. Based on resampling optimisation inputs, a Monte Carlo simulation procedure is employed to create alternative optimisation inputs which are in line with the uncertainty in all forecasts. After repeating the simulation procedure many times, a new efficient frontier and a set of optimal portfolio weights can be derived by an averaging process distilling all the alternative efficient frontiers.

2.3 Theoretical Studies on Optimal Reserve Holdings

2.3.1 Earlier Studies

A great number of theoretical studies on optimal reserve holdings have been developed over the past half century. Earlier works such as Triffin (1946) concentrate on reserve adequacy under the circumstance of limited financial integration. He suggests use of the ratio of reserves to imports (R/M) as an effective yardstick to judge the degree of reserve adequacy for a particular country. Behind this approach is the implicit assumption that reserves are held mainly for international payments. In this ratio approach, a further two ratios have been suggested in the literature for judging the reserve adequacy of countries, namely (1) the reserve to short-term external debt ratio, also known as the 'Greenspan-Guidotti rule', which may be applied as a preferred benchmark to gauge a country's vulnerability to capital account crises (Green and Torgerson 2007), and (2) the reserve to GDP ratio, which has gained popularity for its ease of calculation and direct relevance to policy makers (e.g. Jeanne and Ranciere 2011; Valencia 2010).

Heller (1966) was the first to propose a theoretical framework for analysing optimal reserves in a formal way. His model estimates the optimal level of reserves on the assumption of a fixed exchange rate system without capital flows. Holdings of reserves by central banks are mainly for precautionary purposes such as financing deficits and mitigating speculation. He indicates that reserves holdings can incur opportunity cost, measured by the difference between the social rate on investment of capital and the rate of return on the reserves. He also states that reserves holdings are negatively correlated with their opportunity costs and that the optimal level of reserves for a country is to be arrived at by equating the marginal costs to marginal benefits of holding the reserves. This is analogous to the standard cost-benefit analysis in microeconomics. Clark (1970) extends Heller's approach by establishing a stochastic model. Hamada and Ueda (1977) improve Heller's model through the probability of reserve depletion.

Frenkel and Jovanovic (1981) illustrate optimal reserves in an inventory control framework with continuous time. They assume stochastic fluctuations in the balance of payment, for the smoothing out of which central banks hold reserves. The analysis is based on their study in 1980 on the demand of individuals for money (Frenkel and Jovanovic 1980), known as the buffer stock model. They extend this model to analyse the effect of reserves on cushioning current account deficits. The buffer stock model is crucially dependent on two factors, i.e. the costs for adjustment incurred when reserves reach an undesirable lower bound, and the opportunity cost. Reserve holdings on average hinge negatively on adjustment costs, the opportunity cost of reserves, and exchange rate flexibility; and positively on GDP and the fluctuation of reserves. Jung (1995) introduces an upper bound of reserves as a control variable to overcome possible unrealistic outcomes, since without an upper bound the Frenkel and Jovanovic model may lead to the stochastic process increasing to infinity.

Carrying forward the approach of Heller (1966), Ben-Bassat and Gottlieb (1992) highlight that demand for reserves held by central banks is largely motivated by precautionary considerations, not the transaction purpose. They develop a new model of optimal precautionary reserves for a debtor nation involving country risk and the cost of default. In their maximising model, the total costs consist of both losses arising from default under zero reserves (i.e. reserve depletion), and the opportunity costs under non-zero reserves. The solution of the optimal reserves is realised by minimising the total cost applying the first order conditions. This seminal study has attracted wide interest, and subsequent related research investigates optimal reserves for emerging economies in the face of economic and financial crises, e.g. 1997-1998 in Asia, Brazil in 1999, and Turkey in 2001. The common feature of the Ben-Bassat and Gottlieb model and the applications thereof is their proposition that a central bank can assist its country to alleviate the negative outcomes triggered by economic adversity by holding international reserves.

2.3.2 Mercantilism View vs. Precautionary View

In recent debate on reserve hoarding in emerging economies, one focal point has been the motivation for the rapid accumulation of reserves in these countries. The two main explanations put forward in the literature are those according to the mercantilism view and the precautionary view.

The mercantilism view, as advocated by Dooley et al. (2004), expounds that reserve accumulation is the direct consequence of export-oriented policies implemented by many East Asian countries. Under this development strategy, East Asian countries take all possible measures to promote exports, with a view to creating jobs and stimulating economic growth. A key ingredient of this strategy is undervalued exchange rate, and the accumulation of a large holding of foreign reserves is a reason for, as well as a consequence of, exchange rate undervaluation.

The precautionary view believes that countries hold reserves as self-insurance against the risk of balance of payment crises, including sudden stops and capital flights. Aizenman and Lee (2007) compare the importance of the precautionary and mercantilism motivations and unearth evidence that the precautionary motivation is both statistically and economically significant in explaining reserves accumulation, whereas variables related to the mercantilism view are statistically significant, but not economically significant, indicating the predominance of precautionary motivation.

2.3.3 Precautionary Reserves and Utility Maximisation

Precautionary demand for reserves has now been widely incorporated in theoretical research that tries to model the behaviour of central banks' reserve policy, and in empirical estimation of the optimal level of reserves. This is particularly successful in the studies using the approach of utility maximisation of a representative agent (Jeanne and Ranciere 2011; Jeanne 2007; Barnichon 2008; Durdu et al. 2009; Valencia 2010). Typically, models such as Jeanne and Ranciere (2011) would adapt the precautionary savings theory of macroeconomics to the analysis of determination of optimal foreign reserves. The analysis seeks to solve the welfare maximisation problem of a representative agent and thence the optimal level of foreign reserves as precautionary saving of such an agent.

Jeanne and Ranciere (2011) propose an extended model of their previous work (Jeanne 2007), intended to quantify the optimal level of accumulated international reserves as a form of insurance against capital flow volatility, such as sudden stops of capital inflow to emerging markets. The model is characterised by a representative consumer of a small open economy who may not be able to repay her external debt. This representative consumer has a CRRA preference in discrete infinite time. In the model, the probability of sudden stops is the only source of uncertainty. The economy may experience two states: normality and the state when there is a sudden stop. International reserves are held as self-insurance, allowing the government to smooth its consumer's consumption when a sudden stop occurs. The model seeks to evaluate the optimal level of international reserves in terms of maximisation of the consumer's utility in the face of possible sudden stops. According to the model, reserves are positively correlated with the level of short-term debt, the probability of a sudden stop, and the output losses due to a sudden stop. The authors derive a closed-form solution for maximisation under such a model setting.

The model developed by Barnichon (2008) provides quantification of optimal foreign reserves as insurance for low-to-middle income countries that face more than one external shock, e.g. a natural disaster or terms of trade shock under the balance of payment constraint. It assumes that there are two countries, Home and Foreign, where a representative agent in Home consumes two types of non-storable goods: home goods and foreign goods. The model calibration indicates that the optimal level of reserves is very sensitive to the value of parameters. The calibrated optimal level may show large swings for small changes in one or more key parameters such as the size and persistence of shocks, the importance of the export sector, or the degree of risk aversion.

In a recent study, Valencia (2010) applies a standard precautionary savings model originally explored by Carroll (2004), to illustrate optimal precautionary reserves for Bolivia, whose economy hinges on commodity export more than on foreign capital inflows. The country is therefore more vulnerable to volatility in export revenues than to sudden interruption of capital inflows or sudden stops. Similar to the self-insurance hypothesis by Jeanne and Ranciere (2011), Valencia's (2010) discourse is centred on precautionary savings, under which households respond to uncertainty of their future income by amassing savings. Assuming that households consume only tradable goods and the utility of consumption is to be maximised in the current period, the probability of transitory shocks to export volume is introduced into the model as the only source of uncertainty. Such shocks can be induced for example by resource depletion, which can negatively affect households' future income. As a result, the higher the risk of resource depletion, the higher the level of precautionary reserves tends to be. In model calibration, Valencia (2010) derives the optimal level of reserves for Bolivia in a range from 29 to 37 percent of GDP.

2.4 Related Literature on Reserve Management

Studies on reserve management can be divided into two categories: (1) optimal currency composition of foreign reserves; and (2) strategic asset allocation of foreign reserves.

2.4.1 Reserve Currency Composition

Generally, the literature on the currency composition of foreign reserves can be classified into two categories: an empirical literature attempting to relate the reserve portfolio of central banks to observable country characteristics, and a theoretical literature using portfolio theory to derive the optimal currency composition of reserves.

Empirical studies on the determinants of reserve currency composition have been impeded by the fact that data on the currency composition of reserves at the country level is confidential in most cases. The reserves of fewer than 40% of emerging economies have a known currency composition published in the Currency Composition of Official Foreign Exchange Reserves (COFER) database from the IMF (Beck and Rahbari 2011). Employing confidential data on the currency composition of reserves of 76 countries, Heller and Knight (1978) suggest that a country's exchange rate regime and its trade patterns are significantly related to reserve currency composition, and conclude that transaction demands play an important role in determining reserve currency composition. Their results are supported by both Dooley et al. (1989), who analyse the determinants of the currency composition using the entire country-level COFER data, and Mathieson and Eichengreen (2000), who add that the currency composition of external debt or financial flows can be included as a source of transaction demands. Using the aggregate COFER data, Chinn and Frankel (2007, 2008) suggest that the determinants of reserve currency composition also include the size of the home country, the inflation rate of the reserve currency, exchange rate volatility and the size of the home financial market centre.

Using the aggregate IMF-COFER data, Lim (2007) examines the impact of past exchange rate changes on aggregate currency shares of reserves, and finds evidence of stabilising diversification, i.e. central banks buy the US dollar in the hope of stabilising the market when the US dollar declines. Truman and Wong (2006) and Wong (2007) suggest that developed countries are engaged in passive (do nothing when the US dollar declines) and stabilising diversification, whereas developing countries are engaged in active diversification (sell the US dollar in the hope of profiting from the dollar's decline). Wooldridge (2006) suggests that developing countries have indeed moved away from the US dollar in recent years.

While the empirical literature in general finds evidence for transaction demands as a determinant of reserve currency composition, the existing theoretical literature derives the currency composition of optimal reserves as the solution to an international version of a Markowitz type portfolio problem. Ben-Bassat (1980) suggests applying mean-variance optimisation in terms of a basket of import currencies. Using data from 1976 to 1980, he compares optimal to actual reserve portfolios and finds some evidence for portfolio objectives as a determinant of the currency composition of reserves of the emerging markets, but not those of industrialised countries. Dellas and Yoo (1991) use data on the currency denomination of imports and the reserve composition for South Korea to examine both a mean-variance optimisation model and an import-based version of the consumption capital asset pricing model (CCAPM). They find that the mean-variance approach performs relatively well in explaining at least the share of the main currency, the US dollar.

Among the few attempts to take account of the transaction demands of central banks, Dooley (1987) and Dooley et al. (1989) use a very simple model to show that in the case of a mean-variance optimising central bank, when considering both foreign currency assets and liabilities as well as transaction costs, the composition of gross assets depends on the structure of transaction costs, and the composition of net assets depends on expected returns and co-variances. Papaioannou et al. (2006) develop a dynamic mean-variance framework and compute the optimal reserve portfolio at the world level using a variety of methods to estimate covariance matrices and return expectations, with different reference currencies. They also experiment with imposing different constraints that reflect transaction considerations. The authors find that the reference currency is quantitatively very important, and that the computed optimal share for the euro at the world level is lower than the actual aggregate share published in the COFER database.

Beck and Rahbari (2011) derive optimal portfolios of central banks in a minimum variance framework with two assets and transaction demands caused by sudden stops in capital flows. By estimating optimal dollar and euro shares for 23 emerging economies, they find that: (1) optimal reserve portfolios are dominated by anchor currencies; (2) during the sudden stops, the dollar acts as a safe haven currency, increasing the optimal share of dollar bonds in central bank portfolios; (3) dollar shares should decline as the ratio of debt-to-reserve decreases, and (4) the denomination of foreign currency debt has little importance for optimal reserve portfolios.

In response to the recent debate regarding the need for portfolio diversification, Kim and Ryou (2011) analyse the mean-variance efficiency of the reserve portfolios of central banks. They use likelihood ratio test statistics and test the efficiency of the reserve portfolios of 18 countries from 2008 to 2009. Their findings suggest that the status of the US dollar as an international reserve currency has not declined, despite the fact that the US dollar declined in exchange value during the global financial crisis.

Differing from the traditional mean-variance optimality analysis of asset portfolios, Sheng (2011) takes an alternative approach to detect the latent currency portfolio of Chinese foreign reserves and the underlying strategies of portfolio management during the period from 2000 to 2007, due to the fact that China does not release its currency portfolio to the IMF. Based on a portfolio accounting identity and the budget constraint of China's reserve holding by its central bank, he demonstrates that China significantly and dramatically diversified its reserves out of the US dollar in 2002; however, after this portfolio adjustment, China switched to a portfolio-rebalancing strategy and tried to maintain a stable currency composition. According to his estimation, by the end of 2007 China held about 22% in the euro, 2.5% in the Japanese yen, 4.7% in the Australian dollar, and 3.5% in the British pound. The average annual rate of return was about 3%.

2.4.2 Strategic Asset Allocation for Reserve Management

The research on strategic asset allocation for reserve management is well documented in the literature. Bernadell et al. (2004), Berkelaar et al. (2009) and Coche et al. (2010) edit three volumes on the investigation of various aspects of foreign reserve management, in which some studies focus on the strategic asset allocation of central banks. Notably, Cardon and Coche (2004) propose a blueprint for the management of the strategic asset allocation of central banks, where asset allocation decisions can be carried out by a three-tier governance structure consisting of an oversight committee, investment committee and portfolio management. Fisher and Lie (2004) provide a reserves' strategic asset allocation framework considering various assets (i.e. government bonds, non-government bonds, equities and currency) and guaranteeing sufficient liquidity for trade and intervention requirements, and find that relaxing various constraints can obtain better return for the same risk levels. De Cacella et al. (2010) develop a multi-objective evolutionary optimisation algorithm to obtain a set of viable portfolios using a variable time horizon.

Some studies employ the Black-Litterman (B-L) approach to investigate the strategic asset allocation of reserves. Fernandes et al. (2012) combine the B-L approach and the resampling approach of Michaud and Michaud (2008) to generate a portfolio optimisation for central banks' strategic asset allocation. Petrovic (2010) applies the Black-Litterman approach to central banking practice. Leon and Vela (2011) derive the strategic asset allocation of foreign reserves using a long-term-dependence-adjusted and non-loss-constrained version of the Black-Litterman model to obtain the efficient frontier from a set of investments. To satisfy safety, liquidity and return criteria, the utility maximising portfolio is chosen using an estimation of the Board of Directors' risk aversion.

Another branch of studies on strategic asset allocation for reserve management is called 'Asset-Liability Management' (ALM). Using stochastic programming, Claessens and Kreuser (2007) develop a framework for strategic foreign reserves management integrating risk-return objectives with macroeconomic, macro-prudential and sovereign debt management concerns. Their model can be run on a PC-based platform. They apply the framework to several common reserve management problems and show how it provides institutional guidance through developing benchmarks, portfolio evaluation criteria and management reporting. Romanyuk (2010) overviews ALM and identifies risks, asset allocation, and asset-liability strategies within portfolio management. He also indicates that to specify an objective function of a central bank, one must consider which risk metrics are most appropriate for capturing the risks of its greatest concern, and how to account for the various explicit and implicit constraints on the reserve assets. Romanyuk (2012) investigates how to translate the three common policy objectives for reserves (liquidity, safety, and return) into objective functions for strategic reserves management. He then uses the stochastic programming by Claessens and Kreuser (2007) as the modelling framework to capture the objectives of foreign reserve management of the Bank of Canada. However, he also points out the shortcomings of the traditional approaches, for example that in turbulent market environments and during crises, the diversification paradigm for risk fails; herding behaviour or flight to quality introduce behavioural elements that are not accounted for within the context of diversification, and the diversification paradigm is too limited to capture the risks that become relevant in bad times.

2.5 Sovereign Wealth Funds

The studies on various issues of SWFs have been well documented. Some studies analyse the general issues of SWFs. For example, Mitchell, Piggott, and Kumru (2008) probe three different large publicly-held funds i.e. foreign exchange reserve funds, SWFs, and public pension funds to point out their similarities and differences, showing that they are playing an increasing significant role in international financial markets. Aizenman and Glick (2009) deliver a statistical analysis of the stylized facts of SWFs by evaluating what factors trigger the establishment of SWFs and affect their size and investigating the relationship between the transparency and governance of SWFs and domestic and global governance practices. Das, Lu, Mulder, and Sy (2009) provide a guideline about the establishment of SWFs to policymakers, covering various issues from macroeconomic policy objectives, to the institutional structure, and to specific operational considerations.

Some studies investigate the impact of Sovereign Wealth Fund (SWF) investments on their target firm issues. For instance, Dewenter, Han, and Malatesta (2010) examine the relationship between the announcement of both investments and divestments of SWFs and their corresponding changes in values of the firms where they invest. Kotter and Lel (2011) examine how both investment strategies of SWFs and their impact on the value of target firm are related to the extent of accountability and transparency of SWFs. Knill, Lee and Mauck (2012) explore the return and risk performances of SWF target firms after SWF investment, to answer the question whether the performances of SWF target firms are more closely analogous to those of state-owned firms or firms invested by institutional investors.

Some studies investigate the investment strategies of SWFs. For example, Bernstein, Lerner, and Schoar (2009) probe the SWF direct investments towards private equity and their relationship to the organizational structures of SWFs. Chhaochharia and Laeven (2009) find out that SWFs tend to invest in countries that have similar cultural traits with them, based on a dataset of 30,000 equity investments by SWFs. Dyck and Morse (2011) explore the behaviour of SWF investments in public equities, private firms, and real estate, based on a novel, hand-collected dataset.

Some studies involve in theoretical modelling on SWFs. For example, Aizenman and Glick (2011) develop a model in which they compare the optimal asset diversification into safe assets and risky assets of a central bank with that of a SWF, showing their distinct investment behaviour. Using two countries and two asset classes, Sa and Viani (2011) develop a dynamic general equilibrium model to explore that a shift in portfolio preferences of foreign investors i.e. SWFs may affect various economic variables such as asset prices, consumption, the exchange rate and net debt. Van Den Bremer and Van Der Ploeg (2013) develop an optimal asset management framework for oil-rich economies, in which three funds are necessary to manage: (1) liquidity funds for deal with oil price volatility; (2) investment funds for managing domestic investment, and (3) intergenerational funds for smooth out the benefits across generations. Some studies estimate the risk management of SWFs. For example, Bodie and Briere (2011) develop a new approach to the risk management issue of SWFs, with the help of contingent claim analysis (CCA) originally proposed by Gray, Merton, and Bodie (2007), and apply this approach into the case of Chile.

2.6 Summary

Even though studies on optimal reserve holdings, reserve management, and sovereign wealth funds have well documented, few studies are available for evaluating the mechanism of China's reserve accumulation, and efficiently managing China's reserve assets and sovereign wealth fund. However, the literature on behavioural finance and portfolio choice problems have provided some useful elements to facilitate the investigation of China's related issues on foreign assets. For example, loss aversion, narrow farming, and mental accounting have been demonstrated as the ubiquitous phenomena happened when individuals make their decisions. In the next three chapters, from a behavioural perspective, I investigate optimal holdings of China's foreign reserves and develop both strategic asset allocation for a central bank and an investment strategy for sovereign wealth funds in a multiple-objective manner.

Chapter 3

OPTIMAL HOLDINGS OF LARGE FOREIGN RESERVES IN CHINA: A BEHAVIOURAL PERSPECTIVE

3.1 Introduction

The accumulation of ever larger foreign reserves by many emerging economies, particularly China, has fundamentally challenged the traditional thinking about sound reserve management. Prior studies have generally articulated a reserve management framework centring on some benchmarks for the appropriate reserve level for a country to hold. Where the reserves are below or above the metrics of the benchmarks, or even a single point of reference, this is commonly considered unhealthy for the economy in question and policy actions are then called for. While in the immediate post-war period it was common for developing economies to suffer from reserve inadequacy, nowadays they tend to hold reserves in excess of the benchmark level. In the case of China, at the end of 2011 the country had accumulated reserves of USD 3181 billion, accounting for 44% of its GDP at the official exchange rate and enough to cover 22 months of imports. This level of reserves far exceeds almost all established criteria for optimal reserves for any country. Yet, the extraordinary reserve build-up is still ongoing in China. Given the fact that excess reserve holdings can incur significant cost, the Chinese reserve policy in recent decades is puzzling. The question then arises: Why is this seemingly irrational stockpiling of reserves tolerated, or even encouraged?

Conventional reserve literature has failed to offer a satisfactory answer to this question. While central banks hold reserves for multiple purposes (Roger, 1993), early studies assume that official reserves chiefly serve to fulfil external obligations (Triffin, 1946). Heller (1966) argues that it is not the transaction motive but rather the precautionary motive that is the main driving force for holding reserves. Frenkel and Jovanovic (1981) suggest that central banks hold reserves as a buffer stock to smooth fluctuations of international payments. These approaches have put forward some benchmarks for optimal reserves based on their respective theoretical underpinning, with varying degrees of success historically. But all of them now fail to explain satisfactorily why, in reality, central banks in recent decades have deviated, often hugely, from the suggested optimal benchmarks (Beck and Weber, 2011).

Many recent studies have attempted either to empirically test or to theoretically explore the motives behind high demand for reserves in the emerging markets (Aizenman and Marion, 2003; Wijnholds and Sondergaard, 2007; Jeanne and Rancière, 2011; Park and Estrada, 2009; Tereanu, 2010; Carroll and Jeanne, 2009; Kim, Shirono, and Dabla-Norris, 2011; Sandri, 2010). Unlike previous studies that focus on achieving a balance between the cost and benefit of holding reserves, the recent literature has turned its attention to the welfare implications of reserve accumulation and to offering an analytical framework based on utility maximisation by rational agents.

One prominent venture in this approach is the development of the precautionary saving model of optimal foreign reserves. The earlier work may be found in Ghosh and Ostry (1997), while recent examples include works by Durdu, Mendoza and Terrones (2009), Jeanne and Rancière, (2011), Carroll and Jeanne (2009), and Sandri (2010). This strand of literature has achieved important advances over previous studies. However, like other models using the rationality-based analysis of expected utility, this family of models becomes problematic when applied to the massive accumulation of foreign reserves by emerging countries, particularly China. It remains hard to understand why countries like China would stockpile such a large amount of foreign reserves, which is in stark disagreement with the policy advice offered by this approach.

In all, existing studies have not been very successful in explaining the behaviour of persistent hoarding of reserves in the emerging world.

Research in this field now gradually edges towards a consensus that motives for hoarding reserves in emerging markets are an evolving process during which a country's motive may shift with changing economic conditions (Ghosh et al, 2012).

Often, countries may have manifold of motives for reserve accumulation (Bar-Ilan and Marion, 2009). While precaution is currently a predominant motive in emerging economies, other influences may also at work including reserve stockpiling as a by-product of other policy choices.

In an attempt to work out the puzzle of China's massive hoarding of foreign reserves, this paper develops a model based on the behavioural approach to optimal decision making under uncertainty which was popularized by Barberis, Huang and Santos (2001), among others. In this model, we treat reserve hoardings in China as a combinational process in which the authority's precaution against possible adverse shocks is the underlying force, but the decision maker's cognitive attributes would crucially heighten the precautionary demand for reserve accumulation. It is the interaction of the precautionary motive and cognitive bias of the decision makers that pushes the build-up of foreign reserves up to such a massive level as observed in China.

An analytical model in a behavioural perspective is set up to decode the puzzling development of Chinese reserve stockpiling. Centring on the agent who is cognitively biased when making decisions under uncertainty, the theoretical model embeds the influences of both loss aversion and narrow framing, along with precautionary saving as the main motive for accumulating seemingly large reserves. Then, numerical solution is derived using the Method of Endogenous Grid-points as in Carroll (2006).

Benchmark calibration of the model indicates that the precautionary saving motive for foreign reserves becomes much stronger when the agent is loss averse and has the trait of narrow framing. In all possible scenarios under examination, the level of precautionary reserves is higher for the agent with cognitive biases than for the one without. This is also true for the level of optimal precautionary reserves derived from the model. According to the model calibration and simulation, China's actual holdings of foreign reserves are broadly in line with that predicted by the behavioural model suggesting that the level of foreign reserves that China holds is largely an equilibrium result of the authority's precautionary motive and the traits of its risk profiling.

The current research (e.g. Song et al. (2011); Wen (2011)) indicates that China's massive reserve accumulation is a process influenced by interaction between the authority's precautionary consideration and its cognitive peculiarity featuring loss aversion and narrow framing. The compound effect of these influences underpins China's prudent stance in its foreign reserve policy and complements the current reserve literature by offering a behavioural explanation which underscores the critical importance of cognitive factors as a driving force behind Chinese massive reserve accumulation.

This research also offers critical insights into a critical development of China's increasing role in the world economy in recent years, i.e. the rise of its sovereign wealth fund (Dixon and Monk, 2011). In the first place, China's colossal reserves provide abundant financial resources making the nation comfortably possible to engage in global investment. More important, in managing foreign reserves, the prevailing strategy that the government adopts centres on a task to strike a balance between safety, liquidity and profitability. China's heightened precautionary motive under the influence of decision makers' cognitive attributes often means its reserve investment would lean towards lower-return yet relatively safe assets. To redress the balance, China has transferred a considerable part of its reserves to fund establishment of the sovereign wealth fund known as China Investment Corporation (Aizenman and Glick, 2007; 2009). The CIC has more room in actively undertaking profitable investments outside the country, ranging from investing in financial assets with greater returns to securing strategic raw materials (Dixon and Monk, 2011). In both the level and investment orientation of China's sovereign wealth fund, interaction of precautionary motive and decision makers' cognitive attributes has played a pivotal role. Our behavioural model therefore provides an explanation for the impetus behind the phenomenon emergence of China's sovereign wealth fund.

We begin, in Section 3.2, by reviewing the literature on the motives for reserve accumulation and on the cognitive traits that are commonly found to influence decision making of agents when faced with uncertainty, i.e. loss aversion and narrow framing. In Section 3.3, after laying down the background of income uncertainty in the Chinese economy and specifying model assumptions, we build a behavioural model incorporating loss aversion and narrow framing. The numerical solution of the model is presented in Section 3.4, along with the benchmark calibration results and sensitivity tests for the optimal foreign reserves for the agents under the influence of behavioural biases. We draw conclusions in Section 3.5.

3.2 Related Literature

3.2.1 Conventional Thinking on Optimal Reserves

3.2.1.1 Earlier views

In the context of severe dollar shortage in the period immediately after World War II, Triffin (1946) views foreign reserves as a means of meeting the obligation of external payments, and establishes some benchmarks with regard to a ratio of reserves to imports for judging whether a country has the minimum capability for meeting the obligation. Heller (1966), in the earliest study of the precautionary motive, argues that it is the precautionary purpose, rather than transaction purpose, that mainly drives the demand for accumulating foreign reserves. However, the emphasis of his work is on establishing a framework for cost-benefit analytics.

Frenkel and Jovanovic (1981) suggest that optimal reserves are one that can balance the macroeconomic adjustment costs incurred in the absence of reserves, with the opportunity cost of holding reserves. Assuming a transaction motive, they predict that average reserves hinge negatively upon adjustment cost, the opportunity cost of reserves and exchange rate flexibility, and positively upon GDP and reserve volatility.

3.2.1.2 The mercantilism motive

In their explanation of the mercantilism motive, Dooley, Folkerts-Landau, and Garber (2004) state that reserve accumulation can be understood as the direct consequence of export-oriented policies implemented by most East Asian countries, particularly China, in order to achieve their aims of creating more jobs and maintaining economic growth through promoting exports. However, Aizenman and Lee (2007) compare the importance of the precautionary motive, i.e. self-insurance against the risk caused by sudden stops, with that of the mercantilism motive, and find that variables related to the precautionary motive are both statistically and economically significant in interpreting reserve accumulation, whereas variables related to the mercantilism motive are statistically significant, but not economically significant, which implies the dominance of the precautionary motive in emerging economies' reserve demand. For the case of China, Aizenman and Lee (2008) suggest that China's massive hoarding of reserves takes place under a hybrid of the mercantilism and the precautionary motives.

3.2.1.3 The precautionary motive

Based on the observation that deeper financial integration has increased developing countries' exposure to short-term capital inflows that are subject to sudden stops and reversals (Edwards, 2004), many recent studies on optimal reserves suggest that reserves can be viewed as self-insurance to mitigate and prevent an undesired output drop or the crisis caused by sudden stops or negative shocks to the economy. This is the precautionary motive.

After Heller (1966), who first points out that the precautionary motive is a dominant influence in monetary authorities' decision to hold international reserves, Ben-Bassat and Gottlieb (1992) generate a precautionary model in which reserves can be used by a borrowing country challenged by default on the external debt. Aizenman and Marion (2003) suggest that following the Asian financial crisis, countries in East Asia began to accumulate massive reserves under the precautionary motive. Aizenman and Lee (2007) show that the reserve accumulation by emerging countries is related to variables that reflect the precautionary motive, and that China is not an obvious outlier. Mendoza's (2010) empirical study suggests that China's reserve holding pattern is driven by the precautionary motive, which is in accordance with other developing countries. Using a more elaborated model, García and Soto (2006) conclude that self-insurance against sudden stops plays an important role in accounting for recent hoarding of international reserves.

Recent studies on optimal reserves interpret the precautionary motive of emerging countries using the consumption-based approach. For example, extending the model by Jeanne (2007), Jeanne and Rancière (2011) quantify the optimal level of reserves from the perspective of consumption smoothing against output drop caused by capital flow volatility. Likewise, Durdu et al. (2009) concentrate on potential sudden stops as a determinant of precautionary foreign asset demand. Carroll and Jeanne (2009) derive a tractable model of the net foreign assets in a small open economy to estimate the optimal level of precautionary wealth against an idiosyncratic risk.

The dynamics of reserve accumulation studied by Obstfeld, Shambaugh, and Taylor (2010) is from a further aspect of macroprudence, which is based on financial stability and financial openness in globalised financial integration. In their model, a central bank needs to accumulate reserves to take the responsibility of lender of last resort and therefore prevent its economy from double drains, i.e. both internal drains (runs from bank deposits to currency) and external drains (flight to foreign currency or banks). Hur and Kondo (2011) develop a small open economy model in which large reserve holdings by emerging economies are an optimal response to an increase in foreign debt rollover risk and therefore can prevent the economies suffering from sudden stops. Calvo, Izquierdo, and Loo-Kung (2012) present a statistical model in which optimal reserves can be viewed as the trade-off between the expected cost of sudden stops and the opportunity cost of holding reserves. Their conclusion indicates that reserves can reduce the probability of sudden stop and its attendant costs.

3.2.2 Loss Aversion and Narrow Framing

As application of psychology to agents' financial decision making, behavioural finance studies agents' response to financial anomalies (Shefrin, 2009). One critical aspect of this branch of financial study is the agent's preference, in which loss aversion and narrow framing are two main behavioural elements.

Loss aversion is a central proposition of the Prospect Theory (PT) pioneered by Kahneman and Tversky (1979). They propose a value function that is defined over changes in wealth rather than final asset position as in conventional economics. The agents view outcomes either as gains or losses relative to a certain reference point and are more sensitive to losses than to completely commensurate gains; i.e. more weight is assigned to losses than to equally sized gains.

Loss aversion has been well incorporated into finance research. In its effort to provide a new avenue for a better understanding of financial anomalies, the behavioural approach to finance has made important advances one of which concerns the anomaly caused by the disposition effect (Shefrin and Statman, 1985), which is closely related to loss aversion. Shefrin and Statman (1985) show that, under the influence of such an effect, investors tend to sell stocks that have gained value (winners) and to hold on to stocks that have lost value (losers), relative to the stock's purchase price or the reference point. Odean (1998) further shows that investors will sell winners soon and hold losers long.

Some variants of loss aversion have also been applied to explain reserves accumulation (Aizenman, 1998). This is done mainly through the application of Gul's (1991) disappointment aversion. With this effect, Aizenman shows that a stabilisation fund becomes larger than that under expected utility. Aizenman and Marion (2003) further incorporate loss aversion into an inter-temporal consumption model to examine large reserve holdings by Asian emerging markets.

The second important factor influencing individuals' decision-making behaviours is narrow framing, first labelled by Kahneman and Lovallo (1993), whereby they assess a specific risk under a narrow, rather than a broad frame. As suggested by Barberis and Huang (2007), narrow framing indicates that people assess a specific risk in isolation, separately from their other risks. In other words, people act as if they derive utility directly from the outcome of that specific risk, even if the specific risk is just one of many determining their overall wealth risks.

Kahneman and Lovallo (1993) offer a corresponding interpretation for the organisational level. They suggest that for a decision maker facing a series of decisions, whether or not to use a broad frame depends on how her performance will be evaluated and on the frequency of performance. If her performance is assessed narrowly (e.g. when facing a risk, if her performance is estimated on that risk alone), the decision maker frames decisions narrowly. Thus, in the context of the Chinese central bank, it is reasonable for her to assess the risk of GDP growth narrowly, due to the fact that promoting GDP growth is her primary task and her performance is evaluated based on GDP growth.

The effect works only when narrow framing and loss aversion are combined. Since loss aversion only matters for decisions which trigger gains or losses, it would have little impact on decision making where individuals evaluate the specific risk under a broad frame (Read, Loewenstein and Rabin, 1999). Benartzi and Thaler (1995) attribute the equity premium puzzle to myopic loss aversion, which is the combination of narrow framing and loss aversion. Barberis, Huang and Santos (2001) develop a model that incorporates behavioural factors, prominently loss aversion and narrow framing, into the optimal decision-making process. In explaining the equity premium, they show that investors get utility from consumption while facing volatilities in the value of their financial wealth. Loss aversion over these volatilities and narrow framing of risks only in the stock market may help explain the existence of equity premium. Barberis and Huang (2009) further refine the behavioural model of optimal choice uncertainty.

Conventional theories of optimal level and growth of foreign reserves have met increasing challenges in recent years. Relying on the approach in which rational agent maximises expected utility, to derive optimal reserves has proved unsuccessful in shedding light on the huge reserve hoardings in the emerging world, particularly in China. Against this backdrop, incorporating behavioural factors such as loss aversion and narrow framing may prove to be a promising avenue for a better understanding of the rapid accumulation of reserves in China.

3.3 The Model

To understand China's reserve accumulation behaviour, we first characterise the Chinese growth strategy and the uncertainties surrounding the economic transformation. This sets out the background for delineating assumptions of our model. We then develop a behavioural model of optimal decision making under uncertainty to derive the optimal reserves to explain the Chinese reserve hoarding. Based on Barberis, Huang and Santos (BHS) (2001), this model departs drastically from the conventional consumption-based approach. In what follows, we specify: (A) the approach of BHS (2001); (B) the representative agent's preference informing the maximisation problem; (C) the nature of process generating the resources available to the representative agent, and (D) behavioural factors including loss aversion and narrow framing. In the process, we derive the Euler equations and interpret the precautionary savings motive.

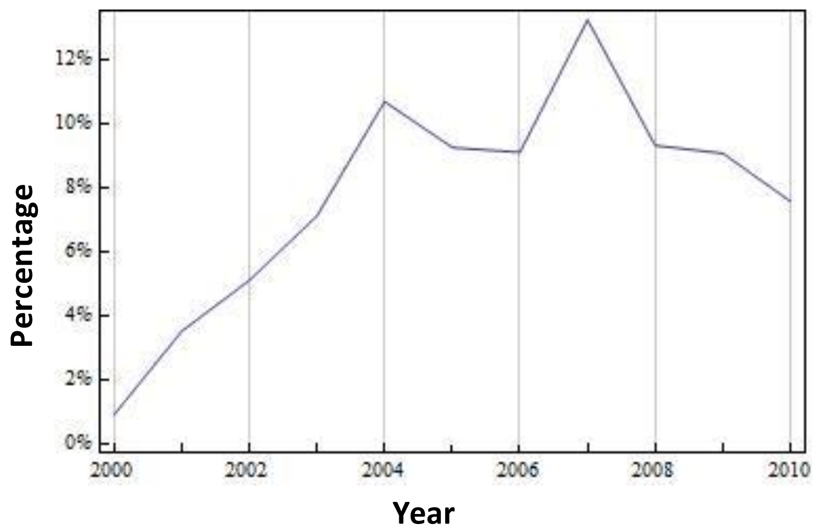
3.3.1 Model Setup: Background Considerations

3.3.1.1 China's growth strategy

In December 1978, China launched its first programme of economic reforms, featuring a bold move to establish a market economy, and the focal point of its economic policy started to shift towards promoting economic growth. Since then, the reforms have achieved remarkable progress and maximising growth has been firmly established as China's overwhelming policy goal. In this environment, growth has become the main criterion for measuring policy performance. It is then conceivable that the Chinese policymakers would assess the effects of any uncertainty mainly with regard to GDP growth, and isolate such effects from those on consumption or total wealth. Consequently, along with consumption, maximising GDP growth can and should be incorporated into the preference of Chinese policymakers.

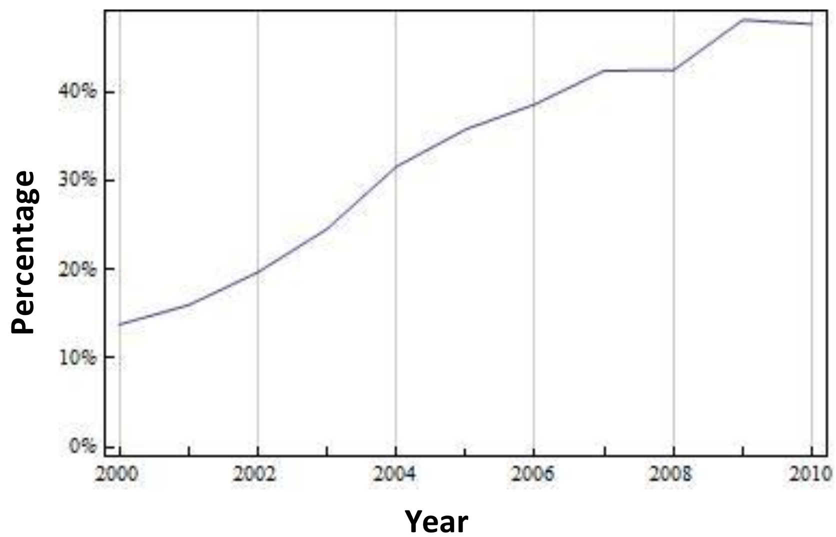
3.3.1.2 Uncertainties facing the Chinese economy

The past three decades have witnessed remarkable growth in China. Meanwhile, the country has rapidly accumulated massive reserves, particularly since its WTO accession in 2001. However, the Chinese strategy of focusing chiefly on economic growth has given rise to imbalances between the decisive move to a market economy and other supportive measures that would enable the establishment of the market institutions. Consequently, Chinese consumers are faced with formidable uncertainties surrounding the future path of welfare and living standards. Both the fast GDP growth and reserve accumulation are shown in the following Figures 3.1 and 3.2 depict the net reserves to GDP ratio and the total reserves to GDP ratio, respectively, while the upper line in Fig. 3.3 shows fast GDP growth.



Source: People’s Bank of China (PBoC)

Figure 3.1 Net Reserves/GDP Ratio

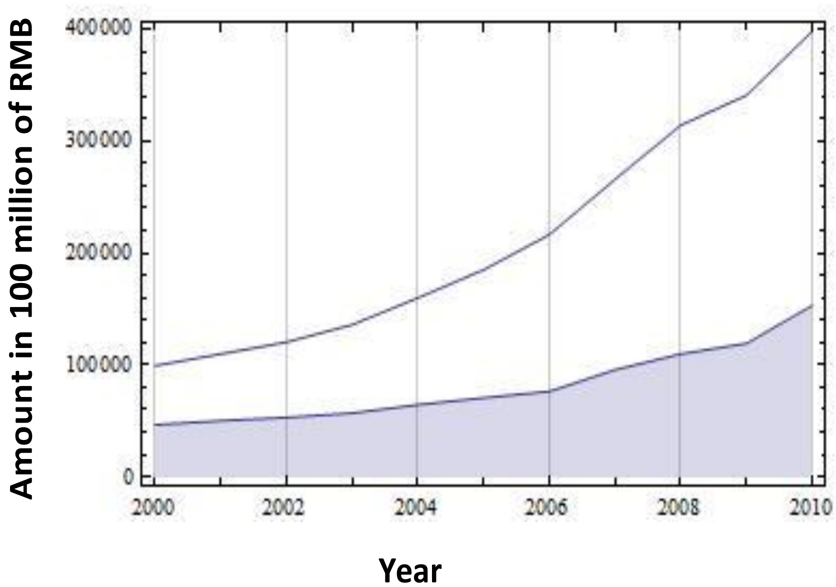


Source: People's Bank of China (PBoC)

Figure 3.2 Total Reserves/GDP Ratio

Other crucial reforms, such as those regarding the financial sector and pension schemes, have clearly lagged behind. For example, due to the incompleteness of its financial reform, the Chinese banking system suffers from fragility and the severe problem of non-performing loans. Aizenman and Lee (2008) show that financial fragility in China is largely the outcome of favourable financing provided to the state-owned enterprises (SOE) and to other targeted borrowers. They indicate that non-performing loans (NPLs) were about 23 per cent of GDP on average for 2002-03. Prasad and Wei (2005) also indicate that the underdeveloped Chinese banking system is vulnerable to external shocks because of the reported NPLs problem and the need for a bailout of the banking system. Prasad (2009) suggests that 'loss of confidence in the banking system' is potentially one of the most serious risks facing the Chinese economy. In addition, the underdevelopment of the financial market means that not only workers but also producers in China are exposed to borrowing constraints (Wen, 2010; Wen, 2011; Song et al., 2011). The current pension reform in China generates a negative shock to the completeness of individuals' insurance policies. Chamon et al. (2010) show that China's high household savings are a result of rising income uncertainty and pension reforms. According to them, the permanent uncertainty of household income is stable, while the transitory uncertainty rises sharply.

Furthermore, an economic development strategy that places most weight on the construction of infrastructure has given rise to imbalances in the economic structure itself. Whereas private consumption in China has been squeezed by the inadequate social security coverage, investment has been an overwhelming contributor to growth (Prasad, 2009). In Figure 3.3, the filled line shows the total amount of private consumption during the last decade, indicating that private consumption is not dominant as a contribution to GDP growth shown by the upper line. Because of the weak private consumption, the Chinese economy is heavily dependent on external demand and so is very vulnerable to external shocks.



Note: The upper line: GDP   and the filled line: Consumption

Source: World Bank: World Development Indicators (Edition: September 2011)

Figure 3.3 GDP Growth and Private Consumption in China

Such imbalances have made the Chinese economy vulnerable to uninsurable aggregate risks, both internally, through problems such as financial fragility, non-performing loans, and inadequate social security coverage, and externally, through collapse of external demand and shocks of global financial crisis (Prasad, 2009). This means that Chinese policy makers have to take into consideration the possibility of a great downside risk of social and political instability and the consequences thereof, as part of its economic decision process.

3.3.1.3 GDP growth and foreign reserves

Foreign reserves accumulated by the Chinese central bank can be seen not only as a means of production smoothing, but also as a precautionary defence mechanism, a cushion against the adverse effects on growth when China is hit by negative shocks.

Reserve accumulation can exercise the function of production smoothing for China. Due to inadequacy of the social security provision, the future for Chinese consumers carries great uncertainty. In the meantime, however, financial markets in China are incomplete in that no contingent financial instruments are available to cover such risk. The Chinese accumulation of colossal foreign reserves at the national level can be viewed as a precaution by the authority to guard against possible dire consequences of such uninsured risk. The massive amount of reserves serves to smooth growth fluctuations and hence cushion against the income risk.

In short, the ongoing economic transformation has brought high uncertainty to Chinese consumers. The incompleteness of the financial markets in China means that agents in the Chinese economy lack the instruments to insure against future risks. In this setting, the central bank accumulates foreign reserves as an Arrow-Debru security or a state contingent claim with a view to smoothing consumption on behalf of the whole society. Thus, reserve accumulation by China can be taken as a precautionary measure that serves to provide self-insurance against income risk and to achieve risk sharing within China and across countries.

3.3.2 Assumptions

For simplicity, we consider a world that consists of two countries: a home country and a foreign country representing the rest of the world. Let the home country be China which is characterised as an open economy[1] with incomplete markets. Further on, we assume the following:

> First, in the home country, there is only one agent representing individuals living with an infinite horizon. The agent is the consumer as well as the producer. Time is discrete and indexed by $t = 0, 1, 2, \ldots$. This sole agent can also be thought of as the central planner (in the form of the central bank) who acts on behalf of the economy. In the context of China, this assumption is reasonable since the Chinese government's overwhelming orientation towards growth targeting has a dominant force driving consumption and production in the country.
>
> Second, there is only one sector in the home country. In this sector only tradable goods are produced and consumed by the representative agent.

[1] An open economy is an economy where economic activities are divided into activities in the domestic sector and in the foreign sector. People in the foreign sector can trade in goods and services with other people outside this economy.

Specifically, home-produced goods are only for export, and the agent consumes only foreign-produced goods. Because all home-produced goods are for export, output or income is denominated in foreign assets, which can be either consumed or saved. Capital stock accumulation for producing output can be financed by savings in foreign assets, which can be used to smooth both consumption and capital stocks.

Third, the representative agent suffers from severe borrowing constraints due to incomplete financial markets. As a result, savings in foreign assets are constrained to be non-negative.

Fourth, the central bank consistently takes steady growth as her main policy object, and sets a target growth rate for the GDP. She also has cognitive biases toward growth, i.e. she is loss averse towards the target GDP growth rate and frames the uncertainty about growth narrowly, i.e. she evaluates this uncertainty by isolating it from consumption or total wealth.

Fifth, markets are incomplete, so that the number of Arrow–Debreu securities is less than the number of states of nature. This shortage of securities restricts the agent from transferring the desired level of wealth among states and so the central bank will fully bear the risks of growth contraction. It then accumulates foreign assets as a precautionary measure to provide self-insurance against adverse shocks to growth.

For emphasising the impact of the representative agent's cognitive biases, a two-country setting is simply used here to investigate the behavioural decision making process of the agent in response to the circumstance outside the economy. Additionally, only a one-sector (foreign-sector) setting in the economy is employed here to facilitate our direct investigation of reserve accumulation in china, as used in many related studies such as Valencia (2010). The assumptions about severe borrowing constraints towards the agent and market incompleteness correspond to the vulnerability of China's financial system, documented by related studies such as Prasad (2009), Song et al. (2011), and Allen et al. (2012).

3.3.3 The Behavioural Model of Optimal Reserves

3.3.3.1 The BHS approach

The model developed by Barberis, Huang and Santos (2001) provides a general preference structure in which the representative agent derives utility from two sources. One is the utility in the conventional sense, i.e. the future utility her current wealth will bring from making the consumption decision. The other is related to possible fluctuations of the value of her financial wealth in expectation, which is reflected in her objective function with an extra term.

Inclusion of this additional source of utility allows the model to depart radically from the standard consumption-based approach to decision making. A notable property of this structure is its flexibility to take into account cognitive biases of agents who make decisions under uncertainty. Drawing on a central idea of the prospect theory of Kahneman and Tversky (1979), their model embeds the notion of loss aversion into decision making under risk, hence the utility over fluctuating financial wealth. In addition to loss aversion, it turns out that other well-established ideas in the psychology literature can also be incorporated into the analysis, such as narrow framing (Barberis and Huang, 2009) and the house money effect as uncovered in Thaler and Johnson (1990).

3.3.3.2 The preference specification

In our model, the central bank as the representative agent in the home country chooses a consumption level C_t and allocates savings, i.e. $M_t - C_t$, between the risk-free asset A_{t+1} and the capital stock I_{t+1} to maximise:

$$E_t \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\rho}}{1-\rho} + \beta B_{t+1} H(\gamma_{t+1}) \right) \qquad (3.1)$$

In the preference specification (3.1), the first term in the parenthesis is CRRA utility over consumption C_t . It is a standard feature of the agent's preference in the consumption-based approach. The parameter ρ is the coefficient of relative risk aversion, which controls the curvature of utility over consumption.

The second term in the parenthesis of (3.1) represents utility from the agent's cognitive biases, as a result of departing from the consumption-based approach. The parameter β is the time discount factor. The scaling factor B_{t+1} is given by:

$$B_{t+1} = B_0 u'(C_{t+1}) = B_0 C_{t+1}^{-\rho} \qquad (3.2)$$

where $B_0 \geq 0$ indicates the coefficient of narrow framing (hereafter NF), which allows control of the overall importance of utility from the agent's cognitive biases relative to utility from consumption. Narrow framing, first labelled by Kahneman and Lovallo (1993), and extended by Barberis, Huang and Santos (2001) and Barberis and Huang (2009), indicates that the agent evaluates a specific risk or uncertainty by isolating it from consumption or from the total wealth. If $B_0 = 0$, the preference specification (3.1) is abbreviated to the consumption-based approach with standard utility, if no cognitive biases.

The term $u'(C_{t+1})$ or $C_{t+1}^{-\rho}$, which is the first-order derivative of utility over consumption C_{t+1}, is introduced to ensure that standard utility and cognitive-biases utility are of the same order as aggregate resources increase over time. The term $H(\gamma_{t+1})$ implies that the agent derives utility from fluctuations of growth and is loss averse towards her GDP growth target, using the linear loss aversion function.

Barberis, Huang and Santos (2001) and Barberis and Huang (2001, 2009) employ a similar setting to embed cognitive biases such as loss aversion function into their model to characterise the behaviour of the representative agent.

3.3.3.3 Resources constraints

Under such a preference specification, the representative agent faces the initial given resources M_t, denominated by net foreign assets, available at the beginning of time t. After consumption decision C_t at the beginning of time t, the agent chooses how to allocate her saving, i.e. $M_t - C_t$, between the risk-free asset A_{t+1} and the capital stock I_{t+1} for the output at the end of time t, i.e. at the beginning of time t+1:

$$M_t - C_t = A_{t+1} + I_{t+1} \qquad (3.3)$$

Due to market incompleteness and inefficiency, the agent is constrained in borrowing, so that she has:

$$A_{t+1} \geq 0 \quad \text{or} \quad M_t \geq C_t + I_{t+1} \qquad (3.4)$$

As the representative of the producer, the agent is assumed to have a Cobb-Douglas production function with normalised-to-unity labour force:

$$Y_{t+1} = I_{t+1}^{\alpha} \qquad (3.5)$$

which is an endogenous transitory GDP growth process experienced by the agent, where the term α is the capital share to GDP and $0<\alpha<1$.

The agent also experiences a permanent GDP growth process:

$$P_{t+1} = G_{t+1} P_t \tag{3.6}$$

where P_{t+1} is permanent GDP growth and G_{t+1} is the permanent GDP growth factor. For simplicity, we assume that $P_{t+1} = P_t$, i.e. $G_{t+1} \equiv 1$, with the consequence that we rule out permanent shocks to income and focus only on the impact of transitory shocks to GDP growth.

We normalise our problem divided by the level of permanent GDP P_{t+1} and use small letters to denote the normalised version of capital letters, such as $m_t = M_t / P_t$, $c_t = C_t / P_t$, and $y_t = Y_t / P_t$. Also, we make the assumption that such ratios are time-invariant. More detailed information on the derivation of the normalised problem can be found in Carroll (2011).

Thus, that the agent faces stochastic transitory GDP growth is captured by adding transitory shocks γ_{t+1} to the Cobb-Douglas production function (3.5):

$$y_{t+1} = \gamma_{t+1} i_{t+1}^{\alpha}, \tag{3.7}$$

where γ_{t+1} is log-normally distributed transitory shocks, i.e. $\log \gamma_{t+1} \sim \mathrm{N}\left(-\sigma_{\gamma}^{2} / 2, \sigma_{\gamma}^{2}\right)$. This assumption about the distribution of γ guarantees that $\log E[\gamma]=0$, which means $E[\gamma]=1$ (the mean value of the transitory shocks is 1).

The transitory shocks γ_{t+1} as the only source of uncertainty to GDP growth indicate the uninsured aggregate shocks that reflect possible internal and/or external risks as described in Section 3.3.1. The risks threaten to cause recession and financial crisis and hence may lead to dire consequences for growth. The occurrence of the uninsurable aggregate shocks implies that the agent has to fully bear the GDP growth risks, due to the lack of state contingent claims.

In the process of choosing how much savings to allocate between the risk-free asset a_{t+1} and the capital stock i_{t+1}, the agent faces the constraint of market resources m_{t+1} available at the beginning of time t+1 (or at the end of time t):

$$m_{t+1} = R_f a_{t+1} + \gamma_{t+1} i_{t+1}^{\alpha} + (1-\delta) i_{t+1} \tag{3.8}$$

where $R_f = 1 + r_f$ is a worldwide risk-free rate factor. The first item on the RHS in equation (3.8) denotes the amount which earns the risk-free rate r_f after decisions of consumption and capital stock. The item $\gamma_{t+1} i_{t+1}^{\alpha}$ shows the transitory shocks to GDP from exports, and the item $(1-\delta) i_{t+1}$ implies the remaining amount of capital stock after production with a coefficient of capital depreciation δ.

3.3.3.4 Loss aversion

We embed a behavioural factor showing cognitive biases, i.e. the loss aversion pioneered by Kahneman and Tversky (1979), into the consumption-based model in the spirit of Barberis, Huang and Santos (2001). Carroll (1998) produces a model in which a consumer can obtain utility from the absolute level of wealth adjusted by consumption as well as from consumption, to interpret the phenomenon that rich people have higher lifetime saving rates because they regard the accumulation of wealth as power or social status.

However, even though our representative agent maximises GDP growth, our model is only concerned with the fluctuations of the value of GDP or income around a reference point. Specifically, in our model setting, the central bank derives utility from consumption as well as from fluctuations of economic growth, but she is loss averse towards such fluctuations around a reference point.

The reference point $\bar{y}_{t+1}$ set by the agent is her expectation of transitory GDP growth y_{t+1}. Recalling that $E[\gamma] \equiv 1$, the reference point can therefore be shown as:

$$\bar{y}_{t+1} = E\left[y_{t+1}\right] = i_{t+1}^{\alpha} \tag{3.9}$$

We then expound the loss-averse agent by a linear loss aversion piecewise function $H(\gamma_{t+1})$ with the help of Fortin and Hlouskova (2011):

$$H(\gamma_{t+1}) = \begin{cases} \gamma_{t+1} i_{t+1}^{\alpha} & \gamma_{t+1} \geq 1 \\ & \textit{for} \qquad \lambda > 1 \\ \gamma_{t+1} i_{t+1}^{\alpha} + \lambda\left(\gamma_{t+1} i_{t+1}^{\alpha} - i_{t+1}^{\alpha}\right) & 0 < \gamma_{t+1} < 1 \end{cases} \tag{3.10}$$

where the term λ is the degree of loss aversion with $\lambda > 1$. If the transitory shock is equal to or greater than 1, i.e. $\gamma_{t+1} \geq 1$, the difference between stochastic transitory GDP growth y_{t+1} and its reference point $\bar{y}_{t+1}$ is equal to or greater than zero, i.e. $\left(\gamma_{t+1} - 1\right) i_{t+1}^{\alpha} \geq 0$, indicating that the expected GDP growth is achieved or over-achieved, hence the utility function is the same as that in standard economics. If $0 < \gamma_{t+1} < 1$, the agent fails to achieve her expected GDP growth and therefore is loss averse, which implies that the resulted utility function is to add the standard one into λ times the difference between y_{t+1} and $\bar{y}_{t+1}$.

3.3.3.5 Euler equations

In the preference specification (3.1), the first term in the parenthesis, i.e. CRRA utility over consumption C_t, can be written in the form of Bellman's equation:

$$V(m_t) = \underset{\{c_t, i_{t+1}\}_0^{\infty}}{Max} \left\{ u(c_t) + \beta E_t V(m_{t+1}) \right\} \tag{3.11}$$

subject to

$$m_{t+1} = R_f (m_t - c_t - i_{t+1}) + \gamma_{t+1} i_{t+1}^{\alpha} + (1-\delta) i_{t+1} \tag{3.12}$$

In each period, the agent must make two decisions. One is about consumption and the other is how to allocate her saving ($m_t - c_t$) between the risk-free asset a_{t+1} and the capital stock i_{t+1}. Thus, we now move to derive the first order conditions (FOCs) with respect to both consumption and capital stock.

In standard economics, the FOCs with respect to both consumption and capital stock are derived using the envelope theorem

$$u'(c_t) = R_f \beta E_t \left[u'(c_{t+1}) \right] \quad (3.13)$$

and

$$u'(c_t) = \beta E_t \left[\Re_{t+1} u'(c_{t+1}) \right] \quad (3.14)$$

respectively, where $\Re_{t+1} = \alpha \gamma_{t+1} i_{t+1}^{\alpha-1} + (1-\delta)$, which is the stochastic return on investing capital stock in GDP growth. Equations (3.13) and (3.14) are the typical Euler equations under stochastic GDP growth in the conventional literature.

However, in the context of our model, the central bank has cognitive biases only towards the transitory shock γ_{t+1}, i.e. the uncertainty about GDP growth. Thus, for the loss-averse agent who frames the uncertainty narrowly, the FOCs to consumption and capital stock are

$$u'(c_t) = R_f \beta E_t \left[u'(c_{t+1}) \right] \quad (3.15)$$

and

$$u'(c_t) = \beta E_t\left[\Re_{t+1} u'(c_{t+1})\right] + \beta B_0 E_t\left[u'(c_{t+1}) H(\gamma_{t+1})\right] \qquad (3.16)^2$$

respectively. The second term on the RHS of equation (3.16) shows the cognitive biases. If $B_0 = 0$, equation (3.16) is reduced to equation (3.14). Equations (3.15) and (3.16) are the behavioural Euler equations with the stochastic GDP growth from the standard literature being combined with loss aversion and narrow framing.

If the agent faces deterministic GDP growth, i.e. $\gamma \equiv 1$, cognitive biases disappear, i.e. $B_0 = 0$, due to the absence of uncertainty. Thus, the FOCs with respect to consumption and to capital stock become:

$$u'(c_t) = R_f \beta E_t\left[u'(c_{t+1})\right] \qquad (3.17)$$

and

$$u'(c_t) = \left(\alpha i_{t+1}^{\alpha-1} + (1-\delta)\right)\beta E_t\left[u'(c_{t+1})\right] \qquad (3.18)$$

[2] The mechanism of derivation of this equation can be found in Proposition 1 in Barberis, Huang, and Santos (2001), also in their appendix.

respectively. The term $\left(\alpha i_{t+1}^{\alpha-1}+(1-\delta)\right)$ is the deterministic return on investing capital stock in GDP growth.

3.3.3.6 Precautionary savings motive

Precautionary savings can be defined as the extra amount of reserves accumulated by the central bank under uncertainty over the amount accumulated under certainty (Carroll and Kimball, 2008). In conventional economics, precautionary savings are the extra amount of reserves under Euler equation (3.14) as against the amount under Euler equation (3.18). If the agent has cognitive biases, precautionary savings can be taken as the extra amount of reserves under Euler equation (3.16) compared to the amount under Euler equation (3.18).

3.4 Numerical Solution

3.4.1 Solving Numerically for Policy Functions

It is difficult to find a closed form solution using analytical methods, so we resort to numerical method to derive the equilibrium reserve level and the dynamics of the reserve accumulation process. This section describes the procedure of numerical solution for the policy functions of the representative agent. The solving algorithm involves dynamic programming, which defines the information about the current situation needed to make a correct decision as the state and the variables chosen at any given state in time are the control variables. By finding a rule that tells what the control variables should be, given possible values of the state, one derives the optimal plan or the policy function. In other words, a policy function is a rule that determines the control variables as a function of the state.

To help clarify the procedure, we redefine:

$$m_t - c_t = s_{t+1} \qquad (3.19)$$

and

$$s_{t+1} = a_{t+1} + i_{t+1} \qquad (3.20)$$

Because the expectation of the Euler equations will depend not only on how much the agent saves, i.e. s_{t+1}, but also on how those savings are allocated between the risk-free asset a_{t+1} and capital stock i_{t+1} with stochastic returns, there are two control variables: c_t and i_{t+1}. The resources m_t are the state variable. The expectation must be defined as a function of the choice of both variables.

Thus, our problem involves two control variables simultaneously, as is implied by the two first order conditions with regard to consumption and to capital stock under uncertainty. Equations (3.13) and (3.15) indicate that both standard economics and behavioural economics have the same first order condition (FOC) with regard to consumption, while they have different FOCs to capital stock. Combining equations (3.13) and (3.14), the FOC to capital stock in standard economics can be rewritten as

$$R_f \beta E_t \left[u'(c_{t+1}) \right] = \beta E_t \left[\Re_{t+1} u'(c_{t+1}) \right] \qquad (3.21)$$

Incorporating equations (3.15) and (3.16), the FOC to capital stock in behavioural economics can be written as

$$R_f \beta E_t \left[u'(c_{t+1}) \right] = \beta E_t \left[\Re_{t+1} u'(c_{t+1}) \right] + \beta B_0 E_t \left[u'(c_{t+1}) H(\gamma_{t+1}) \right] \qquad (3.22)$$

Hence, in standard economics, the two FOCs are (3.13) and (3.21) respectively, while in behavioural economics, the two FOCs are (3.15) and (3.22).

We can solve this multidimensional optimisation problem by transforming it into a sequence of two simple optimisation problems. First, we evaluate the two optimal levels of asset allocation given the defined grid vector of total savings s_{t+1} on the basis of two different scenarios, i.e. equations (3.21) and (3.22), respectively. Second, we approximate the respective consumption decisions, i.e. consumption functions based on these two optimal levels of asset allocation given the same grid vector of s_{t+1}.

Rearranging equations (3.21) and (3.22) respectively, we obtain the conditions for optimal asset allocation:

$$\left(R_f - E_t \left(\Re_{t+1} \right) \right) E_t \left[u'(c_{t+1}) \right] = 0 \qquad (3.23)$$

and

$$\left(R_f - E_t\left(\Re_{t+1} + B_0 H(\gamma_{t+1})\right)\right) E_t\left[u'(c_{t+1})\right] = 0 \tag{3.24}$$

After defining a grid vector for the total amount of savings, $s_{t+1} = a_{t+1} + i_{t+1}$, we use a numerical root-finder to satisfy these two conditions of asset allocation as in equations (3.23) and (3.24), in order that:

$$\left(R_f - E_t\left(\alpha\gamma_{t+1} i^{*\alpha-1}_{t+1} + (1-\delta)\right)\right) E_t\left[u'(c_{t+1})\right] = 0 \tag{3.25}$$

and

$$\left(R_f - E_t\left(\left(\alpha\gamma_{t+1} i^{*\alpha-1}_{t+1} + (1-\delta)\right) + B_0 H^*(\gamma_{t+1})\right)\right) E_t\left[u'(c_{t+1})\right] = 0 \tag{3.26}$$

respectively. In terms of equations (3.25) and (3.26), we can solve for the two pairs of the optimal level of capital stock i^*_{t+1} and risk-free asset a^*_{t+1} respectively, given the chosen grid vector for the end of period total amount of savings s_{t+1}.

Second, with these two pairs of the optimal level of capital stock i^* and the risk-free asset a^* for the corresponding two conditions of asset allocation in hand, rearranging the first order conditions to consumption (3.13) and (3.15), we obtain:

$$c_t\left(m_t\right) = \left(\beta R_f E_t\left[c_{t+1}\left(R_f\,(s_{t+1} - i^*_{t+1}) + \gamma_{t+1} i^{*\alpha}_{t+1} + (1-\delta) i^*_{t+1}\right)^{-\rho}\right]\right)^{-1/\rho} \tag{3.27}$$

where $m_t = c_t + s_{t+1}$.

Based on equation (3.27), the policy function of consumption can be solved by backward iteration until convergence, using the Method of Endogenous Grid-points pioneered by Carroll (2006). We initialise the consumption function of the representative agent at a hypothetical last period in which all the available resources are consumed. Given the defined grid-points of end of period savings $s_{t+1} \geq 0$ (the non-negative savings resulting from the borrowing constraints), using the budget constraints it is straightforward to compute the endogenous grid-points of resources m_t, i.e. $m_t = c_t + s_{t+1}$, consistent with each considered combination of consumption c_t and end of period savings s_{t+1}. By linearly interpolating the pairs (m_t, c_t), we can evaluate the consumption function of the second to last period. Then, we follow the same step for the representative agent to interpolate the consumption function until its convergence.

3.4.2 The Baseline Calibration

Having analytically explored the determination of reserve accumulation, and in particular the influence of cognitive biases of the decision maker, the model is calibrated to empirically assess the effects of the determinants and the extent to which the behavioural factors affect the dynamics of reserve build-up in China. The calibration results provide the basis for us to gauge the optimal foreign reserve accumulation for China that is in alignment with fundamentals and take into consideration the behavioural influence in decision making under uncertainty. Parameter values in the baseline calibration are chosen based on standard literature such as Carroll and Jeanne (2009) and Valencia (2010). The benchmark calibration will be subject to sensitivity tests later. Table 3.1 reports the baseline values.

Table 3.1 List of Model Input Parameters and Values for Baseline Calibrations

Parameter description	Parameter label	Baseline value
Inter-temporal discount factor	β	0.94
The coefficient of risk aversion	ρ	2
World interest rate	Rf	1.04
Capital share of production function	α	0.2
Depreciation rate	δ	0.1
The degree of loss aversion	λ	2.25
The coefficient of narrow framing	NF	2
The values of transitory shocks	γv	{0.9, 1, 1.1}
The probabilities of transitory shocks	γprob	{0.25, 0.5, 0.25}

We use the conventional CRRA utility function $u(C_t) = \frac{(C_t)^{1-\rho}}{1-\rho}$, with $\rho = 2$. The discount factor is set at 0.94 and the world risk-free rate factor is set at 1.04, to guarantee the impatience condition $R_f \beta < 1$. We set the capital share in the production function to be equal to 0.2 and the depreciation rate of capital at 0.1. The degree of loss aversion is set to 2.25, as is typical in the behavioural literature. The effect of narrow framing is set to be $NF = 2$ for the baseline coefficient, implying that the central bank believes that it is twice more important for her to derive utility from GDP growth than from consumption. Finally, we show transitory shocks by creating two sequences, i.e. both the values of transitory shocks denoted by γ_v and the probabilities of transitory shocks denoted by γ_{prob} to meet $E[\gamma] \equiv 1$.

The numerical solution of the model boils down to finding a time-invariant policy function of consumption as the level of resources $c_t(m_t)$ that determines the representative agent's consumption decision. The baseline consumption functions under both conventional economics and behavioural economics are depicted in Figure 3.4.

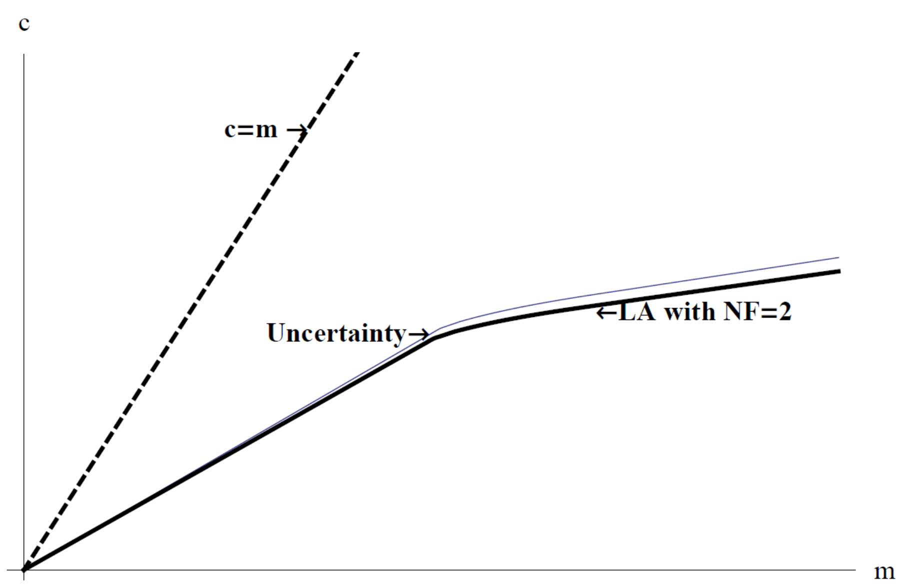


Figure 3.4 Consumption Functions under Uncertainty vs. LA with NF=2

In Figure 3.4, the horizontal axis shows the level of resources m_t, and the vertical axis shows the level of consumption c_t. The dash line is the 45-degree line, implying the borrowing constraint $c = m$. The thin solid line depicts the baseline optimal consumption rule with the conventional rational agent under uncertainty. The thick solid line shows the baseline optimal consumption function under transitory shocks with behavioural economics in which the agent has cognitive biases on GDP growth fluctuations, i.e. the agent are influenced by both loss aversion and narrow framing $(NF = 2)$. At each level of resources m_t, the marginal propensity to consume (MPC) under uncertainty by the agent who is cognitively biased is lower than that under conventional uncertainty. The gap between the two demonstrates that precautionary saving motive is strengthened when incorporating loss aversion and narrow framing into the model.

3.4.3 Optimal Accumulation of Reserves and Sensitivity Analysis

The calibration results can be interpreted further in the light of the buffer-stock saving behaviour described by Carroll (2011), which sheds light on the determination of optimal accumulation of reserves. According to Carroll (2011), the agent holds assets, i.e. savings, mainly to buffer unpredictable fluctuations of income and therefore to shield her consumption. When facing important income uncertainty the buffer-stock saving behaviour can arise, whereby the agent is both impatient, having desire to spend down her assets or to borrow against future income to finance current consumption, and prudent, which means that, *à la* Kimball (1990), the agent has a precautionary saving motive. Under plausible situations, the tension between her impatient desire to spend down assets and her prudent reluctance to draw down assets too far implies the existence of a target level of wealth (in our context, a target level of reserves). If the actual wealth is below the target level, fear (prudence) will be stronger than impatience and the agent will try to save, while if the actual wealth is above the target level, impatience will dominate over prudence and the agent will reduce her wealth.

Following this exposition, we first derive the target level of resources m_t, based on which we derive the target level of the corresponding risk-free asset a_t as the proxy for the optimal level of reserves. Because of the assumption of one sector in the economy, the amount of imports can be viewed as a proxy for the consumption level. This implies that we can obtain the optimal reserves/imports ratio by dividing the optimal level of reserves by the long-run consumption level. Furthermore, we apply the Hodrick-Prescott filter to the observed imports-to GDP ratio, in order to obtain the ratio of the long-run consumption to GDP. Finally, the optimal reserves to GDP can be derived by multiplying the optimal reserves/imports ratio by the long-run consumption/GDP ratio.

Following this process, the model calibration results suggest that the baseline optimal ratio of reserves to GDP for the rational agent is 15.46% (shown in bold in Table 3.2) under standard uncertainty; while, for the agent with cognitive biases, the optimal level of foreign reserves is much higher, reaching 52.40% (shown in bold in Table 3.2) of GDP when $NF = 2$.

To check the robustness of our model in various plausible scenarios, we conduct sensitivity analyses to examine how the optimal level of reserves changes when parameters change. For simplicity, we report results given variations in the coefficients on narrow framing and the discount factor. The former determines the overall importance of the agent deriving utility from fluctuations of GDP growth, rather than from consumption. The discount factor determines the impatience attribute of the agent. Table 3.2 below indicates the resulting optimal ratio of reserves to GDP under different values of the two parameters.

Table 3.2 Sensitivity Analysis

	Uncertainty (NF=0)	NF=1	NF=1.5	NF=2	NF=2.5	NF=3	NF=4	NF=5
Beta=0.92	6.59%	19.26%	27.89%	34.49%	40.13%	45.18%	54.02%	61.21%
Beta=0.94	**15.46%**	30.28%	42.48%	**52.40%**	60.72%	68.03%	80.43%	90.87%
Beta=0.96	102%	138%	185%	238%	295%	356%	486%	619%

The sensitivity analysis generates sizable variation in the optimal level of reserves. Scaled by GDP, the reserves to GDP ratio varies with changes in the two parameters. For each level of the discount rate, the behavioural factors such as loss aversion and narrow framing consistently bring about optimal reserve levels that are considerably higher than that for the conventional rational agent under uncertainty. It is intuitive that the more the central bank cares about GDP growth, the more she needs reserve assets as a precautionary motive to provide self-insurance against income risk, due to market incompleteness.

3.5 Conclusions

That China should have persistently accumulated ever larger foreign reserves is perplexing. Existing literature has rightly pointed out that reserve accumulation is a process influenced by multiple factors and in which the precautionary motive plays a pivotal role. However, on the whole, prior research has not been very successful in providing a satisfactory explanation for the observed massive reserve build-up in the emerging world, particularly China. This chapter develops a behavioural model of optimal reserve accumulation to decode the puzzling development. Departing from the conventional reserve literature that hinges on rationality of agents, our approach is centred on the agent who is cognitively biased when making decisions under uncertainty. Influences of both loss aversion and narrow framing are embedded into the model of precautionary saving as the main motive for accumulating seemingly large reserves.

Benchmark calibration of the model indicates that taking into consideration agents' cognitive biases is critically important to achieve a better understanding of the stance on international reserves in China. We show that the precautionary motive for reserve accumulation is strengthened when the agent is loss averse and has the trait of narrow framing. In almost all possible scenarios emerging from sensitivity simulation, the levels of precautionary reserves are higher for the agent with these cognitive biases than the one without. When the model is calibrated with the parameter values are set to the levels that are plausibly representative of reality, we find that the optimal reserve accumulation for China would be around 52% of GDP, assuming the economy faces uncertainty, the loss aversion index is 2.25 as is common in the literature and the authority regards utility from GDP movements is twice important than that from consumption, i.e. the coefficient of narrow framing being 2.

These findings shed critical lights on a better understanding of the Chinese reserve policy. The seemingly excessive reserve holdings by China are in fact broadly in line with the optimal level of reserve accumulation predicted by the behavioural model. This implies that the rapid accumulation of massive reserves in China is likely an equilibrium response by the Chinese central bank under influence of behavioural biases towards loss aversion and narrow framing when facing uncertainty which has increased in recent years of global financial crisis. The model underscores the critical importance of the decision markers' cognitive attributes as a driving force behind China's growth of reserves and thus complements the current literature by way of providing a plausible explanation for the Chinese puzzle of reserve accumulation from a behavioural perspective.

The research also has implications on a critical development in the world economy, i.e. the rise of Chinese sovereign wealth fund. Known as China Investment Corporation (CIC), this sovereign wealth fund was set up in 2007 through transfer of assets from China's official reserve holdings. With start-up capital of $ 200 billion initially and later increased to $400 billion, the CIC has become a major channel for Chinese funds flowing out of the country for international investment. It is now an active portfolio investor and assertive seeker of natural resources globally. Interaction of Chinese decision makers' precautionary motive and cognitive biases has shaped CIC's emergence and growth in two crucial ways. In the first place, the massive reserve holdings consequent to the interaction have quantitatively enabled large outflow of the Chinese assets. Second, China's heightened precautionary motive under the influence of decision makers' cognitive attributes brings with it an investment structure that leans towards lower-return safe assets. To redress the balance between safety, liquidity and profitability of reserve assets, the CIC is made to exist and is allowed to pursing profitable opportunities outside the country. Interaction of precautionary motive and decision makers' cognitive attributes therefore constitutes an important imputes for the creation and development of China's sovereign wealth fund. By gaining insights into how such interaction takes place in China and its consequent impacts on China's reserve management, this research enriches our understanding of the fundamental forces behind the rise of sovereign wealth fund from China.

Chapter 4

STRATEGIC ASSET ALLOCATION FOR A CENTRAL BANK WITH MULTIPLE OBJECTIVES IN FOREIGN RESERVES MANAGEMENT

4.1 Introduction

Strategic asset allocation is instrumental in achieving sound management of foreign reserves. Given its perceived contribution to yield performance (Blake et al. 1999), strategic asset allocation of foreign reserves takes on a growing interest in a time of low international yield and rising levels of reserves as we are witnessing in recent years. For large reserve holders such as China, the yield potential of strategic asset allocation is particularly important. Carrying the colossal reserve stocks alone incurs the country sizable opportunity costs, not to mention the potential of large losses due to valuation effects of international currency movements. Yu (2011) claims that the real value of China's foreign reserves is whipsawed by the price drop of the US treasuries and devaluation of the dollar. Wang (2012) shows that, for 2001 through 2011, the average yearly opportunity cost of China's reserve holdings is 114 billion dollars, or 2.6% of GDP. Counting on other costs, the total net returns would be -641.7

billion dollars. As such, it is imperative to seek improving China's allocation of net official foreign assets.

Central banks hold foreign reserves for a multiplicity of purposes, such as to back up a country's domestic currency, manage the exchange rate through market intervention, and therefore support and maintain confidence in the monetary and exchange rate policies. Reserves can also be employed to protect a country from external vulnerability by maintaining sufficient liquidity to absorb shocks during financial crisis (IMF, 2004).

This set of purposes conditions central banks' management of reserve investment into a multi-facet process. Central to this process is the multiple objectives of reserve management featuring "safety, liquidity and profitability". Central banks are highly risk-averse investors in the first place. This psychological profile predetermines that preservation of the capital value of reserves is central banks' utmost priority, leading to their investment concentrating on programs that can ensure the safety of their assets, although the returns on such investment are inescapably low (Fisher and Lie, 2004). Second, to align with the missions that central banks hold reserves for, reserve management is tasked to assign an appropriate portion of assets which have a high degree of liquidity to smooth impacts of negative shocks in the world economy. Third, given the massive stocks of foreign assets, it would be desirable that the reserves can bring home reasonable returns from prudent investment of the foreign assets while reserve management is conducted in an international environment characterised by uncertainty and volatile capital movements. With the rapid accumulation of foreign reserves in many emerging and developing countries, it also becomes possible for central banks in these countries to allocate certain portion of their external assets to higher investment without compromising the comprehensive health of the country's reserve holdings. In the circumstances, Berkelaar et al. (2010b) and Borio et al, (2008) report that, with the amount of reserves being in excess of what is needed, many central banks are seeking higher returns on their reserve assets. As a result, 'safety, liquidity and profitability (returns)' are generally accepted as the objectives of reserve management (Nugee, 2000, and IMF 2001). With these objectives, central banks have more than one goal for their reserve management. In other words, not only do central banks desire to fulfil their responsibility of preserving capital and maintaining adequate liquidity, but also they would pursue relatively high returns to accomplish efficient management of massive reserves.

Traditional strategic asset allocation for foreign reserves relies mainly on the mean-variance (MV) approach to portfolio management originally proposed by Markowitz (1952). In this approach, mean-variance investors view their portfolio as a whole and derive optimal asset allocation based on the overall expected returns and risk. For central banks' management of foreign reserves, the approach does not explicitly inform how central banks may invest their external assets in a multiple-goal way.

Behavioural finance has emerged as a complement of the conventional finance including the portfolio management. Shefrin and Statman (2000) develop the behavioural portfolio theory (BPT), which is a goal-based theory in which investors divide their wealth into a variety of mental accounts of a set of portfolios corresponding to various goals [3]. A central feature of BPT is that investors take their portfolios not as a whole, but as distinct mental accounts in a set of assets, where mental accounts are connected with particular goals and where attitudes toward risk vary across mental accounts (Statman, 2008).

Das, Markowitz, Scheid and Statman (2010) present a further development in the field of asset allocation by offering a framework that incorporates the mean-variance theory of portfolio management (MVT) and the behavioural portfolio theory (BPT). In this framework, investors view their portfolios as collections of mental accounting (MA) sub-portfolios, where each sub-portfolio is connected with a goal and each goal has a threshold level. Risk in each sub-portfolio can be measured by the probability of failing to reach the threshold level by means of VaR (Value at Risk). Known as the mean-variance mental accounting (MVMA) approach, Das et al. (2010) demonstrate that their framework is mathematically equivalent to the mean-variance solution. MVMA investors seek to choose the portfolio with maximum expected returns subject to the VaR constraint capturing the account's motive. Consistent with Markowitz (1952), optimal portfolios within various accounts are on the mean-variance frontier.

[3] For an introduction to mental accounting, see for example Thaler (1999) and Nofsinger (2011, Chapters 6 and 7).

Finally, as a combination of sub-portfolios, the aggregate portfolio is also on the efficient frontier.[4]

With the rapid accumulation of foreign reserves in many emerging markets, recent years has witnessed a growing interest in the literature on strategic allocation of a country's external assets. For example, Cardon and Coche (2004) propose a blueprint for the management of the strategic asset allocation for central banks, where asset allocation decisions can be carried out by a three-tier governance structure consisting of an oversight committee, investment committee and portfolio management. Fisher and Lie (2004) provide a framework for reserves' strategic asset allocation that considers various assets (e.g. government bonds, non-government bonds, equities and currency) and guaranteeing sufficient liquidity for trade and intervention requirements. In this framework, they show that relaxing various constraints can obtain better returns for the same level of risks De Cacella et al. (2010) develop a multi-objective evolutionary optimisation algorithm to obtain a set of viable portfolios using a variable time horizon. Volumes edited by Berkelaar, Coche and Nyholm (2010a), and Coche, Nyholm and Petre (2011) contain a number of studies which contribute to strategic asset allocation for central banks.

[4] This result assumes that short sales are allowed. In the case where short sales are not allowed, Das et al. (2010) suggest that the aggregate portfolio lies close to the mean-variance frontier.

In the field of asset allocation, a very important new advance in recent years is the Black-Litterman (B-L) model, which can overcome the error-maximising of the mean-variance optimisation, i.e. the high sensitivity of the optimal portfolio weights to the expected-return inputs often results in extreme solutions (Michaud, 1989, and Best and Grauer, 1991). Black and Litterman (1992) extend the mean-variance analysis by incorporating the Bayesian estimation into their model. Lucid discussion of the Bayesian analysis and the B-L model can be found in Lee (2000) and Christodoulakis (2002). Walters (2011) and Meucci (2010) survey the original B-L model and its various extensions.

The intuitive appeal of the B-L model is the use of the equilibrium excess returns as prior for the distribution of asset returns derived from the CAPM model. This implies that the expected excess returns in this model are obtained from the assumption that the market portfolio is the optimal portfolio of risky assets. Based on these equilibrium returns, the specific views of each investor (which can be regarded as additional information or further insights) are combined with the prior to generate the posterior distribution of asset returns. Barros Fernandes et al. (2012) combine the B-L approach with the resampling approach of Michaud and Michaud (2008) to generate a portfolio optimisation for central banks' strategic asset allocation. Petrovic (2010) applies the Black-Litterman model to central banking practice. León and Vela (2011) present a long-term-dependence-adjusted and non-loss-constrained version of the Black-

Litterman model to derive the efficient frontier based on their estimation of the Board of Directors' risk aversion.

Other than the applications of the B-L model, some studies concentrate on its various extensions. For example, Qian and Gorman (2001) present a method to integrate views on the covariance matrix as well as views on the returns. Fusai and Meucci (2003) propose a way to measure how consistent a posterior estimate of the mean is with regards to the prior, or some other estimate. Krishnan and Mains (2005) present a method to incorporate additional factors into the B-L model. Giacometti et al (2007) investigate the improvement of the original B-L model by both applying more realistic approaches to asset returns, e.g. the normal, the t-student, and the stable distributions, and alternative risk measures such as dispersion-based risk measures, VaR, and CVaR (conditional value at risk).

On the practical front, the recent trend of reserve management can be summarised in two aspects. On the one hand, some studies on strategic asset allocation use the so-called 'investment tranche' as their way of deriving optimal asset allocation when the central banks accumulating huge reserve stocks. For example, Berkelaar et al (2010b) suggest that some central banks have notionally divided their reserve assets into separate tranches, which includes a tranche of investment in broader asset classes that shows the low risk appetite to seek higher returns. On the other hand, with the unfolding of the global financial crisis that started around 2007, central banks have changed their risk preference, shifting their investable wealth towards favouring safe assets. In the circumstances, reserve managers now have a strong tendency to hold safe assets in view of both their value preservation policy and their need for ready liquidity.

Inspired by the central banks' practice of investment tranching and by the recent advances of behavioural portfolio models featuring mental accounting, in this chapter we propose a new method for central banks' strategic asset allocation by combining the behavioural approach to asset allocation with improvements on return forecast offered by the Black-Litterman model. This eclectic approach takes into consideration of behavioural factors that may influence reserve managers' risk-return profile. Underscoring the practical importance of mean variance mental accounting (MVMA), we assume that central banks have two mental accounts (sub-portfolios) or tranches. One is a 'precautionary sub-portfolio' showing higher risk aversion. Governed by the precautionary motive, this sub-portfolio is tasked to play safe hence earn lower returns. If successful, this sub-portfolio fulfils both safety and liquidity objectives. The other account is presented by an 'investment sub-portfolio' showing lower risk aversion. This sub-portfolio is investment oriented, which seeks for relatively high returns and thus to fulfil the return or profitability objective. An aggregate portfolio is then constructed by combining the two sub-portfolios. In each account, risk is measured by the probability of not reaching the threshold return level. For robust tests, we also design alternative aggregate portfolios by making different allocations of the total investable reserves into combinations of the two sub-portfolios. This will allow capturing the distinct risk attitudes of reserve managers.

With the MVMA framework, we use the Black-Litterman model to obtain both the equilibrium returns and the B-L returns as our improved forecasts, and therefore to derive the two sets of optimal asset allocation for foreign reserve. In the case of China, taking into consideration of the recent trends of both China's holdings of US Treasury securities and the investable universe of reserve managers, we combine the MVMA analysis and the B-L model to derive optimal asset allocation for China's central bank.

Our study contributes to the literature in this area in several ways: (1) We extend Das et al.'s (2010) work to reserve management; (2) conventional models are extended to the case where the investor has multiple goals; and (3) the Black-Litterman model is extended to take into consideration of influences of behavioural factors. For the first time we offer an approach that is designed to help central banks' manage their strategic asset allocation of foreign reserves, which takes into consideration of behavioural factors that affects reserve management and take advantage of improved return forecast provided by the Black-Litterman model.

The rest of the chapter is organised as follows. In section 4.2, we present the behavioural reserve management framework by combining the MVMA framework with the B-L model, based on which we propose a multiple-goal strategic asset allocation for central banks, with explicit consideration of behavioural influences. In section 4.3, we apply the approach to the Chinese case of reserve management. Conclusions are presented in section 4.4.

4.2 The Behavioural Reserve Management Framework

In this section, we first depict the mean-variance mental accounting (MVMA) framework by Das et al. (2010) to underpin the theoretical consideration in relation to reserve management. We then use the Black-Litterman (B-L) model as a means to improve return forecasts. By combining the MVMA framework and the B-L approach, we finally derive strategic asset allocation for central banks, and thus propose a multiple-goal reserve management policy.

4.2.1 The Mean Variance Mental Accounting (MVMA) Problem

In our model setting, the reserve manager selects portfolio weights $\mathbf{w} = \left[w_1,...,w_n\right]'$ for n assets, where the assets have an expected return vector $\boldsymbol{\mu} \in R^n$ and a return covariance matrix $\boldsymbol{\Sigma} \in R^{n \times n}$. The MV problem is expressed by:

$$\max_w w'\mu - \frac{\gamma}{2} w'\boldsymbol{\Sigma} w \qquad (4.1)$$

subject to the fully invested constraint

$$\mathbf{w}'\mathbf{1} = 1 \qquad (4.2)$$

where $\mathbf{1} = [1,1,...,1]' \in R^n$, and γ is the risk aversion coefficient, which balances the trade-offs in the mean-variance space.

Using the Lagrange-multiplier method, the solution to optimal asset allocation in closed form is[5]

$$\mathbf{w} = \frac{1}{\gamma}\mathbf{\Sigma}^{-1}\left[\boldsymbol{\mu} - \left(\frac{\mathbf{1}'\mathbf{\Sigma}^{-1}\boldsymbol{\mu} - \gamma}{\mathbf{1}'\mathbf{\Sigma}^{-1}\mathbf{1}}\right)\mathbf{1}\right] \in R^n \qquad (4.3)$$

Unlike the standard MV problem, the reserve managers specify γ, which means they choose different values for $\gamma > 0$, and then solve problem (4.1) in terms of solution (4.3). With a collection of different risk-aversion values in hand, they can maximise mean-variance utility to find corresponding points on the efficient frontier.

Based on equations (4.1) to (4.3), we introduce the Mental Accounting (MA) factor. The MVMA reserve manager takes her portfolios as collections of MA sub-portfolios, in which each sub-portfolio is mapped onto a goal. Following Das et al. (2010), we assume that the reserve manager has difficulties in stating her precise risk-aversion coefficient (γ), but is comfortable to announce her threshold levels for each goal and

[5] The detailed derivation of this solution can be found in Appendix in section 4.5.

the maximum probabilities of failing to reach them. Ultimately, the MVMA reserve manager acts as if she has different risk preferences in each of the mental accounts. Thus, solving the MA problem is equivalent to solving a standard MV problem with a specific 'implied' risk-aversion coefficient.

For a certain mental account, the reserve manager considers a threshold level of return H for portfolio p, and regards the maximum probability of the portfolio failing to reach portfolio return $r(p)$ as α. Thus, she has

$$\text{Prob}\left[r(p) \leq H\right] \leq \alpha \tag{4.4}$$

We assume that portfolio returns are normally distributed. In terms of VaR, inequality (4.4) implies the following inequality:

$$H \leq \mathbf{w}'\boldsymbol{\mu} + \Phi^{-1}(\alpha)\left[\mathbf{w}'\boldsymbol{\Sigma}\mathbf{w}\right]^{1/2} \tag{4.5}$$

where $\Phi(\bullet)$ is the cumulative standard normal distribution function.

The reserve manager's aim is to derive at optimal asset allocation from equation (4.3) subject to the constraint (4.5). Optimisation cannot be achieved unless the constraint (4.5) is an equality. As a result, the solution to the reserve manager's implied risk aversion γ and the optimal weights $\mathbf{w}(\gamma)$ is implied by the following equations:

$$H = \mathbf{w}(\gamma)'\boldsymbol{\mu} + \Phi^{-1}(\alpha)\left[\mathbf{w}'(\gamma)\boldsymbol{\Sigma}\mathbf{w}(\gamma)\right]^{1/2} \qquad (4.6)$$

where

$$\mathbf{w}(\gamma) = \frac{1}{\gamma}\boldsymbol{\Sigma}^{-1}\left[\boldsymbol{\mu} - \left(\frac{\mathbf{1}'\boldsymbol{\Sigma}^{-1}\boldsymbol{\mu} - \gamma}{\mathbf{1}'\boldsymbol{\Sigma}^{-1}\mathbf{1}}\right)\mathbf{1}\right] \qquad (4.7)$$

Plugging equation (4.7) into equation (4.6), it is straightforward to find the solution to equation (4.6) based on which one can obtain different values of the risk preference γ.

Thus, the portfolio optimisation problem for the MVMA reserve manager is specified by a threshold level of return H and a probability value α. When the reserve manager specifies her MA preferences for each sub-portfolio through the parameter pair (H, α), they implicitly denote what their risk preferences (γ) are over the given portfolio choice set $(\boldsymbol{\mu}, \boldsymbol{\Sigma})$. With the risk aversion coefficient (γ), the reserve manager can derive their optimal asset allocation.

However, for reserve management, short selling is not allowed. Thus, we must call for quadratic programming (QP) optimisers. Following Das et al. (2010), the full problem with short-selling constraints is as follows:

$$\text{Solve}_{\gamma}\ \mathbf{w}(\gamma)'\boldsymbol{\mu} + \Phi^{-1}(\alpha)\sqrt{\mathbf{w}(\gamma)'\boldsymbol{\Sigma}\mathbf{w}(\gamma)} = H \qquad (4.8)$$

where $\mathbf{w}(\gamma)$ is the solution to the following MV problem:

$$\max_{w} w'\boldsymbol{\mu} - \frac{\gamma}{2} w'\boldsymbol{\Sigma} w \qquad (4.9)$$

subject to the full invested constraint and short-selling constraints

$$\mathbf{w}'\mathbf{1} = 1 \text{ , } \mathbf{w} \geq 0 \text{ and } \mathbf{w} \leq 1 \qquad (4.10)$$

Thus, the reserve manager solves the nonlinear equation (4.8) based on the variable γ, which determines the portfolio weights $\mathbf{w}(\gamma)$ derived by solving the QP in equations (4.9) and (4.10). For a specified γ, the reserve manager needs to check whether the solution $\mathbf{w}(\gamma)$ can make equation (4.8) hold. If not, she must move γ appropriately and then solves the QP until equation (4.8) holds.

4.2.2 The Black-Litterman Model

We use the Black-Litterman model to improve our input forecast, i.e. the expected returns. This model employs the equilibrium returns as the starting point for its estimation. Equilibrium returns are inferred from the market capitalisation weights, using a 'reverse optimisation process'. Black and Litterman (1992) argue that this process, based on market capitalisation weights, can derive at consensus excess returns, which are consistent with the tangency portfolio of the Capital Asset Pricing Model. With the market forces of supply and demand in equilibrium, the weight allocation across the investment universe is expected to be optimal and the optimal weight can therefore act as the basis for asset allocation.

We follow Satchell and Scowcroft (2000) and Idzorek (2005) to state the Black-Litterman model. In this model, given the risk aversion coefficient δ that indicates the level of risk against returns of the market portfolio, the historical variance covariance matrix $\mathbf{\Sigma}$, and the vector of market capitalisation weights $\mathbf{w}_M$, the reverse optimisation process can provide the vector of implied equilibrium returns $\boldsymbol{\mu}_M$ in excess of the risk-free rate as

$$\boldsymbol{\mu}_M = \delta \mathbf{\Sigma} \mathbf{w}_M \tag{4.11}$$

If the reserve manager does not agree with the implied equilibrium excess returns, she can introduce her own views. Specifically, she may take the implied equilibrium returns as the prior distribution and regards the corresponding forecasted returns as forward-looking views-based returns, to form the posterior Black-Litterman returns. For example, assume there are k views, which can be either relative or absolute and are represented in the $k \times 1$ vector $\mathbf{Q}$. The $k \times n$ matrix $\mathbf{P}$ then is used to define these views: $\mathbf{Q} = \mathbf{P} \cdot \mathbf{r}_a$. The first view is represented as a linear combination of expected returns denoted by the first row of $\mathbf{P}$. A confidence level is associated with each of the views implied by $\mathbf{Q}$. Therefore, the investor's beliefs can be described by a normal view distribution: $\mathbf{P} \cdot \mathbf{r}_a \sim N(\mathbf{Q}, \mathbf{\Omega})$, where $\mathbf{\Omega}$ is a $k \times k$ diagonal covariance matrix.

In the same vein, the confidence in the equilibrium model and the derived implied returns can be defined. Consequently, we obtain the prior equilibrium distribution: $\mathbf{r}_a \sim N\left(\boldsymbol{\mu}_M, \tau\boldsymbol{\Sigma}\right)$, where τ is a known quantity indicating the uncertainty level to scale the historical covariance matrix $\boldsymbol{\Sigma}$.

Following the Bayesian estimation method, the reserve manager can generate the posterior Black-Litterman returns as follows:

$$E\left(\mathbf{r}_{BL}\right)=\left[\left(\tau\boldsymbol{\Sigma}\right)^{-1}+\mathbf{P}'\boldsymbol{\Omega}\mathbf{P}\right]^{-1}\times\left[\left(\tau\boldsymbol{\Sigma}\right)^{-1}\boldsymbol{\mu}_M+\mathbf{P}'\boldsymbol{\Omega}\mathbf{Q}\right] \qquad (4.12)$$

4.2.3 Strategic Asset Allocation with Multiple Goals

Combining the MVMA framework and the Black-Litterman model, we propose a multiple-goal reserve management policy to generate strategic asset allocation for central banks.

The strategic asset allocation in this setting can be achieved through following steps. First, to comply with the objectives of safety, liquidity and profitability, the reserve manager regards her portfolios as a collection of two MA sub-portfolios. The first is a ‘precautionary sub-portfolio’, where the manager specifies higher risk-aversion parameters and expects this portfolio to earn lower returns with lower risks. This sub-portfolio can preserve capital and maintain liquidity, which makes it easier to intervene in the market during periods of crisis and thus to fulfil the central bank’s mission of stabilising the economy. The second portfolio is an ‘investment sub-portfolio’, where the reserve manager assigns lower risk-aversion parameters to pursue relatively higher returns with higher risks. This can satisfy the manager’s desire to seek higher returns given her enormous reserve positions. Then, an aggregate portfolio is constructed by combining these two sub-portfolios in a certain proportion. The different allocations of the total investable reserves across the two sub-portfolios imply distinct overall risk attitudes.

Next, before entering into her MA sub-portfolios, the reserve manager first selects her investment classes from the investment universe available to her. With that, she obtains the implied equilibrium returns $\boldsymbol{\mu}_M$ based on market capitalisation weights, and the B-L returns $E\left(\mathbf{r}_{BL}\right)$ based on their forecasts according to the updated information in a Bayesian approach.

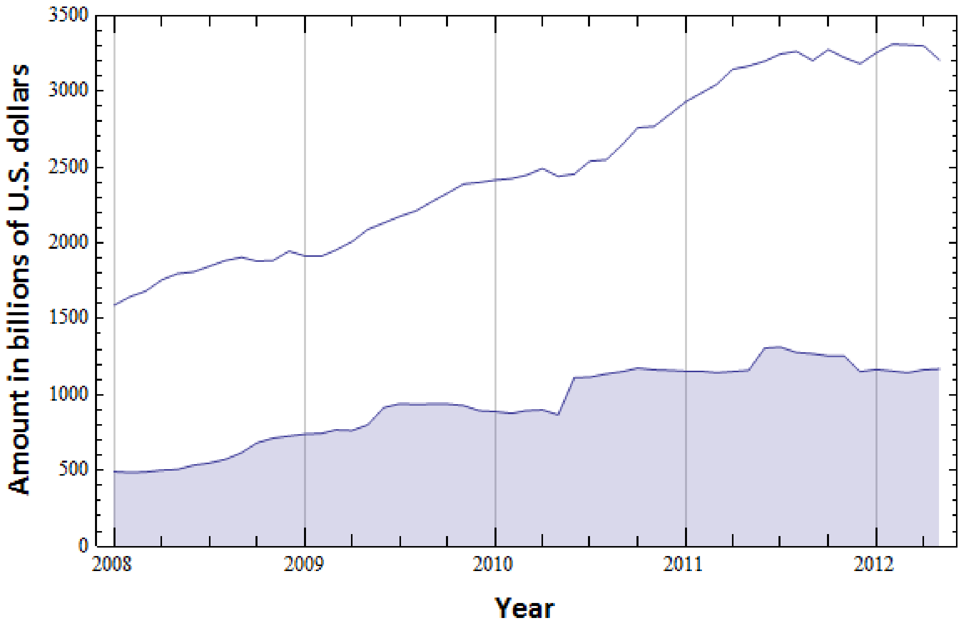
Finally, with the equilibrium excess returns $\boldsymbol{\mu}_M$ and the B-L excess returns $E\left(\mathbf{r}_{BL}\right)$ already derived, the reserve manager works out the two sub-groups of optimal asset allocation by solving equations (4.8) to (4.10), and compares and analyses the results to make her final asset allocation decision.

4.3 Strategic Asset Allocation for China's Foreign Reserves

In this section, we illustrate application of our approach by way of the Chinese case. Before doing so, we first briefly introduce the structure of China's holdings of foreign reserves in terms of US Treasury securities. To put the case in comparative perspectives, we also discuss the investable universe for central banks around the global. Against this background, we show our selection of asset classes and analyse data characteristics.

4.3.1 Recent Trends of Chinese Holdings of US and Other Foreign Assets

The Chinese central bank, i.e. the People's Bank of China, has never publicly announced the allocation of its reserve investment. But one may obtain hints from the data of China's holdings of US Treasuries as published by US Department of the Treasury. Figure 4.1 below shows China's total amount of reserves and the breakdown of its holding of US Treasuries from January 2008 to May 2012.



Sources: The People's Bank of China and U.S. Department of The Treasury

Figure 4.1 China's Total Amount of Reserves and its Holdings of US Treasuries

In Figure 4.1, the upper line shows the path of China's total amount of foreign reserves, while the filled line depicts China's holdings of US Treasuries. As of July 2011, China's holdings of US assets had reached the peak, i.e. 1314.90 billion US dollars. Since then, China's holdings of US assets have shown a moderate down trend. By May 2012, the latest figure available to this study shows that China holds 1169.60 billion US assets, accounting for 36.48% of China's total foreign reserves (excluding gold). Thus, the Figure indicates that despite the rapid accumulation of foreign reserves, the share of American assets that China holds has been stable, implying that is making diversification efforts, largely of those new stock of foreign reserves.

Table 4.1 illustrates the composition of China's holdings of US assets as of June 30, 2011. According to the table, 75.39% of them, or 1727 billion dollars in amount, is made up of long-term Treasury securities, while 14.19% are long-term agency securities. Others asset classes account for 10.42% of the total, including equity, long-term corporate securities, and short-term debt.

Table 4.1 Composition of China's Holdings of Total US Assets

Type of Security	Long-Term Treasury	Long-Term Agency	Equity	Long-Term Corporate	Short-Term Debt	Total
Amount (billions of US dollars)	1302	245	159	16	5	1727
Percentage	75.39%	14.19%	9.21%	0.93%	0.29%	100%

Sources: US Department of the Treasury, Report on Foreign Portfolio Holdings of US Securities as of June 30, 2011.

China's diversification efforts are palpable. On March 12^{th} 2012, Reuters News Agency reports that Yi Gang, head of China's State Administration of Foreign Exchange (SAFE), states that the portion of China's $3.2 trillion of reserves invested in Eurozone assets has increased in value, making returns above the rate of inflation, and that more would go into yen-denominated assets when the time is right. In particular, he said that 'we will carry out investments in the Japanese government bond (JGB) market or other fixed-income products'.

4.3.2 Investment Universe for China and Selection of Asset Classes

It is vital for official reserve managers to first define their investment universe, i.e. the set of asset classes from assets will be selected to construct the portfolio. This is a crucial preliminary step towards forming the basis for the reserve investment policy. Several recent studies have investigated the trend of reserve management, which reveal important insights into central banks' investment universe. According to the IMF (2011), government bonds have been the dominant asset class for central banks' reserve investment. Borio et al. (2008), however, suggest that central banks that hold a huge amount of foreign reserves have broadened the set of asset classes, which means more investable asset classes and instruments become available to them. With this new created possibility, these large reserve holders can invest their foreign reserves not only in traditional assets, i.e. lower risk assets for both liquidity and safety purposes such as Treasury Bills, bank deposits, government and supranational bonds, but also in higher risk assets, such as corporate bonds and equities, to satisfy the return objective. As a result, investment tranches have been established by some central banks other than liquidity tranches, seeking a higher return in the long run. While IMF (2011) claims that these investment tranches account for a small portion of total investable reserves, however, for large reserve holders such as China, the absolute total size of these investment tranche still could be formidable.

One critical development in central banks' reserve management is the fact that the global financial crisis has changed the risk preference of reserve managers, shifting more investable reserves towards safe assets, i.e. the assets with low credit and market risks and high market liquidity (IMF, 2012). McCauley and Rigaudy (2011) investigate the foreign reserve management in the crisis and after, suggesting that official reserve managers have shifted their reserves towards Treasury and Agency bills. IMF (2012) indicates that investors' shift to quality assets have given rise to an upsurge in demand for safe assets by various types of investors, such as banks, official reserve managers, and Sovereign Wealth Funds (SWF). IMF (2012) also investigates the universe of potentially safe assets, finding that global investors' universe of safe assets has broadened to include highly rated OECD government securities, relatively lower rated OECD government securities, supranational debts, US agency debt, and corporate debt (of investment grade).

Morahan and Mulder (2013) conduct a survey of central banks who manage reserves within IMF member countries including China, aiming to obtain insight into the reaction of reserve managers during the 07-08 crisis. They find out that, compared with their holdings of shifting into higher-yielding, higher-risk investments before the crisis, half of respondents to the survey have a tendency to hold a higher proportion of safer assets after the crisis, which implies that many countries including China are expected to conduct flight-to-quality behaviour throughout the market due to the crisis.

Based on China's past investment practice and the recent development of global reserve management under the impact of the financial crises, we select sixteen asset classes as our investment opportunity set. Most of these are safe assets, including nine advanced countries' government bonds, US Treasury Bills (bank deposits), US corporate bonds, US agency securities, and supranational bonds. The rest are relatively higher risk assets, including some US, Eurozone, and UK equities.

4.3.3 Data and Implementation

Our empirical application is based on 16 indices of bonds and equities. For bonds, we employ nine advanced countries' government bond indices, one 3-month US Treasury Bill index, one US corporate bond index, one US agency index from Bank of America Merrill Lynch, and one supranational bond index from Citi Group Bond Index USBIG. For equities, S&P 100, S&P EURO, and S&P UK are used as the proxies for US, Eurozone, and UK equities, respectively. Monthly total return indices are used over the sample period from January 1995 to December 2011, with a total of 204 observations. All total return indices are calculated in a log-return style based on a US-dollar denomination and the 3-month US T-Bill is taken as the risk-free rate. Table 4.2 reports the descriptive statistics for all asset classes considered.

Table 4.2 Descriptive Statistics

Name	Market	Instrument Type	Mean	Standard Deviation
US GOVT	USA	Long-term Bonds	5.67%	3.89%
CANADA GOVT	Canada	Long-term Bonds	8.58%	9.03%
AUSTRALIA GOVT	Australia	Long-term Bonds	8.86%	13.11%
UK GOVT	UK	Long-term Bonds	6.71%	10.10%
SWISS GOVT	Switzerland	Long-term Bonds	5.97%	11.65%
GERMANY GOVT	Germany	Long-term Bonds	5.81%	11.93%
FRENCH GOVT	France	Long-term Bonds	6.38%	12.06%
ITALIAN GOVT	Italy	Long-term Bonds	7.53%	12.13%
JAPAN GOVT	Japan	Long-term Bonds	4.09%	9.65%
US CORP	USA	Corporate	6.89%	6.49%
US AGENCY	USA	Agency	5.85%	3.61%
TBILL 3M	USA	Bank Deposit or Short-term Bonds	3.44%	2.02%
SUPRANATIONAL	Supranational	Supranational	6.36%	5.00%
US EQUITY	USA	Equity	8.13%	22.71%
EURO EQUITY	Euro Zone	Equity	8.82%	27.26%
UK EQUITY	UK	Equity	8.18%	25.42%

Notes: The table shows descriptive statistics for all selected asset classes. Our calculations use monthly data. The mean and standard deviations are annualised.

For bonds, US agency has the lowest standard deviation except for the 3-month T-Bill. For all government bonds, the Australia government bond has the best performance with the highest standard deviation, while the US government bond has the lowest standard deviation. All three equity assets have very high volatilities but relatively lower annual returns than during normal times, due to the fact that the sample period covers the recent financial crises.

For the sake of analytical exercise, we consider two different classifications of all selected asset classes. First, following IMF (2012), the selected asset classes are divided into two asset types, whereby all three equity asset classes are classified as risky assets, while other asset classes are classified as safe assets. Second, the selected asset classes are divided into their own currencies based on the location of their markets, although all are calculated on the basis of US dollars. Table 4.3 shows the asset classes and their corresponding currencies.

Table 4.3 Asset Classes and their Currencies

Currency	Market	Asset Class
US Dollars	USA & Supranational	US GOVT, US CORP, US AGENCY, TBILL 3M, US EQUITY, & SUPRANATIONAL
Pounds Sterling	UK	UK GOVT & UK EQUITY
Euros	Germany, France, Italy & Euro Zone	GERMANY GOVT, FRENCH GOVT, ITALIAN GOVT, & EURO EQUITY
Japanese Yen	Japan	JAPAN GOVT
Swiss Francs	Switzerland	SWISS GOVT
Other Currencies	Canada & Australia	CANADA GOVT & AUSTRALIA GOVT

Notes: All selected asset classes are classified into their own currencies based on the location of their markets. The currency categories are based on the database of Composition of Official Foreign Exchange Reserves (COFER) published by the IMF.

In Table 4.3, we consider six main categories of currency in terms of the COFER database published by the IMF. Supranational bonds are classified under US Dollars because of their US-dollar denomination, while Canada and Australia government bonds fall under Other Currencies.

Before entering into the MVMA framework, we use the Black-Litterman approach to improve our return forecasts. First, based on the market capitalisations of all asset classes considered, the reverse optimisation process by way of equation (4.11) is evoked to provide us with the equilibrium excess returns on all these asset classes. Second, taking the equilibrium excess returns as prior, reserve managers introduce their forward-looking investment views. Given the impact of the recent global financial crises, we assume that reserve managers favour more conservative investment strategies, under which government bonds are deemed the best way of flight to safety, hence government bonds are favourable than equities. Using equilibrium excess returns as a reference, reserve managers formulate their three conservative investment views as follows: (1) US equity will outperform US government bonds only by 2.60%; (2) Euro equity will outperform German government bonds only by 3.80%; and (3) UK equity will outperform UK government bonds only by 3.10%. The confidence levels of all three investment views are equal to 50%.

Table 4.4 presents market weights and two estimates of expected excess returns on all selected asset classes. According to Table 4.4, the equilibrium excess returns on US government bonds and US equity are 0.12% and 7.73%, respectively, a difference of 7.61%. However, the 2.60% in the first investment view is less than 7.61% by which the returns on US equity exceeds the returns on US government bonds, indicating that reserve managers expect the B-L approach to tilt the portfolio away from US equity in favour of US government bonds. Similarly, the other two investment views also imply their expectation of shifting the portfolio towards government bonds. Thus, all three investment views display that reserve managers have a tendency to invest in government bonds rather than in equities. As a result, comparing the third column and the last column in Table 4.4, the B-L excess returns on all three equities are less than the equilibrium excess returns of those.

Table 4.4 Market Weights and Return Estimates

Name	Market Weights	Equilibrium Excess Returns	The B-L Excess Returns
US GOVT	22.90%	0.12%	0.14%
CANADA GOVT	1.96%	2.38%	1.80%
AUSTRALIA GOVT	0.79%	3.70%	2.59%
UK GOVT	2.63%	2.86%	1.96%
SWISS GOVT	0.24%	1.64%	1.15%
GERMANY GOVT	3.17%	2.41%	1.62%
FRENCH GOVT	3.24%	2.59%	1.71%
ITALIAN GOVT	3.55%	2.84%	1.80%
JAPAN GOVT	20.97%	0.72%	0.26%
US CORP	5.92%	1.65%	1.24%
US AGENCY	4.15%	0.16%	0.17%
TBILL 3M	2.89%	0.09%	0.09%
SUPRANATIONAL	1.73%	0.38%	0.37%
US EQUITY	15.27%	7.73%	5.25%
EURO EQUITY	6.34%	9.24%	6.93%
UK EQUITY	4.24%	7.98%	6.07%

Notes: Market weights are obtained by using market capitalisation data of all asset classes. Equilibrium excess returns are derived by the reverse optimisation process, i.e. equation (4.11). The B-L excess returns are gained via equation (4.12).
Sources: Market capitalisation data of all safe assets are from BIS Securities Statistics on the BIS official website. The data of all risky assets are from Standard & Poor's official website.

With equilibrium and the B-L returns, we are now in a position to investigate the strategic reserve asset allocation using the MVMA framework. By solving equations (4.8) to (4.10), we derive at two sets of optimal weights for all asset classes. Based on each of these optimal weight sets, we construct our two MA sub-portfolios, i.e. the precautionary and investment sub-portfolios, through specifying different risk-aversion coefficients and considering the risk-return profiles. We also construct different aggregate portfolios by dividing the total investable reserves into two MA sub-portfolios in various proportions. Specifically, we construct three distinct aggregate portfolios: the first is based on an 80:20 division across the two sub-portfolios (80% of the total investable reserves from the precautionary sub-portfolio and 20% from the investment portfolio); the second is based on a 50:50 division, and the third on a 30:70 division. The three aggregate portfolios correspondingly indicate high, moderate, and low risk-aversion attitudes of the reserve managers, respectively. Finally, we probe into the mental accounting problem for all portfolios according to equation (4.5). In each portfolio, various threshold levels of returns correspond to the maximum probabilities of that portfolio failing to reach those threshold return levels.

4.3.4 Main Results

4.3.4.1 The results based on equilibrium returns

Table 4.5 provides information on holdings of MV efficient portfolios for the two MA sub-portfolios and three aggregate portfolios under the equilibrium return estimate. As suggested by Mehra and Prescott (1985), the range of risk aversion coefficient should be within the interval from 0 to 10. Thus, it is important to control this coefficient to ensure that it lies in the suggested interval. Classifying reserve managers as more conservative investors, we specify the risk aversion coefficient as between 5 and 10. Consequently, reserve managers do not care about seeking very high returns but emphasis on lower market risks.

Table 4.5 Holdings of Efficient Portfolios of Two Sub-Portfolios and Three Aggregate Portfolios for Equilibrium Returns

Risk Aversion:	γ = 9.938	γ = 5.261	80:20 Mix	50:50 Mix	30:70 Mix
Asset Classes	Precautionary Sub-portfolio	Investment Sub-portfolio	Aggregate Portfolio 1	Aggregate Portfolio 2	Aggregate Portfolio 3
US GOVT	0.07%	12.34%	2.53%	6.21%	8.66%
CANADA GOVT	0.36%	2.33%	0.76%	1.35%	1.74%
AUSTRALIA GOVT	3.65%	1.29%	3.18%	2.47%	2.00%
UK GOVT	0.00%	3.23%	0.65%	1.62%	2.26%
SWISS GOVT	2.58%	1.48%	2.36%	2.03%	1.81%
GERMANY GOVT	3.39%	2.70%	3.25%	3.04%	2.90%
FRENCH GOVT	0.27%	2.71%	0.76%	1.49%	1.98%
ITALIAN GOVT	0.02%	3.51%	0.72%	1.76%	2.46%
JAPAN GOVT	15.73%	21.29%	16.84%	18.51%	19.62%
US CORP	7.93%	3.05%	6.95%	5.49%	4.51%
US AGENCY	0.06%	5.11%	1.07%	2.58%	3.59%
TBILL 3M	53.28%	2.57%	43.14%	27.93%	17.79%
SUPRANATIONAL	0.07%	11.49%	2.35%	5.78%	8.06%
US EQUITY	6.49%	16.57%	8.50%	11.53%	13.54%
EURO EQUITY	0.29%	7.00%	1.63%	3.64%	4.98%
UK EQUITY	5.82%	3.33%	5.32%	4.57%	4.08%
Total Weights	100%	100%	100%	100%	100%
Expected Return	5.00%	6.36%	5.27%	5.68%	5.95%
Std. Dev.	4.00%	7.45%	4.69%	5.72%	6.41%

Notes: The portfolio weights for all portfolios are obtained using the solutions in equations (4.6) to (4.10). The expected returns and standard deviations of all portfolios are presented at the bottom of the table.

According to Table 4.5, for the precautionary sub-portfolio, when the risk-aversion coefficient set at a higher value, i.e. $\gamma = 9.938$, the largest holdings in the portfolio would be American 3-month T-Bill. For the investment portfolio, when the value of risk-aversion parameter is relatively low, i.e. $\gamma = 5.261$, largest holdings would be Japanese government bonds. For the three aggregate portfolios, holding the aggregate portfolio 1 displays the highest risk aversion. Here, the allocation of 43.14% of the total investable reserves to the US 3-month T-Bill implies that reserve managers focus more on their need to maintain ready liquidity in order for the government to intervene in the market if necessary. In contrast, holding the aggregate portfolio 3 indicates that reserve managers have relatively low risk aversion and therefore desire more to seek higher return.

Table 4.6 presents the optimal asset allocation between safe assets and risky assets based on the results from Table 4.5. For the precautionary sub-portfolio, nearly 90% of the holdings are in safe assets. For the investment sub-portfolio, the allocation between safe and risky assets is nearly 75:25. For the three aggregate portfolios, although the allocation to safe assets exceeds 75% in all of the cases the proportion of risky assets increases steadily.

Table 4.6 Holdings of Safe and Risky Assets of Two Sub-Portfolios and Three Aggregate Portfolios for Equilibrium Returns

Risk Aversion:	γ = 9.938	γ = 5.261	80:20 Mix	50:50 Mix	30:70 Mix
Asset Types	Precautionary Su-bportfolio	Investment Sub-portfolio	Aggregate Portfolio 1	Aggregate Portfolio 2	Aggregate Portfolio 3
Safe assets	87.41%	73.11%	84.55%	80.26%	77.40%
Risky assets	12.59%	26.89%	15.45%	19.74%	22.60%
Total Weights	100%	100%	100%	100%	100%
Expected Return	5.00%	6.36%	5.27%	5.68%	5.95%
Std. Dev.	4.00%	7.45%	4.69%	5.72%	6.41%

Notes: The results are based on the outcomes from Table 4.5 and the classification of asset types is by the IMF (2012).

Table 4.7 shows the resulting composition of currencies for the two sub-portfolios and three aggregate portfolios in terms of the classification of currencies from Table 4.3 and the results from Table 4.5. In all portfolios, the largest holdings are US assets. For the sub-portfolios, the greater the risk-aversion coefficient, the larger are the holdings of US assets. This is consistent with our findings about the asset structure in all the aggregate portfolios.

Furthermore, comparing the category of ‘US Dollars’ in Table 4.7 with the category of ‘Safe Assets’ in Table 4.6, in each portfolio, all the ratios of US assets to safe assets exceed 70%, which indicates that, for reserve managers favouring the conservative and value-preservation policies, US assets are viewed as the best for flying to safety. Other than US-dollar assets, Table 4.7 shows that the assets based on Japanese yen, the euro, and pounds-sterling denominations are the main channels for optimal portfolio diversification.

Table 4.7 Composition of Currencies of Two Sub-Portfolios and Three Aggregate Portfolios for Equilibrium Returns

Risk Aversion:	γ = 9.938	γ = 5.261	80:20 Mix	50:50 Mix	30:70 Mix
Currencies	Precautionary Sub-portfolio	Investment Sub-portfolio	Aggregate Portfolio 1	Aggregate Portfolio 2	Aggregate Portfolio 3
US Dollars	67.89%	51.13%	64.54%	59.51%	56.16%
Pounds Sterling	5.82%	6.56%	5.97%	6.19%	6.34%
Euros	3.97%	15.91%	6.36%	9.94%	12.33%
Japanese Yen	15.73%	21.29%	16.84%	18.51%	19.62%
Swiss Francs	2.58%	1.48%	2.36%	2.03%	1.81%
Other Currencies	4.01%	3.63%	3.94%	3.82%	3.74%
Total Weights	100%	100%	100%	100%	100%
Expected Return	5.00%	6.36%	5.27%	5.68%	5.95%
Std. Dev.	4.00%	7.45%	4.69%	5.72%	6.41%

Notes: The results are obtained based on the outcomes from Table 4.5 and the classification of currencies is from Table 4.3.

Table 4.8 investigates the MA problem by solving equation (4.5) and presents the combinations of threshold return levels and corresponding maximum probabilities of not reaching them for the two sub-portfolios and three aggregate portfolios. We can see that the maximum probabilities that the reserve managers would have negative returns are 11% and 20% for the precautionary and investment sub-portfolios, respectively, and for aggregate portfolios 1, 2 and 3 they are 13%, 16%, and 18%, respectively. These results correspond to decreasing risk aversions in the two sub-portfolios and three aggregate portfolios. It is convenient and efficient for using this VaR constraint to capture the risk perception of reserve managers in each portfolio. Equation (4.7) tells us that the portfolio weights are not linearly proportional to the risk-aversion parameter γ, which indicates that the risk-aversion parameter implied in all three aggregate portfolios is distinct from the weighted average of the risk-aversion parameters of the two sub-portfolios.

Table 4.8 Threshold Return Levels and Corresponding Maximum Probabilities of Not Reaching Them for Equilibrium Returns

Risk Aversion:	γ = 9.938	γ = 5.261	80:20 Mix	50:50 Mix	30:70 Mix
Threshold (H)	Precautionary Sub-portfolio Prob[r<H]	Investment Sub-portfolio Prob[r<H]	Aggregate Portfolio 1 Prob[r<H]	Aggregate Portfolio 2 Prob[r<H]	Aggregate Portfolio 3 Prob[r<H]
-15.00%	0.00	0.00	0.00	0.00	0.00
-10.00%	0.00	0.01	0.00	0.00	0.01
-5.00%	0.01	0.06	0.01	0.03	0.04
0.00%	0.11	0.20	0.13	0.16	0.18
5.00%	0.50	0.43	0.48	0.45	0.44
10.00%	0.89	0.69	0.84	0.78	0.74
15.00%	0.99	0.88	0.98	0.95	0.92
Expected Return	5.00%	6.36%	5.27%	5.68%	5.95%
Std. Dev.	4.00%	7.45%	4.69%	5.72%	6.41%

Notes: The results are computed using equation (4.5) after obtaining portfolio returns and the standard deviations for each portfolio.

4.3.4.2 Results based on B-L returns

In this part, all the results are based on the B-L return estimates. After reserve managers state their conservative investment views by shifting the portfolio towards government bonds, Table 4.9 to Table 4.12 correspond to and convey the same information as Tables 4.5 to 4.8, respectively.

Compared with the results in Table 4.5, Table 4.9 shows that in each portfolio, holdings of the US 3-month T-Bill increase while holdings of US equity decrease, which is the result of the more conservative investment strategy of reserve managers in response to the upsurge in demand for safe assets under the influence of the global financial crisis. Also, all the resulting expected portfolio returns and standard deviations in each portfolio after adding reserve manager's views are less than those under estimates with the equilibrium excess returns, indicating that reserve managers care more about managing the market risks than about seeking higher returns.

Table 4.9 Holdings of Efficient Portfolios of Two Sub-Portfolios and Three Aggregate Portfolios for the B-L Returns

Risk Aversion:	γ = 9.938	γ = 5.261	80:20 Mix	50:50 Mix	30:70 Mix
Asset Classes	Precautionary Sub-portfolio	Investment Sub-portfolio	Aggregate Portfolio 1	Aggregate Portfolio 2	Aggregate Portfolio 3
US GOVT	0.60%	17.73%	4.03%	9.17%	12.59%
CANADA GOVT	3.52%	4.80%	3.77%	4.16%	4.42%
AUSTRALIA GOVT	0.42%	0.09%	0.35%	0.25%	0.19%
UK GOVT	0.03%	0.02%	0.03%	0.02%	0.02%
SWISS GOVT	3.92%	0.79%	3.29%	2.35%	1.73%
GERMANY GOVT	0.07%	0.05%	0.07%	0.06%	0.06%
FRENCH GOVT	0.05%	0.03%	0.04%	0.04%	0.03%
ITALIAN GOVT	0.02%	0.01%	0.02%	0.02%	0.02%
JAPAN GOVT	13.11%	17.49%	13.99%	15.30%	16.18%
US CORP	5.54%	0.07%	4.44%	2.81%	1.71%
US AGENCY	0.63%	2.17%	0.94%	1.40%	1.71%
TBILL 3M	62.43%	15.25%	52.99%	38.84%	29.41%
SUPRANATIONAL	0.72%	21.46%	4.86%	11.09%	15.23%
US EQUITY	0.02%	0.00%	0.01%	0.01%	0.01%
EURO EQUITY	0.46%	10.84%	2.54%	5.65%	7.73%
UK EQUITY	8.47%	9.20%	8.62%	8.84%	8.98%
Total Weights	100%	100%	100%	100%	100%
Expected Return	4.27%	5.02%	4.42%	4.65%	4.79%
Std. Dev.	2.99%	5.51%	3.49%	4.25%	4.75%

Notes: The portfolio weights of all portfolios are obtained using the solutions in equations (4.6) to (4.10). The expected returns and standard deviations of all portfolios are presented at the bottom of the table.

For proportion of the holdings between safe and risky assets, Table 4.10 displays that in each portfolio, holdings of safe assets under the conservative views are greater than those under equilibrium returns, compared with the results in Table 4.6.

Table 4.10 Holdings of Safe and Risky Assets of Two Sub-Portfolios and Three Aggregate Portfolios for the B-L Returns

Risk Aversion:	γ = 9.938	γ = 5.261	80:20 Mix	50:50 Mix	30:70 Mix
Asset Types	Precautionary Sub-portfolio	Investment Sub-portfolio	Aggregate Portfolio 1	Aggregate Portfolio 2	Aggregate Portfolio 3
Safe assets	91.05%	79.96%	88.83%	85.50%	83.29%
Risky assets	8.95%	20.04%	11.17%	14.50%	16.71%
Total Weights	100%	100%	100%	100%	100%
Expected Return	4.27%	5.02%	4.42%	4.65%	4.79%
Std. Dev.	2.99%	5.51%	3.49%	4.25%	4.75%

Notes: The results are summarised based on the results in Table 4.9 and the classification of asset types is by the IMF (2012).

In comparison with Table 4.7, Table 4.11 shows that, with the B-L returns, for each portfolio, holdings of both US and UK assets out of all investable asset classes increase, while holdings of both Euro and Japanese assets decrease.

Table 4.11 Composition of Currencies of Two Sub-Portfolios and Three Aggregate Portfolios for the B-L Returns

Risk Aversion:	γ = 9.938	γ = 5.261	80:20 Mix	50:50 Mix	30:70 Mix
Currencies	Precautionary Sub-portfolio	Investment Sub-portfolio	Aggregate Portfolio 1	Aggregate Portfolio 2	Aggregate Portfolio 3
US Dollars	69.92%	56.69%	67.28%	63.31%	60.66%
Pounds Sterling	8.50%	9.22%	8.65%	8.86%	9.00%
Euros	0.60%	10.93%	2.67%	5.77%	7.83%
Japanese Yen	13.11%	17.49%	13.99%	15.30%	16.18%
Swiss Francs	3.92%	0.79%	3.29%	2.35%	1.73%
Other Currencies	3.93%	4.89%	4.13%	4.41%	4.60%
Total Weights	100%	100%	100%	100%	100%
Expected Return	4.27%	5.02%	4.42%	4.65%	4.79%
Std. Dev.	2.99%	5.51%	3.49%	4.25%	4.75%

Note: The results are obtained based on the results in Table 4.9 and the classification of currencies in Table 4.3.

For the MA problem, Table 4.12 indicates that in each portfolio, adding reserve managers' conservative views does decrease the maximum probabilities of failing to reach threshold return levels, due to the fact that in each portfolio the performances, i.e. the expected portfolio returns and standard deviations, decrease to some extent, compared with the results in Table 4.8.

Table 4.12 Threshold Return Levels and Corresponding Maximum Probabilities of Not Reaching Them for the B-L Returns

Risk Aversion:	γ = 9.938	γ = 5.261	80:20 Mix	50:50 Mix	30:70 Mix
Threshold (H)	Precautionary Sub-portfolio Prob[r<H]	Investment Sub-portfolio Prob[r<H]	Aggregate Portfolio 1 Prob[r<H]	Aggregate Portfolio 2 Prob[r<H]	Aggregate Portfolio 3 Prob[r<H]
-15.00%	0.00	0.00	0.00	0.00	0.00
-10.00%	0.00	0.00	0.00	0.00	0.00
-5.00%	0.00	0.03	0.00	0.01	0.02
0.00%	0.08	0.18	0.10	0.14	0.16
5.00%	0.60	0.50	0.57	0.53	0.52
10.00%	0.97	0.82	0.94	0.90	0.86
15.00%	1.00	0.96	1.00	0.99	0.98
Expected Return	4.27%	5.02%	4.42%	4.65%	4.79%
Std. Dev.	2.99%	5.51%	3.49%	4.25%	4.75%

Notes: The results are computed using equation (4.5) after obtaining portfolio returns and standard deviations for each portfolio.

4.4 Conclusions

In this chapter, we propose a behavioural strategic asset allocation for foreign reserves to derive a multiple-goal reserve management policy for central banks. We design two sub-portfolios (mental accounts): the ‘precautionary sub-portfolio’ and the “investment sub-portfolio”. The precautionary sub-portfolio exhibits higher risk aversion and favours safe and liquid assets. Such a sub-portfolio is therefore capable of fulfilling both safety and liquidity objectives of the reserve management. The ‘investment sub-portfolio’ exhibits lower risk aversion and can satisfy reserve managers’ need to seek higher returns and thus fulfil the return objective. We also design different aggregate portfolios to display the distinct overall risk attitudes of reserve managers. Under this investment policy, we use the Black-Litterman approach to improve our return forecasts and therefore to overcome the maximisation problem of mean-variance optimisation. Using equilibrium returns as a starting point, the B-L returns are obtained by adding the reserve managers' views.

Taking China as an example, we apply this behavioural reserve management framework to practical use. In line with the current trend of central banks' reserve management and their evolving investment universe, our approach sheds critical lights on optimal asset allocation in a volatile world under the impacts of the global financial crisis. Against conventional method, our approach shows several advantages. First, the creation of a sub-portfolio associated with a certain goal allows reserve managers to make investment decisions in a straightforward manner. Fail this, reserve managers with multiple investment objectives must choose portfolios based on the overall expected returns and their standard deviations. Second, risk can be measured by the maximum probabilities of not reaching the threshold of each goal as illustrated in Tables 4.7 and 4.11, rather than by the standard deviation of the returns of the overall portfolio. This measurement ensures that reserve managers can measure risks directly and efficiently. Using these advantages, not only can reserve managers specify different degrees of risk aversion to formulate their desired sub-portfolios, but also they can adjust the allocations of their total investable reserves across sub-portfolios to construct different aggregate portfolios, and can establish their desirable aggregate portfolio based on this risk measurement.

For future research, one may consider broadening the set of asset classes to expand the investable universe of official reserve managers. This may even include the real assets such precious metals and stones, real estate assets and commodities. Of particular interest would be gold as an asset class. Gold has a long history as a reserve asset. In the current volatile world where safe assets are in great demand, gold's attribute as a safe asset takes on a growing interests by global reserve managers. According to the IMF (2012), gold, as a potentially safe asset, has global market capitalisation of 8.4 trillion US dollars, accounting for 11% of total global safe assets. Thus, taking into consideration of investment opportunity in gold would be an important avenue for reserve managers to expand the diversification possibility.

4.5 Appendix

Following Das et al. (2010), to solve the maximisation problem (4.1), we set up Lagrangian with coefficient λ:

$$\max_{w,\lambda} L = w'\mu - \frac{\gamma}{2} w'\Sigma w + \lambda\left[1 - w'\mathbf{1}\right] \qquad \text{(A-1)}$$

The first-order conditions are

$$\frac{\partial L}{\partial w} = \mu - \gamma\Sigma w - \lambda\mathbf{1} = 0 \qquad \text{(A-2)}$$

$$\frac{\partial L}{\partial \lambda} = 1 - w'\mathbf{1} = 0 \qquad \text{(A-3)}$$

Note that equation (A-2) is a system of n equations. Rearranging equation (A-2) gives

$$\Sigma w = \frac{1}{\gamma}\left[\mu - \lambda \mathbf{1}\right] \qquad \text{(A-4)}$$

and pre-multiplying both sides of this equation by Σ^{-1} gives

$$w = \frac{1}{\gamma}\Sigma^{-1}\left[\mu - \lambda \mathbf{1}\right] \qquad \text{(A-5)}$$

Because of the equation includes λ, the solution here for portfolio weights is not yet complete. So we still need to solve for λ. Pre-multiplying equation (A-5) by $\mathbf{1}^{'}$ gives

$$\mathbf{1}^{'} w = \frac{1}{\gamma}\mathbf{1}^{'}\Sigma^{-1}\left[\mu - \lambda \mathbf{1}\right] \qquad \text{(A-6)}$$

$$1 = \frac{1}{\gamma}\left[\mathbf{1}^{'}\Sigma^{-1}\mu - \lambda \mathbf{1}^{'}\Sigma^{-1}\mathbf{1}\right] \qquad \text{(A-7)}$$

which can now be solve for λ to get

$$\lambda = \frac{\mathbf{1}^{'}\Sigma^{-1}\mu - 1}{\mathbf{1}^{'}\Sigma^{-1}\mathbf{1}} \qquad \text{(A-8)}$$

Plugging λ back into equation (A-5) gives the closed-form solution for the optimal portfolio weights:

$$w = \frac{1}{\gamma}\Sigma^{-1}\left[\mu - \left(\frac{\mathbf{1}'\Sigma^{-1}\mu - \gamma}{\mathbf{1}'\Sigma^{-1}\mathbf{1}}\right)\mathbf{1}\right] \in R^{n}$$

This optimal solution w is an n-vector.

Chapter 5

A MULTIPLE-GOAL INVESTMENT STRATEGY FOR SOVEREIGN WEALTH FUNDS: THE CASE OF CHINA

5.1 Introduction

Sovereign Wealth Funds (SWFs) are public funds owned by general governments, which are referred to as institutional investors holding foreign financial assets with a long-term investment horizon to transfer their national wealth across generations. SWFs are not new. The first SWF in the world can date back to 1854, when Permanent School Fund (PSF) was established by the U.S. state of Texas[6]. However, not until 2000 did the number and size of SWFs begin to boom, because of the rapid growth of current account surpluses of both Asian emerging economies and commodity-based economies over the past decade. Consequently, according to the estimation of SWF Institute, up to March 2013, more than 50 economies have founded their own SWFs

[6] For detailed information, please see term "Permanent School Fund" in Wikipedia.

and their total asset holdings have a total of US$ 5.36 trillion. Although the current SWF asset holdings are far less than US$ 33.9 trillion in global pension funds at the end of 2012[7], and even less than US$ 10.94 trillion in global official reserve holdings at the end of 2012[8], the SWF industry as a whole have emerged as a prominent investor in global capital markets.

China's first SWF on record, the China Investment Corporation (CIC), was established in September 2007, with an initial capital injection of US$ 200 billion. Its founding is largely prompted by the intention of the Chinese government to mitigate the costs of carrying the massive and ever-growing foreign reserves by pursuing higher returns from investing the excessive reserves. At the end of 2012, the external assets under CIC management stood at US$ 482 billion, one of the largest in the world's SWFs (TheCityUK, 2013).

SWF investment in recent years has exhibited two critical changes. First, the recent global financial crisis prompts SWFs to play some role in reaching out for financial stability. Many countries have injected sizable capital into systemically important banks to help them deal with financial distress. This shifts the role of SWFs from being an investor who transfers wealth from now to the future to serve as a promoter

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[7] See the 'Sovereign Wealth Funds' report launched in March 2013 at the website of TheCityUK.

[8] See the COFER data of IMF updated in March 2013.

of financial stability who provides contingent liquidity to domestic financial systems when necessary. IMF (2008b) confirms that SWF's capital injections can facilitate stability of the recipients' share prices by reducing share price volatility in the short run, and thus SWFs are able to fulfil a shock-absorbing function.

Second, with the growing size of SWF assets, many countries have established more than one SWFs or assigned different mandates to their one SWF, to achieve varying policy objectives such as providing liquidity needs in the short run and transfer wealth in the long run. According to Kunzel et al. (2010) and IMF (2011), Chile has founded two SWFs: a Social and Economic Stabilization Fund and a Pension Reserve Fund, to meet its short-term and long-term macroeconomic objectives. Singapore has also created two SWFs, i.e. Temasek Holdings and Government of Singapore Investment Corporation, with the former being a saving fund and the latter a foreign reserve investment fund. The Kuwait Investment Authority as a singular institute serves two SWF functions: a stabilization fund and a savings fund. In Norway's case, its Government Pension Fund Global performs three functions in one: a stabilization fund, a savings fund, and a pension reserve fund. In all, it is common for SWFs to pursue a multiple-goal strategy for their investments.

In the context of China, despite the remarkable economic growth it has achieved in recent decades, the country remains faced with considerable uninsured risks, particularly in the financial area. Allen et al. (2012) suggest that China's current financial system is vulnerable both to traditional financial crises and to the simultaneous currency, banking and stock market crises, which can seriously disrupt the economy and undermine social stability. Other serious risks are also present in the economy. For example, Qiu (2013) maintains that the rapidly ageing population and the potential funding crisis of China's National Social Security Fund represent a severe social challenge to China's continuing economic prosperity. Against this backdrop, it would be not entirely pertinent for China to use foreign reserves, which are huge, only for reaping higher financial yields. It is necessary and desirable for China to mandate its SWFs multiple tasks ranging from seeking higher returns, to providing support to financial stability, and to supporting provision of social security, to list just a few. In this light, the Chinese government may administer its SWF by setting up various types of fund to meet the needs of achieving multiple policy objectives, which calls for the formulation of a multiple-goal investment strategy.

However, the existing literature has been relatively spars on formulating such a strategy[9]. This chapter aspires to fulfil towards this void by proposing a multiple-goal SWF investment framework for China. The modelling attempt will feature the embedding of the Black-Litterman model (Black and Litterman, 1992) into the Mean Variance Mental Accounting framework introduced by Das, Markowitz, Scheid, and Statman (2010). The Black-Litterman (B-L) model is an approach of formulating

[9] Van Den Bremer and Van Der Ploeg (2013) propose an optimal asset management framework which includes three funds, but their study is only for oil-rich economies.

forward-looking return forecasts to overcome the error-maximising of the mean-variance optimisation (Best and Grauer, 1991), which uses the implied equilibrium excess returns as the starting point, combine subjective investor views, and thus form the posterior expected return estimates based on the Bayesian estimation method[10]. Das et al (2010) combine the mean-variance theory of portfolio management (MVT) by Markowitz (1952) and the behavioural portfolio theory (BPT) by Shefrin and Statman (2000). This framework allows investors to take their portfolios as collections of mental accounting (MA) sub-portfolios. Each sub-portfolio is not only associated with the specified risk-aversion coefficient in the MVT problem, but also with a goal where there are a threshold return level and a probability in the MA problem. Risk tolerance in each sub-portfolio can be measured by the probability of failing to reach the threshold return level by means of Value at Risk (VaR). Das et al (2010) demonstrate that the MVT problem is mathematically equivalent to the MA problem. As a result, investors in this framework can choose the portfolio with maximum expected returns subject to the VaR constraint capturing the account's motive. In line with Markowitz (1952), optimal portfolios within various accounts are located on the efficient frontier. As a result of combining all sub-portfolios, the aggregate portfolio

[10] Lucid discussion of the Bayesian analysis and the B-L model can be found in Lee (2000) and Christodoulakis (2002). Meucci (2010) and Walters (2011) survey the original B-L model and its various extensions.

is also located on the efficient frontier. Various extensions to Das et al (2010) can be found in Alexander and Baptista (2011) and Baptista (2012).

From a normative perspective, our multiple-goal SWF investment framework can guide sovereign wealth managers on how to efficiently operate their SWFs. We propose that the SWF comprises three mental accounts, or sub-portfolios. The first is a 'liquidity sub-portfolio', in which the managers specify higher risk-aversion coefficients and invest in a short investment horizon for providing contingent liquidity supports to both internal and external banking sectors to cushion against the possible negative effects triggered by traditional financial crises or some 'twin crisis'. The second is an 'investment sub-portfolio', where the managers specify medium risk-aversion parameters, and invest in a medium-term investment horizon for funding contingent domestic liabilities, e.g. contingent pension payments. The third is a 'bequest sub-portfolio', where the managers with lower risk-aversion parameters invest in a long-term investment horizon, attempting to transfer their wealth across generations. As a result, according to different types of SWFs, the managers can construct their distinct aggregate portfolios by allocating their total investable wealth across the three sub-portfolios in a variety of proportions. While the optimal ratio of each sub-portfolio to the total investable wealth can be investigated in a separate work in future research, in the current chapter, we employ the B-L model to obtain both the equilibrium total returns and the B-L total returns as our improved forward-looking return forecasts, and therefore to derive the two sets of optimal asset allocations for

SWFs. With the MVMA framework, we run an empirical analysis based on China's SWFs by selecting 16 indices, including cash equivalents, fixed income, equity, and alternative asset.

The rest of the chapter is organised as follows. In section 5.2, we review recent stylized facts about SWFs. In section 5.3, we outline the growth pattern and the potential risks facing China's economy, and China's sovereign wealth funds. In section 5.4, we put forward our multiple-goal investment framework for China's SWF. In section 5.5, we apply our approach to an empirical analysis of China's case. Conclusions are presented in section 5.6.

5.2 Stylized Facts about Sovereign Wealth Funds

5.2.1 Overview of Sovereign Wealth Funds

Sovereign Wealth Funds are not a new phenomenon. For example, the first SWF can date back to the second half of the 19th century (1854), when the U.S. state of Texas established the Permanent School Fund (PSF), which serves to invest its assets endowed with public lands in return for funding of public educational institutions[11].

[11] See footnote 6.

The first commodity SWF of a sovereign state is the Kuwait Investment Authority, the oil fund created by the Kuwait Government in 1953, which manages financial investments derived from oil export revenues to transfer the wealth associated with non-renewable resources across generations. In 1974, the government of Singapore founded Temasek Holdings to administrate assets owned by government-linked companies, and in 1981, set up the Government Investment Corporation (GIC) to manage its both internal and external savings for meeting its macroeconomic objectives. In 1991, Norway established Government Pension Fund Global to invest the surplus wealth originating from its petroleum income and therefore to insulate its government budgets from the highly fluctuation of oil prices[12].

Since 2000, however, the number and size of SWFs have raised dramatically, due to rapid growth of current account surpluses of commodity-exporting economies and Asian emerging economies over the past decade. Commodity-exporting economies, whose public sectors govern commodity exports or tax the incomes gained by their private commodity exporters, have expanded the sovereign asset holdings because of the recent commodity price boom, while Asian emerging economies have transferred a part of huge official reserve holdings resulting from export-led growth policy to fund their SWFs (Aizenman and Glick 2009). As a result, up to March 2013, more than 50

[12] See SWFs Institute website.

countries have established their SWFs and their total asset holdings amount to US$ 5.36 trillion, based on the estimation of SWF Institute website.

SWFs can be classified in terms of two criteria. On the one hand, according to their source of funding, SWF can be grouped as commodity-based SWFs and non-commodity SWFs. Commodity-based SWFs are funded mainly from oil exports, gas, and other important minerals (e.g. the Gulf Cooperation Council[13], Norway, Russia, and Chile), while Non-commodity SWFs are funded by the transfer of assets from both official foreign reserves and government budget surpluses (e.g. China and other Asian countries)[14]. Table 5.1 shows the profile of commodity-based SWFs, including fund name, the year founded, current SWF asset size, and information of rating transparency, while Table 5.2 displays non-commodity-based SWFs, according to SWF rankings in the website of SWF Institute.

On the other hand, in terms of their distinct mandates and policy objectives, SWFs can be categorised as four types: Stabilization Funds, Saving Funds, Pension Reserve Funds, and Reserve Investment Funds[15] (IMF 2012). Table 5.3 exhibits the objectives

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[13] The Gulf Cooperation Council includes six Middle Eastern countries i.e. Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates (UAE).

[14] See the footnote 7.

[15]IMF (2012) lists the countries owning SWFs and their corresponding fund types. Stabilization Funds are those in Azerbaijan, Bahrain, Botswana, Chile, Kiribati, Mexico, Oman, Russia, Timor-Leste, and Trinidad and Tobago. Saving Funds are those in: Abu Dhabi, Alberta (Canada), Alaska (US), Bahrain, Brunei, Kazakhstan, Kuwait, Malaysia, Norway, Qatar, Russia, and Singapore. Pension Reserve Funds

of the four types of SWFs and their observed asset allocations at the end of 2010, based on publicly available data for selected 30 SWFs which meet the definition outlined in the Santiago Principles.

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are those in: Australia, Chile, Ireland, and New Zealand. Reserve Investment Funds are those in: China, Korea, and Singapore.

Table 5.1 Commodity-Based Sovereign Wealth Funds

Country	Fund Name	Year Founded	Current Asset Size by Billion USD	Linaburg-Maduell Transparency Index
Algeria	Revenue Regulation Fund	2000	56.70	1
Azerbaijan	State Oil Fund	1999	32.70	10
Botswana	Pula Fund	1994	6.90	6
Brunei	Brunei Investment Agency	1983	30.00	1
Canada	Alberta's Heritage Fund	1976	16.40	9
Chile	Social and Economic Stabilization Fund	2007	15.00	10
	Pension Reserve Fund	2006	5.90	10
East Timor	Timor-Leste Petroleum Fund	2005	11.80	8
Iran	National Development Fund of Iran	2011	42.00	5
Kazakhstan	Kazakhstan National Fund	2000	61.80	8
Kuwait	Kuwait Investment Authority	1953	342.00	6
Libya	Libyan Investment Authority	2006	65.00	1
Mexico	Oil Revenues Stabilization Fund of Mexico	2000	6.00	n/a
Norway	Government Pension Fund - Global	1990	715.90	10
Oman	State General Reserve Fund	1980	8.20	1
Qatar	Qatar Investment Authority	2005	115.00	5
Russia	National Welfare Fund	2008	175.50	5
Saudi Arabia	SAMA Foreign Holdings	n/a	532.80	4
	Public Investment Fund	2008	5.30	4
UAE-Abu Dhabi	Abu Dhabi Investment Authority	1976	627.00	5
	International Petroleum Investment Company	1984	65.30	9
	Mubadala Development Company	2002	53.10	10
UAE-Dubai	Investment Corporation of Dubai	2006	70.00	4
US-Alaska	Alaska Permanent Fund	1976	45.00	10
US-Texas	Texas Permanent School Fund	1854	25.50	9
US-Wyoming	Permanent Wyoming Mineral Trust Fund	1974	5.60	9

Sources: The author's compilation based on SWF rankings in the website of www.Swfinstitute.org.

Notes: This table depicts the profile of commodity-based SWFs selected based on their data availability, in which the listed SWFs are the funds whose asset sizes have exceeded 5 billion US dollars. Current asset size is the size updated in March 2013. The Linaburg-Maduell Transparency Index was invented at the SWF Institute, an approach of rating transparency with regard to SWFs, where the minimum score is 1, and a minimum rating of 8 is recommended to claim adequate transparency.

According to Table 5.1, 50% of commodity-based SWFs have been established since 2000. Currently, Kuwait, Norway, Saudi Arabia, and UAE-Abu Dhabi have SWF asset holdings exceeding US$ 100 billion, among which, Norwegian Government Pension Fund – Global is the largest fund, holding US$ 715.90 billion. The Linaburg-Maduell Transparency Index was created by Carl Linaburg and Michael Maduell at the SWF Institute, which is an approach of rating transparency concerning SWFs. This index is developed by introducing ten essential principles that describe SWF transparency to the public and assigning each principle to one point, in which the minimum score is 1, and a minimum rating of 8 is recommended to claim adequate transparency. More than 50% of commodity-based SWFs are scored less than 8, showing inadequate transparency. All SWFs of developed economies in Table 5.1 gain a rating of more than 8, displaying their transparent information disclosure. The public accountability and transparency of SWFs are the prerequisites for sound SWF management and good corporate governance. It is vital for policymakers to capture sufficient data on SWFs' activities and therefore to facilitate economic analysis (IMF 2008a). The other important standard of the transparency issue of SWFs can refer to the "Generally Accepted Principles and Practices", also known as the "Santiago Principles", which is a set of principles properly guiding SWFs' all activities, presented by the International Working Group of Sovereign Wealth Funds (IWG) in September 2008 (IWG 2008). Das, Mazarei, and Stuart (2010) review the development of the Santiago Principles, stressing that elements of disclosure and transparency are embedded throughout all three sections of Santiago Principles, rather than forming a separate section.

Table 5.2 Non-Commodity Sovereign Wealth Funds

Country	Fund Name	Year Founded	Current Asset Size by Billion USD	Linaburg-Maduell Transparency Index
Australia	Australian Future Fund	2006	83.00	10
Bahrain	Mumtalakat Holding Company	2006	7.10	9
Brazil	Sovereign Fund of Brazil	2008	5.30	9
China	SAFE Investment Company	1997	567.90	4
	China Investment Corporation	2007	482.00	7
	National Social Security Fund	2000	160.60	5
China-Hong Kong	Hong Kong Monetary Authority Investment Portfolio	1993	298.70	8
France	Strategic Investment Fund	2008	25.50	9
Ireland	National Pensions Reserve Fund	2001	19.40	10
Malaysia	Khazanah Nasional	1993	39.10	5
New Zealand	New Zealand Superannuation Fund	2003	16.60	10
Peru	Fiscal Stabilization Fund	1999	7.10	n/a
Russia	Russian Direct Investment Fund	2011	11.50	n/a
Singapore	Government of Singapore Investment Corporation	1981	247.50	6
	Temasek Holdings	1974	157.50	10
South Korea	Korea Investment Corporation	2005	56.60	9
US-New Mexico	New Mexico State Investment Council	1958	16.30	9

Sources: The author's compilation based on SWF rankings in the website of www.Swfinstitute.org.

Notes: This table describes the profile of non-commodity SWFs selected based on their data availability, in which the listed SWFs are the funds whose asset sizes have exceeded 5 billion US dollars. Current asset size is the size updated in March 2013. The Linaburg-Maduell Transparency Index was invented at the SWF Institute, an approach of rating transparency with regard to SWFs, where the minimum score is 1, and a minimum rating of 8 is recommended to claim adequate transparency.

In the light of Table 5.2, nearly 60% of non-commodity SWFs have been founded since 2000. China, China-Hong Kong, and Singapore have current SWF asset holdings overpassing US$ 100 billion, among which, China's SAFE Investment Company amount to US$ 567.90 billion, taking the lead in the non-commodity SWFs. With regard to the transparency issue, almost 60% of non-commodity SWFs are scored more than 8, showing adequate transparency.

Table 5.3 Objectives of SWFs by Type and Their Observed Asset Allocations

	Stabilization Funds	Saving Funds	Pension Reserve Funds	Reserve Investment Funds
Objective	Insulate government budgets and economies from commodity price volatility and external shocks	Share cross-generational wealth by transfering non-renewable assets into a diversified portfolio of foreign financial assets to provide for future generations	Meet future pension liabilities on the governments' balance sheets	Reduce reserve holding costs and pursue higher returns
Cash	5%	4%	9%	3%
Fixed Income	91%	26%	19%	25%
Equities	4%	55%	39%	66%
Alternative Asset	0%	15%	33%	6%
Safe Assets	96%	30%	28%	28%
Risky Assets	4%	70%	72%	72%
Total	100%	100%	100%	100%

Sources: The authors' compilation based on Box 3.1 from IMF (2012).
Notes: This table shows Objectives of SWFs by Type and their observed asset allocations at the end of 2010 in terms of IMF (2012), in which Safe Assets include Cash and Fixed Income, while Risky Assets contain Equities and Alternative Assets.

As shown in Table 5.3, there are four asset types usually used for SWF investment: cash, fixed income, equities, and alternative asset. The former two belong to safe assets, while the latter two belong to risky assets. On the whole, Stabilization Funds invest their wealth mainly into safe assets including 91% in fixed income and 5% in cash, whereas other three funds are largely risky investors, i.e. more than 70% of their wealth are invested into risky assets, while the remaining into safe assets. The observed investment patterns show that the four types of SWFs are heterogeneous towards the risk preference and tolerance, based on their different macroeconomic objectives. Das, Lu, Mulder, and Sy (2009) suggest that Stabilization Funds tend to invest in a short horizon due to their objective to insulate government budgets from more frequent commodity price volatility, resulting in a high allocation to fixed income assets for meeting contingent liquidity needs; whereas, the other types of SWFs tend to invest in a long horizon, allowing for their asset allocations to broader asset classes. Thus, with the exception of Stabilization Funds, most SWFs act as investors in a long-term investment horizon and limited liquidity needs, which can accept short-term volatility and bear some long-term risks (IMF 2008b; IMF 2011).

In fact, with the rapid growth of the size of SWF assets, many countries tend to administrate their SWFs by establishing more than one SWF or allocating their one SWF into different types of SWFs, to achieve their various macroeconomic policy objectives. According to Kunzel et al (2010) and IMF (2011), for example, Chile has founded two SWFs: Social and Economic Stabilization Fund and Pension Reserve Fund, attempting to meet its short-term and long-term macroeconomic objectives. Singapore has also created two SWFs: Temasek Holdings and Government of Singapore Investment Corporation, where the former is a saving fund and the latter is a reserve investment fund. Besides, Kuwait Investment Authority serves as two types of SWFs: a stabilization fund and a saving fund, while Norway's Government Pension Fund Global as three types: a stabilization fund, a saving fund, and a pension reserve fund.

5.2.2 The role of Financial Stability of SWFs during the 07-08 Financial Crises

The recent financial crises have given SWFs an opportunity to play the role of financial stability by injecting their significant capital into systemically important Western banks that were financially distressed due to market stress in 07-08. Table 5.4 displays a series of capital injections from a number of SWFs to Western banks during the time from May 07 to July 08.

Table 5.4 Main Capital Injections from SWFs into Banks during 07-08 Financial Crises

Foreign Bank	Date*	SWF	Value (U.S.$ Billion)	Stake (%)	Deal Features
Blackstone (U.S.)	May-07	China Investment Corporation	3	9.9	Nonvoting units in limited partership; 10% ceiling; 3-year lock-in and >3-year divestiture period
Barclays (UK)	Jun-07	Qatar Investment Authority	3.5	6.42	Common stock by exercising presold rights issues
	Jul-07	Temasek	n/a	2.6	Common stock
Standard Chartered (UK)	Aug-07	Temasek	n/a	11	Common stock
Citigroup (U.S.)	Nov-07	Abu Dhabi Investment Authority	7.5	n/a	4.9% convertible units at 11% interest
	Nov-07	Kuwait Investment Authority	3	n/a	2% optional convertible preferred stock; 9% dividend
	Jan-08	Government of Singapore Investment Corporation	6.88	n/a	3.7% optional convertible preferred stock; 7% dividend; noncallable prior to year 7; 20% conversion premium; 6-month lockup
UBS Switzerland	Dec-07	Government of Singapore Investment Corporation	n/a	n/a	Convertible debt securities at 9% interest; must be converted into shares within 2 years
Morgan Stanley (U.S.)	Dec-07	China Investment Corporation	5	n/a	Convertible units at 9% interest
Merrill Lynch	Dec-07	Temasek	4.4	9.4	Mandatory convertible preferred stock; 9% interest; option to buy additional U.S. $600 million worth of stock
	Jan-08	Kuwait Investment Authority	2	3.3	Mandatory convertible preferred shares; 9% interest
	Jan-08	Korean Investment Corporation	2	3.3	n/a
	Feb-08	Temasek	0.6	1.23	Common stock
	Jul-08	Temasek	0.9	n/a	Common stock

Sources: Originally from Table 1 in Pistor (2009) and the authors' sifting by eliminating transactions both between governments and Banks and between other financial institutions and banks. Notes: *Organised by first date involving a transaction with the bank in question.

On the one hand, some financial institutions were funded by more than one SWF. For example, Barclays of UK was funded by Qatar Investment Authority (QIA) and Temasek of Singapore; Citigroup by Abu Dhabi Investment Authority (ADIA), Kuwait Investment Authority (KIA), and Government of Singapore Investment Corporation (GIC); and Merrill Lynch by Temasek, KIA, and Korean Investment Corporation (KIC). On the other hand, some SWFs injected capital into more than one Western bank. For instance, China Investment Corporation (CIC) injected US$ 3 billion, a 9.9% stake into Blackstone, and US$ 5 billion into Morgan Stanley of US; and KIA injected US$ 3 billion into Citigroup and US$ 2 billion, a 3.3% stake into Merrill Lynch. Temasek did capital injections into the most financial institutions: a 2.6% stake into Barclays, an 11% stake into Standard Chartered of UK, and US$ 5.9 billion in total into Merrill Lynch.

IMF (2008b) investigates capital injections from SWFs into financial institutions during the time from Nov 2007 to Feb 2008, suggesting that the announcements of SWF capital injections can facilitate the stability of share prices of the recipients by reducing share price volatility in the short run, and thus that SWFs are able to be a shock-absorbing role due to shrinking short-term market volatility. Bolton, Samama, and Stiglitz (2012) indicate that, although their capital injection behaviour may not be the most efficient way to react to financial crises, SWFs may serve as a useful role in mitigating crises by providing liquidity and insurance to financially distressed institutions due to a greater short-term stress from financial markets. Such countercyclical investment strategies can deliver valuable stability to international financial markets.

5.2.3 Summary

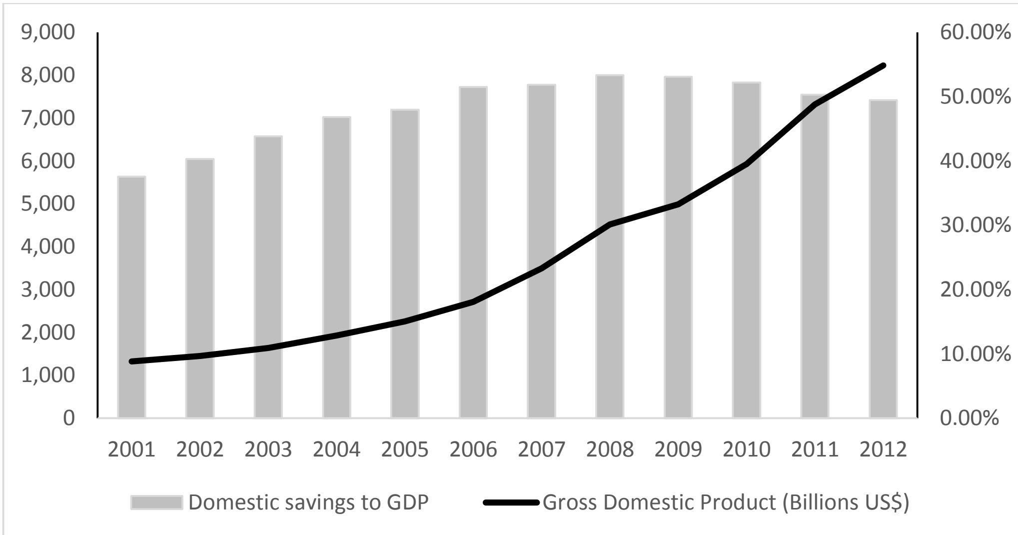
Following the rapid rise of both number and size of SWFs, SWFs as a group has played a prominent role in international capital markets, especially during the recent financial crises. The recent experience of SWF management implies that SWFs not only can be typical investors with long-term investment horizon for the purpose of transferring their national wealth across generations, but also can provide sufficient liquidity to important financial institutions when necessary as a means of self-insurance to cushion against the adverse effects on their economic growth triggered by systemic risks.

Most SWFs have been attempting to accomplish the aforementioned two objectives by various ways, such as setting up more than one SWF or dividing one SWF into several types. Thus, they implement a de facto multiple-goal investment strategy. However, existing related literature does not provide a theoretical framework on it. In the section 5.4, we will bridge this gap by explicitly proposing a multiple-goal SWF investment framework through incorporating the Black-Litterman model into the Mean Variance Mental Accounting (MVMA) framework, in order to facilitate sound SWF investment framework.

5.3 China’s Economy and its Sovereign Wealth Fund

5.3.1 The Growth Pattern of the Chinese Economy

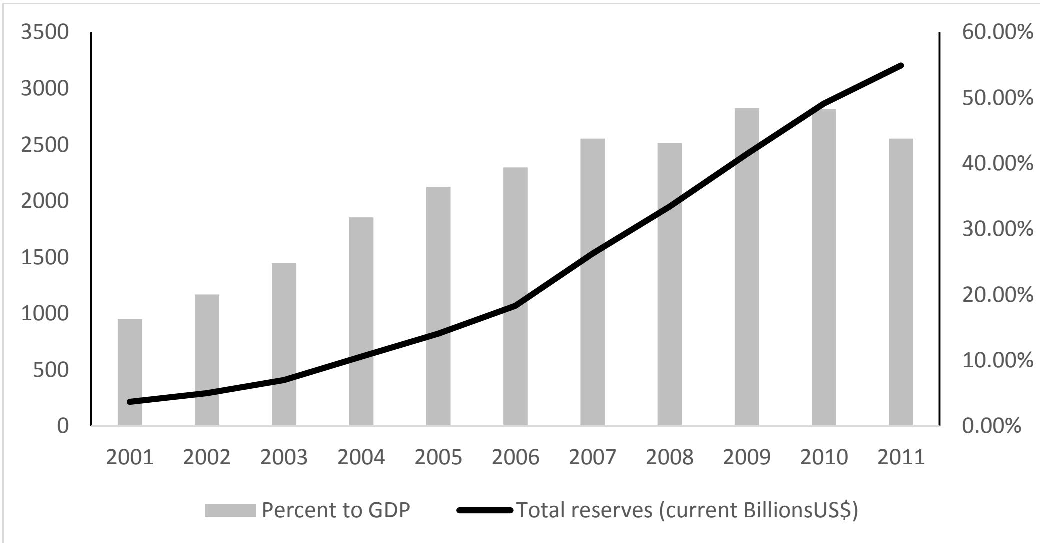
Since launching its first programme of economic reforms in December 1978, China has experienced fast economic growth, with a remarkable 9.9% annual real GDP growth on average from 1979 to 2011. Particularly since its WTO accession in 2001, China has witnessed both fast foreign reserve accumulation and rapid economic growth. According to Morrison (2013), there are two main factors explaining this rapid economic growth in China: the first is large-scale capital investment, financed by hefty domestic savings and foreign investment; the second is rapid productivity growth. Figure 5.1 shows China’s GDP growth and the domestic savings/GDP ratio from 2001 to 2012.



Source: CEIC 2013

Figure 5.1 China's GDP Growth and the Domestic Savings/GDP Ratio

According to Figure 5.1, since 2001 the size of China's GDP has increased dramatically, from 1,325 billion USD in 2001 to 8,227 billion USD in 2012. Meanwhile, the domestic savings/GDP ratio has remained at a relatively high level, more than 40% from 2002 to 2012, peaking at 53.35% in 2008. Such a high level of saving rate provides a stable source for domestic investment. Figure 5.2 illustrates China's total foreign reserves and the total reserves/GDP ratio from 2001 to 2011.

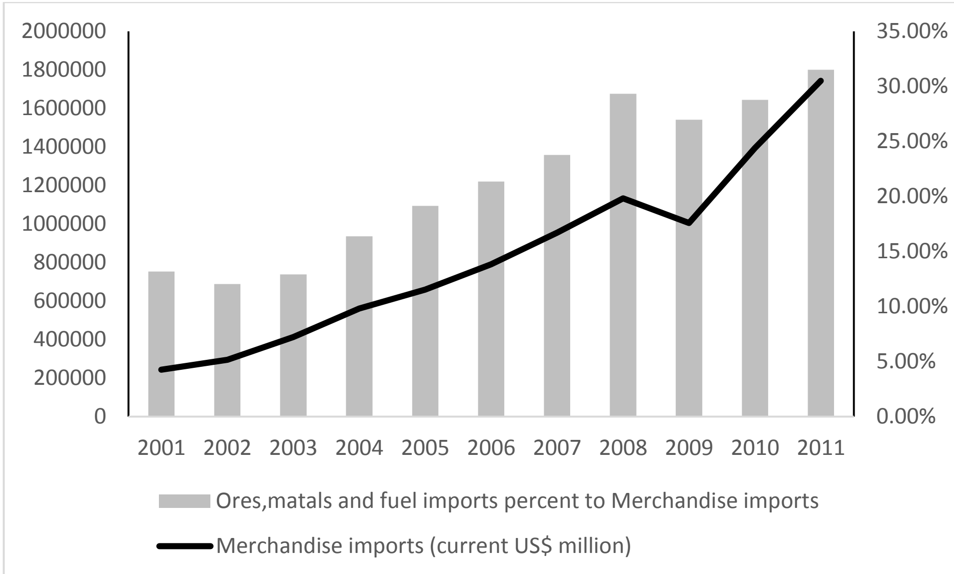


Source: World Bank Database: World Development Indicators (WDI) 2013

Figure 5.2 China's Total Foreign Reserves and the Total Reserves/GDP Ratio

As we can see from Figure 5.2, the size of total foreign reserves augmented from 216 billion USD at the end of 2001 to 3,203 billion USD at the end of 2011, indicating huge current account surpluses and foreign direct investment (FDI) during this period. At the same time, the total reserves to GDP ratio gradually increased, peaking at 48.40% in 2009, then declining slightly to 43.76% in 2011.

In addition, China's economic development has followed a trend of increasing dependence on the imports of raw materials. Figure 5.3 depicts China's total merchandise imports and the raw material imports/total imports ratio.



Note: The Raw Material Imports include crude oil, gas, metals, and resources.

Source: World Bank Database: World Development Indicators (WDI) 2013

Figure 5.3 China's Total Merchandise Imports and the Raw Material Imports/Total Imports Ratio

As shown in Figure 5.3, since 2001, the size of China's total imports grew from 243.5 billion USD in 2001 to 1,743.5 billion USD in 2011. Meanwhile, the raw material imports/total imports ratio also expanded, from 13.17% in 2001 to 31.52% in 2011.

5.3.2 Large Risks Facing the Chinese Economy

In spite of China's huge economic achievement during the last decade, there are large risks facing China's economy. First of all, the current underdevelopment of China's financial system may suffer from potentially uninsured risks. For example, Prasad and Wei (2005) argue that China's underdeveloped banking system is subject to external shocks due to the reported Non-Performing Loans (NPLs) problem. Prasad (2009) indicates that ‘loss of confidence in the banking system’ is potentially one of the most severe risks facing China’s economy. Allen et al. (2012) suggest that China’s current financial system is vulnerable to traditional financial crises and to the ‘twin crisis’ of simultaneous currency and banking and stock market crises, which can seriously disrupt the economy and social stability. Second, the current pension reform in China exerts a negative effect on its sustainable economic growth. Due to the rapidly ageing population and the potential funding crisis of China’s National Social Security Fund, there is a severe social challenge facing China’s continuing economic prosperity (Qiu, 2013).

5.3.3 The Investment Pattern of CIC

In September 2007, China’s State Council invested 200 billion USD out of China’s then 1.4 trillion in foreign reserves to establish the China Investment Corporation (CIC), China’s first sovereign wealth fund on record, for the purpose of reducing reserve holding costs and pursuing higher returns. According to the estimation of TheCityUK (2013), at the end of 2012 the CIC held under management foreign financial assets of 482 billion USD. The CIC has invested in a wide range of assets, containing bonds, equities, and alternative assets. Table 5.5 shows the CIC’s asset allocations from 2008 to 2011, according to the annual reports for those four years.

Table 5.5 The CIC's Asset Allocations

Type of Investment	2008	2009	2010	2011
Cash Funds and Others	87.40%	32%	4%	11%
Fixed-Income Securities	9.00%	26%	27%	21%
Equities	3.20%	36%	48%	25%
Alternative Investment	0.40%	6%	21%	43%
Safe Assets	96.40%	58.00%	31.00%	32.00%
Risky Assets	3.60%	42.00%	69.00%	68.00%

Source: The CIC's Annual Reports from 2008 to 2011.
Note: This table shows the global asset allocations of the CIC from 2008 to 2011. Alternative Investments include direct investments into non-public companies, private equity, hedge funds, real estate and infrastructure. Safe Assets include Cash Funds and Others and Equities, while Risky Assets include Fixed-Income Securities and Alternative Investment.

As reported in Table 5.5, in 2008 the CIC invested most of its holdings (87.40%) in cash funds and 9.00% in fixed-income securities, a total of 96.40% in safe assets. However, in the subsequent three years, taking its global investment losses in the 07-08 crisis as a lesson, the CIC changed its asset allocation by shifting its portfolio from cash funds and others to alternative investment, including direct investments in non-public companies, private equity, hedge funds, real estate and infrastructure. At the end of 2011, 43% of CIC holdings were in alternative investment and 25% in equities, resulting in 68% of holdings in risky assets.

The Central Huijin Investment Corporation (Central Huijin), a CIC subsidiary, has injected substantial amounts of capital into several of China's large state-owned and systemically important banks, hence providing liquidity support. Table 5.6 reports the top five portfolio holdings of Central Huijin in China's large state-owned banks. As can be seen from Table 5.6, at the end of 2011, Central Huijin had a 47.60% share of ownership in the China Development Bank (CDB), 35.40% in the Industrial and Commercial Bank of China (ICBC), 40.10% in the Agricultural Bank of China (ABC), 67.60% in the Bank of China (BOC), and 57.10% in the China Construction Bank (CCB).

Table 5.6 Top Five Portfolio Holdings of Central Huijin

Financial Institute	2008	2009	2010	2011
China Development Bank	48.70%	48.70%	48.70%	47.60%
Industrial and Commercial Bank of China	35.40%	35.30%	35.40%	35.40%
Agricultural Bank of China	50.00%	50.00%	40.00%	40.10%
Bank of China	67.50%	67.50%	67.60%	67.60%
China Construction Bank	48.20%	57.00%	57.10%	57.10%

Source: The CIC's Annual Reports from 2008 to 2011.
Note: This table shows the top five portfolio holdings of Central Huijin from 2008 to 2011.

As a global institutional investor, the CIC has played a significant role in providing financial stability by injecting its capital into important Western financial institutions. For example, as reported by Pistor (2009), in May 2007 the CIC injected US$ 3 billion, a 9.9% stake, into Blackstone (US), and in Dec 2007 US$ 5 billion into Morgan Stanley (US).

5.4 The Multiple-Goal SWF Investment Framework

5.4.1 The Structure of SWF Governance

Before proposing our multiple-goal SWF investment framework, it is of necessity to investigate existing research on the structure of SWF governance, which can facilitate our understanding of a holistic element to good fund governance. The International Working Group of Sovereign Wealth Funds (IWG), which is formed by 24 countries collectively owning 26 SWFs[16], launched the famous "Santiago Principles" in 2008, a set of 24 individual principles for guiding all arrangements and practices of SWF governance. According to IWG (2008), the Santiago Principles cover three distinct parts: (1) legal framework, objectives, and macroeconomic policies; (2) institutional framework and governance structure; and (3) investment and risk management framework.

The first part asks SWFs to publicly disclose their relationships with other state bodies, macroeconomic policy purpose, and general approach to funding, withdrawal, and spending rules. The second part stipulates that, to have a sound governance framework, SWFs should clearly and effectively divide roles and responsibilities; implement their strategies in an independent manner; clearly define their accountability framework; be audited annually in line with national or international auditing standards; and publicly disclose their governance framework, objectives, and relevant financial information. The third part asks SWFs to disclose their investment policy, which should be consistent with their stated objectives, risk tolerance, and investment strategy; state their investment decisions, which must aim to maximise risk-adjusted financial returns; formulate a framework for managing their operational risks; and measure and report their assets and investment performance to the owner (IWG 2008).

[16] In the 24 countries, both Russia and Singapore have two SWFs, respectively.

Hammer, Kunzel, and Petrova (2008) summarise institutional and operational practices towards SWFs by surveying 21 members of the IWG based on the Santiago Principles. Their survey findings suggest that operational practices of SWFs vary significantly, due to their distinct natures and legal personalities. For example, stabilization funds operate differently from the other types of funds, because they have diverse policy objectives, institutional frameworks, and accountability arrangements, forming distinct investment policies and risk management frameworks. They also find out that SWFs within the same type have similar practices, and that the SWF group as a whole have some broader common practices.

Ang (2010) proposes the four benchmarks of SWFs, which form the basis for designing, implementing, and measuring SWFs. The first one is the Benchmark of Legitimacy. As the most important benchmark, it request SWFs to be the vehicles of transferring sovereign wealth from present time to the future, ensuring that such national wealth is not immediately spent and thus that SWFs can undertake the long-term perspectives. He suggests that to have well-developed legal institutions is a prerequisite for maintaining legitimacy. The second is the Benchmark of Integrated Policy and Liabilities, which implies that SWFs should recognise the economic environment in which they operate, identify their implicit liabilities, and therefore formulate optimal spending rules for facilitating their government policies. The third is Governance Structure and Performance Benchmark. To meet this benchmark, SWFs should have their professional managers, who need choose an appropriate benchmark with their governance structure, adopt a sound risk management framework, and thus derive optimal portfolio allocations by maximising their returns subject to their specified constraints. The last is the Long-Run Equilibrium Benchmark, which is the least important compared to the others. In a long-term investment horizon, it is necessary for SWFs to have well-functioning capital markets, free capital flows across countries, good fund governance, and the maintenance of shareholder rights over time. Furthermore, the long-term horizon needs SWFs to consider some externalities such as climate change, child labour, and water management.

5.4.2 The Multiple-Goal SWF Investment Strategy

In this part, we propose a multiple-goal SWF investment framework for all four types of funds by embedding the Black-Litterman (B-L) model into the Mean Variance Mental Accounting (MVMA) framework. Our investment framework can be placed into the third part of the Santiago Principle i.e. investment and risk management framework or into the third benchmark of Ang (2010) i.e. Governance Structure and Performance Benchmark, based on the proposed multiple objectives.

Before introducing the MVMA framework, we employ the B-L model to improve our return forecasts. Following Satchell and Scowcroft (2000) and Idzorek (2005), a "reverse optimisation process" can tell us implied equilibrium excess returns $\boldsymbol{\mu}_M$ as:

$$\boldsymbol{\mu}_M = \delta \boldsymbol{\Sigma} \mathbf{w}_M \qquad (5.1)$$

where $\boldsymbol{\mu}_M$ is a $n \times 1$vector for n assets; δ is the risk aversion coefficient, implying the level of risk against market portfolio returns; $\boldsymbol{\Sigma}$ is the historical variance covariance matrix with $\Sigma \in R^{n \times n}$; and $\mathbf{w}_M$ is the $n \times 1$vector of market capitalisation weights.

The implied equilibrium excess returns are used as the starting point or a prior for further return forecasts. If sovereign wealth managers do not agree with them, they can introduce their own views and therefore form the B-L returns. Based on the Bayesian estimation method, the managers can derive posterior B-L excess returns $E(\mathbf{r}_{BL})$ as their forward-looking return forecasts:

$$E\left(\mathbf{r}_{BL}\right) = \left[\left(\tau \boldsymbol{\Sigma}\right)^{-1} + \mathbf{P}'\boldsymbol{\Omega}\mathbf{P}\right]^{-1} \times \left[\left(\tau \boldsymbol{\Sigma}\right)^{-1} \boldsymbol{\mu}_M + \mathbf{P}'\boldsymbol{\Omega}\mathbf{Q}\right] \qquad (5.2)$$

where $E(\mathbf{r}_{BL})$ is a $n \times 1$ vector; $\mathbf{P}$ is a $k \times n$ matrix forming k views for n assets ($k \leq n$); $\mathbf{Q}$ is $k \times 1$vector showing the prior means of the view portfolios; and $\boldsymbol{\Omega}$ is a $k \times k$ diagonal covariance matrix measuring the degree of the managers' confidence in their own views.

As a result, with the implied equilibrium excess returns $\boldsymbol{\mu}_M$ and the B-L excess returns $E(\mathbf{r}_{BL})$ in hand, we can obtain the implied equilibrium total returns $\boldsymbol{\mu}_M^T$ and the B-L total returns $E(\mathbf{r}_{BL}^T)$ by adding the risk-free rate to them respectively.

After forming forward-looking return forecasts, we now enter into the MVMA framework. Due to SWFs being unleveraged positions, we need resort to Quadratic Programming (QP) optimisers to derive the solutions under short-selling constraints. Following Das et al. (2010), sovereign wealth managers can employ Value at Risk (VaR) as their risk management framework, which can be expressed by the MVMA problem as[17]

$$\text{Solve}_{\gamma}\ \mathbf{w}(\gamma)'\boldsymbol{\mu}+\Phi^{-1}(\alpha)\sqrt{\mathbf{w}(\gamma)'\boldsymbol{\Sigma}\mathbf{w}(\gamma)}=H \qquad (5.3)$$

where H is a threshold level of return for portfolio p; $\Phi(\bullet)$ is the cumulative standard normal distribution function; α is the maximum probability of the portfolio not reaching portfolio return $r(p)$; $\boldsymbol{\mu}$ is a $n\times1$ vector of expected returns, which can be replaced by $\boldsymbol{\mu}_M^T$ and $E(\mathbf{r}_{BL}^T)$; and $\mathbf{w}(\gamma)$ is the optimal weights for n assets as a

[17] Equation (5.3) implies that $\text{Prob}\left[r(p)\le H\right]\le\alpha$, which is analogous to $VaR_{\alpha}=H$ in the language of risk management.

function of the managers' implied risk aversion coefficient γ, which is the first order condition as the solution to the following MV problem:

$$\max_{\mathbf{w}} \mathbf{w}'\boldsymbol{\mu} - \frac{\gamma}{2}\mathbf{w}'\boldsymbol{\Sigma}\mathbf{w} \qquad (5.4)$$

subject to the full invested constraint and short-selling constraints

$$\mathbf{w}'\mathbf{1} = 1 \text{ , } \mathbf{w} \geq 0 \text{ and } \mathbf{w} \leq 1 \qquad (5.5)$$

According to equations from (5.3) to (5.5), for each sub-portfolio, each VaR constraint which is specified by a threshold level H and a probability value α in the MA problem corresponds to a particular implied coefficient of risk aversion γ in the MV problem. Thus, sovereign wealth managers solves the nonlinear equation (5.3) based on a specified γ i.e. a specified sub-portfolio, and thus derive the optimal portfolio weights $\mathbf{w}(\gamma)$ by solving the QP in equations (5.4) and (5.5). For the specified γ or sub-portfolio, the managers need check if the solution $\mathbf{w}(\gamma)$ can make equation (5.3) hold. If not, they must change γ properly and then solves the QP until equation (5.3) holds.

Embedding the B-L model into the MVMA framework, our multiple-goal investment strategy for China's SWF can be accomplished through three steps. First, to meet various macroeconomic policies such as providing liquidity support and transferring wealth across generations, sovereign wealth managers take their portfolios as a collection of three sub-portfolios. Table 5.7 displays the profile of our designed three sub-portfolios, including their policy objectives, risk tolerance, and investment horizon.

Table 5.7 Objectives, Risk Tolerance, and Investment Horizon of three Sub-Portfolios

Sub-Portfolio	Policy Objective	Risk Tolerance	Investment Horizon
Liquidity	Provide contingent liquidity supports to both internal and external banking sectors to cushion the possible negative effects caused by traditional financial crises and a "twin crisis"	Lower	Short
Investment	Invest in a medium-term goal to fund contingent domestic liabilities	Modest	Medium
Bequest	Transfer national wealth from now to the future and benefit next generations	Higher	Long

Notes: This table shows profiles of the designed three sub-portfolios for our multiple-goal SWF investment strategy.

The first is a ‘liquidity sub-portfolio’, where the managers specify higher risk-aversion coefficients, showing lower risk tolerance; and they invest in a short investment horizon for providing contingent liquidity support to both internal and external banking sectors to cushion against the possible negative effects triggered by traditional financial crises or ‘twin crisis’. The second is an ‘investment sub-portfolio’, in which the managers specify medium risk-aversion parameters, implying modest risk tolerance; and they invest in a medium-term investment horizon for funding contingent domestic liabilities, e.g. contingent pension payment. The third is a ‘bequest sub-portfolio’, in which the managers with lower risk-aversion parameters invest in a long-term investment horizon, attempting to transfer such national wealth from now to the future and thus to benefit subsequent generations. As a result, according to different types of funds, the managers can construct their distinct aggregate portfolios by allocating their total investable wealth across the three sub-portfolios in a variety of proportions. Generally, for a ‘conservative SWF’ (e.g. Stabilization Fund), most of the total investable wealth (more than 50%) should be allocated to the liquidity sub-portfolio, and the remainder into the other two, aiming mainly to meet large liquidity needs; whereas, for a ‘progressive SWF’ (e.g. Saving Fund, Pension Reserve Fund, or Reserve Investment Fund), most of the wealth should be allocated to the bequest sub-portfolio, and the remainder into the other two, due to their limited liquidity needs.

Second, before entering into their three sub-portfolios, the managers first choose their investment classes out of the available investment universe. They derive the implied equilibrium total return $\boldsymbol{\mu}_M^T$ in the light of market capitalization weights, and the B-L total returns $E(\mathbf{r}_{BL}^T)$ in the light of their forward-looking investment views. Finally, using $\boldsymbol{\mu}_M^T$ and $E(\mathbf{r}_{BL}^T)$ respectively, the managers figure out the two sub-groups of optimal asset allocation for the three sub-portfolios by solving equations (5.3) to (5.5), and construct their specified aggregate portfolios based on their overall policy objectives.

5.5 Empirical Analysis

5.5.1 Investment Universe of SWFs and Selection of Asset Classes

It is essential for sovereign wealth managers to first delineate their investment universe, i.e. the set of asset classes which will be selected for portfolio construction. This is a pivotal step towards forming the basis for the investment policy of SWFs. Some recent studies have probed various investment patterns for all types of SWFs, revealing important insights into their investment universe. As shown in Table 5.3, IMF (2012) investigates the observed asset allocations of the four types of SWFs at the end of 2010 based on the selected 30 SWFs, suggesting that the four asset types are used for SWF investment: cash, fixed income, equities, and alternative asset. By and large, Stabilization Funds are highly risk-averse institutional investors, while other three Funds are investors with relatively higher risk tolerance. IMF (2011) also examines the investment patterns of all types of SWFs based on these four asset types, and emphasises that specific factors such as the age of the SWF, its funding source, and its investment horizon could give rise to differences in asset allocations even if some SWFs have analogous objectives.

Kunzel et al (2011) compare the observed asset allocations of some SWFs based on these four asset types before the 2008 financial crisis with those after the crisis. They suggest that the recent crisis has affected the asset allocations of SWFs in different ways. For example, some stabilization funds such as Trinidad and Tobago's have decreased their holdings of Cash due to moving to Fixed Income, whereas Ireland National Pension Reserve Fund have increased its holdings of cash. Some Saving Funds such as Norway's and Canada's have increased their holdings of equities. The Korea Investment Corporation (KIC), one of Reserve Investment Funds, has introduced alternative asset investment and increased their holdings of equities. Finally, they conclude that these shifts are fund-specific and reflect individual circumstances. In addition, according to TheCityUK (2013), some SWFs have invested their funds in real estate. For example, China Investment Corporation (CIC) spent £245 million on purchase of Winchester House, the London headquarters of Deutsche Bank. Other SWFs such as Korea Investment Corporation (KIC) Azerbaijan's State Oil Fund, and Norway' Government Pension Fund Global (GPFG) have made investments in real estate in London during 2012.

In line with the recent observation of SWFs' asset allocations, we select sixteen asset classes covering the four asset types as our investment opportunity set. Half of these are safe assets, including the long-term government bonds of four developed countries, US corporate bonds, US Agencies, US Asset Backed Securities and US 3-month Treasury Bills. The rest are risky assets, comprising equities of four advanced economies, and four alternative assets.

5.5.2 Data and Implementation

For empirical analysis, we employ 16 indices, comprising bonds, equities and alternative assets, to mimic various market risk factors at the long-term investment horizon. For bonds, we use the long-term government bond indices of four advanced countries (USA, UK, Germany, and Australia), one US Agency bond index, one US asset backed security index, one 3-month US Treasury Bill index, and one US corporate bond index, all of which come from Bank of America Merrill Lynch. For equities, S&P 500, S&P EURO, S&P UK, and S&P ASX300 are employed as the proxies for US, Eurozone, UK, and Australia equities, respectively. For the four alternative assets, S&P GLOBAL REIT[18], S&P GSCI Commodity, UBS North American Infrastructure & Utilities, and UBS UK Infrastructure & Utilities are used as our proxies of China's SWF global investment in alternative assets. Monthly total return indices are employed over the sample period from January 1995 to January 2013, with a total of 217 observations. All total return indices are calculated in a log-return style based on a US-dollar denomination. The 3-month US T-Bill is approximated as the risk-free rate.

[18] REIT stands for Real Estate Investment Trust, one type of Alternative Asset in the US.

Table 5.8 reports the descriptive statistics for all asset classes considered. Among all government bonds, the Australia government bond has the best mean return with the highest standard deviation, while the US government bond has the lowest standard deviation. The German government bond has a slightly higher return than the US government bond, but has a relatively higher standard deviation. For all risk assets including equities and alternatives, UK Infrastructure & Utilities has highest mean return with 13.13%, while Euro equity has highest standard deviation with 22.93%. US T-Bill 3 Month has both lowest mean return and lowest standard deviation in all selected asset classes, showing the quality of highest safety.

Table 5.8 Descriptive Statistics

Name	Market	Instrument Type	Mean	Standard Deviation
US GVT	USA	Long-term Bonds	5.72%	3.14%
UK GVT	UK	Long-term Bonds	7.09%	8.71%
GERMAN GVT	Germany	Long-term Bonds	5.90%	10.59%
AUSTRALIA GVT	Australia	Long-term Bonds	9.22%	12.07%
US CORP	USA	Corporate	7.41%	5.49%
US AGENCIES	USA	Agencies	5.74%	2.74%
US ABS	USA	Asset Backed Securities	5.31%	2.36%
US T-BLL 3M	USA	Cash Equivalents	3.15%	0.65%
US EQUITY	USA	Equities	8.48%	16.80%
UK EQUITY	UK	Equities	7.91%	17.65%
EURO EQUITY	Euro Zone	Equities	7.70%	22.93%
AUSTRALIA EQUITY	Australia	Equities	11.32%	22.39%
GLOBAL REIT	International	Alternatives	10.61%	20.68%
GLOBAL COMMODITY	International	Alternatives	4.50%	23.71%
NA INFRA & UTIL	North America	Alternatives	9.24%	15.47%
UK INFRA & UTIL	UK	Alternatives	13.13%	16.39%

Notes: This table shows descriptive statistics of all considered asset classes. Our calculations employ monthly data. The mean returns and standard deviations are reported annually.

Before running the MVMA framework, we improve our expected return forecasts using the B-L model. Using the implied equilibrium excess returns as the starting point, sovereign wealth managers formulate their forward-looking investment views. Studies such as IMF (2012) suggest that the recent financial crises have caused a rise in the demand for safe assets, boosting their price in global markets based on their limited availability. Consequently, taking equilibrium excess returns as a reference, the managers infer that government bonds are more favourable, and make three conservative assumptions: (1) US equity will outperform US government bonds by only 5.5%; (2) UK equity will exceed UK government bonds by only 3.05%; and (3)

Australia equity will exceed Australia government bonds by only 3%. In addition, the managers expect that the US and Canada economies will perform better than the UK economy, forming the fourth view that NA INFRA & UTIL will exceed UK INFRA & UTIL by 2.8%. The confidence levels of all four investment views are set at 50%.

Table 5.9 shows market weights of the selected asset classes and their two estimates, i.e. equilibrium total returns and the B-L total returns. Concerning market weights, US equity has the largest market capitalization of all the selected asset classes; US government bonds and US agencies have the second and the third largest, respectively; while the UK Infrastructure & Utilities has the least market capitalization. Due to the three conservative assumptions and the one investment view favouring NA INFRA & UTIL, with the exception of North American Infrastructure & Utilities, B-L total returns of all risky assets are slightly less than the equilibrium total returns. For safe assets, only B-L total returns of US government bonds, US agencies, and US T-Bill 3M are not less than those of the equilibrium total returns.

Table 5.9 Market Weights and Return Estimates

Name	Market Weights	Equilibrium Total Returns	The B-L Total Returns
US GVT	23.72%	3.02%	3.12%
UK GVT	2.73%	4.94%	4.77%
GERMAN GVT	3.29%	5.26%	5.02%
AUSTRALIA GVT	0.82%	7.24%	6.63%
US CORP	6.14%	4.23%	4.21%
US AGENCIES	13.60%	3.21%	3.26%
US ABS	0.33%	3.40%	3.39%
US T-BLL 3M	3.00%	3.12%	3.12%
US EQUITY	24.12%	10.67%	9.70%
UK EQUITY	4.40%	10.99%	9.55%
EURO EQUITY	6.57%	13.08%	11.29%
AUSTRALIA EQUITY	2.25%	12.45%	10.73%
GLOBAL REIT	2.15%	10.87%	9.69%
GLOBAL COMMODITY	5.37%	9.54%	8.95%
NA INFRA & UTIL	1.32%	7.64%	7.78%
UK INFRA & UTIL	0.21%	7.93%	6.52%

Sources: Market capitalization data of all safe assets are from BIS Securities Statistics on the BIS official website. The data of all risky assets are from DataStream.
Notes: Market weights are obtained based on market capitalization data of all asset classes. Equilibrium total returns and the B-L total returns are derived by adding the risk-free rate to equilibrium excess returns and the B-L excess returns, respectively.

With equilibrium and the B-L total return, we now use the MVMA framework to implement our multiple-goal investment strategy for China's SWF. By working out equations (5.3) to (5.5), we obtain the two sets of optimal portfolio weights for the selected asset classes. According to each of these sets of optimal weights, we construct our three sub-portfolios, i.e. the liquidity, the investment, and the bequest sub-portfolios, by specifying three distinct risk-aversion parameters from high to low, to achieve our various macroeconomic policy objectives. We also construct distinct aggregate portfolios by allocating the total investable wealth into the three sub-portfolios in a variety of proportions. Specifically, we construct two different aggregate portfolios: the first, which is to mimic a 'conservative SWF', is based on an 50:30:20 division across the three sub-portfolios (50% of the total investable wealth from the liquidity sub-portfolio, 30% from the investment sub-portfolio, and 20% from the bequest sub-portfolio); the second, which is to mimic a 'progressive SWF', is based on a 10:40:50 division. Finally, we investigate the MA problem for all portfolios based on equation (5.3). Within each portfolio, a VaR constraint makes various threshold levels of returns map into their maximum probabilities of not reaching those threshold return levels.

5.5.3 Main Results

5.5.3.1 The results based on equilibrium returns

Table 5.10 shows the holdings of efficient portfolios for the three sub-portfolios and two aggregate portfolios for all asset classes under the equilibrium return estimates. Although Mehra and Prescott (1985) suggest that the range of risk aversion coefficient should be within the interval from 0 to 10, many studies, such as Ait-Sahalia and Brandt (2001), employ the range of risk aversion coefficient from 0 to 20. We argue that the value in risk aversion coefficient only conveys the degree of risk aversion for investors. As a result, our selection of risk aversion coefficient is within the range from 0 to 20.

Table 5.10 Holdings of Efficient Portfolios of the three Sub-Portfolios and the two Aggregate Portfolios for Equilibrium Returns

Risk Aversion:	γ = 12.725	γ = 5.526	γ = 3.312	50:30:20 Mix	10:40:50 Mix
Asset Classes	**Liquidity Sub-portfolio**	**Investment Sub-portfolio**	**Bequest Sub-portfolio**	**Aggregate Portfolio 1**	**Aggregate Portfolio 2**
US GVT	10.90%	27.48%	0.03%	13.70%	12.10%
UK GVT	0.89%	2.86%	0.29%	1.36%	1.38%
GERMAN GVT	1.92%	4.53%	9.71%	4.26%	6.86%
AUSTRALIA GVT	1.36%	1.23%	4.35%	1.92%	2.80%
US CORP	4.10%	9.23%	0.79%	4.98%	4.50%
US AGENCIES	2.22%	3.08%	0.02%	2.04%	1.47%
US ABS	2.06%	0.09%	0.02%	1.06%	0.25%
US T-BLL 3M	54.53%	0.05%	0.01%	27.28%	5.48%
US EQUITY	11.59%	27.30%	42.87%	22.56%	33.51%
UK EQUITY	2.24%	4.39%	6.34%	3.70%	5.15%
EURO EQUITY	2.90%	7.33%	12.55%	6.16%	9.50%
AUSTRALIA EQUITY	0.96%	2.39%	5.51%	2.30%	3.81%
GLOBAL REIT	1.02%	2.33%	5.84%	2.38%	3.96%
GLOBAL COMMODITY	2.39%	5.88%	8.66%	4.69%	6.92%
NA INFRA & UTIL	0.73%	1.34%	2.42%	1.25%	1.82%
UK INFRA & UTIL	0.20%	0.50%	0.58%	0.37%	0.51%
Cash Equivalents	54.53%	0.05%	0.01%	27.28%	5.48%
Bonds	23.46%	48.50%	15.20%	29.32%	29.35%
Equities	17.68%	41.40%	67.28%	34.72%	51.97%
Alternatives	4.33%	10.05%	17.51%	8.68%	13.21%
Safe Assets	77.99%	48.55%	15.21%	56.60%	34.82%
Risky Assets	22.01%	51.45%	84.79%	43.40%	65.18%
Total Weights	100%	100%	100%	100%	100%
Expected Returns	4.98%	7.40%	10.17%	6.74%	8.54%
Std. Dev.	3.87%	8.82%	14.69%	7.52%	11.26%

Notes: The portfolio weights for all portfolios are obtained using the solutions in equations (5.3) to (5.5). The expected returns and standard deviations of all portfolios are presented at the bottom of the table.

According to Table 5.10, for the liquidity sub-portfolio, with the highest risk-aversion parameter out of the three sub-portfolios, i.e., $\gamma = 12.725$, its expected return gains 4.98%, with standard deviation of 3.87%. As a result of its lower risk tolerance, the liquidity sub-portfolio holds 77.99% in safe assets, comprising 54.53% in cash equivalents and 23.46% in bonds; and 22.01% in risky assets, made up of 17.68% in equities and 4.33% in alternatives. For the investment sub-portfolio, with $\gamma = 5.526$, the largest holding would be US government bonds (27.48%) and the second largest would be US equity (27.30%). Because of its medium risk tolerance, this portfolio holds 48.55% in safe assets (0.05% in cash equivalent and 48.50% in bonds) and 51.45% in risky assets (41.40% in equities and 10.05% in alternatives). For the bequest sub-portfolio, with $\gamma = 3.312$, the largest holding would be US equity (42.87%) and the second largest would be Euro equity (12.55%). As a consequence of its having the highest risk tolerance out of the three, this portfolio holds 15.21% in safe assets (0.01% in cash equivalents and 15.20% in bonds) and 84.79% in risky assets (67.28% in equities and 17.51% in alternatives). The aggregate portfolio 1 (50:30:20 mix) holds 56.60% in safe assets and 43.40% in risky assets, implying its relatively higher risk averse attitude, while the aggregate portfolio 2 (10:40:50 mix) holds 65.18% in risky assets and the remainder in safe assets, indicating its higher risk tolerance.

Table 5.11 depicts the threshold levels of return and the corresponding maximum probabilities of not reaching them for the three sub-portfolios and the two aggregate portfolios under equilibrium return estimates. The results in this Table probe the

Mental Accounting problem by solving a VaR constraint, i.e. equation (5.3), to measure the risk tolerance of each portfolio.

Table 5.11 Threshold Return Levels and Corresponding Maximum Probabilities of Not Reaching Them for Equilibrium Returns

Risk Aversion:	γ = 12.725	γ = 5.526	γ = 3.312	50:30:20 Mix	10:40:50 Mix
Asset Classes	Liquidity Sub-Portfolio	Investment Sub-Portfolio	Bequest Sub-portfolio	Aggregate Portfolio 1	Aggregate Portfolio 2
-10.00%	0.01%	2.43%	8.49%	1.30%	4.98%
-5.00%	0.50%	7.99%	15.09%	5.91%	11.46%
-3.00%	1.96%	11.92%	18.50%	9.75%	15.27%
0.00%	9.91%	20.07%	24.44%	18.49%	22.40%
3.00%	30.45%	30.89%	31.27%	30.93%	31.13%
5.00%	50.21%	39.28%	36.24%	40.83%	37.66%
10.00%	90.27%	61.59%	49.54%	66.76%	55.15%
Expected Returns	4.98%	7.40%	10.17%	6.74%	8.54%
Std. Dev.	3.87%	8.82%	14.69%	7.52%	11.26%

Notes: The results are computed using equation (5.3) after obtaining portfolio returns and standard deviations for each portfolio.

In Table 5.11, we can observe that the maximum probabilities that sovereign wealth managers would have negative returns are 9.91%, 20.07%, and 24.44% for the liquidity, the investment, and the bequest sub-portfolios, respectively, and for the aggregate portfolios 1 and 2 they are 18.49% and 22.40%, respectively. On the other hand, the maximum probabilities of not reaching 10% threshold return levels are 90.27%, 61.59%, and 49.54% for the liquidity, the investment, and the bequest sub-portfolios, respectively, and for the aggregate portfolios 1 and 2 they are 66.76% and

55.15%, respectively. These results suggest that the liquidity sub-portfolio offers the best way of flight to safety among the three sub-portfolios, while the bequest sub-portfolio has the highest probability of earning higher return; and that holdings in the aggregate portfolio 1 are relatively safer than those in the aggregate portfolio 2.

5.5.3.2 Results based on the B-L returns

In this sub-section, all the results are according to the B-L return estimates. After the wealth managers state their three conservative investment views and the one investment view favouring NA INFRA & UTIL, Table 5.12 and Table 5.13 correspond to and convey the same information as Tables 5.10 and 5.11, respectively.

Table 5.12 Holdings of Efficient Portfolios of the three Sub-Portfolios and the two Aggregate Portfolios for the B-L Returns

Risk Aversion:	γ = 12.725	γ = 5.526	γ = 3.312	50:30:20 Mix	10:40:50 Mix
Asset Classes	**Liquidity Sub-portfolio**	**Investment Sub-portfolio**	**Bequest Sub-portfolio**	**Aggregate Portfolio 1**	**Aggregate Portfolio 2**
US GVT	12.91%	27.42%	0.05%	14.69%	12.28%
UK GVT	1.20%	2.96%	0.19%	1.53%	1.40%
GERMAN GVT	3.35%	8.28%	11.16%	6.39%	9.23%
AUSTRALIA GVT	1.27%	1.31%	4.23%	1.87%	2.77%
US CORP	4.74%	10.13%	0.13%	5.43%	4.59%
US AGENCIES	0.31%	0.16%	0.04%	0.21%	0.12%
US ABS	0.59%	0.06%	0.04%	0.32%	0.10%
US T-BLL 3M	54.41%	0.04%	0.03%	27.22%	5.47%
US EQUITY	13.74%	32.22%	50.06%	26.55%	39.29%
UK EQUITY	0.01%	0.01%	0.09%	0.03%	0.05%
EURO EQUITY	0.49%	1.32%	4.38%	1.51%	2.76%
AUSTRALIA EQUITY	0.03%	0.02%	0.95%	0.21%	0.48%
GLOBAL REIT	0.05%	0.03%	1.90%	0.41%	0.97%
GLOBAL COMMODITY	2.66%	6.38%	10.20%	5.28%	7.92%
NA INFRA & UTIL	4.26%	9.66%	16.55%	8.34%	12.57%
UK INFRA & UTIL	0.00%	0.00%	0.02%	0.01%	0.01%
Cash Equivalents	54.41%	0.04%	0.03%	27.22%	5.47%
Bonds	24.36%	50.31%	15.84%	30.44%	30.48%
Equities	14.27%	33.57%	55.47%	28.30%	42.59%
Alternatives	6.97%	16.08%	28.66%	14.04%	21.46%
Safe Assets	78.77%	50.36%	15.87%	57.66%	35.95%
Risky Assets	21.23%	49.64%	84.13%	42.34%	64.05%
Total Weights	100%	100%	100%	100%	100%
Expected Returns	4.60%	6.54%	8.70%	6.00%	7.43%
Std. Dev.	3.49%	7.93%	13.21%	6.77%	10.13%

Notes: The portfolio weights for all portfolios are obtained using the solutions in equations (5.3) to (5.5). The expected returns and standard deviations of all portfolios are presented at the bottom of the table.

Table 5.13 Threshold Return Levels and Corresponding Maximum Probabilities of Not Reaching Them for the B-L Returns

Risk Aversion:	γ = 12.725	γ = 5.526	γ = 3.312	50:30:20 Mix	10:40:50 Mix
Asset Classes	**Liquidity Sub-Portfolio**	**Investment Sub-Portfolio**	**Bequest Sub-portfolio**	**Aggregate Portfolio 1**	**Aggregate Portfolio 2**
-10.00%	0.00%	1.86%	7.85%	0.90%	4.27%
-5.00%	0.29%	7.30%	14.99%	5.20%	11.00%
-3.00%	1.46%	11.47%	18.79%	9.17%	15.17%
0.00%	9.34%	20.51%	25.51%	18.75%	23.17%
3.00%	32.27%	32.80%	33.30%	32.86%	33.11%
5.00%	54.51%	42.33%	38.96%	44.11%	40.54%
10.00%	93.91%	66.88%	53.91%	72.26%	60.03%
Expected Returns	4.60%	6.54%	8.70%	6.00%	7.43%
Std. Dev.	3.49%	7.93%	13.21%	6.77%	10.13%

Notes: The results are computed using equation (5.3) after obtaining portfolio returns and standard deviations for each portfolio.

Compared with the results in Table 5.10, Table 5.12 illustrates that, for the liquidity sub-portfolios, with the exception of the Australia government bond, holdings of all other government bonds have increased slightly, which indicates that those conservative investment views shift the portfolio towards government bonds. For each portfolio in Table 5.12, due to the view favouring North American Infrastructure & Utilities, holdings of the NA INFRA & UTIL increase, which causes a shift in the composition of risky assets from equities to alternatives. However, because of the overall conservative investment views, for each portfolio, both the expected returns and standard deviations under the B-L return estimates are lower than those under equilibrium return estimates.

For the MA problem, Table 5.13 implies that, for the liquidity sub-portfolio, the maximum probability of having a negative threshold return level is 9.34%, slightly less than the probability reported in Table 5.11, due to the fact that the performances in this sub-portfolio, i.e. the expected portfolio return and standard deviation, decline to some degree, compared with the results in Table 5.11.

5.6 Conclusions

The recent trend of SWF investment practices can be summarized in two aspects. On the one hand, the 07-08 financial crises seem to shift the nature of SWFs, suggesting that SWFs are not only investors with a long-term investment horizon for transferring wealth from now to the future, but also need to provide contingent liquidity to systemically important financial institutions when necessary. On the other hand, with the rapid rise of the size of most SWFs, they usually attempt to accomplish these two objectives by constructing more than one SWF or dividing one SWF into several types. Thus, most SWFs implement a de facto multiple-goal investment strategy.

However, existing related literature has never provided a theoretical framework on it. In this chapter, we explicitly propose a multiple-goal SWF investment framework for China's SWF by embedding the Black-Litterman model into the Mean Variance Mental Accounting framework. The B-L model is used as a means of forming forward-looking return forecasts, while the MVMA framework help us to achieve multiple goals. In our proposed framework, we assume that there are three sub-portfolios i.e. goals: the precautionary, the investment, and the bequest sub-portfolios. Our investment framework and risk management framework can converge to equation (5.3), in which, for each sub-portfolio, each VaR constraint which is specified by a threshold level H and a probability value α in the MA problem corresponds to a particular implied coefficient of risk aversion γ in the MV problem. Risk tolerance can be measured by VaR. For aggregate portfolios, we can construct their distinct ones by allocating their total investable wealth across the three sub-portfolios in a variety of proportions, according to different types of funds. For example, concerning Stabilization Funds, most of the total investable wealth (e.g. more than 50% or even more) should be allocated into the precautionary sub-portfolio, and the remaining into the other two, mainly aiming to smooth out their government budgets against the fluctuation of commodity prices; whereas, concerning the other three types of funds, most of the wealth should be allocated into the bequest sub-portfolio, and the remaining into the other two, due to their limited liquidity needs.

For future research, the chapter suggests that, for a certain SWF, the optimal ratio of each sub-portfolio to its total investable wealth is beyond the scope of this chapter. But it is a very important issue, especially when different SWFs have very distinct risk exposures. Thus, it is necessary to explore the optimal size of each sub-portfolio for a certain SWF conditional on its unique economic environment.

Chapter 6

CONCLUSIONS

6.1 Main Findings

This thesis engages in theoretical modelling and empirical testing of China's management of official foreign assets, where China's central bank and sovereign wealth fund are the representative agents in a risky world. Specifically, this research focuses on exploring the decision making of these representative agents, by incorporating some behavioural elements into the agents' traditional risk preferences in order to improve the performance of standard models in both positive and normative ways. The first decision, made by China's central bank, as the only agent representing all players in the economy and hence who is both consumer and producer, is how to allocate output or income denominated in foreign assets between current consumption and savings for funding future consumption. The second decision, made by both the reserve manager and the sovereign fund manager as representative agents, is how to invest the savings settled by the first decision in an optimal way so as to meet distinct macroeconomic objectives and investment strategies.

After providing a comprehensive review of the related literature, this thesis investigates the first decision from a normative perspective; i.e. it develops a nonstandard model of optimal reserve holdings and thus expounds the reserve accumulation behaviour by China's central bank, in a behavioural framework that deals with decision making under uncertainty introduced by Barberis et al. (2001), among others. Assuming that the agent is subject to cognitive biases such as loss aversion and narrow framing when evaluating uninsured income risks in terms of fluctuations in GDP growth, our model embeds influences of these cognitive biases into the model of precautionary motive for large reserve stockpiling. Our model indicates that the precautionary saving motive is strengthened when the agent is cognitively biased, implying that the more the policy maker cares about GDP growth, the more she needs reserve assets as a precautionary means of providing self-insurance against uninsured income risks.

The thesis next probes the second decision problem by proposing a multiple-objective investment framework for China's central bank reserve management and for China's SWF's investment. This involves employing a novel approach that incorporates the Black-Litterman model into the Mean Variance Mental Accounting (MVMA) framework developed by Das et al. (2010).

For reserve management in China, two sub-portfolios are designed to meet the multiple objectives of 'safety, liquidity, and profitability'. The first is the precautionary sub-portfolio, which exhibits higher risk aversion and favours safe and liquid assets. Such a sub-portfolio is thus capable of fulfilling both safety and liquidity objectives of reserve management. The second is the 'investment sub-portfolio', which displays lower risk aversion and can satisfy reserve managers' desire for seeking higher returns and thus fulfill the return objective.

Aggregate portfolios are also naively formed to show various optimal portfolio weights, based on different overall risk attitudes of the reserve manager. Under this investment strategy, the Black-Litterman (B-L) model is used to improve return forecasts and thus to overcome the maximisation problem of mean-variance optimisation. Employing equilibrium returns as a starting point, the B-L returns are obtained by adding the reserve managers' views. Eventually, taking China as an example, this behavioural reserve management framework is applied to practical use.

For the management of sovereign wealth fund in China, this thesis focuses on its investment strategy. Correspondingly, three sub-portfolios are created for its various assigned tasks over different investment horizons. The first is the 'liquidity sub-portfolio', over which the fund manager is specified higher risk-aversion coefficients, showing lower risk tolerance, and the manager invests in a short investment horizon for providing contingent liquidity supports as a means of self-insurance to cushion the possible negative effects triggered by for example commodity price volatility or systemic risks. The second is the 'investment sub-portfolio', where the manager is assumed to have medium risk-aversion, i.e. moderate risk tolerance, and the manager invests in a medium-term investment horizon for funding contingent domestic liabilities (e.g. contingent pension payment for Pension Reserve Funds). The third is a 'bequest sub-portfolio', over which the manager has lower risk-aversion and invests in a long-term investment horizon with a view to transferring national wealth from now to the future and thus to benefit future generations. Distinct aggregate portfolios can be constructed by allocating their total investable wealth across the three sub-portfolios in a variety of proportions, according to different types of funds. This multiple-goal investment framework is also applied to the case of China to derive optimal investment decisions for the nation's sovereign wealth fund.

6.2 Theoretical and Policy Implications

This thesis provides important implications for China's economic policy makers and foreign asset managers. For the policy makers, I argue that the observed increasing Reserves/GDP ratio over the last decade can be attributed to imbalances in the economic structure itself, caused by current economic strategy i.e. overemphasising on GDP maximisation with great reliance on export-led policy. On the one hand, due to its great reliance on export-led policy, the economy is apt to suffer from external shocks and therefore is exposed to more vulnerability, particularly in current financial crisis. On the other hand, overemphasising on GDP maximisation implies that more resources have been poured into physical infrastructure rather than into human capital and social security, which has brought about the underdevelopment of some crucial social reforms, such as financial reforms and pension reforms. Financial underdevelopment and inefficient pension reforms generate inadequate social security coverage. As a result, private consumption is weak and both domestic saving rates and

Reserves/GDP ratio are high. In brief, facing large uncertainties caused by current economic strategy, it is indispensable that individuals tend to allocate their income more into savings as a self-insurance in response to the current uncertain economic circumstances. Thus, my findings suggest that if the policy makers do not change current growth pattern, reserve accumulation in China seems to continue, and that a shift in the country's economic model must be done from export-led growth toward greater reliance on domestic demand, particularly household consumption.

For the foreign asset managers, contributing to the literature on strategic asset allocation for central banks and investment strategies for SWFs, the behavioural foreign asset management framework provides a theoretical underpinning to indicate how to implement a multiple-objective investment strategy for both reserve and SWF managers. Against conventional method, this framework shows two advantages. First, the creation of a sub-portfolio associated with a certain goal allows both managers to make investment decisions by specifying their implied risk aversion coefficients. Second, risk can be measured by the maximum probabilities of not reaching the threshold of each goal, i.e. the VaR constraints. This measurement ensures that the managers can measure risks directly and efficiently. Using these two advantages, not only can the managers specify different degrees of risk aversion to formulate their desired sub-portfolios, but also they can adjust the allocations of their total investable reserves across sub-portfolios to construct different aggregate portfolios, and can establish their desirable aggregate portfolio based on this risk measurement. This behavioural foreign asset management framework can be widely used by central banks who hold excessive reserves or by countries who own SWFs. Advanced economies and emerging and developing countries may employ this framework to achieve their sound reserve and SWF management practices.

6.3 The Limitations of This Study and Future Research

This thesis has some limitations. First, the current reserve management framework does not consider the issues related to the liability side within fund management, which is one of most important elements for developing sound fund management policy. Second, the current investable universe for reserve management is not extensive. Third, for SWF investment strategies, the aggregate portfolios are naively constructed by only allocating the total investable wealth across the three sub-portfolios in a variety of proportions.

In response to these limitations, some directions for future research can be listed as below:

> First, asset-liability management (ALM), as an alternative to fund management, has been well documented (Romanyuk 2010). Therefore, the first direction for future research would be to use different approaches under

ALM to derive optimal investment decisions for central banks' management of reserves.

The second direction is to consider broadening the set of asset classes to expand the investable universe of official reserve managers. Gold would be of particular interest as an asset class. Gold has a long history as a reserve asset. In the current volatile world where safe assets are in great demand, gold's attribute as a safe asset is attracting growing interest from global reserve managers. Thus, consideration of the investment opportunity offered by gold would be an important avenue for reserve managers to expand the possibilities for diversification.

Third, for efficient management of China's SWF, it is both important and desirable to derive the optimal shares of each sub-portfolio in the total of China's investable external wealth, taking into consideration of Chinese SWF's unique risk exposure. Therefore, the third direction for future research would be to engage in theoretical modelling to explore the optimal size of each sub-portfolio for China's SWF, conditional on the changing economic environment.

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