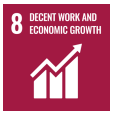


Evaluating the Impact of Macroeconomic Policies in a Partially Dollarized Economy: The Case of Cambodia

A Dissertation

Submitted to the National Graduate Institute for Policy Studies (GRIPS)

in Partial Fulfillment of the Requirements for the Degree of

Ph.D. in Advanced Policy Studies

by

Johann Chhoeung

March 2024

To my dear deceased father, Rev. Chhoeung Yim

Evaluating the Impact of Macroeconomic Policies in a Partially Dollarized Economy: The Case of Cambodia

Thesis Abstract

This thesis covers two main research topics on dollarization in Cambodia. Chapter 3 discusses the effects of the currency requirement in loan policy on banking and financial institutions. Cambodia is a partially dollarized country, with high dollarization since it opened itself to the world in the 1990s. Dollarization has hindered the National Bank of Cambodia (NBC) from implementing its monetary policy. While NBC has implemented various measures against dollarization, these are soft measures meant primarily to affect the public's behavior and not necessarily force them to stop using foreign currencies. In an effort to more effectively address the persistently high degree of dollarization, on December 1, 2016, the National Bank of Cambodia issued a hard measure—an administrative measure—to influence the level of dollarization within the banking system. Specifically, the policy is a national currency promotion (de-dollarization) regulation that mandates banking and financial institutions to increase their loan share in Khmer riel (KHR) to at least 10% of the total loan portfolio, which includes both KHR and US dollars (USD) mostly. This policy took effect on the date of issue and required full compliance by all institutions by December 31, 2019 (i.e., three years later). We are interested in the unintended effect of this policy. Therefore, we use policy evaluation methodology by applying a state-space model with aggregate loan data to estimate the counterfactual and evaluate the impact of the policy on banking and financial institutions in Cambodia over the implementation period. We use the CausalImpact R package for our approach.

Contrary to our initial hypothesis that this policy might result in losses for the banking system, it had a positive side effect.

Chapter 4 assesses the impact of foreign interest rate shock on Cambodia's small open and dollarized economy using the small open economy real business cycle (SOE-RBC) model. We also assess the responses to preference and technology shocks, which are quite usual in such a model. The model is originally used to estimate a standard or non-dollarized small open economy with an incomplete asset market where residents purchase risk-free foreign bonds to insure their wealth. We frame Cambodia's economy to fit the model due to its high level of dollarization, where people make deposits and transact in USD to hedge their wealth against devaluation risk and by making assumptions on certain features of the economy. This allows us to apply the model by substituting the interest rate on foreign bonds in the original model with the domestic term deposit interest rate in US dollars. We use data from Cambodia and Bayesian estimation to generate impulse responses that confirm our intuitions, where the foreign interest rate shock is negatively related to domestic consumption and investment while positively associated with the trade balance and current account. However, the Bayesian variance decomposition shows that foreign interest rate shock is not the primary driver of the business cycle, contrary to our expectations.

Keywords: Bank, Cambodia, de-dollarization, dollarization, loan currency, MFI, state-space model, policy evaluation, DSGE, SOE-RBC, small open economy

Acknowledgment

First, I extend my deepest gratitude to Jesus Christ, my Lord and Savior, whose divine guidance has led me on this academic journey and sustained me throughout.

I am immensely thankful to my advisor, Professor Roberto Leon Gonzalez, whose unwavering support and expert guidance have been instrumental in successfully completing my doctoral study and this thesis. His patience, motivation, and profound knowledge have been a source of inspiration, and I am truly fortunate to have had such an exceptional mentor. I also express my gratitude to my sub-advisors, Professor Ponpoje Porapakkarm and Professor Lim Guanie, who read my thesis and provided constructive comments. Additionally, comments from Professor Ippei Fujiwara, external referee, and Professor Stephan Litschig, acting chairperson of the doctoral programs committee, which I received on the day of my defense, were very constructive. In addition, I thank Professor Kazushi Takahashi, program director of G-Cube, who heard my presentation several times and provided insightful comments.

I express my sincere appreciation to all the professors at GRIPS whose courses have enriched my learning experience and laid the foundation for this thesis. Their invaluable insights and teachings have been crucial in shaping my academic endeavors.

Special gratitude is extended to the dedicated administration team at GRIPS and the G-Cube program, particularly for their relentless efforts in fostering the success of all G-Cube students. I am especially grateful for the kindness extended to me, which has made my academic journey smoother.

My heartfelt thanks go to my classmates whose support and care have been a constant source of academic and personal strength. Their camaraderie has made my time in Japan memorable.

I would like to express my most profound appreciation to my family—my mother, brother, and sister—for their unwavering support from afar. My dear deceased father, who looks down from heaven, must be pleased with my achievement. He placed his trust in me on this journey when he was alive, and his memory has been a driving force behind my accomplishments.

Lastly, I am grateful to my scholarship sponsor, JICA, for their generous support in facilitating my studies and life in Japan. I also appreciate my workplace, the National Bank of Cambodia, for allowing me to pursue my studies and sponsoring me with data and regular allowance.

To God be the glory for the opportunities and blessings bestowed upon me throughout this journey.

Johann Chhoeung

Table of Contents

List of Figures

List of Tables

List of Abbreviations

DSGE: Dynamic Stochastic General Equilibrium

FCD: Foreign Currency Deposits

JICA: Japan International Cooperation Agency

KHR: Khmer Riel

LPCO: Liquidity-Providing Collateralized Operation

MFI: Micro Finance Institution

NBC: National Bank of Cambodia

NCD: Negotiable Certificate of Deposit

RBC: Real Business Cycle

SOE-RBC: Small-Open Economy Real Business Cycle

USD: US Dollar

Chapter 1: Introduction

This thesis consists of two core chapters: Chapters 3 and 4. Chapter 3 highlights Cambodia's enduring struggle with dollarization and its implications for the National Bank of Cambodia (NBC). Chapter 4 explores the macroeconomic responses within the country, particularly concerning foreign interest rate shock. These two narratives offer a comprehensive view of Cambodia's unique economic landscape.

Since embracing globalization in the early 1990s, Cambodia has grappled with a high degree of dollarization, as highlighted in Chapter 2. Dollarization, the widespread use of foreign currency alongside the local currency, has posed significant challenges for Cambodia's central bank, the NBC. This phenomenon has impeded the NBC's ability to implement effective monetary policy. While the NBC has attempted various measures to reduce dollarization, these strategies have primarily relied on soft incentives rather than forceful mandates.

To address this persistent issue, the NBC introduced an administrative measure in 2016, as described in Chapter 3. This policy mandated that banks and financial institutions increase their loan portfolios in KHRs to at least 10% of the total loans (total loans consist of KHR and USD loans). Surprisingly, this hard measure had a positive side effect, contrary to our initial expectation: it provides a glimmer of hope in the battle against dollarization.

Chapter 4 delves into the economic dynamics of Cambodia, particularly its response to foreign interest rate shock. This analysis was facilitated by the country's high degree of dollarization, allowing us to frame an existing model for Cambodia for convenience. We apply the small open economy real business cycle (SOE-RBC) model to estimate Cambodia's economy. Our finding reveals that a foreign interest rate shock

causes expected movements in the macroeconomic variables of the Cambodian economy. However, it fails to confirm our expectation that foreign interest rate shock is the primary driver of the business cycle.

Nevertheless, connecting the findings from Chapters 3 and 4, we see that Cambodia's struggle with dollarization is not isolated but intricately linked to its broader economic dynamics. The administrative measures implemented by the NBC, as described in Chapter 3, are essential components in addressing dollarization and rebalancing the economy. These measures, which met with skepticism initially, have shown that innovative approaches can yield unexpected positive outcomes.

In conclusion, Cambodia's journey toward reducing dollarization and understanding its economic responses to external shocks is a testament to its resilience and adaptability. The insights from these two findings underscore the importance of holistic economic analysis and dynamic policy measures in shaping the future of Cambodia's economy. As the nation continues to evolve globally, observing how these intricate dynamics unfold will be fascinating.

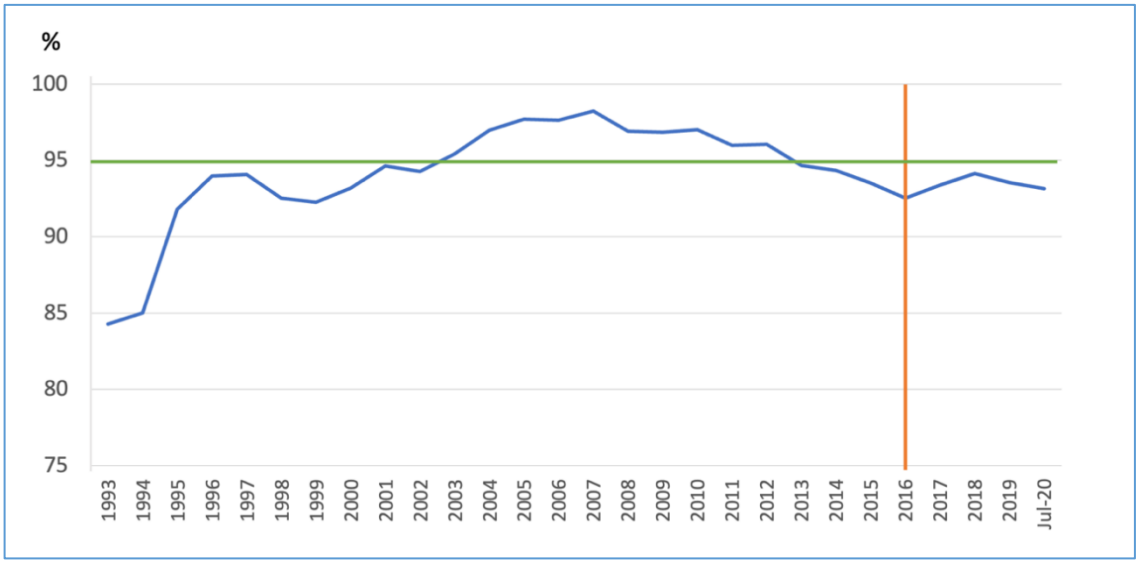
Chapter 2: Background

This chapter presents the recent background of dollarization in Cambodia which led to the adoption of countermeasures against dollarization.

2.1-Current Situation of Dollarization in Cambodia

Dollarization occurs when a country uses foreign currencies instead of the local currency (Yeyati & Rey, 2006). When a country uses foreign currencies alongside the local currency, it is called partial dollarization (Armas, 2015). Partial dollarization, commonly loosely referred to as dollarization (without the word *partial*), has persisted since Cambodia opened itself to globalization in the early 1990s. Therefore, we use the terms dollarization and partial dollarization interchangeably to refer to partial dollarization. For simplicity, our study refers to dollarization as the use of USD alone (although a small percentage of other foreign currencies are used in some bordering regions) because USD is the primary foreign currency in Cambodia. Dollarization, as measured by the share of USD to total deposits (deposit in KHR plus deposit in USD), has stagnated at 95% on average over the previous 20 years before 2016 (Figure 2.1). We chose to analyze up to 2016 because this year is pivotal for a policy implementation described in the next chapter.

Figure 2.1: USD Deposit to Total Deposits, in Percentage, 1993–July 2020

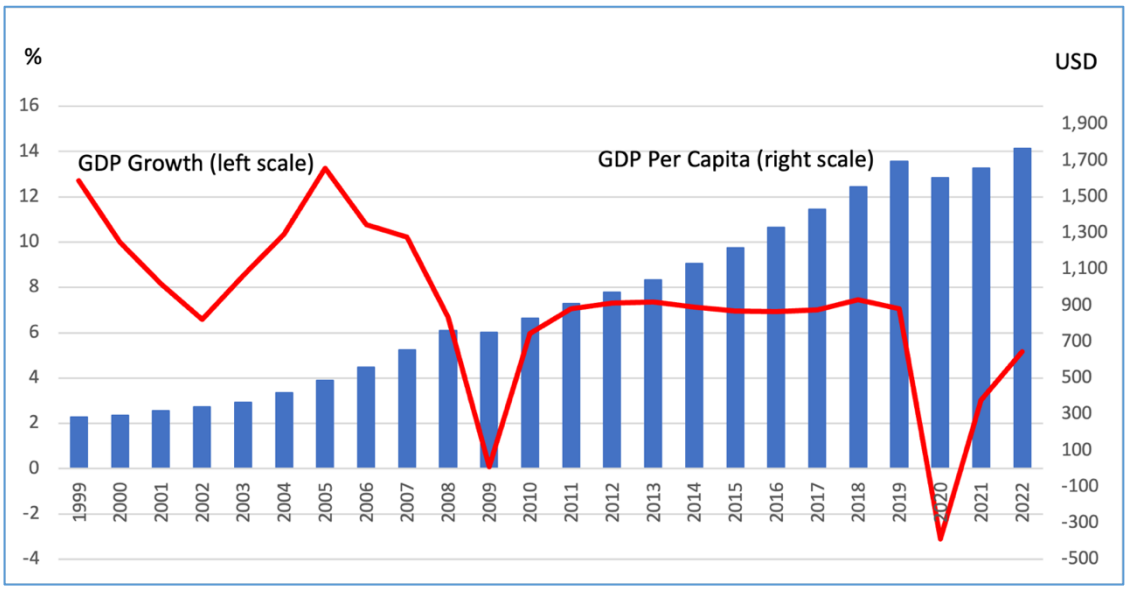


Source: National Bank of Cambodia

As mentioned in the author's master's thesis, "The Monetary Determinants of Foreign Currency Deposits in Cambodia,[1]" the root cause of Cambodia's dollarization is unique, as dollarization was not originally motivated by economic situations, although these concerns came into play subsequently. Instead, dollarization was caused by lingering war and insecurity, making people distrust the local currency as a secure means to preserve wealth. As the root cause is not economic, good economic performance does not ensure a reduction in dollarization level. In fact, against the backdrop of the persistently high dollarization in Figure 2.1, GDP growth has also been high, averaging approximately 7%, before and after the Global Financial Crisis and relatively low inflation since the Global Financial Crisis (except during COVID-19) (Figures 2.2 and 2.3 below).

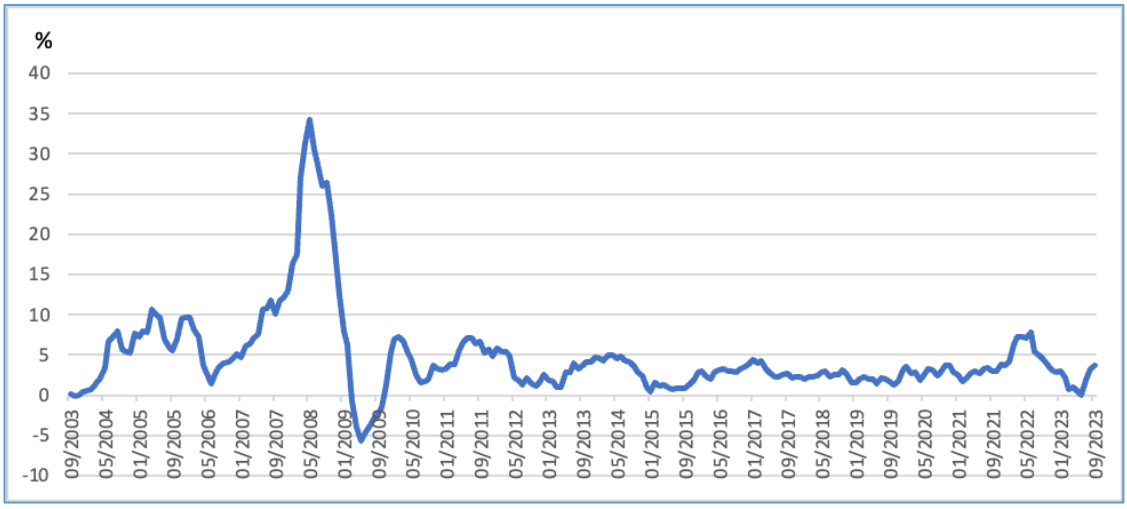
[1] Chhoeung, J. (2017). *The monetary determinants of foreign currency deposits in Cambodia* (thesis).

Figure 2.2: GDP Growth and GDP per Capita, 1999–2022



Source: National Bank of Cambodia

Figure 2.3: Headline Inflation, September 2003–September 2023



Source: National Bank of Cambodia

The enduring nature of dollarization, even in the face of consistent economic growth and low inflation, is referred to as *dollarization hysteresis*. Dollarization hysteresis refers to a situation where dollarization continues to persist even though the fundamentals that initially caused it have returned to their initial state (Oomes, 2003). This phenomenon signifies a condition where the adoption of a foreign currency becomes

irreversible. Consequently, this irreversible preference for foreign currency has made these deposits a significant component of overall bank deposits.

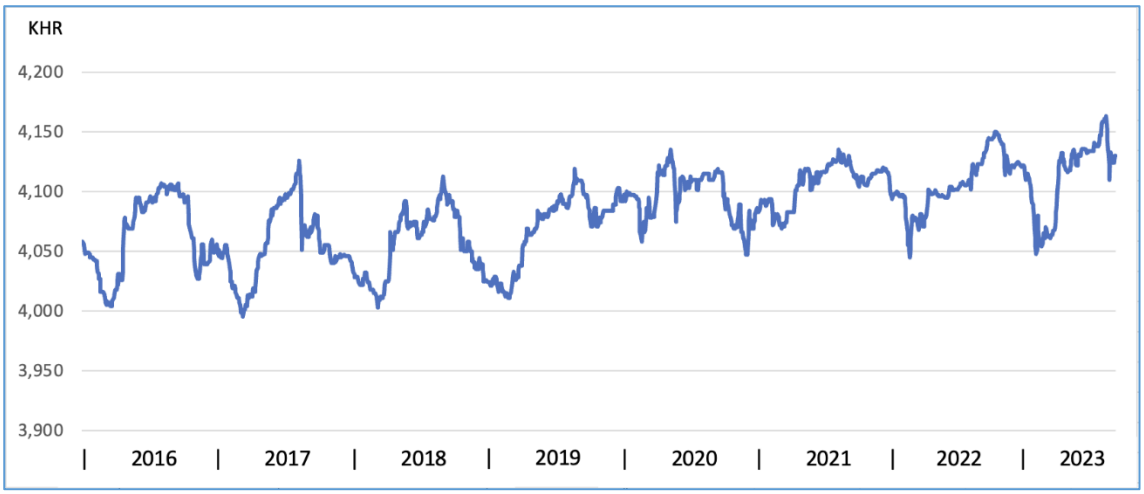
2.2-Implications of Dollarization on Monetary Policy in Cambodia

Dollarization poses a significant challenge to NBC's monetary policy. The government and the NBC have tried to de-dollarize through various market mechanism measures, including maintaining a stable exchange rate with USD, making the deposit rate in KHR higher than in USD, imposing a higher reserve requirement rate on foreign currency deposits, requiring taxes to be paid in KHR, paying salary to government officials in KHR, and raising public awareness through various campaigns. Tangible hard or administrative measures were attempted because such actions could have disastrous effects on the economy.

2.2.1-Exchange Rates

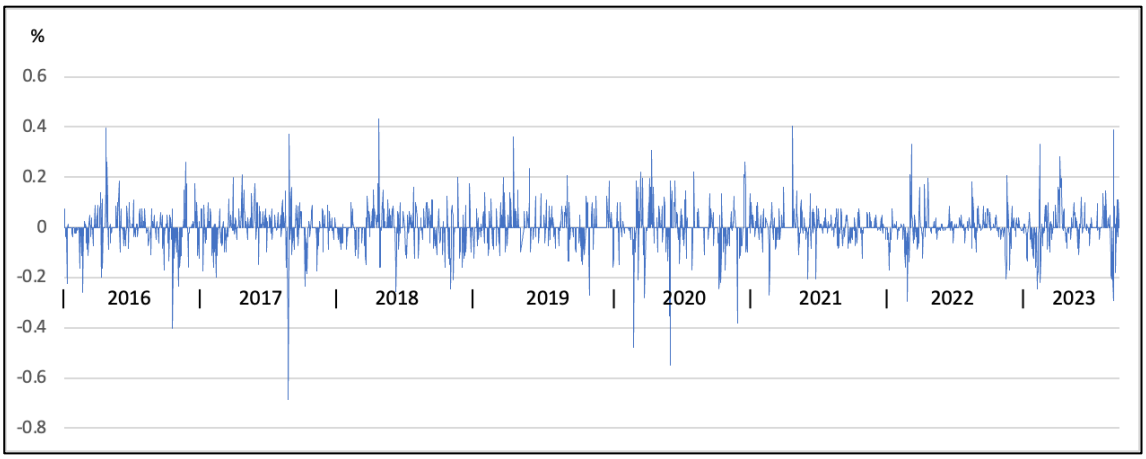
Maintaining a stable exchange rate reduces risk, increases confidence in the local currency, and encourages local currency transactions. The exchange rate between the KHR and USD has been stable through FX intervention (Figure 2.4). The fluctuation of the daily exchange rate is low, between +/-1% (Figure 2.5).

Figure 2.4: Daily Market Exchange Rate, KHR per USD, Mid-Point, 2016–September 2023



Source: National Bank of Cambodia

Figure 2.5: Daily fluctuation is within +/-1%, 2016–September 2023



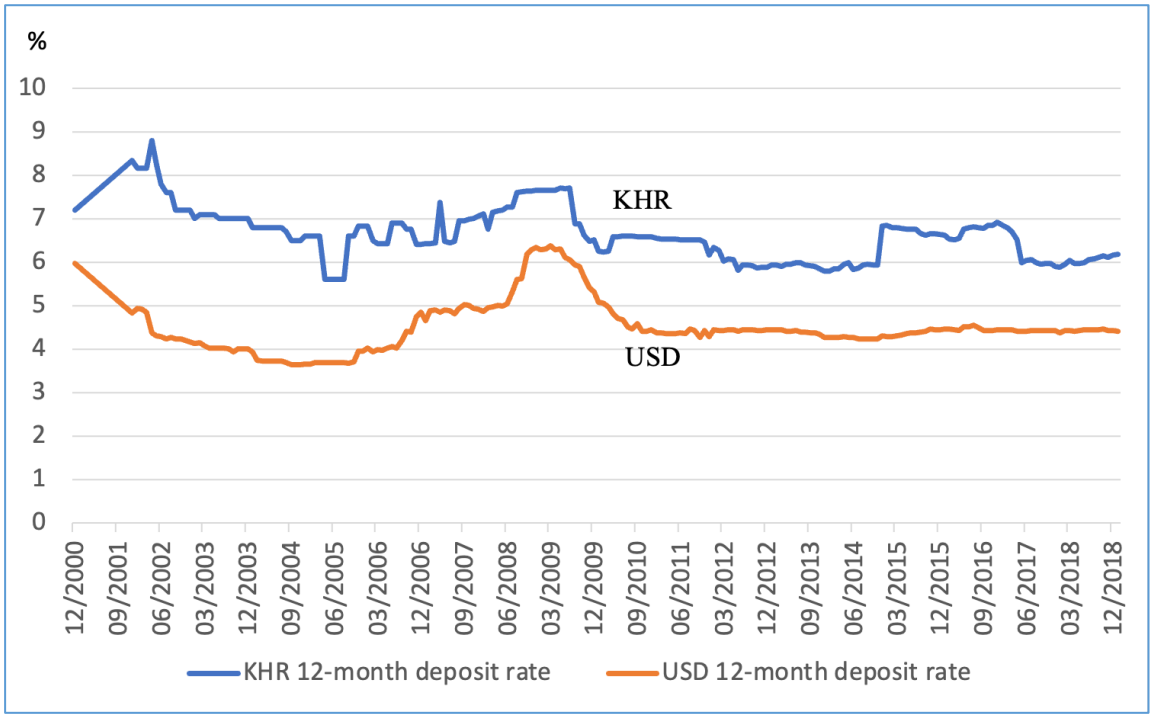
Source: National Bank of Cambodia

2.2.2-Deposit Interest Rates

The stable exchange rate allows banking and financial institutions to offer higher KHR deposit interest rates than USD, as the perceived risks associated with currency fluctuations are lower. This is a direct result of the stability, which in turn reinforces de-dollarization. The average difference between deposit interest rates in KHR and USD is

approximately 2%.

Figure 2.6: Deposit Interest Rates in KHR and USD, December 2000–December 2018

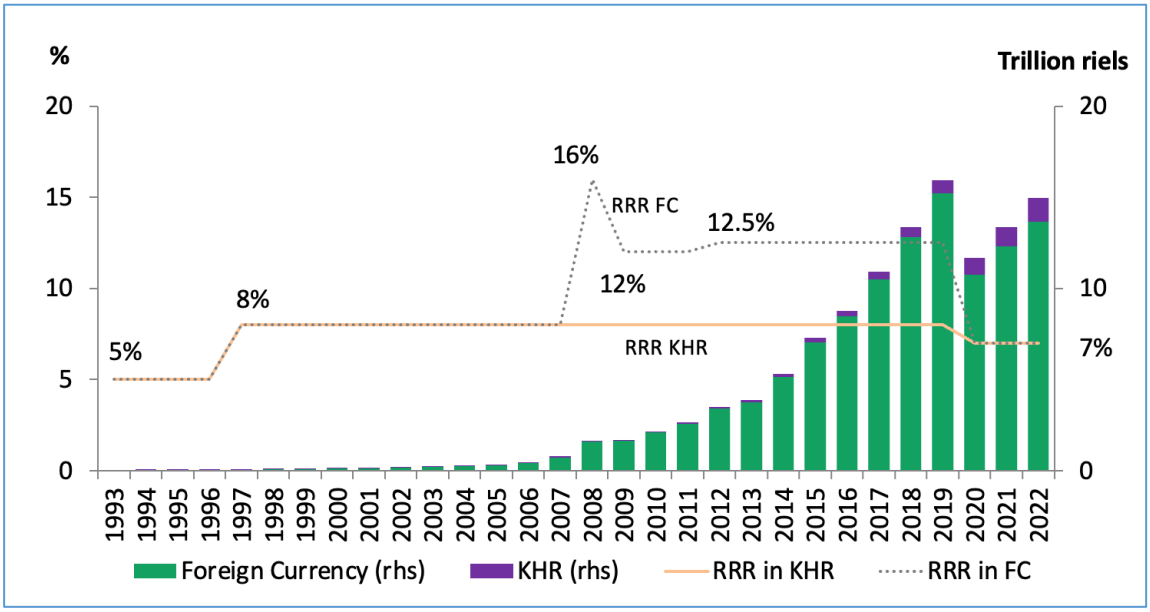


Source: National Bank of Cambodia

2.2.3-Reserve Requirement Ratios

While it is attractive to deposit in KHR due to higher KHR deposit rates, this might translate into higher KHR lending rates than the USD deposit rates, which are less attractive for borrowers. To deal with this, the NBC imposes different reserve requirements on deposits in KHR and foreign currency. Since 2009, KHR and foreign currency deposits have been subject to different reserve requirement rates, with those for foreign currency being higher than KHR. For instance, the rate was 16% in 2008 and 12.5% in 2019, while the KHR rate remained at 8% since 1997. In 2019, both rates were adjusted to the same level of 7% due to the Government's economic rebounding policy in response to COVID-19 (Figure 2.7).

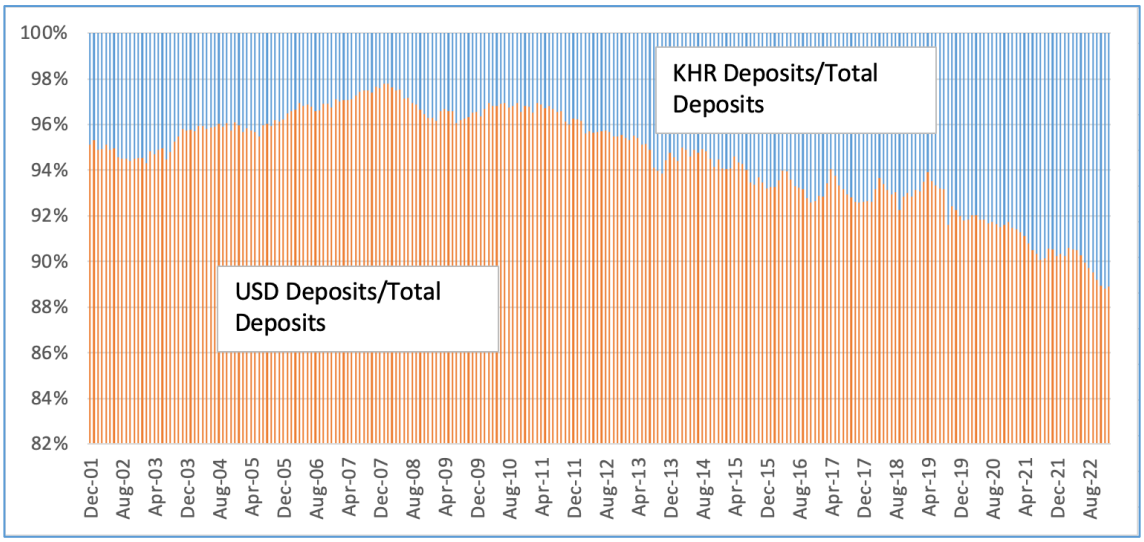
Figure 2.7: Reserve Requirement Ratios, 1993–2022



Source: National Bank of Cambodia

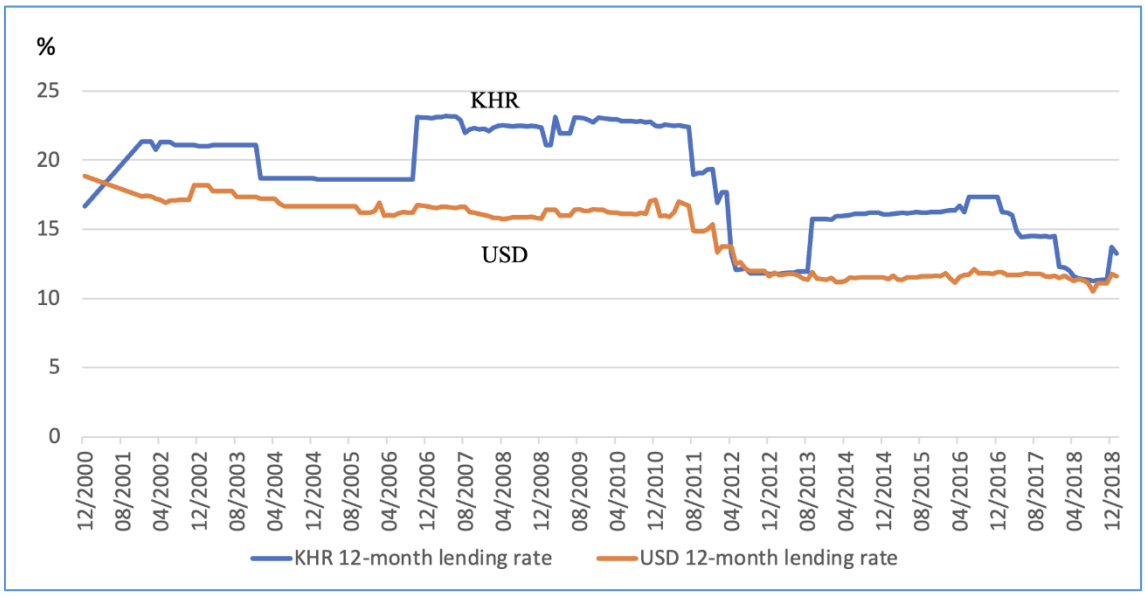
Despite the NBC's efforts to lower the KHR lending rate through reserve requirement ratios, the country's deposit structure, where the banking system is overwhelmed with USD deposits, does not allow the KHR lending rate to be lower than the USD lending rate. Figure 2.8 illustrates how overwhelmed the banking system is with USD deposits compared to KHR deposits. As a result, the lending interest rate in KHR is higher than the USD's (Figure 2.9).

Figure 2.8: Share of USD Deposits and KHR Deposits



Source: National Bank of Cambodia

Figure 2.9: Lending Interest Rates in KHR and USD, December 2000–December 2018



Source: National Bank of Cambodia

2.2.4-Other Policies

In addition to the policies mentioned above, the NBC actively promotes the use of the national currency, raising awareness about the drawbacks of dollarization. However, it is hard to evaluate the effectiveness of such measures.

2.3-Conclusions

In order to study the costs of dollarization and the de-dollarization policies, this thesis briefly presents the current condition of dollarization and countermeasures to dollarization in Cambodia. Despite good economic performance and stability as evidenced by high GDP growth, low inflation, and stable exchange rates, dollarization and foreign currency deposits have persisted over the years, contrary to expectations under favorable economic conditions. This dollarization hysteresis, within deposit compositions, has made foreign currency deposits disproportionate.

Next, we raise the measures taken by NBC to address dollarization. The measures aim to make KHR more attractive than the USD, especially using exchange rate stability and factors that keep KHR deposit rates high and lending rates low. The NBC is still unable to lower the KHR lending rate. Furthermore, the combined effectiveness of the measures does not reduce dollarization. Therefore, maintaining the stability of the national currency and making it attractive is insufficient for de-dollarization. Thus, the official measures taken over a long period call for new measures. In the next chapter, we examine de-dollarization policy that looks imposing.

Chapter 3: Assessment of the Effects of the Currency Requirement in Loan Policy on Banking and Financial Institutions in Cambodia

Abstract

Cambodia is a partially dollarized country, with high dollarization since it opened itself to globalization in the early 1990s. Dollarization has hindered the National Bank of Cambodia (NBC) from conducting its monetary policy. While NBC has implemented various measures against dollarization, it is important to note that these are soft measures meant to influence people's incentives and do not necessarily forbid them to use foreign currencies. In an effort to more effectively address the persistently high level of dollarization, on December 1, 2016, the NBC issued a hard measure—an administrative one—to influence dollarization within the banking system. Specifically, the policy is a national currency promotion (de-dollarization) regulation that mandates banking and financial institutions to increase their loan share in KHR to at least 10% of the total loan portfolio, which includes KHR and USD loans mostly. This policy took effect on the issue date and required full compliance by all institutions by December 31, 2019 (three years later). We are interested in the unintended effect of this policy on the business of banking and financial institutions. Therefore, we use policy evaluation methodology by applying a state-space model with aggregate loan data to estimate the counterfactual and evaluate the impact of the policy on banking and financial institutions in Cambodia over the implementation period. We use the CausalImpact R package for our approach. Contrary to our initial expectation that this policy might have resulted in losses for the banking system, it had a positive side effect.

Keywords: De-dollarization, impact evaluation, loan currency, state-space model

3.1-Background and Purpose

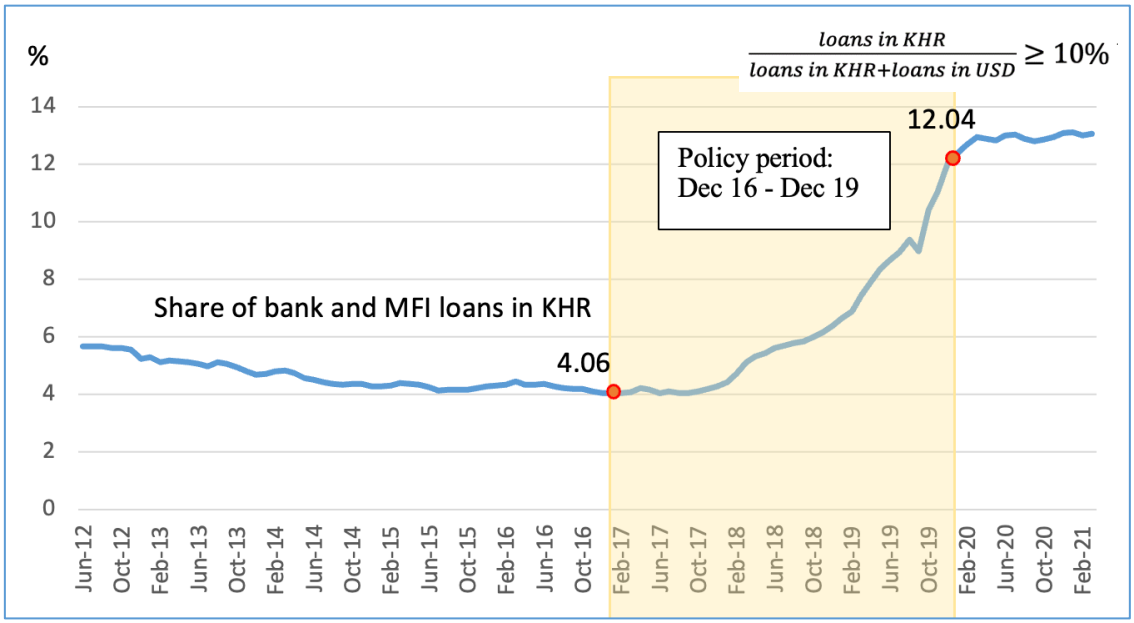
Cambodia is a partially dollarized country where people use USD alongside KHR. Dollarization started in the early 1990s and was market-driven. The root cause is political instability coupled with poor macroeconomic management. Dollarization has maintained a persistent trend, and its measure based on the share of foreign currency deposits to total deposits has been approximately 95% over the last 10 years. This poses a significant challenge to NBC's attempt to implement its own monetary policy, which is currently deprived. The government and the NBC have tried to de-dollarize through various market mechanism measures, including maintaining a stable exchange rate with USD, imposing a higher reserve requirement rate on foreign currency deposits, requiring taxes to be paid in KHR, paying salary to government officials in KHR, and raising public awareness through various campaigns. However, the outcome has not been fruitful or is hard to measure. For this reason, in December 2016, the NBC issued an administrative de-dollarization measure—a hard measure— requiring banking and financial institutions[2] to increase their loan share in KHR to 10% of the total loan portfolio by late 2019. The original statement states: "All institutions shall have their loans in national currency at least 10% (ten percent) of their total loan portfolio, which will take effect from the signing date [December 1, 2016] and be fully implemented by December 31, 2019.[3]" In other words, banking and financial institutions must fulfill the ratio of

[2] Banking and financial institutions include banks (commercial banks, specialized banks), microfinance institutions (MFIs), and microfinance deposit-taking institutions (MDIs). The distinction between MFIs and MDIs is that MFIs give loans only, while MDIs can give loans and take deposits, too. However, due to common usage where people loosely refer to MDIs as MFIs, we find it convenient to use the term 'MFIs' to encompass both MDIs and MFIs interchangeably. That way, we can conveniently refer to two entities—banks and MFIs—in the following section.

[3] Available online: Article 4, Prakas on Provision of Credit in National Currency of Banking and Financial Institutions: https://www.nbc.org.kh/download_files/legislation/prakas_eng/Prakas-on-providing-KHR-credit-eng.pdf

$\frac{loans\ in\ KHR}{loans\ in\ KHR+loans\ in\ USD} \geq 10\%$ by the end of 2019. This policy spanned three years because these institutions needed time to adapt their business model in a heavily dollarized environment before they could maintain this minimum ratio from the deadline onward.[4] Meanwhile, the NBC also proposed an accommodating policy by putting in place a KHR liquidity-providing facility called Liquidity-Providing Collateralized Operations (LPCO) to help fund KHR for the institution.[5] As the policy is a regulation aiming at setting a new threshold for loan share in KHR, the majority of institutions complied with the deadline at the individual and aggregate levels. Figure 3.1 illustrates the aggregate-level compliance, where the ratio of bank and MFI loans combined in KHR to total loans rose from 4% in December 2016 to 12% in December 2019.

Figure 3.1: Ratio of Aggregate KHR Loans to Total Loans, June 12–March 21



Source: Author's calculation based on data from NBC

[4] We clarify that banks and financial institutions are required to maintain a minimum 10% threshold even after 2019, the deadline for the policy. The loan share policy, therefore, serves as a transitional measure to establish the new loan currency ratio.
[5] October 2016

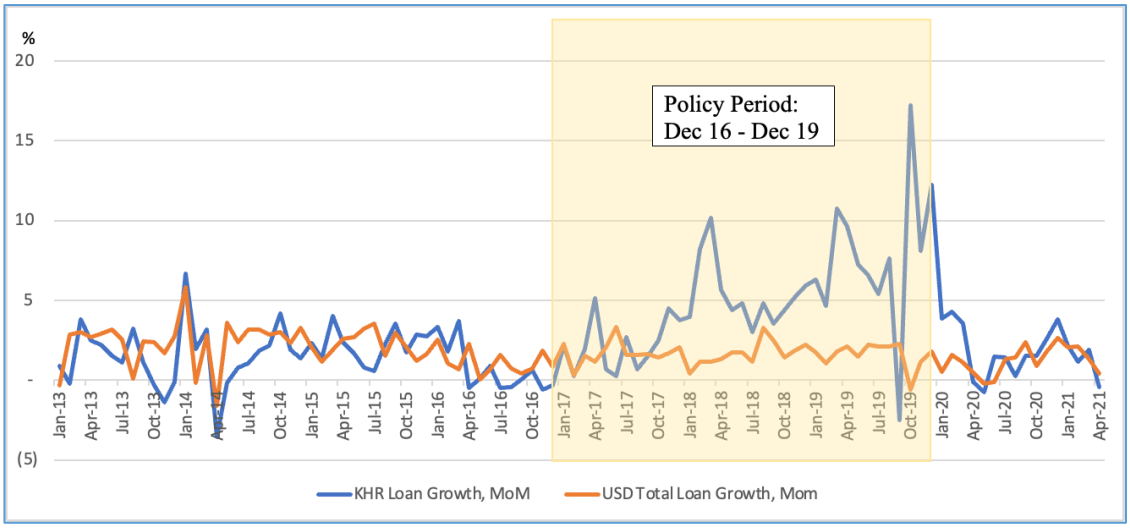
This was credit de-dollarization, and NBC used banking and financial institutions as channels to de-dollarize the economy. We consider four ways that banking and financial institutions can comply with this policy: 1-Increasing KHR loans while keeping USD loans unchanged; 2-Increasing KHR and USD loans, but increasing loans in KHR faster; 3-Increasing KHR and USD loans, but slowing down USD loans; and 4-Decreasing loans in USD (Figure 3.2).

Figure 3.2: Four Possibilities to Comply with the Loan Currency Regulation

$1-\frac{loan\ in\ KHR}{loan\ in\ KHR+loan\ in\ USD}$ x100	increase loan in KHR
$2-\frac{loan\ in\ KHR}{loan\ in\ KHR+loan\ in\ USD}$ x100	increase both, but increase KHR faster
$3-\frac{loan\ in\ KHR}{loan\ in\ KHR+loan\ in\ USD}$ x100	increase both, but make USD increase slower
$4-\frac{loan\ in\ KHR}{loan\ in\ KHR+loan\ in\ USD}$ x100	decrease loan in USD

With these options, banking and financial institutions face double constraints: 1-They needed to increase loans in KHR substantially. This is particularly difficult because the KHR loan share was only 4% before the policy introduction. Moreover, loan currency choice in a dollarized economy depends on market demand, which is generally low for KHR; 2-Banking and financial institutions needed to increase KHR loans faster than the USD loans to achieve the minimum 10% share by the deadline. If KHR loans could not be increased, it would constrain them to reduce USD loans to maintain the share, which would significantly reduce profits. The fact that they needed to increase KHR loans faster than USD loans is evidenced by the data on loan growth in KHR and USD, where KHR loans grew faster than USD loans (Figure 3.3).

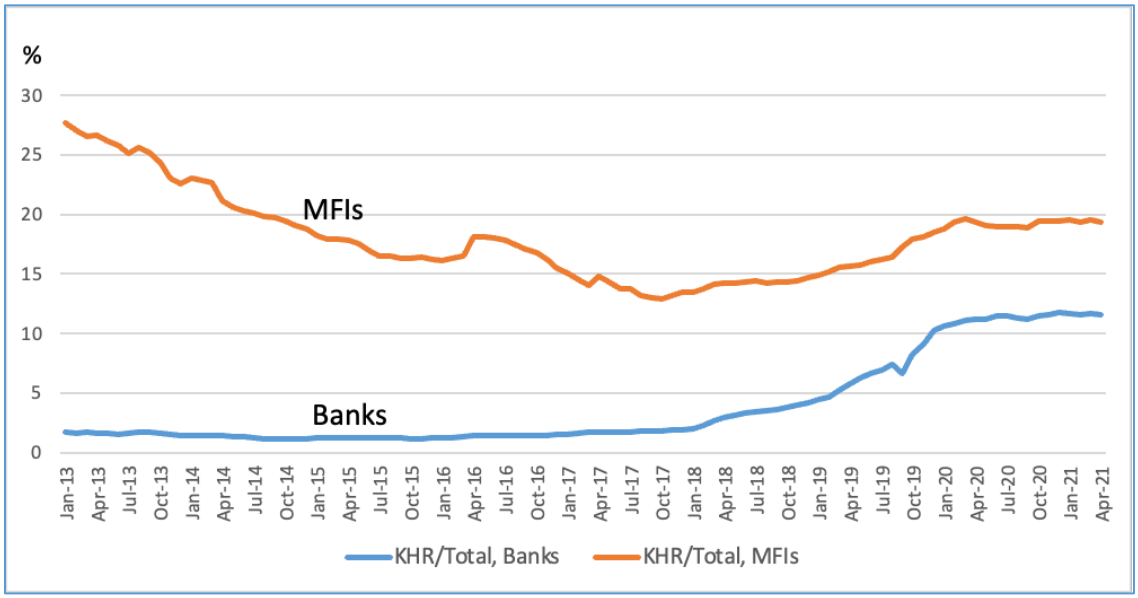
Figure 3.3: Monthly Loan Growth by Currency, January 2013–April 2021



Source: Author's calculation based on data from NBC

Banking and financial institutions consist of banks (commercial banks and specialized banks) and microfinance institutions (MFIs). Banks and MFIs share similarities and differences in various aspects. Operationally, both are involved in providing loans to the public. However, while banks can accept deposits, most MFIs cannot by regulation. This distinction affects their lending capacity, with banks typically offering larger loans than MFIs. Consequently, MFIs predominantly serve smaller entities with a greater need for loans in the local currency, which they are equipped to provide. Therefore, in general, bank business is based on the USD, so banks have difficulties complying with the 10% threshold regulation. By contrast, the MFI business is based in the KHR, making it easier to comply. Therefore, the cost of the above policy to banking and financial institutions would likely translate into the cost to banks alone. Figure 3.4 illustrates that the banks are based on USD and MFIs on KHR. Because banks are heavily based in USD and MFIs are heavily based in KHR, banks have a much lower KHR loan share than MFI.

Figure 3.4: KHR Loan Share by Banks and MFIs, January 2013–April 2021



Source: Author's calculation based on data from NBC

This study assesses the regulation costs of banking and financial institutions at the aggregate level by considering their impact on total loans (in both currencies combined). By this, we estimate the extent of the total loans that changed due to the policy compared to the counterfactual since the policy constrained loan composition, making each loan by currency unable to vary independently of the other. We chose loans as the proxy for impact assessment because loans are the main product of banking and financial institutions, and we have high-frequency data (monthly) for our analysis. Alternatively, we could also compare actual profits to counterfactual profits. However, as we cannot have profits at high frequency (only annual profits are available[6]), we use the available data on profits to perform robustness checks. Knowing the regulation cost is important because it helps us assess whether the regulation constraint is worth the economic cost forgone and, consequently, whether we should continue or relax the regulation.

[6] Banks and financial institutions report their profits once a year.

3.2-Literature Review

Dollarization is a phenomenon where the residents of a country use foreign currency to replace any function of the local currency (Yeyati & Rey, 2006). In most cases, the USD is the foreign currency used by the residents, while the definition covers the usage of any foreign currency (for instance, the euro is used in European post-transition countries (Lebre de Freitas, 2004; Tkalec, 2013; Yeyati & Rey, 2006), where the phenomenon is called euroization). Dollarization can be classified into *de jure* dollarization, when a country officially adopts a foreign currency as the legal tender, and *de facto* dollarization, when it is unofficially adopted but used alongside the local currency (Alvarez-Plata & García-Herrero, 2008; Ize & Yeyati, 2005). The latter can be further classified into currency substitution, when the foreign currency is used as a medium of exchange alongside the local currency, and financial dollarization, when it is used as a store value of assets and liabilities.[7] Therefore, financial dollarization generally includes dollarization on deposits and loans because foreign currency deposits are the assets of depositors and liabilities of banks, and foreign currency loans are the assets of banks and liabilities of borrowers. Our study focuses on a policy that addresses foreign currency loans or loan dollarization.

Dollarization can have various causes which have in common the nature of eroding confidence in the local currency. For instance, these causes could be poor macroeconomic management leading to high inflation (like in Latin American countries), fear that the exchange rate would be made floating, leading to the adoption of a stable currency (like the euroization in Central and Eastern European countries (Feige & Dean,

[7] Financial dollarization includes deposit dollarization and loan dollarization.

2004)), and political instability. The political and macroeconomic causes apply to Cambodia, which experienced prolonged political instability from the 1970s to the 1990s and a high inflation episode during the country's reconstruction in the 1980s (Tal & Dabadie, 2007). As a result, using hard currency like the USD could prevent the loss of wealth value. Moreover, dollarization has other advantages, especially in attracting foreign investments, as it prevents loss from exchange rate depreciation or devaluation when investors reap their investment benefits.

However, dollarization also has disadvantages. In the currency substitution case, the dollarized country loses control over its monetary policy, making the central bank unable to use policy rate to achieve domestic inflation target when necessary (Alvarez-Plata & García-Herrero, 2008; Ize & Yeyati, 2005; Yeyati & Rey, 2006). This is the case in Cambodia, Ecuador, El Salvador, and Zimbabwe. In financial dollarization, where, for instance, banks have funds in the USD and deploy loans in the local currency, they are exposed to exchange rate devaluation risk due to currency mismatch (Alvarez-Plata & García-Herrero, 2008; Contreras et al., 2018; Ize & Yeyati, 2005; Kokenyne et al., 2010). In both cases, the country also suffers seigniorage loss, which is the revenue from printing money. In addition, according to Schmitt-Grohe and Uribe (2001), a dollarized economy bears higher welfare costs of business cycles than a country that adopts inflation targeting, money growth rate pegs, and devaluation rate rules.

The perceived risk and welfare loss associated with dollarization justifies the de-dollarization efforts by some countries. Alvarez-Plata and García-Herrero (2008) classified de-dollarization policies into two approaches: (i) a "hands-on approach" where the country uses administrative measures to discourage the population from using foreign currencies, and (ii) a more "hands-off approach" where the country tries to divert foreign

currency usage by strengthening both its currency and economy. Existing literature seems to agree on the long-term adverse effect of administrative measures and prefers de-dollarization through macroeconomic measures (de la Torre & Schmukler, 2004; Kokenyne et al., 2010). However, Alvarez-Plata and García-Herrero (2008) and Ize and Yeyati (2005) warned that macroeconomic measures may not work if the root cause of dollarization is not macroeconomic and has become a hysteresis.[8] In this case, an administrative policy may be necessary.

Empirical studies on administrative de-dollarization measures are scarce, possibly because many countries do not implement them for fear of economic costs or because they are too broad to quantify. Fortunately, one market-driven de-dollarization policy in Peru resembles the administrative policy in our study, which we think is helpful to review.

- **Briefing on De-dollarization Policy in Peru**

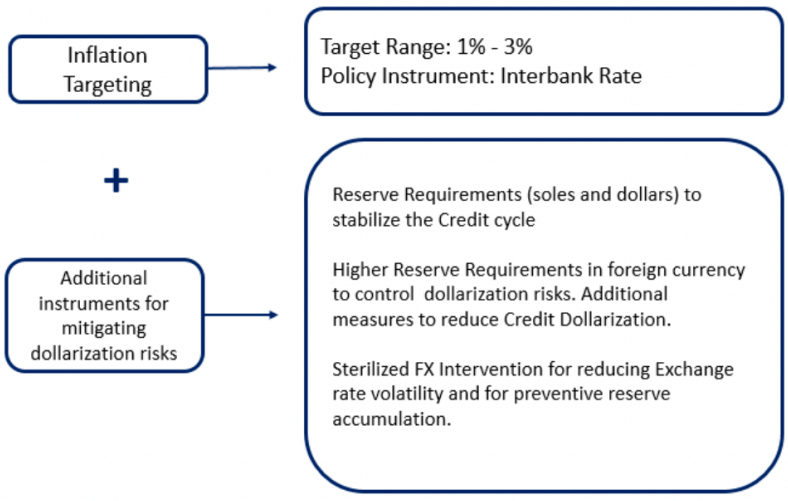
Castillo et al. (2016) and Contreras et al. (2019) relate a case of a de-dollarization policy in Peru where the central bank imposed additional reserve requirements on banks to reduce the amount of foreign currency available for giving loans in foreign currency to the public. This particular policy is one of the several de-dollarization measures in force with a precise objective. As for the background, Peru is like Cambodia, where dollarization takes the form of currency substitution and financial dollarization. For instance, banks can lend directly in USD to borrowers, exposing banks to devaluation risk because borrowers may default if they receive income in local currency. Peru was aware of this issue, and as part of de-dollarization, in 2002, the central bank adopted inflation targeting to win back public confidence away from the USD. In 2010, Peru implemented

[8] Hysteresis here means that dollarization has spread through so strongly that it cannot be reverted, regardless of the root cause of it.

a higher reserve requirement ratio for USD deposits to raise the cost of USD loans. Besides, the central bank also intervened in the FX market to reduce exchange rate volatility. The outcome was fruitful as the USD stock available for loans declined. Not satisfied, in 2013, Peru further imposed additional reserve requirements on funds in USD. The rule for additional reserve requirement is that if any bank has USD stocks of funds exceeding a certain threshold, it must deduct a specific portion of that excess amount and deposit it as additional required reserves. Therefore, banks have no incentive to maintain USD stocks beyond the threshold because they cannot use the excess amount while still paying interest. Castillo et al. (2016) and Contreras et al. (2019) found that the additional reserve requirement policy imposed on banks influenced the composition of loans in USD and the local currency of the borrowers.

Figure 3.5: As cited by Castillo et al. (2016)

Figure 1: Monetary Policy Framework of the BCRP (Armas *et al.*, 2014)



Although this policy is market-driven, it looks similar to the administrative loan share policy in Cambodia because it addresses loans in foreign currency and affects the

total loan composition. The difference is that the Peruvian policy does not impose any constraints on banks. However, in Cambodia, banks needed to maintain at least 10% of the total loans in local currency.

3.3-Research Gap

Although rare, de-dollarization policies similar the Cambodian policy could exist in other countries, such as Peru. However, existing studies focus only on their effectiveness, that is, how much they reduce banks' and borrowers' preference for foreign currencies. No study seems to have investigated the side effects of the policies on the economy or a particular sector yet. Therefore, our research fills the gap in the literature on dollarization by studying the side effects of the de-dollarization policy on banking and financial institutions.

3.4-Research Question

Considering loans as the proxy evaluating the impact on banking and financial institutions, our research question is: Did the loan policy positively or negatively impact the stock of total loans by banking and financial institutions (because loans are their main profit-driving factors)? In other words, how significantly did the total loans deviate from the counterfactuals?

3.5-Hypotheses

We have two hypotheses:

1-The impact on total loans is negative. The intervention negatively impacted the total loan disbursement of banks (i.e., bank loans in KHR and USD) because it negatively

impacted bank loans (the actual loans are lower than the counterfactual loans). This is because to fulfill the requirement ratio of 10%, banks needed to hasten giving loans in KHR while slowing down the loans in USD. Banks could not increase all loan types simultaneously because the share requirement constrains them. This hypothesis is based on the assumption that people accept a loan based on their preferred currency, which is not KHR due to dollarization, and that it is unlikely that banks could change their preference in a short period. This is our preferred hypothesis.

2-The impact on total loans is positive. The actual loans are higher than the counterfactual loans because banks were able to increase demand. In this case, we investigate the mechanism because it seems unlikely that the demand could increase by itself so quickly in a short period of time.

3.6-Data

We use monthly data of aggregate loans by banks and MFIs from November 2010 to January 2020 and by currency (KHR and USD, all converted to KHR), totaling 113 observations (the first 73 observations being of the pre-policy period and the last 40 observations being of the policy and post-policy periods). We also use annual aggregate profits by banks and MFIs and other data such as LPCO, NCDs, interbank transactions, and interest rates to perform robustness checks.

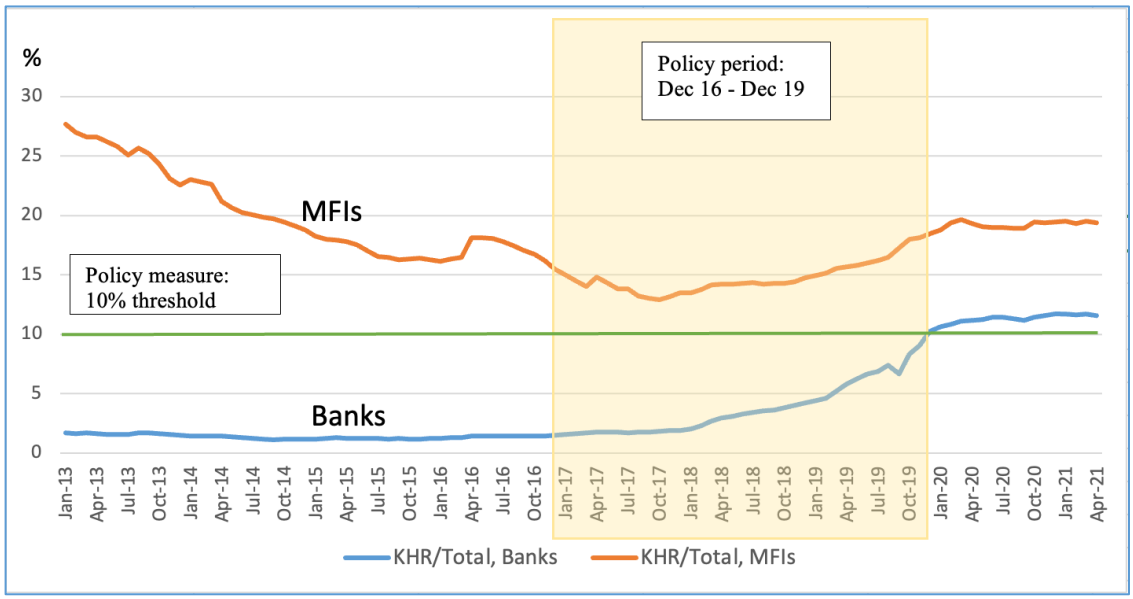
3.7-Methodology

3.7.1-Observation on the Impact of the Policy on Loans by Banks and MFIs

The loan policy targeted all banks and MFIs; thus, in terms of policy evaluation, they all belong to the treatment group. However, by considering the share of aggregate

loans in KHR to total aggregate loans by banks and MFIs, we observe that MFIs have always complied with the policy since before the intervention (Figure 3.6). This is due to the nature of their operations, which require using KHR, which is different from banks. Therefore, the policy should not significantly impact the usual MFIs' business model.

Figure 3.6: KHR Loan Share of Total Loans by Banks and MFIs, January 2013–April 2021. MFIs have always complied with the policy even before the intervention.

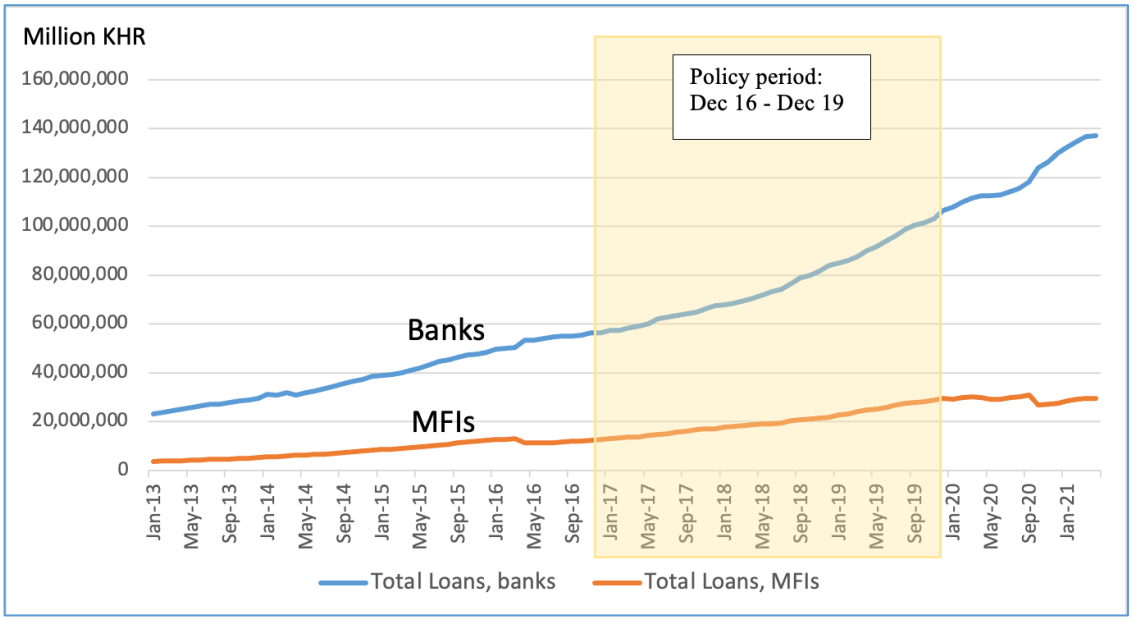


Source: Author's calculation based on data from NBC

Next, considering the total loans by banks and MFIs (KHR and USD combined), we see that both loans have a steady trend, while the MFIs' trend is steadier, even during the intervention period (Figure 3.7). Therefore, considering that MFIs' loans likely receive no significant effect from the policy, as discussed earlier, coupled with their stable trend, we designate MFIs as the control group. Therefore, the impact of the policy on total loans is equivalent to the impact on loans by banks alone, as MFIs are unaffected by the policy, although they belong to the treatment group. This observation enables us to use MFI loans as a predicting regressor to construct the counterfactual of the bank loans,

which we will describe shortly. Notably, this method of isolating the unaffected treatment group from the entire treatment group is similar to the setup made in Castillo et al. (2016). For instance, in studying the impact of the Peruvian additional reserve requirement policy on credit dollarization, the authors took bank customers below the threshold for additional reserve requirement, thus unaffected by the policy, as the control group. The customers from these banks do not change their behavior toward foreign currency loans as their banks are unaffected.

Figure 3.7: Total Loans in KHR and USD by Banks and MFIs, January 2013–April 2021. Loans by banks and MFIs have a steady trend before intervention, whereas MFIs' trend is steadier.



Source: Author's calculation based on data from NBC

3.7.2-Estimating Impact on Total Aggregate Loans

As MFI loans are immune to policy, the impact on total loans, comprising bank and MFI loans, translates into the impact on bank loans alone. Therefore, in estimating the impact on total aggregate loans, we specifically evaluate the impact on bank loans. In Brodersen et al. (2015), "Inferring Causal Impact Using Bayesian Structural Time-Series Models," the author conducted impact evaluation using a diffusion-regression state-space model to predict the counterfactual of the variable of interest in the scenario of no intervention. A synthetic control is employed as the predictor. We utilize the same method in our analysis. We construct the counterfactual over the implementation period by using the time series of bank loans before the policy introduction and the time series of MFI loans before and during the intervention as the predictor. We then compare the actual series to the counterfactual one to identify significant differences. In modeling terms, we estimate the counterfactual using a local level state-space model[9] with seasonality and a regressor representing the variable of the unaffected group (in our case, MFI loans). The model is specified as follows:

[9] This model is called the state-space model because there is the presence of a state variable, that is, a variable with dynamic feature, which is the trend μ_t. In general, the "state" in a state-space model refers to the hidden variables that capture the underlying system dynamics being modeled. These state variables represent unobservable internal characteristics or conditions of the system, and they evolve over time based on certain rules or equations. The "space" represents the set of all possible values that the hidden state variables can take at each time step. This mathematical space is defined by the transition equations (how the state evolves) and observation equations (how the state relates to the observed data). It encompasses the entire range of possible states the system can be in.

$$y_t = \mu_t + \tau_t + \beta' x_t + \varepsilon_t, \qquad \varepsilon_t \sim N(0, \sigma_\varepsilon^2)$$

$$\mu_{t+1} = \mu_t + \eta_t, \qquad \eta_t \sim N\left(0, \sigma_\eta^2\right)$$

$$\tau_{t+1} = -\sum_{S=0}^{10} \tau_{t-s} + \zeta_t, \qquad \zeta_t \sim N(0, \sigma_\zeta^2)$$

Where:

y_t: observed variable, aggregate bank loans.

μ_t: unobserved state variable, which is the trend component of bank loans. Controlling for trends takes away its effect on the data.

τ_t: seasonal component of bank loans, which is the difference in effect in each month compared to the base group. The sum of all the differences in effect over 12 months equal zero. Controlling for seasonality takes away its effect on the data.

x_t: regressor, which is aggregate MFI loans. MFI loans help predict the path of the counterfactual bank loans during the intervention.

ε_t: represents the observation noise, which accounts for measurement error in the observed data.

η_t *and* ζ_t represent the process noise associated with the level and slope, respectively. These noises capture unmodeled changes in the trend and are typically assumed to be normally distributed.

3.7.3-Assumptions

For the above model to work, two assumptions need to be satisfied: i. the structure of the bank and MFI loans are captured by a constant β, and ii. the policy does not affect MFIs, which constitute the control group. We address these assumptions below.

i/-Assumption 1: Constant β

First, Figure 3.7 appears to confirm this assumption. However, given the possibility of a time-varying β, we can compare a model with a constant β to a model with a time-varying β over the pre-policy period to determine which yields better results. Since this is the pre-intervention period, we use MFI loans as the predictor without waiting for assumption ii to be verified. We compare the previously mentioned constant β model with an alternative time-varying coefficient model described below:

$$y_t = \mu_t + \tau_t + \beta'_t x_t + \varepsilon_t, \qquad \varepsilon_t \sim N(0, \sigma_\varepsilon^2)$$

$$\mu_{t+1} = \mu_t + \eta_t, \qquad \eta_t \sim N(0, \sigma_\eta^2)$$

$$\tau_{t+1} = -\sum_{S=0}^{10} \tau_{t-s} + \zeta_t, \qquad \zeta_t \sim N(0, \sigma_\zeta^2)$$

$$\beta_{t+1} = \beta_t + \upsilon_t, \qquad \upsilon_t \sim N(0, \sigma_\upsilon^2)$$

We use a data frame covering the period from November 2010 to November 2016 (the first 73 series), predating the policy intervention in December 2016.

The steps are as follows:

1-Estimate the model with a constant β and the model with time-varying β to obtain the posterior estimates for the standard deviations of ε_t, ζ_t, η_t and υ_t in each case.

2-Obtain the in-sample one-step ahead forecasts from both models and compare the forecasts with actual data in each case to obtain a cumulative absolute error.[10] The model with a smaller cumulative absolute error is better.

Figure 3.8: Comparing Cumulative Absolute Error

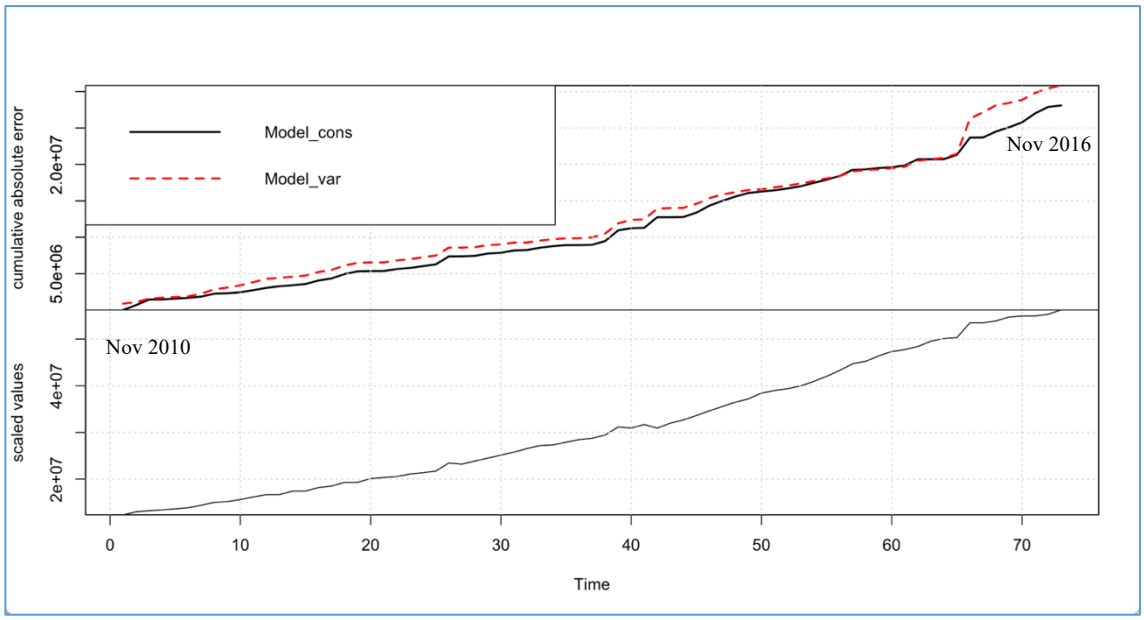


Figure 3.8 shows that the model with a constant coefficient (Model_cons) generally exhibits a lower cumulative absolute error than the model with a time-varying coefficient (Model_var), which generates forecasts closer to the actual data. This assessment, therefore, justifies our intuition gained from observing the data to use the model with a constant coefficient.

[10] Therefore, starting from the actual y_1, we forecast y_{2f}, y_{3f}, etc., using the variance obtained from the estimation of the entire sample. We obtain the forecast errors $e=y_2-y_{2f}$, y_3-y_{3f}, etc., and then sum them up. We compare the model using the package CompareBstsModels in R.

ii/-Assumption 2: MFI Loans Are Unaffected by the Policy

As explained above, the nature of MFI loans in KHR makes them unaffected by the policy, as the policy targets only the threshold. Additionally, we test whether MFI loans can be used to predict bank loans in the pre-policy period. The rationale for this method is that if somehow we can use the unaffected group to predict the counterfactual of the affected group during the intervention and find the effect significant, we should also be able to use the same model to predict bank loans in the pre-policy period. In this case, we expect to find the predicted values not significantly different from the actual values. To achieve this, we ran CausalImpact in R on an imaginary intervention that occurred in the middle of the pre-policy series, specifically on the 37th observation date (November 2014) (there are 73 pre-policy observations). We obtained the following results:

Table 3.1: Impact of the imaginary policy is not significant

```
Posterior inference {CausalImpact}

  Unit: Million KHR
                          Average              Cumulative
Actual                    4.3e+07              1.6e+09
Prediction (s.d.)         3.9e+07 (3.2e+06)    1.4e+09 (1.2e+08)
95% CI                    [3.2e+07, 4.5e+07]   [1.2e+09, 1.7e+09]

Absolute effect (s.d.)    3.4e+06 (3.2e+06)    1.3e+08 (1.2e+08)
95% CI                    [-2.8e+06, 1.0e+07]  [-1.1e+08, 3.8e+08]

Relative effect (s.d.)    8.8% (8.2%)          8.8% (8.2%)
95% CI                    [-7.3%, 26%]         [-7.3%, 26%]

Posterior tail-area probability p:   0.10741
Posterior prob. of a causal effect:  89%
```

Figure 3.9: Counterfactual series is not significantly different from the actual series

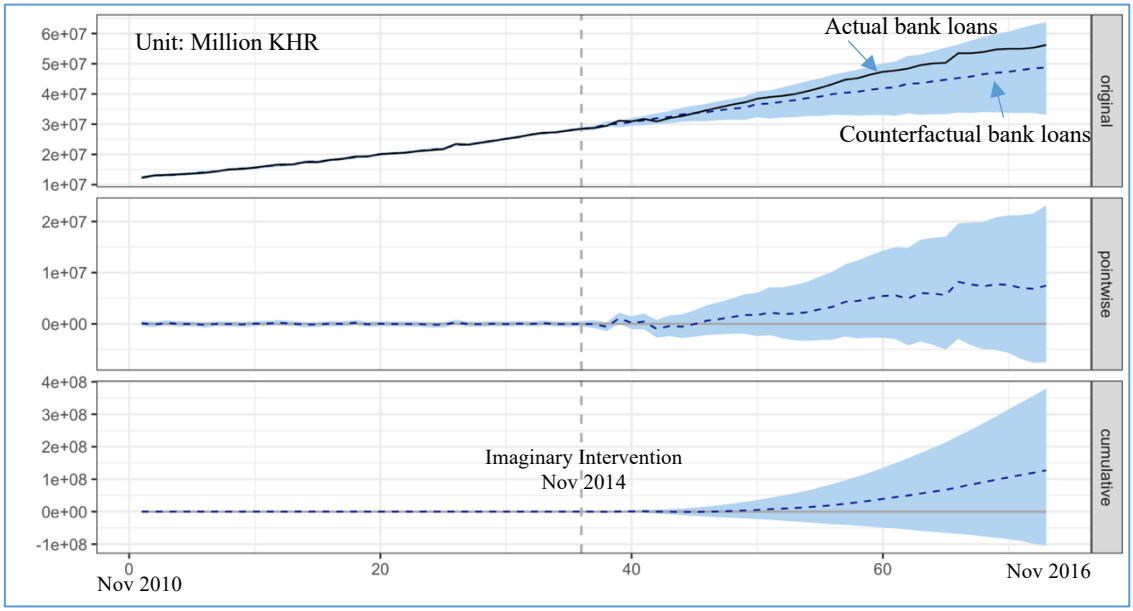


Figure 3.9 shows no significant difference between the counterfactual and the actual series over the pre-real intervention period. Therefore, the aggregate MFI loans can be used as the predictor.

Although we have demonstrated that the aggregate MFI loans are unaffected by the policy and can function as a predictor, examining the loan share in KHR by banks and MFIs in Figure 3.6 above prompts us to acknowledge the possibility that policies other than the policy in question, if not random decisions, could have simultaneously influenced y_t and x_t. For instance, introducing the NBC's loan disbursement facility (LPCOs, discussed in Section 3.9.2) could be one reason, if not a major reason, causing the share of KHR loans to total loans by MFIs to move as it did for the share of loans by banks. We recognize this caveat in controlling for every omitted variable as a limitation to our estimation. However, the test shows that the usual path of MFI loans is suitable as a predictor.

3.8-Estimation Results

We use the CausalImpact R package,[11] which estimates the following steps:

1-It estimates the model using only the pre-policy implementation data. By estimating, we mean that it estimates the standard deviations of the level, trend, and seasonal component based on the pre-policy data and our prior belief. We use Bayesian estimation to generate the posteriors of those values.

2-Using the estimated model and the post-policy implementation data on x_t, it obtains the forecasts of y_t after the policy implementation.

3-It compares the forecasts with the actual data to estimate the impact of the policy.

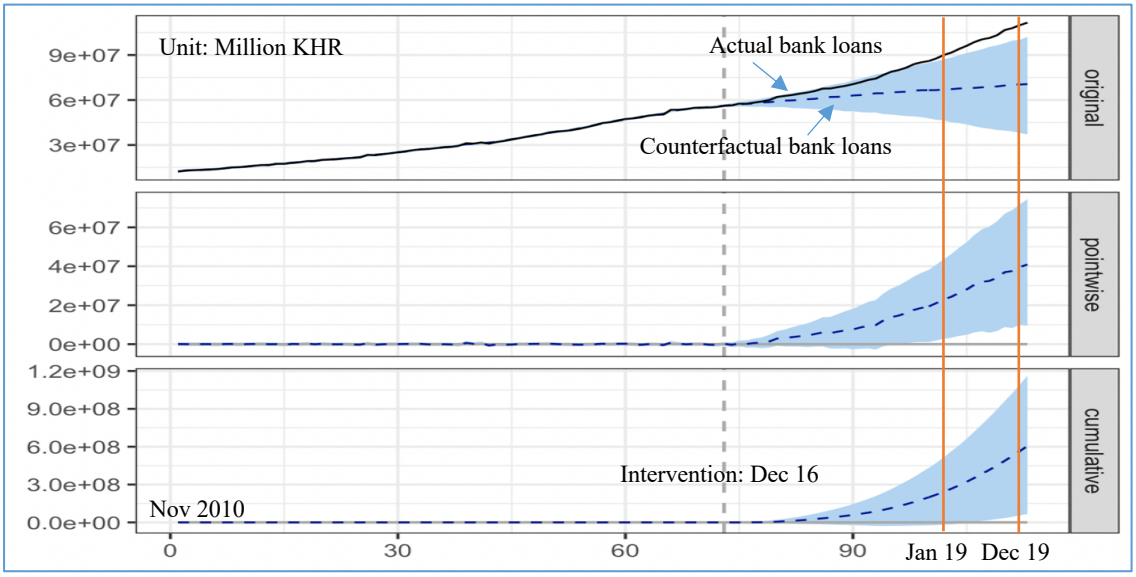
We estimate the above model using aggregate monthly bank loans with MFI loans as the predictor. We obtain the results below.

Table 3.2: Impact of the policy is positive, making actual loans exceed counterfactual

```
Posterior inference {CausalImpact}
    Unit: Million KHR
                          Average              Cumulative
Actual                    7.9e+07              3.2e+09
Prediction (s.d.)         6.4e+07 (7.0e+06)    2.6e+09 (2.8e+08)
95% CI                    [5e+07, 7.7e+07]     [2e+09, 3.1e+09]

Absolute effect (s.d.)    1.5e+07 (7.0e+06)    6.1e+08 (2.8e+08)
95% CI                    [1.7e+06, 2.9e+07]   [6.7e+07, 1.2e+09]

Relative effect (s.d.)    24% (11%)            24% (11%)
95% CI                    [2.6%, 45%]          [2.6%, 45%]

Posterior tail-area probability p:   0.01556
Posterior prob. of a causal effect:  98.444%
```

[11] CausalImpact 1.3.0, Brodersen et al., Annals of Applied Statistics (2015)

Figure 3.10: Actual bank loans exceed counterfactual, and significant effect started from January 2019



Based on the outcome in Table 3.2 and Figure 3.10, the policy has a high probability of causal impact with a posterior tail-area probability of 0.01556. The policy positively impacts bank loans, confirming our second hypothesis. Based on Table 3.2, the average amount of bank loans is 79 trillion KHR, higher than the average prediction of 64 trillion KHR. The difference between the actual and counterfactual averages is 15 trillion KHR. Based on Figure 3.10, the significant effect started from January 2019 onwards, suggesting that banks tried their best to lend out KHR.

The positive impact on bank loans suggests that the policy incentivized banks to increase both KHR and USD loans simultaneously; banks just needed to keep KHR loans growing faster than USD loans. If so, it means that the de-dollarization policy was a success. However, increasing KHR loan demand in such a short period is hard to expect. Considering the significant effect that just started in January 2019, the period was shorter

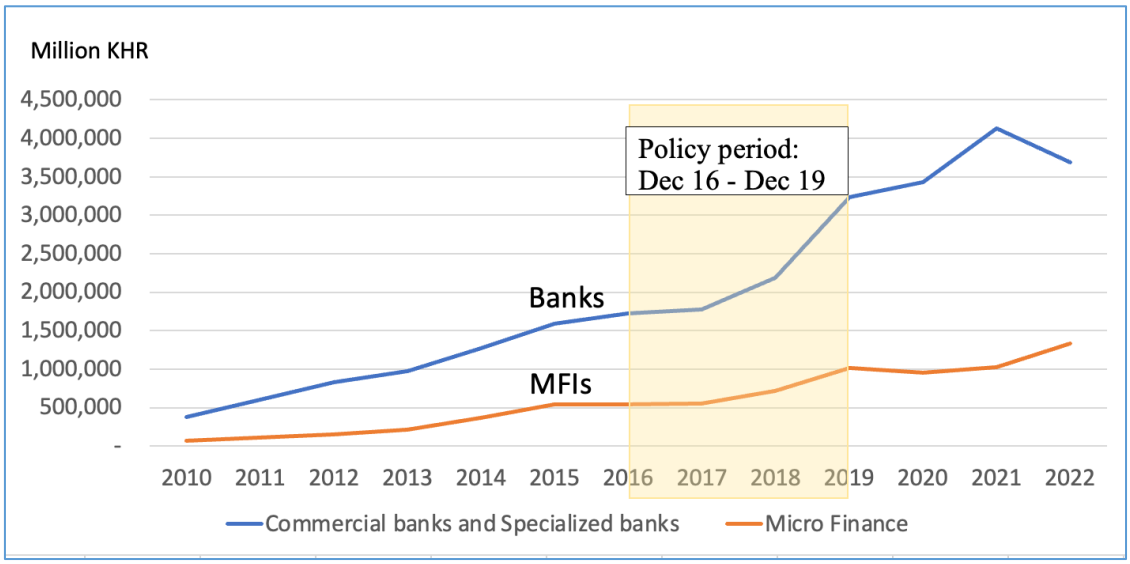
than the whole implementation period. We will attempt to explain this fact in the next section.

3.9-Robustness Checks

We cross-check the above finding with aggregate profits by estimating the policy's impact on profits. The purpose is to confirm the impact on loans because the impacts on loans and profits should have the same direction. The reason that we chose profits for performing robustness checks and not as the principal proxy is that profits can come from sources other than loans, which are the main product of banking and financial institutions. In addition, this is because banks and financial institutions do not report profits frequently.

3.9.1-Net Profits

Figure 3.11: Net Profits, Annual, 2010–2022



Source: National Bank of Cambodia

Ideally, we want to evaluate the impact of the policy on profits, similar to what we did for loans, using the state-space model. Unfortunately, we could not formally perform this analysis due to the limited availability of profit data (13 observations) recorded at a low frequency, such as annually. Nevertheless, Figure 3.11 shows that the net profits of banks and MFIs, especially banks, increased, which is to be expected after finding the positive impact of the policy on bank loans. Despite the few annual profit data, we estimated the local level state-space model without seasonality, and we obtain the following outcome:

Table 3.3: Impact of the policy is positive, making actual bank profits exceed counterfactual

```
Posterior inference {CausalImpact}
  Unit: Million KHR
                          Average             Cumulative
Actual                    2.9e+06             2.0e+07
Prediction (s.d.)         2.0e+06 (565718)    1.4e+07 (3960028)
95% CI                    [758800, 2.9e+06]   [5311601, 2.0e+07]

Absolute effect (s.d.)    895919 (565718)     6271433 (3960028)
95% CI                    [24159, 2.1e+06]    [169115, 1.5e+07]

Relative effect (s.d.)    45% (29%)           45% (29%)
95% CI                    [1.2%, 107%]        [1.2%, 107%]

Posterior tail-area probability p:   0.02257
Posterior prob. of a causal effect:  97.743%
```

Figure 3.12: Actual bank profits started to exceed counterfactual at the end of 2019

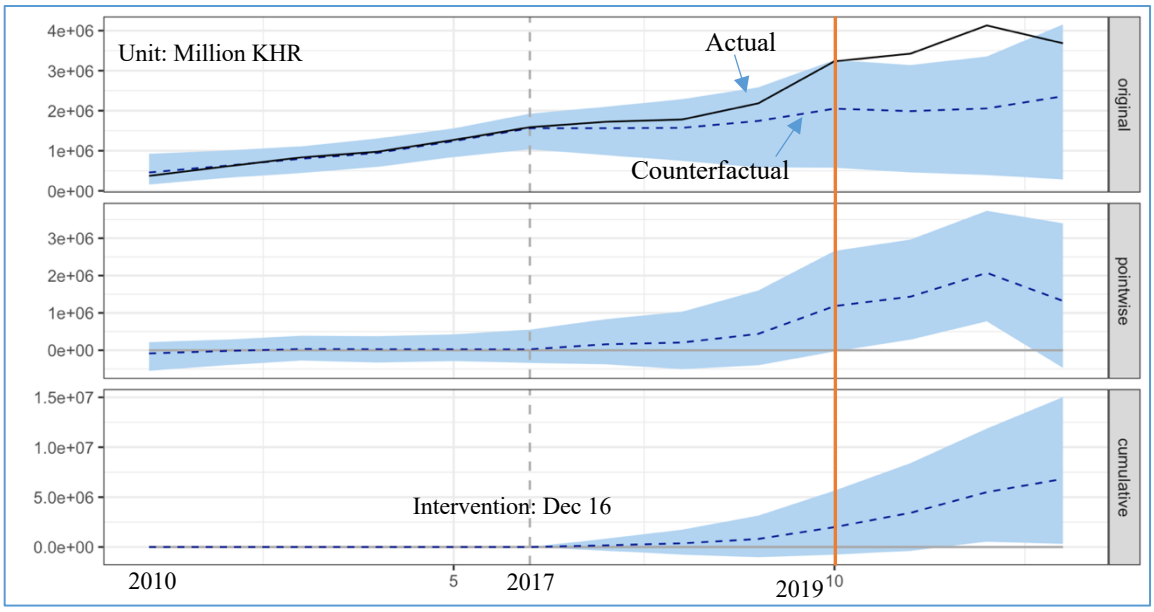


Figure 3.12 shows that, even with the few annual data, actual bank profits exceeded the counterfactual at the end of 2019. This observation confirms the positive side effect of the policy. As all these findings oppose our initial hypothesis of a negative impact, we attempt to explain the mechanism.

3.9.2-Mechanism

- Source of Khmer Riel Funding

In a dollarized country like Cambodia, commercial banks that primarily deal in foreign currencies often encounter difficulties sourcing local currency when needed. Regarding the current de-dollarization policy, having access to funds in KHR has proven beneficial in complying with the regulation. According to an interview with the

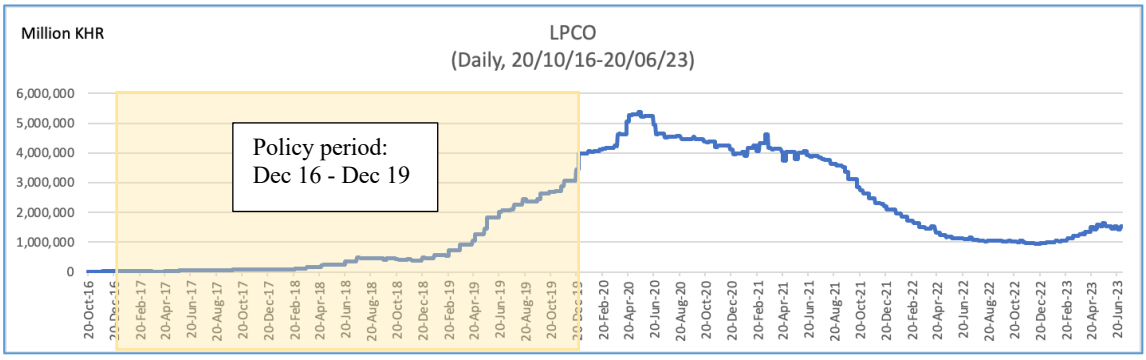
Association of Banks in Cambodia,[12] the NBC has introduced supportive tools, such as Negotiable Certificate Deposits (NCDs) and Liquidity Providing Collateralized Operations (LPCOs), to encourage using KHR in addition to regulating banks to provide at least 10% of their loans in KHR.

LPCO is a local currency (KHR) easing facility introduced in October 2016 to provide KHR to banking and financial institutions. Subscribing to LPCO basically means contracting a loan in KHR from NBC. LPCO was potentially introduced for the purpose of implementing this policy. In Figure 3.13, LPCO shows a sharp increase during the implementation period, indicating that banks and financial institutions resorted to it to secure funding for KHR loan disbursement.

NCD is a type of securities issued by the NBC that is designed to absorb liquidity from the banking system. Commercial banks can invest in NCDs in either KHR or USD. While commercial banks can reduce their lending in USD, they can still generate profits from their USD funds by investing in NBC's NCD denominated in USD. Figure 3.14 shows that the outstanding NCD in USD increased during the policy period, while NCD in KHR remained relatively stable and low. Moreover, because NCD in USD is used as collateral to acquire KHR funding, the simultaneous rise in NCD in USD and LPCO confirms that commercial banks turned to LPCO as a source of funds.

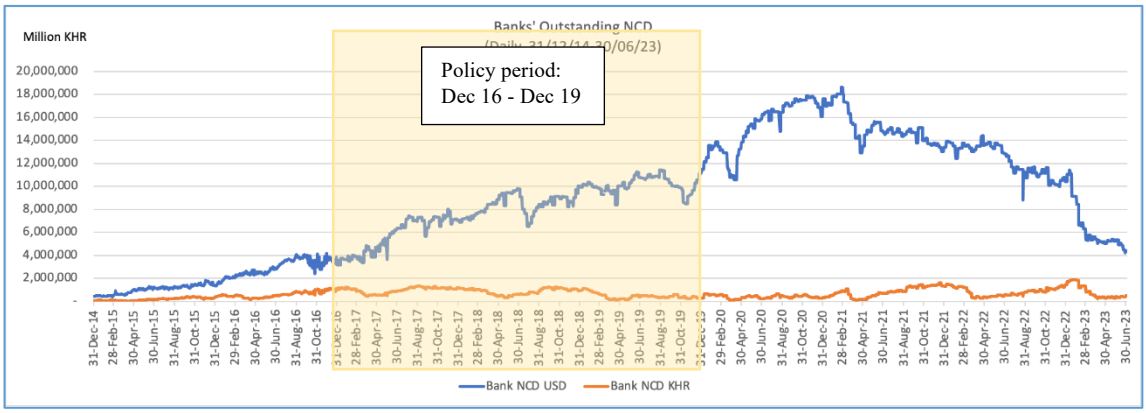
[12] "All member banks of the Association of Banks in Cambodia have followed 10% loan portfolio in Riel as mandated by the NBC", *The Khmer Times*, March 31, 2023

Figure 3.13: LPCO increased during the policy period



Source: National Bank of Cambodia

Figure 3.14: The Bank's outstanding NCD in USD increased while it was low in KHR



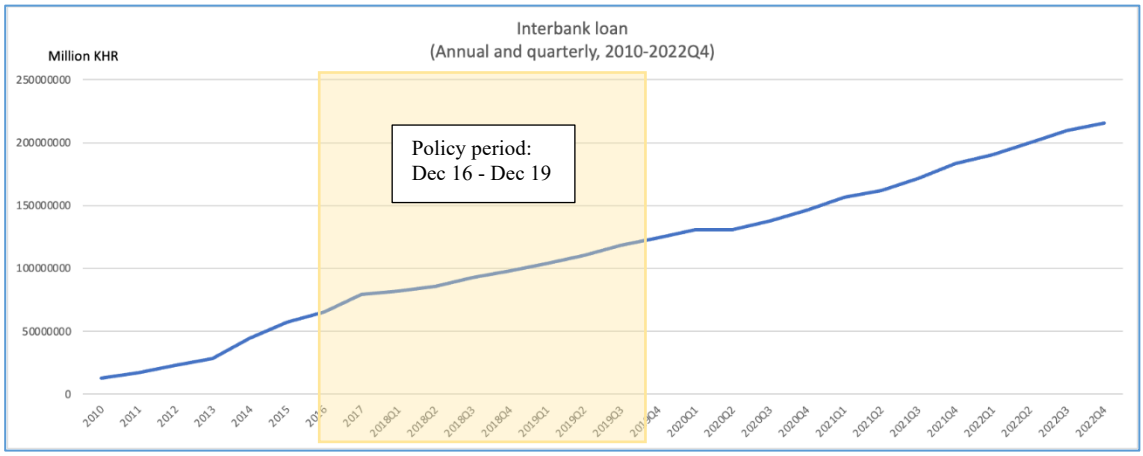
Source: National Bank of Cambodia

- Interbank Lending

One way for commercial banks to increase their loans in KHR is to target sectors with a strong preference for KHR, and in this case, MFIs are the focal point. This strategy is confirmed by the interviewed bankers, as reported in the media: "Cambodian commercial banks showed a stronger preference for providing riel loans to microfinance institutions (MFI) as they rushed to increase the share of the local currency" (The *Phnom Penh Post*, November 13, 2018).

Figure 3.15 displays data for interbank loans in all currencies (converted to KHR) and indicates a consistent increase, including during the policy period. We assume these are fund flows from commercial banks to MFIs. We regret that at the time of realizing this research, we do not have more granular data that separates the various bank currencies or shows the direction of the funds. However, we anticipate that the rise in funds is driven by the flow of KHR from commercial banks to MFIs.

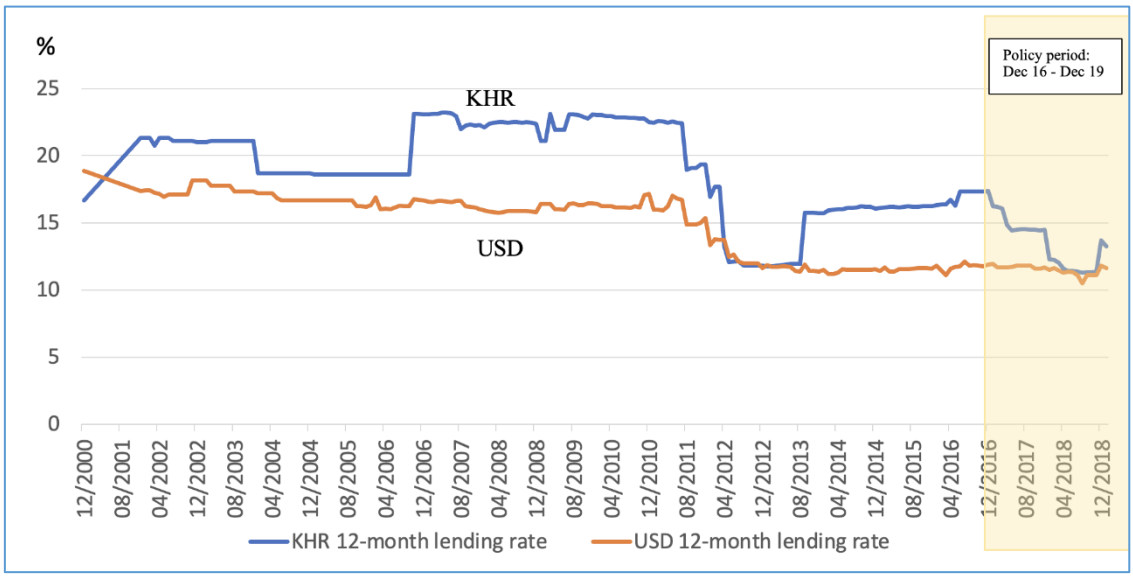
Figure 3.15: Interbank Loans



Source: National Bank of Cambodia

Complementarily, we can look at how KHR loan interest rates decreased during the policy period to make them attractive (Figure 3.16).

Figure 3.16: KHR lending rates decreased during the policy period



Source: CEIC

3.10-Limitations

As mentioned in the assumption section, although we have demonstrated that aggregate MFI loans are unaffected by the policy, we acknowledge that the share of KHR loans by MFIs could vary, resulting from various factors influencing the share of KHR loans by banks and MFIs simultaneously.

Regarding interbank transactions, which likely facilitated the flow of KHR loans from banks to MFIs, based on the available data, we could not confirm the direction of these transactions, specifically whether they were genuinely from banks to MFIs, despite the knowledge that interbank transactions occurred during that time.

A crucial consideration is the extended 3-year implementation window. Any shock that differentially affects banks from MFIs over this period could impact the actual and counterfactual bank loan amounts, thus influencing the effect estimates. Additionally,

using loan amounts to measure policy impact is incomplete, as it does not account for the likelihood of repayment.

Concerning the data, the entry of new banks or MFIs or the transition of MFIs into banks may also influence changes in liquidity and loans. Notably, the number of banks and MFIs is not constant, and their statuses can change. However, these variations should not significantly affect our analysis, considering the fact that most institutions remain the same.

The current thesis utilizes aggregate data on loans from banks and MFIs. Future research should investigate how the conclusions may vary when using microdata.

3.11-Conclusions and Implications

Contrary to our initial preferred hypothesis that this policy might have resulted in losses for the banking system, it had a positive side effect. Based on the estimation results in the light of the original wording of the regulation, which does not forbid interbank lending, we conclude that the impact of the policy is overall positive, not only in terms of its direct effects but also in terms of its side effects. This positive outcome was made possible by the NBC's support, primarily through the liquidity-providing facility LPCO, as well as the existing channels for fund circulation from commercial banks to MFIs.

The results show that the policy was beneficial to banking and financial institutions. The policy has continued beyond 2019. We believe this research makes the NBC optimistic as de-dollarization needs more work. Indeed, the NBC needs to focus more on addressing dollarization from 2020 as it has recently received a blue light from the government to implement the Plan for the Promotion of the Use of National Currency

at the national level after having unsuccessfully lobbied for it for many years.[13] Despite a debate over the prematurity of tackling dollarization, NBC believes it needs to act more or less aggressively from right now to contain dollarization before hysteresis becomes intense. Therefore, the output of this research on administrative policy serves as a precedent for other de-dollarization policies.

However, when considering the essence of the de-dollarization policy itself, drawing such a conclusive judgment of its success becomes challenging. De-dollarization policy should rather aim to discourage people from using foreign currencies and encourage them to use local currency. Due to the possibility of interbank lending, the policy may not significantly influence the public behavior beyond its impact on the internal interbank lending processes within the banking system.

In addition to the current policy, we suggest that the NBC implement and moderate, rather than overly strict, restrictions on lending from banks to MFIs. This approach would incentivize banks to lend in the local currency (KHR). However, we should consider the crowding-out effect that this policy may have on MFIs in the short and long run because now banks are required to give more KHR loans.

Regarding the literature on dollarization in Cambodia's case, this policy is an example that demonstrates the success of an administrative measure, at least within the banking system, which somewhat contradicts established beliefs regarding the ineffectiveness and drawbacks of such measures. Regarding methodology, we have seen a case where we use a sub-series to predict the counterfactual of another series to perform policy evaluation.

[13] The government has been reluctant to adopt a national strategy to address dollarization as it has so far benefited Cambodia, especially in attracting FDIs.

Chapter 4: Assessing the Impact of Foreign Interest Rate Shock on Cambodia's Small Open and Dollarized Economy Using Small Open Economy Real Business Cycle (SOE-RBC) Model

Abstract

We estimate the responses of macroeconomic aggregates to foreign interest rate shock in Cambodia's economy using the small open economy real business cycle (SOE-RBC) model. We also assess the responses to preference and technology shocks, which are quite usual in such a model. The model is originally used to estimate a standard or non-dollarized small open economy with an incomplete asset market where residents purchase risk-free foreign bonds to insure their wealth. We frame Cambodia's economy to fit the model due to its high degree of dollarization, where people make deposits and carry out transactions in USD to hedge against risks and by assuming certain features of the economy. This allows us to apply the model to estimate Cambodia's economy by substituting the interest rate on foreign bonds in the original model with the domestic term deposit interest rate in USD. We use Bayesian estimation and data from Cambodia to generate impulse responses that confirm our intuitions, where the foreign interest rate shock is countercyclical to domestic consumption and investment while positively related to the trade balance and current account. However, the results show that the foreign interest rate shock is not the major driver of the business cycle, contrary to our expectations.

Keywords: Cambodia, dollarization, DSGE, foreign interest rate shock, small open economy, SOE-RBC

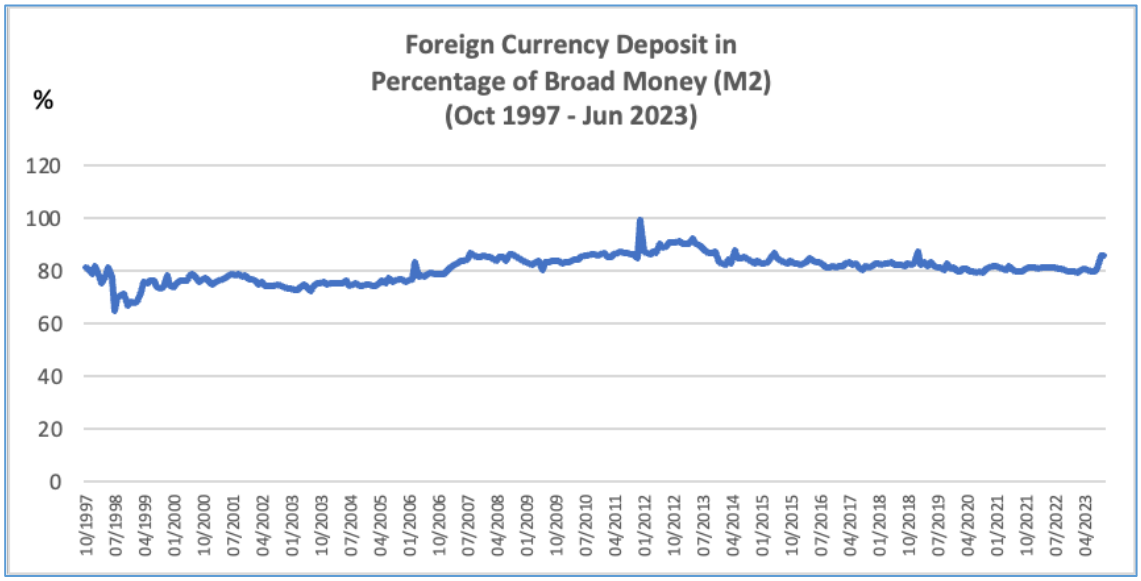
4.1-Introduction

Cambodia is a small open economy due to its small domestic market and heavy reliance on international trade and investment. The ratio of balance payment of the current account to GDP is -25.6% (2022), while the average 5-year figure is -18.4%. The FDIs (net inflow) to GDP ratio is 12% (2022).[14] This makes the country vulnerable to external and internal shocks. External shocks, like changes in global demand, interest rates, exchange rates, or trade policies, can directly impact the country's exports and imports, affecting important factors such as GDP, employment, and inflation. Internal shocks, such as government policy changes or shifts in consumer and investor confidence, can also impact the economy by influencing spending and investment decisions.

In addition to being a small open economy, as discussed in Chapters 2 and 3, Cambodia is highly dollarized. We emphasize that the impact of dollarization is not limited solely to the banking system in terms of deposits and loans, constituting financial dollarization. Instead, it extends across various sectors of the economy. Notably, 80% of broad money comprises foreign currency deposits (Figure 4.1), with consistently high rates since inception, implying a significant dependence on foreign currencies for the country's money supply.

[14] These figures come from the statistics published by the National Bank of Cambodia.

Figure 4.1: Foreign currency deposit is dominant in the composition of broad money (M2)

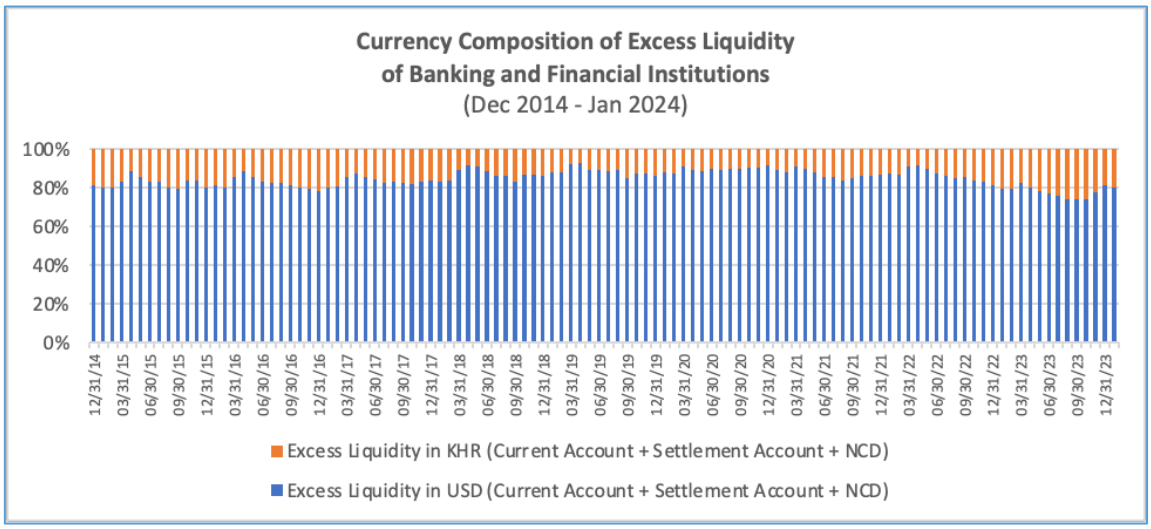


Source: National Bank of Cambodia

As for excess liquidity,[15] which represents the cash that each financial institution must maintain at the NBC, around 80% is denominated in USD (Figure 4.2). Excess liquidity often includes cash or other highly liquid assets that banks hold to meet short-term obligations or regulatory requirements. The vast proportion of excess liquidity in USD suggests a significant portion of the country's economic activities is conducted in that currency.

[15] Excess Liquidity = Current Account + Settlement Account + Negotiable Certificate of Deposit

Figure 4.2: Excess liquidity is predominantly denominated in USD



Source: National Bank of Cambodia

Survey data could provide insights into the population's behavior regarding the choice of currency for transactions. We extracted the following figures from a survey conducted by the NBC and JICA in 2014–2015[16] in various parts of Cambodia.

First, in the household survey of 2,273 respondents, the surveyed households received, on average, approximately 40% of their income from all sources in foreign currencies (Figure 4.3, non-blue area), mainly in USD. However, they received over 50% of wages and salaries in foreign currencies[17] (Figure 4.4, non-blue area). These figures reflect that relatively large amounts of transactions are carried out in foreign currencies, mostly USD for households. The hubs like Phnom Penh and Siem Reap are the most dollarized.

[16] Dollarization in Cambodia: Evidence from a survey conducted in 2014–2015
[17] Employees in the private sector are largely paid in USD, while the public sector pays in KHR. Rural households also receive income in KHR.

Figure 4.3: Currency Composition of Income by Area

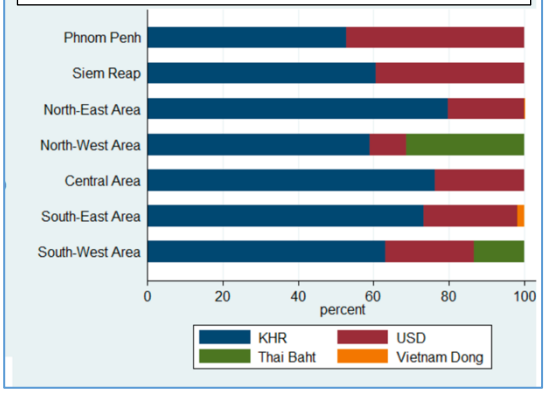
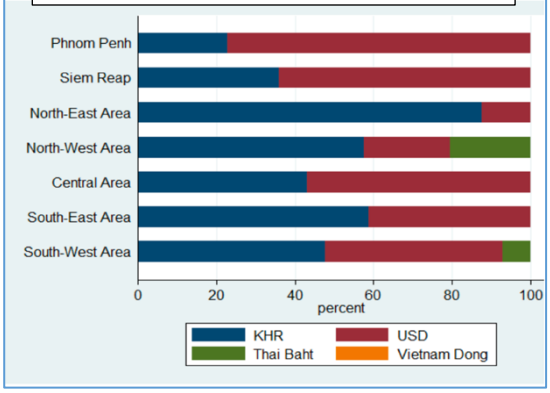


Figure 4.4: Currency Composition of Wage/Salary Income by Area



Source: Dollarization in Cambodia: Evidence from a survey conducted in 2014–2015

Regarding the currency composition of savings and loans of households mostly with banks, MFIs, and friends, savings and borrowings in foreign currencies are in high demand, with savings comprising approximately 70% (Figure 4.5, non-blue area) and borrowings comprising approximately 80% (Figure 4.6, non-blue area). This indicates households prefer holding assets and liabilities in foreign currencies.

Figure 4.5: Currency Composition of Savings by Area

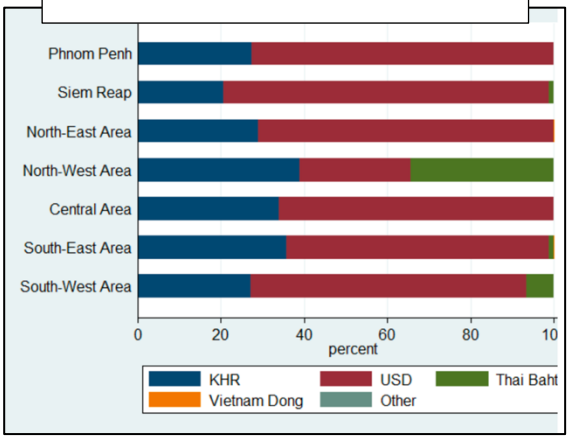
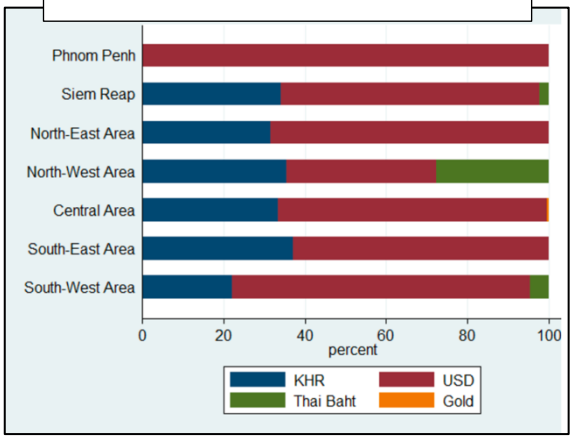


Figure 4.6: Currency Composition of Loans by Area



Source: Dollarization in Cambodia: Evidence from a survey conducted in 2014–2015

From these observations, we conclude that households exhibit a high degree of dollarization behavior. This means they heavily rely on, transacts in, and holds assets or liabilities in foreign currency, mainly US dollars.

Enterprises exhibit a higher degree of dollarization in their transactions compared to households. Among the 856 enterprise respondents, primarily from wholesale and retail trades, manufacturing, and accommodation and food service activities, approximately 60% of their transactions involve foreign currencies, as confirmed by the currency composition of revenues (Figure 4.7, non-blue area) and expenditures (Figure 4.8, non-blue area).

Figure 4.7: Currency Composition of Revenues (Enterprises)

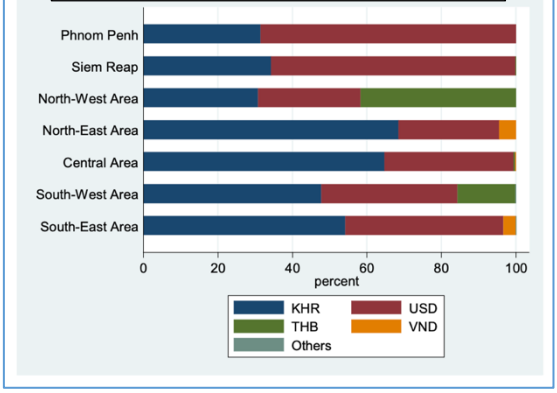
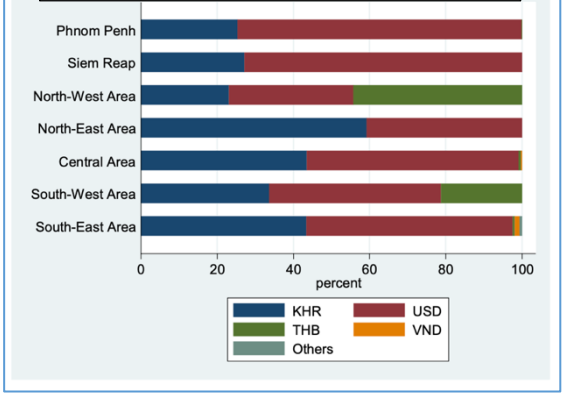


Figure 4.8: Currency Composition of Expenditure (Enterprises)



Source: Dollarization in Cambodia: Evidence from a survey conducted in 2014–2015

Due to the high degree of dollarization in Cambodia, both inside and outside the banking system, it will be interesting to observe how macroeconomic variables respond to a shock in the USD interest rate abroad. We also want to estimate a dynamic stochastic general equilibrium (DSGE) model for Cambodia's case.

4.2-Literature Review

We study the foreign interest rate shock in a highly dollarized economy to examine how influential foreign interest rates are in driving business cycles. Given the widespread presence of foreign currencies in the country, we often expect the shock to significantly influence the business cycle. Various studies on the effect of interest rate shock in regular economies show contradictory results. For example, Mendoza (1991) and Correia et al. (1995) found that an interest rate shock has a minimal impact on macro variables in equilibrium compared to domestic shocks, contrary to expectations. Meanwhile, Neumeyer and Perri (2004) identified the interest rate shock as the main driver of the business cycle.

DSGE models are useful in estimating the dynamics of macroeconomic variables in response to shocks. DSGE models enable economic agents to optimize their behavior by allocating consumption, investment, and labor subject to constraints and shocks, aiming to achieve the highest utility. Agents utilize utility functions, constraints, and shock equations to accomplish this. Assuming market clearing in every period, we solve for the policy function, representing the optimized values of aggregate variables (Jose, 2016). Many studies use DSGE models to analyze standard or non-dollarized economies. However, not many use them to estimate dollarized economies. Among the ones that use DSGE models to estimate dollarized economies, for instance, Schmitt-Grohe and Uribe (2001) study the costs of dollarization by comparing the welfare costs of business cycles in a dollarized economy during shocks to the costs arising in regular economies of various monetary policy regimes and found the dollarization case the most costly. Castillo et al. (2016) incorporate currency substitution and price dollarization into the regular economy model to replicate the Peruvian economy and found that the model

with dollarization explains the dynamic of macroeconomic variables better than the model without dollarization. Djukić et al. (2017) modify a model of a small open regular economy by incorporating financial euroization to identify the primary channels through which monetary transmission occurs and found the model matches the Serbian economy. As for Cambodia, to our knowledge, not many studies use DSGE models to estimate its economy yet.[18]

The study "Closing Small Open Economy Models" by Schmitt-Grohe and Uribe (2001) is of great interest. The authors introduced an RBC model within the classical framework for a small open economy with incomplete asset markets in a regular non-dollarized economy, where residents purchase foreign government bonds to hedge their wealth against the risk of devaluation. Interestingly, this situation could mirror a dollarized economy. In a small open economy with partial dollarization at a high level where people have a significant preference for foreign currency, like Cambodia, residents will likely depend on domestic foreign currency deposits to safeguard wealth, which we expect to be highly influenced by foreign interest rates. In this scenario, the deposit interest rate in foreign currency is comparable to the foreign bond interest rate used in the study.

4.3-Research Question

Our research aims to address the rarity of studies using DSGE models to estimate macroeconomic dynamics in Cambodia. We estimate the model of Schmitt-Grohe and

[18] The author is aware of one research using DSGE model under New Keynesian framework, Yonsei University, National Bank of Cambodia (2016) *Modeling for Macroeconomic Analysis and Inflation Forecasting*. Bank of Korea.

Uribe (2001) using Cambodia's data to analyze the dynamic responses of various macroeconomic variables to foreign interest rate shock and internal shocks.

4.4-Methodology

We follow the first model used in Schmitt-Grohe and Uribe (2001), "Closing Small Open Economy Models." The study introduces a model for a small open economy with incomplete asset markets (SOE-RBC), particularly the bond market, leading residents to purchase foreign government bonds to insure their wealth. In Uribe's models, due to an incomplete asset market structure, the residents of a country borrow or lend funds from or to the rest of the world to smooth out their consumption. Therefore, they use foreign bond interest rates, not domestic interest rates.

As seen throughout this thesis, including in the introduction of the present chapter, Cambodia is a highly dollarized country where dollarization infiltrates the banking system as well as the income and expenditure of the population. In order to facilitate the application of the above model, it is convenient to assume that Cambodia is fully dollarized. Hence, we make two assumptions for the model: i/-Cambodia is fully dollarized, the dollar market is perfectly elastic (matched by trade balance), and ii/- the dollar interest rate is independent of the demand and supply of domestic dollars.

One important feature of Uribe's model resides in the debt evolution equation:

$$d_t = (1 + r_{t-1})d_{t-1} - y_t + c_t + i_t + \Phi(k_{t+1} - k_t)$$

or

$$y_t + d_t = (1 + r_{t-1})d_{t-1} + c_t + i_t + \Phi(k_{t+1} - k_t)$$

where d_t is borrowing or lending in terms of foreign bonds. As Uribe's model is an endowment economy, if at time *t* the household is given a resource y_t and issues bond d_t

on foreign bond market, they have to pay for previous bond interest rate and principal $(1 + r_{t-1})d_{t-1}$ and consumption c_t, investment i_t, and capital adjustment cost $\Phi(k_{t+1} - k_t)$. The incomplete asset market in the standard model features in r_t being the foreign bond rate.

To simulate a fully dollarized economy from the model, the foreign bond interest rate needs to be replaced by the prevalent domestic foreign currency deposit interest rate in Cambodia. In addition, like in Uribe's first models, we follow Uzawa (1968) by endogenizing the discount factor. The reason is this modification makes the steady state independent of initial conditions.[19] In applying the model to Cambodia, we observe the dynamics of aggregate variables upon introducing three shocks: foreign interest rate, technology, and preference shocks.

To estimate the parameters of our DSGE model, we use the Bayesian method, where we use calibration parameters in "Closing Small Open Economy Models" by Schmitt-Grohe and Uribe (2001) as the initial values. We then use prior distributions and a Markov Chain Monte Carlo (MCMC) algorithm to recover the posterior distribution of the parameters given the observed data and the chosen priors. We return the posterior parameters to the models to generate Bayesian impulse responses.

4.5-Models

We apply Schmitt-Grohe and Uribe (2001) to Cambodia's economy and introduce the three shocks: foreign interest rate (q_t), technology (A_t), and preference shocks (u_t). We denote the shocks in red. The models become as follows:

[19] See Schmitt-Grohe, S. and Uribe Martín (2003) "Closing small open economy models"

- *Household*

$$E_0 \sum_{t=0}^{\infty} \theta_t U_t(u_t c_t, h_t) \qquad (1)$$

$$where\ U_t(u_t c_t, h_t) = \frac{(u_t c_t - \omega^{-1} h_t^{\omega})^{1-\gamma} - 1}{1-\gamma}$$

This function represents the household's lifetime utility, which we assume to be the same for every household in the economy of infinite numbers. It calculates the expected sum of utility flows (U_t) for all periods. Considered at present time, those utilities are discounted by a discount factor for each period (θ_t). From the utility function, we see that utility increases in consumption (c_t) and decreases in labor (h_t). γ is the coefficient of relative risk aversion, which measures an individual's willingness to bear risk. It quantifies how an individual's utility or satisfaction from consumption changes in response to changes in wealth or income.[20] Additionally, u_t represents the preference shock. Placing the shock on c_t means that the household can suddenly derive unusual utility from consumption.

- *Constraints*

The above utility function is subject to the following constraints. First, following Uzawa (1968), the discount factor changes for each period and is endogenized as follows:

$$\theta_0 = 1 \qquad (2)$$

$$\theta_{t+1} = \beta_t(c_t, h_t)\theta_t \qquad t \geq 0 \qquad (3)$$

$$where\ \beta_t(c_t, h_t) = [1 + c_t - \omega^{-1} h_t^{\omega}]^{-\psi_1}$$

[20] The coefficient of relative risk aversion is a parameter that determines the shape of an individual's utility function. A higher value of γ indicates a higher degree of risk aversion, meaning the individual is more sensitive to changes in wealth and prefers lower risks. Conversely, a lower value of γ implies lower risk aversion, indicating that the individual is more tolerant of risk and willing to accept higher uncertainty.

where $\beta_c < 0$, $\beta_h > 0$. The endogenous discount factor is convenient for calculation purpose in the open economy model because it addresses the non-stationarity in the equilibrium equations, represented by the random-walk process, which occurs if we use a fixed value discount factor. Precisely for this specification, impatience grows as consumption increases, resulting in a decrease in the discount factor. Conversely, as work effort increases, the value attributed to money rises, leading to an increase in the discount factor.

In the original model of an incomplete asset market economy, residents hedge against risks by investing in foreign bonds. By assuming that Cambodia has full dollarization and that the supply of USD is elastic, we frame the model to Cambodia by substituting foreign bonds with domestic USD deposits and foreign bond interest rate with domestic USD deposit interest rate. Therefore, the evolution of domestic debt position (net) in foreign currency, d_t, is given by:

$$d_t = (1 + q_{t-1} r_{t-1}) d_{t-1} - y_t + c_t + i_t + \Phi(k_{t+1} - k_t) \qquad (4)$$

$$where\ \Phi(x) = \frac{\Phi}{2} x^2$$

{d_t is your domestic debt position in foreign currency [positive (debt) or negative (deposit)], which is your asset. d_{t-1} is your borrowing (liability) (think another way, it is our negative deposit account)}

where $q_t r_t = r_{USD,t}$ denotes the domestic foreign currency interest rate at which domestic residents can borrow in period t, y_t domestic output, c_t consumption, i_t gross investment, and k_t physical capital. We assume that r_t is constant, and so $r_t = \bar{r}$, whereas q_t is a shock with a mean equal to 1. Therefore $r_{USD,t}$ is a random variable with a mean equal to

$\bar{r}$. The function $\Phi(.)$ captures capital adjustment costs. We include capital adjustment costs to ensure capital stability because capital is typically very volatile in a small open economy. Implementing capital investment costs discourages volatile investments both upon entering and exiting. It follows that $\Phi(.)$ is assumed to satisfy $\Phi(0) = \Phi'(0) = 0$, meaning that in a steady state, where $k_{t+1} = k_t$, the costs are nil, and the slope is also nil, implying that the relative price of capital goods in terms of consumption goods is unity.

The firm's production function is the regular one, having capital and labor services as inputs:

$$y_t = A_t F_t(k_t, h_t) \tag{5}$$

$$where\ F_t(k_t, h_t) = k_t^{\alpha} h_t^{1-\alpha}$$

where A_t is an exogenous stochastic productivity shock.

The evolution of the stock of capital is:

$$k_{t+1} = i_t + (1 - \delta)k_t \tag{6}$$

where $\delta \in (0,1)$ is the rate of depreciation of physical capital.

- *Exogenous shock equations*

We introduce three shocks: foreign interest rate shock, affecting the domestic interest rate of foreign currency; technology, and preference shocks. The shocks evolve following AR(1) and have the following form:

$$log(q_t) = \rho_r log(q_{t-1}) + \varepsilon_t^r \ \textit{(foreign interest rate shock)} \tag{7}$$

$$log(A_t) = \rho_A log(A_{t-1}) + \varepsilon_t^A \ \textit{(technology shock)} \tag{8}$$

$$log(u_t) = \rho_u log(u_{t-1}) + \varepsilon_t^u \ \textit{(preference shock)} \tag{9}$$

- *Competitive equilibrium*

In competitive equilibrium, households choose processes $\{c_t, h_t, y_t, i_t, k_{t+1}, d_t, \theta_{t+1}\}_{t=0}^{\infty}$ to maximize the utility function (1) subject to Equations (2)–(6) and the no-Ponzi scheme condition:

$$\lim_{j\to\infty} E_t \frac{d_{t+j}}{\prod_{s=1}^{j}(1+r_s)} \leq 0. \tag{10}$$

The no-Ponzi scheme is the assumption that in the final period, the agent will not die in debt. Therefore, the creditor will not lose money, and funds will not disappear from the system. To recap, we have household utility function, constraints, and shock equations as follows:

$$\max_{\{c_t,h_t,y_t,i_t,k_{t+1},d_t,\theta_{t+1}\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \theta_t U_t(u_t c_t, h_t)$$

$$U_t(u_t c_t, h_t) = \frac{(u_t c_t - \omega^{-1} h_t^{\omega})^{1-\gamma} - 1}{1-\gamma}$$

$$\theta_0 = 1$$

$$\theta_{t+1} = \beta_t(c_t, h_t)\theta_t$$

$$\beta_t(c_t, h_t) = [1 + c_t - \omega^{-1} h_t^{\omega}]^{-\psi_1}$$

$$d_t = (1 + q_{t-1} r_{t-1}) d_{t-1} - y_t + c_t + i_t + \Phi(k_{t+1} - k_t)$$

$$\Phi(x) = \frac{\Phi}{2} x^2$$

$$y_t = A_t F_t(k_t, h_t)$$

$$F_t(k_t, h_t) = k_t^{\alpha} h_t^{1-\alpha}$$

$$k_{t+1} = i_t + (1-\delta)k_t$$

Shocks:

$$log(q_t) = \rho_r log(q_{t-1}) + \varepsilon_t^r \text{ (foreign interest rate shock)}$$

$$log(A_t) = \rho_A log(A_{t-1}) + \varepsilon_t^A \text{ (technology shock)}$$

$$log(u_t) = \rho_u log(u_{t-1}) + \varepsilon_t^u \text{ (preference shock)}$$

No-Ponzi scheme:

$$\lim_{j\to\infty} E_t \frac{d_{t+j}}{\prod_{s=1}^{j}(1+r_s)} \leq 0$$

- *First order conditions:*

Let $\eta_t, \lambda_{1t}, \lambda_{2t}, and\ \lambda_{3t}$ be the Lagrange multipliers on Equations (3), (4), (5), and (6), respectively, where $\lambda_t = \lambda_{1t} = -\lambda_{2t} = \lambda_{3t}$ (see appendix for these equalities). The first-order conditions of the household's maximization problem are shown in Equations (3)-(10):

First-order conditions in compact forms:

$$d_t - (1 + q_{t-1}r_{t-1})d_{t-1} + y_t - c_t - i_t - \Phi(k_{t+1} - k_t) = 0 \quad (11)$$

$$y_t - A_t F_t = 0 \quad (12)$$

$$i_t + (1-\delta)k_t - k_{t+1} = 0 \quad (13)$$

$$\lambda_t = E_t \lambda_{t+1} \beta_t(c_t, h_t)(1 + q_t r_t) \quad (14)$$

$$U_c(u_t c_t, h_t) - \eta_t \beta_c(c_t, h_t) = \lambda_t \quad (15)$$

$$\eta_t = -E_t U_{t+1}(u_{t+1}c_{t+1}, h_{t+1}) + E_t \eta_{t+1}\beta_{t+1}(c_{t+1}, h_{t+1}) \quad (16)$$

$$-U_h(u_t c_t, h_t) + \eta_t \beta_h(c_t, h_t) = \lambda_t A_t F_h(k_t, h_t) \quad (17)$$

$$\lambda_t[\Phi'(k_{t+1} - k_t) + 1] = E_t \lambda_{t+1}\beta_t(c_t, h_t)[\Phi'(k_{t+2} - k_{t+1}) +$$

$$A_{t+1}F_k(k_{t+1}, h_{t+1}) + (1-\delta)] \quad (18)$$

First-order conditions in explicit forms for U, β, Φ, and F (we use the same equation numbers):

$$d_t = (1 + q_{t-1}r_{t-1})d_{t-1} - y_t + c_t + i_t + \frac{\Phi}{2}(k_{t+1} - k_t)^2 \quad (11)$$

$$y_t = A_t k_t^{\alpha} h_t^{1-\alpha} \quad (12)$$

$$k_{t+1} = i_t + (1-\delta)k_t \quad (13)$$

$$\lambda_t = (1 + c_t - \omega^{-1} h_t^{\omega})^{-\psi_1}(1 + q_t r_t) E_t \lambda_{t+1} \quad (14)$$

$$\lambda_t = u_t (u_t c_t - \omega^{-1} h_t^{\omega})^{-\gamma} + \eta_t \psi_1 (1 + c_t - \omega^{-1} h_t^{\omega})^{-\psi_1 - 1} \quad (15)$$

$$\eta_t = -E_t \frac{(u_{t+1} c_{t+1} - \omega^{-1} h_{t+1}^{\omega})^{1-\gamma} - 1}{1-\gamma} + E_t \eta_{t+1} (1 + c_{t+1} - \omega^{-1} h_{t+1}^{\omega})^{-\psi_1} \quad (16)$$

$$h_t^{\omega-1}(u_t c_t - \omega^{-1} h_t^{\omega})^{-\gamma} + \eta_t \psi_1 h_t^{\omega-1}(1 + c_t - \omega^{-1} h_t^{\omega})^{-\psi-1} =$$

$$\lambda_t A_t (1-\alpha) k_t^{\alpha} h_t^{-\alpha} \quad (17)$$

$$\lambda_t [1 + \Phi(k_{t+1} - k_t)] = (1 + c_t - \omega^{-1} h_t^{\omega})^{-\psi_1} E_t \lambda_{t+1} [A_{t+1} \alpha k_{t+1}^{\alpha-1} h_t^{1-\alpha} +$$

$$1 - \delta + \Phi(k_{t+2} - k_{t+1})] \quad (18)$$

We use four observed variables while there are only three shocks; for technical reasons, we include a measurement error equation for investment in addition to the shock equation: $i_{observed} = i_t - i_{ss} + mesurement\ error$ to circumvent stochastic singularity of the model.

4.6-Estimation

4.6.1-Data

We use four types of Cambodian data: GDP, consumption, investment, and term deposit interest rate in USD from 2002q1 to 2022q4 (84 observations) for the observed variables. We use the term deposit interest rate because it is comparable to the foreign bond interest rate in the incomplete asset market, a small, open, non-dollarized economy. Except for interest rates, which are available at high frequency, the other data are only available annually, so we interpolated them to quarterly frequency. GDP, consumption, and investment enter the model in the natural logarithm form and per capita term, while

interest rate enters in the natural logarithm of the gross rate form. We include one measurement error in the data for investment to avoid singularity and be able to estimate the model. We use a one-sided HP filter to detrend the data.

We set the depreciation rate δ to 0.1 according to Schmitt-Grohe and Uribe (2001), who follow Mendoza (1991), to the Canadian economy. We set the net long-run interest rate, $\bar{r}$, by the average term deposit interest rates in US dollars to 0.011, and long-run debt position to GDP, $\bar{d}$, to 0.138 based on Cambodia's data.

Table 4.1: Fixed Values

$\bar{r}$	$\bar{d}$	δ
0.011	0.138	0.1

We estimate the remaining parameters using Bayesian estimations based on the prior setting below:

Table 4.2: Priors

Parameter	Prior distribution	Prior mean	Prior standard deviation
γ	inv_gamma_pdf	2	0.1
ω	normal_pdf	1.5	0.1
α	beta_pdf	0.3	0.01
φ	normal_pdf	0.02	0.07
ρ_r	beta_pdf	0.6	0.01
ρ_A	beta_pdf	0.8	0.1
ρ_u	beta_pdf	0.6	0.01

σ_r	inv_gamma_pdf	0.001	1
σ_A	inv_gamma_pdf	0.001	1
σ_u	inv_gamma_pdf	0.005	0.5
σ_{ME}	inv_gamma_pdf	0.001	1

4.6.2-Bayesian Impulse Responses

We use the Bayesian impulse response function to analyze the response of DSGE variables to a temporary exogenous shock. The Bayesian impulse responses incorporate the principle of Bayesian statistics, involving updating prior beliefs based on observed data. This approach enables us to comprehend how the economy responds and adjusts over time following a specific shock. It provides valuable insights into the short-term and long-term effects as well as the propagation mechanisms of various shocks on the economy.

This technique applies shock to the model's steady state, and we observe the model's response over time. The response is typically measured to be interpreted in terms of percentage change in level in key economic variables, for instance, output, consumption, and investment, in response to a one standard deviation of a selected shock. By examining the model's response to different types of shock, we can understand how the economy will likely react to external or internal disturbances. Note that the variables displayed in the tables below are in natural logarithms. The vertical axis is measured in log value, representing a deviation from the steady, and the horizontal axis represents the timeline.

Bayesian impulse response functions represent the mean impulse responses, and the gray-shaded areas represent the highest posterior density intervals.

- *Foreign Interest Rate Shock*

Figure 4.9: Orthogonalized Shock to Interest Rate

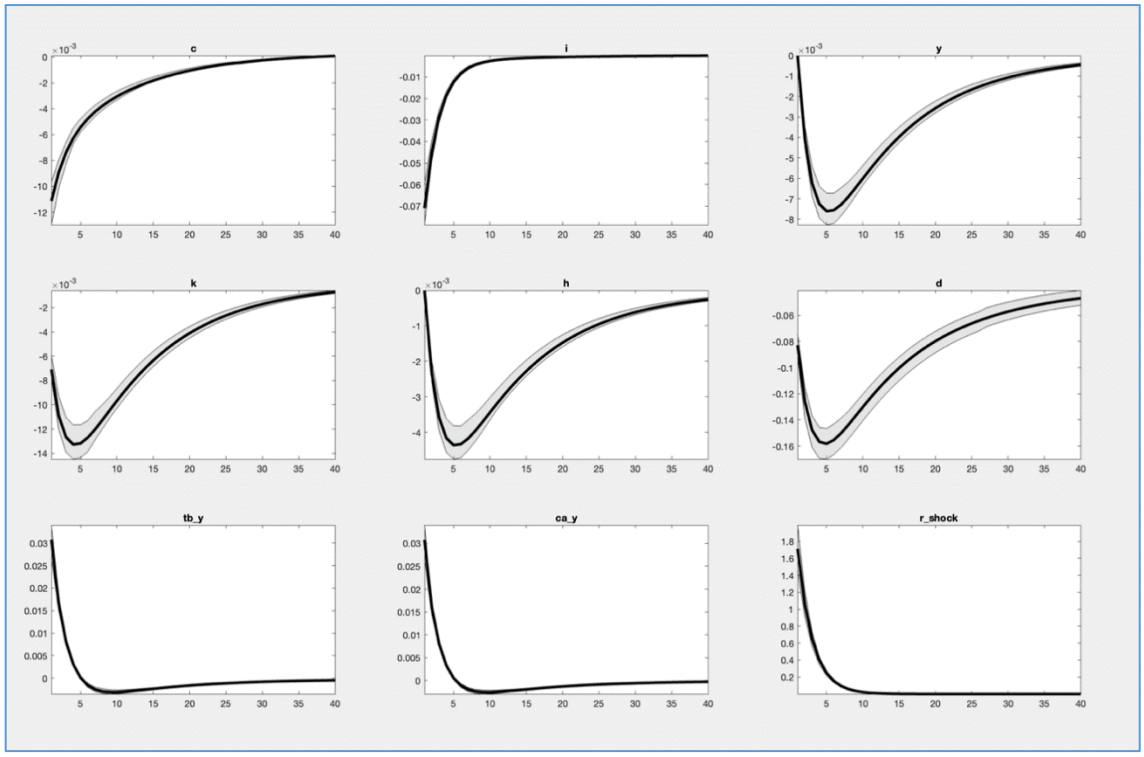


Figure 4.9 shows the impulse responses of the variables of interest to a one standard deviation rise in the world US dollar interest rate (e_r). The shock to the interest rate occurs in the country's issuing currency, specifically the United States, and it impacts the USD deposit interest rate in Cambodia (r_shock). Since the economy is dollarized, a one standard deviation shock to the US interest rate results in an immediate increase in the domestic USD deposit gross rate (r_shock=1.7, i.e., gross deposit rate increases 5.473 times).

Regarding the movements, an interest rate shock causes expected shifts in the variables. Investment decreases because the shock also raises interest rates on loans in US dollars, while consumption decreases because residents prefer to save their money. Capital, GDP, labor rates, and borrowing in US dollars also experience decreases, albeit

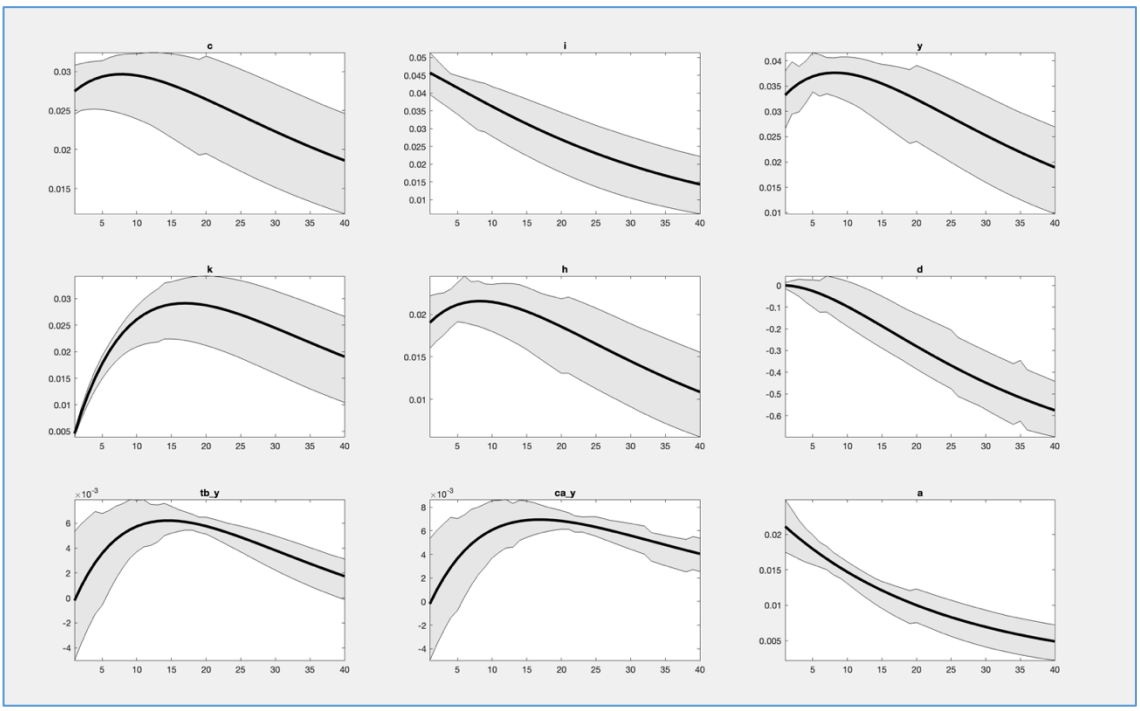
with a lag. The overall decrease in major macro variables results in an increase in the trade balance and current account.

However, regarding the magnitudes, a world interest rate shock has a small impact on all variables, contrary to our expectations, given its strong impact on domestic interest rates. For instance, in response to one standard deviation of world interest rate shock, c = -0.01 (i.e., natural logarithm of consumption =-0.01), meaning that consumption drops from the steady state by 0.9950%, and y=-0.0075, a reduction in output of 0.745%. The magnitudes are thus very small. The variable most significantly impacted is investment: i=-0.07, leading to an investment decrease of 6.5136%.

Notably, although we did not specifically address the USD loan interest rate, it is evident that the shock causes it to increase too. Therefore, in a dollarized economy like Cambodia, where investment loans are primarily in USD, there is a decline in investment.

- *Technology Shock*

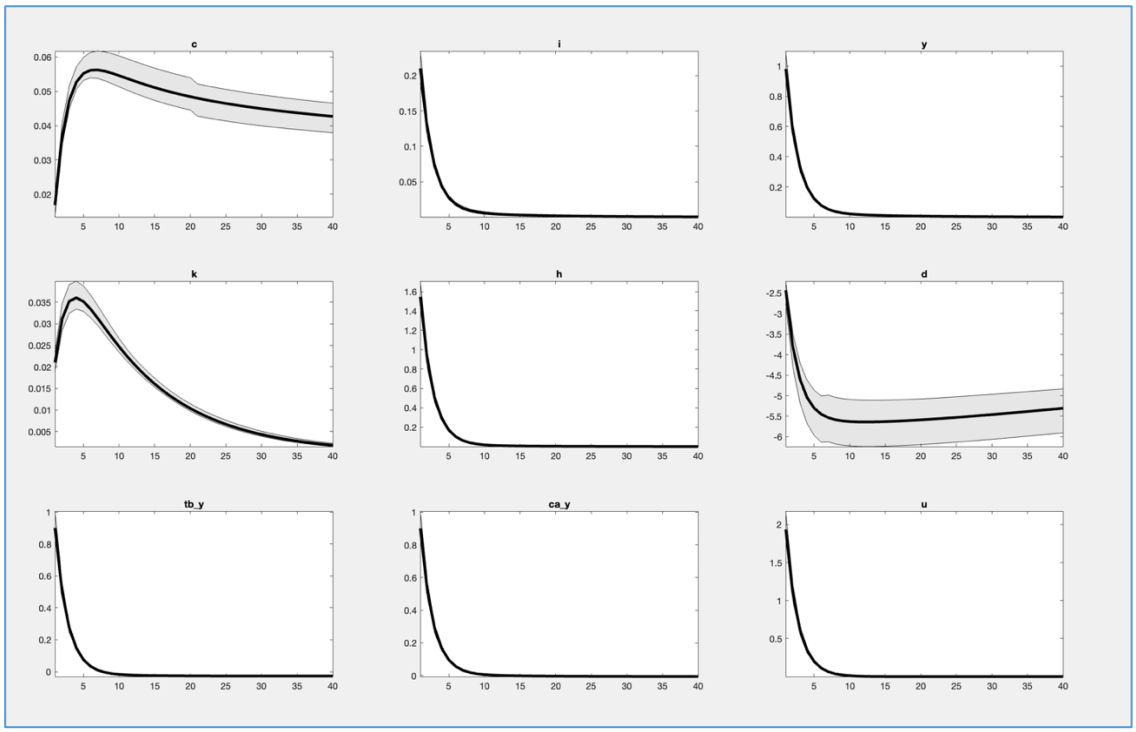
Figure 4.10: Orthogonalized Shock to Technology



The shock to technology could be a global or a domestic shock that positively affects many variables due to increased efficiency. The movement of the variables is expected, and the magnitudes are large. For instance, c=0.026 (consumption increases from 2.6% from the steady state), i=0.046 (investment increases 4.7%), and y=0.034 (output increases 3.4%). The positive technology shock leads to a decrease in debt over time since now the country relies less on borrowing.

- *Preference Shock*

Figure 4.11: Orthogonalized Shock to Utility



A preference shock refers to a sudden increase in preference for a specific component of the utility function, in our case, consumption. When the shock hits in time 0, the household in this model does not consume a lot immediately but prefers increasing investment and work hours first. This leads to an increase in trade balance and current

account. Only afterward that the household increases consumption. The shock has a large impact on the variables too: c=0.055 (consumption increases 5.6% from steady state), i=0.22 (24.6%), and y=1 (171.8%).

4.6.3-Variance Decomposition

Table 4.3: Posterior Mean Variance Decomposition (in Percentage)

	ε_t^r	ε_t^A	ε_t^u
c	0.11	12.45	87.44
i	7.21	36.42	56.38
y	0.04	3.56	96.40
k	4.06	68.34	27.60
h	0.01	0.49	99.50
d	0.01	2.86	97.13
tb_y	0.11	0.34	99.55
ca_y	0.11	0.15	99.74

In Table 4.3, the variance decomposition analysis examines the contribution of different shocks to the variability of macroeconomic variables. Despite the country's dollarization, the foreign interest rate shock, as an external shock, has a smaller impact on macro variables compared to the technology shock (a structural shock) and the preference shock (an internal shock). Therefore, the findings could imply that, even after dollarization, the country's macroeconomic dynamics are still more significantly influenced by internal factors such as technology and preference shocks. This underscores

the importance of considering both internal and external factors when analyzing the drivers of macroeconomic fluctuations and formulating appropriate policies.

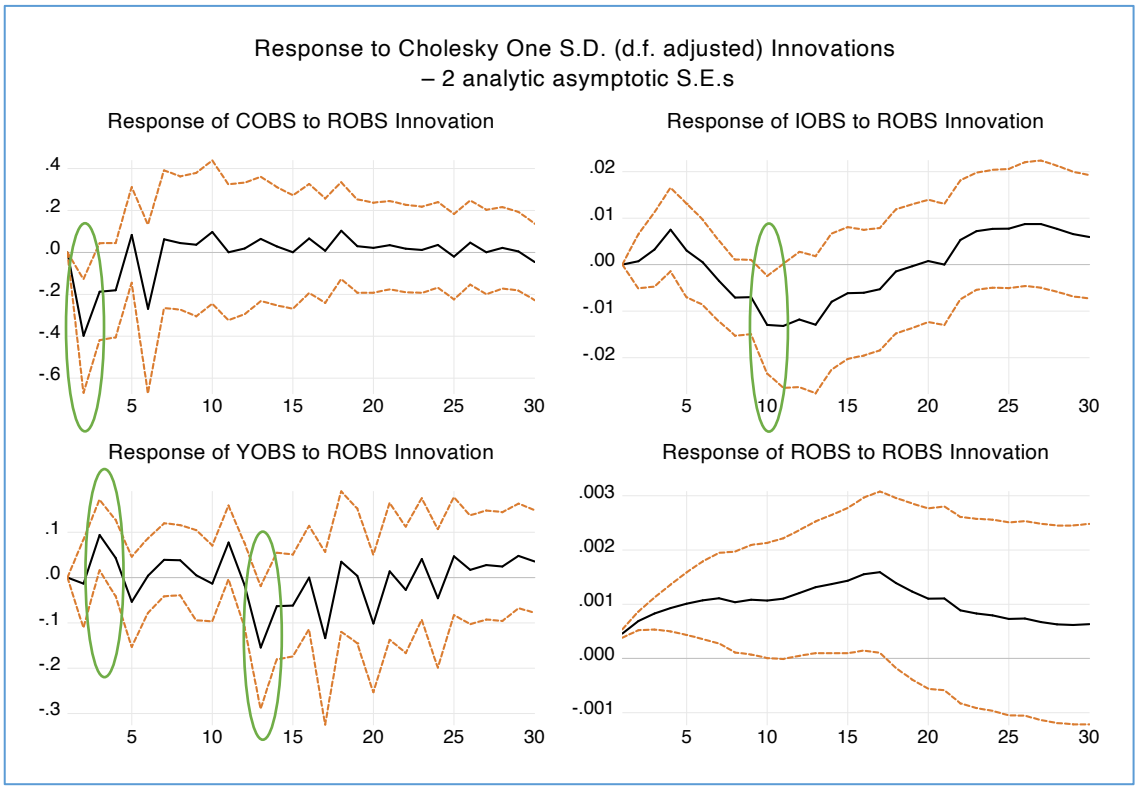
Our findings align with Mendoza (1991), whose model we based ours on, and Correia et al. (1995). In their models, an interest rate shock has only a minimal impact on macro variables in equilibrium compared to domestic shocks. Furthermore, our results, like theirs, show that the shock has the largest impact on investment compared to other variables.

It is worth noting that our results and Mendoza's (1991) findings contrast with those of Neumeyer and Perri (2004), where the interest rate shock mainly drives the business cycle. The difference arises because the latter models the economy differently, making improvements, especially by incorporating interest rates into the production function. In a traditional model like ours, the firm's production function does not involve interest rates because we assume a frictionless production process, where the firm rents capital from households, produces goods, sells them, and repays labor simultaneously. However, Neumeyer and Perri (2004) introduced improvements by allowing friction in the process, requiring firms to borrow working capital (i.e., cash) in advance as a fraction of the wage to be paid before the production of goods takes place, covering the friction. This borrowing introduces interest rates into the production function. Therefore, when an interest rate shock occurs just before the time of production, it can affect the firm's labor demand at a given wage. The labor supply, as also assumed by the study, is elastic so the firm can respond in an optimizing manner subject to interest rate shock. Consequently, in equilibrium, the interest rate shock can affect labor demand, output, and employment as well.

4.6.4-VAR Impulse Responses

To validate the impulse responses of the interest rate shock, we employ an unrestricted VAR model encompassing variables such as output, consumption, investment, and interest rates. The results confirm the impulse responses of the interest rate shock on output, consumption, and investment, albeit with some nuanced details. These variables exhibit responses to interest rate shocks with lags, which are not as immediate as observed in the DSGE environment. Regarding the output response, it initially increases and only subsequently experiences a decrease. While these movements align mostly with our expectations, similar to DSGE models, foreign interest rate shock still does not emerge as the primary driver of the business cycle.

Figure 4.12: Impulse Responses from VAR



(COBS=Consumption, IOBS=Investment, YOBS=Output, ROBS=Interest rate)

4.7-Limitations

Our research has the following limitations:

Temporal interpolation: The primary limitation of our research stems from the interpolation of data from an annual to quarterly frequency. Apart from interest rates, other variables such as output, consumption, and investment are subject to potential inaccuracies introduced during the interpolation process. Future research should consider obtaining more granular data to enhance the precision of our findings.

Assumption of full dollarization: Given the highly dollarized nature of the Cambodian economy, we assume full dollarization in our model. This assumption simplifies the analysis but may not fully capture the nuanced dynamics of transactions in both USD and KHR. Future studies should explore models incorporating partial dollarization to account for transactions conducted in both currencies, providing a more comprehensive understanding of the economic landscape.

Interest rates have limited interaction with other variables: Our research fails to confirm our expectation that the shock to interest rates will drive the business cycle. This could be due to the limited direct interaction of interest rates with other relevant economic factors. Future research should explore the possibility of enhancing these interactions.

4.8-Conclusions

This research estimates an SOE-RBC model for Cambodia to examine the responses of macroeconomic variables to three shocks: interest rate, technology, and preference shocks. Based on Bayesian impulse responses, the model appears to align with reality, suggesting its suitability for application in a partially dollarized economy. Among

the three shocks, the interest rate shock deserves more attention as it reveals the cost of dollarization. It demonstrates the extent to which a dollarized economy relies on foreign countries, leading to reduced consumption and increased debt expenses. Therefore, de-dollarization is a valid policy option that Cambodia has attempted. However, based on the variance decomposition, the interest rate shock is not the driver of the business cycle, contrary to our expectation, and internal shocks such as technology and preference shocks have a greater influence on the country's macroeconomic dynamics. This could be due to model specifications. Future research should involve estimating multiple models to compare results. Future research should try different models incorporating the exact features of partial dollarization and more interactions of the exchange rate with other variables.

Chapter 5: Overall Conclusions

In conclusion, despite Cambodia's deeply entrenched dollarization issue, a glimmer of hope exists. Although currently effective within the banking system only, the positive impact identified through our estimation of the loan currency policy suggests a potential avenue for optimism. Sustaining and possibly expanding this regulatory framework could be a key component of the de-dollarization strategy. However, a prudent approach necessitates integrating hard and soft measures to mitigate potential losses, recognizing the inherent vulnerabilities of banking and financial institutions.

A critical aspect of the de-dollarization endeavor involves visualizing the true cost of dollarization on the economy. Our analysis underscores a discernible cost, and elucidating this economic reality could catalyze more effective problem-solving. Convincing stakeholders of this cost is pivotal to garnering collective support and facilitating a smoother de-dollarization process.

The subsequent imperative is to engage in a concerted effort to educate and inform the general population about the advantages and disadvantages of dollarization. This initiative extends beyond mere dissemination of information; it aims to shape public perception and cultivate a more informed and supportive environment for de-dollarization initiatives.

In navigating the complex de-dollarization landscape, it is evident that a multi-faceted approach incorporating regulatory measures, stakeholder engagement, and public awareness signals a gradual but impactful transformation. By weaving these strategic threads, Cambodia can pave its way toward a more realizable and economically de-dollarized economy.

References

Alvarez-Plata, P., & García-Herrero, A. (2008). *To Dollarize or De-Dollarize: Consequences for Monetary Policy.* SSRN Electronic Journal. https://doi.org/10.2139/ssrn.1428828

Armas, A. (2015). Chapter 12: Monetary Policy in a Partially Dollarized Economy: Peru's Experience with Inflation Targeting. In *Peru Staying the Course of Economic Success*. essay, International Monetary Fund.

Brodersen, Kay H., Fabian Gallusser, Jim Koehler, Nicolas Remy, and Steven L. Scott. "Inferring Causal Impact Using Bayesian Structural Time-Series Models." The Annals of Applied Statistics 9, no. 1 (2015). https://doi.org/10.1214/14-aoas788.

Castillo, P., Vega, H., Serrano, E., & Burga, C. (2016). *De-dollarization of credit in Peru: the role of unconventional monetary policy tools*. Bcrp.gob.pe. Retrieved 21 September 2021, from https://www.bcrp.gob.pe/docs/Publicaciones/Documentos-de-Trabajo/2016/documento-de-trabajo-02-2016.pdf. (working paper)

Chhoeung, J. (2017). *The monetary determinants of foreign currency deposits in Cambodia* (thesis), Hitotsubashi University.

Contreras, A., Gondo, R., Ore, E., & Forero, F. (2019). *Assessing the impact of credit de- dollarization measures in Peru*. Bcrp.gob.pe. Retrieved 21 September 2021, from https://www.bcrp.gob.pe/docs/Publicaciones/Documentos-de-Trabajo/2019/documento-de-trabajo-005-2019.pdf. (working paper)

Correia, I., Neves, J.C. and Rebelo, S. (1995) 'Business cycles in a small open economy', *European Economic Review*, 39(6), pp. 1089–1113. doi:10.1016/0014-2921(94)00105-9.

de la Torre, A., & Schmukler, S. (2004). *Coping with Risk through Mismatches : Domestic and International Financial Contracts for Emerging Economies*. Openknowledge.worldbank.org. Retrieved 23 September 2021, from https://openknowledge.worldbank.org/handle/10986/16216.

Feige, E., & Dean, J. (2004). *Dollarization and euroization in transition countries: currency substitution, asset substitution, network externalities, and irreversibility* (pp. 303-319). Oxford Scholarship Online. (book)

Jose, C. J. C. (2016). *Understanding dsge*. Vernon Press.

Kokenyne, A., Ley, J., & Veyrune, R. (2010). *Dedollarization*. Elibrary.imf.org. Retrieved 22 September 2021, from https://www.elibrary.imf.org/downloadpdf/journals/001/2010/188/001.2010.issue-188-en.xml. (working paper)

Lebre de Freitas, M. (2004). The dynamics of inflation and currency substitution in a small open economy. *Journal Of International Money And Finance*, *23*(1), 133-142. https://doi.org/10.1016/j.jimonfin.2003.10.003 (journal)

Mendoza, E., (1991). Real business cycles in a small-open economy. *American Economic Review* 81, pp797 – 818.

National Bank of Cambodia, *Evidence from a Survey Conducted in 2014-2015*, October 20, 2016. National Bank of Cambodia.

Neumeyer, P. and Perri, F. (2004) *Business cycles in emerging economies: The role of interest rates* [Preprint]. doi:10.3386/w10387.

Oomes, N. (2003). Network Externalities and Dollarization Hysteresis: The Case of Russia. Retrieved 14 January 2021, from https://www.imf.org/en/Publications/WP/Issues/2016/12/30/Network-Externalities-and-Dollarization-Hysteresis-The-Case-of-Russia-16475

Schmitt-Grohe, S. and Uribe, M. (2001) "Stabilization policy and the costs of Dollarization," *Journal of Money, Credit and Banking*, 33(2), p. 482.

_____ (2003) "Closing small open economy models," *Journal of International Economics*, 61(1), pp. 163–185.

Tal, N., & Dabadie, M. (2007). *Dollarization in Cambodia*. Nbc.org.kh. Retrieved 22 September 2021, from https://www.nbc.org.kh/download_files/publication/others_eng/NoteMD117-14_article_dollarization.pdf. (NBC publication)

Tkalec, M. (2013). Monetary determinants of deposit euroization in European post-transition countries. *Panoeconomicus*, *60*(1), 89-101. https://doi.org/10.2298/pan1301089t

Uribe, M., & Schmitt-Grohé, S. (2017). The Open-Economy Real-Business-Cycle Model. In *Open economy macroeconomics*. essay, Princeton University Press.

Uzawa, H., (1968). Time preference, the consumption function and optimum asset holdings. In: *Wolfe, J.N. (Ed.), Value, Capital and Growth: Papers in Honor of Sir John Hicks.* The University of Edinburgh Press, Edinburgh, pp. 485–504.

Yeyati, E. L., & Rey, H. (2006). Financial Dollarization: Evaluating the Consequences. *Economic Policy*, *21*(45), 63–118. http://www.jstor.org/stable/3601043

Yonsei University, National Bank of Cambodia (2016) *Modeling for Macroeconomic Analysis and Inflation Forecasting*. Bank of Korea.

Websites:

"All member banks of the Association of Banks in Cambodia have followed 10% loan portfolio in Riel as mandated by the NBC", *The Khmer Times*, March 31, 2023

"Cambodian commercial banks showed a stronger preference for providing riel loans to microfinance institutions (MFI) as they rushed to increase the share of the local currency" (The *Phnom Penh Post*, November 13, 2018).

Cambodia securites exchange(csx). CSX. (n.d.). http://csx.com.kh/data/statistic/listPosts.do?MNCD=60401 direct

Monetary and financial statistics data. (n.d.). https://www.nbc.gov.kh/english/economic_research/monetary_and_financial_statistics_data.php

Regulation: Nbc.org.kh. (2016). Retrieved 21 September 2021, from https://www.nbc.org.kh/download_files/legislation/prakas_eng/Prakas-on-providing-KHR-credit-eng.pdf.

Appendix

Chapter 4

1-Equilibrium Equations

$$E_0 \sum_{t=0}^{\infty} \theta_t U_t(u_t c_t, h_t)$$

$$U_t(u_t c_t, h_t) = \frac{(u_t c_t - \omega^{-1} h_t^{\omega})^{1-\gamma} - 1}{1-\gamma}$$

Subject to:

$$\theta_0 = 1$$

$$\theta_{t+1} = \beta_t(c_t, h_t)\theta_t$$

$$\beta_t(c_t, h_t) = [1 + c_t - \omega^{-1} h_t^{\omega}]^{-\psi_1}$$

$$d_t = (1 + q_{t-1} r_{t-1}) d_{t-1} - y_t + c_t + i_t + \Phi(k_{t+1} - k_t)$$

$$\Phi(x) = \frac{\Phi}{2} x^2$$

$$k_{t+1} = i_t + (1-\delta)k_t$$

$$y_t = A_t F_t(k_t, h_t)$$

$$F_t(k_t, h_t) = k_t^{\alpha} h_t^{1-\alpha}$$

Shocks:

$$log(q_t) = \rho_r log(q_{t-1}) + \varepsilon_t^r \text{ (foreign interest rate shock)}$$

$$log(A_t) = \rho_A log(A_{t-1}) + \varepsilon_t^A \text{ (technology shock)}$$

$$log(u_t) = \rho_u log(u_{t-1}) + \varepsilon_t^u \text{ (preference shock)}$$

No-Ponzi scheme:

$$\lim_{j \to \infty} E_t \frac{d_{t+j}}{\prod_{s=1}^{j}(1+r_s)} \leq 0$$

Endogenous variables: $\{d_t, c_t, h_t, y_t, i_t, k_{t+1}, \eta_t, \lambda_{1t}, \lambda_{2t,} \lambda_{3t,} \theta_{t+1}\}$

Shocks variables: $\{q_t, A_t, u_t\}$

Endogenous shocks: $\{\varepsilon_t^r, \varepsilon_t^A, \varepsilon_t^u\}$

$$\mathcal{L} = E_0 \sum_{t=0}^{\infty} \theta_t U_t(u_t c_t, h_t)$$

$$+ E_0 \sum_{t=0}^{\infty} \eta_t[\theta_{t+1} - \beta_t(c_t, h_t)\theta_t]$$

$$+ \lambda_{1t}\theta_t[d_t - (1 + q_{t-1}r_{t-1})d_{t-1} + y_t - c_t - i_t - \Phi(k_{t+1} - k_t)]$$

$$+ \lambda_{2t}\theta_t(y_t - A_t F_t) + \lambda_{3t}\theta_t[i_t + (1-\delta)k_t - k_{t+1}]$$

FOC:

$$\frac{\partial \mathcal{L}}{\partial \eta_t} = \theta_{t+1} - \beta_t(c_t, h_t)\theta_t$$

$$\Rightarrow \theta_{t+1} - \beta_t(c_t, h_t)\theta_t = 0 \quad (1)$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_{1t}} = \theta_t[d_t - (1 + q_{t-1}r_{t-1})d_{t-1} + y_t - c_t - i_t - \Phi(k_{t+1} - k_t)]$$

$$\Rightarrow d_t - (1 + q_{t-1}r_{t-1})d_{t-1} + y_t - c_t - i_t - \Phi(k_{t+1} - k_t) = 0 \quad (2)$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_{2t}} = \theta_t(y_t - A_t F_t)$$

$$\Rightarrow y_t - A_t F_t = 0 \quad (3)$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_{3t}} = \theta_t[i_t + (1-\delta)k_t - k_{t+1}]$$

$$\Rightarrow i_t + (1-\delta)k_t - k_{t+1} = 0 \quad (4)$$

$$\frac{\partial \mathcal{L}}{\partial \theta_{t+1}} = \eta_t + E_t U_{t+1}(u_{t+1}c_{t+1}, h_{t+1}) - E_t \eta_{t+1}\beta_{t+1}(c_{t+1}, h_{t+1})$$
$$+ E_t \lambda_{1(t+1)}[d_{t+1} - (1 + q_t r_t)d_t + y_{t+1} - c_{t+1} - i_{t+1} - \Phi(k_{t+2}$$
$$- k_{t+1})] + E_t \lambda_{2(t+1)}(y_{t+1} - A_{t+1}F_{t+1}) + E_t \lambda_{3(t+1)}[i_{t+1} + (1$$
$$- \delta)k_{t+1} - k_{t+2}]$$

$$\Rightarrow \eta_t + E_t U_{t+1}(u_{t+1}c_{t+1}, h_{t+1}) - E_t \eta_{t+1}\beta_{t+1}(c_{t+1}, h_{t+1})$$
$$+ E_t \lambda_{1(t+1)}[d_{t+1} - (1 + q_t r_t)d_t + y_{t+1} - c_{t+1} - i_{t+1} - \Phi(k_{t+2}$$
$$- k_{t+1})] + E_t \lambda_{2(t+1)}(y_{t+1} - A_{t+1}F_{t+1}) + E_t \lambda_{3(t+1)}[i_{t+1} + (1$$
$$- \delta)k_{t+1} - k_{t+2}] = 0$$

Based on (2), (3), (4), we obtain:

$$\eta_t + E_t U_{t+1}(u_{t+1}c_{t+1}, h_{t+1}) - E_t \eta_{t+1}\beta_{t+1}(c_{t+1}, h_{t+1}) = 0$$

$$\Rightarrow \eta_t = - E_t U_{t+1}(u_{t+1}c_{t+1}, h_{t+1}) + E_t \eta_{t+1}\beta_{t+1}(c_{t+1}, h_{t+1}) \quad (5)$$

$$\frac{\partial \mathcal{L}}{\partial d_t} = \lambda_{1t}\theta_t - E_t \lambda_{1(t+1)}\theta_{t+1}(1 + q_t r_t)$$

$$\lambda_{1t}\theta_t - E_t \lambda_{1(t+1)}\theta_{t+1}(1 + q_t r_t) = 0$$

$$\lambda_{1t} = E_t \lambda_{1(t+1)} \frac{\theta_{t+1}}{\theta_t}(1 + q_t r_t)$$

$$\Rightarrow \lambda_{1t} = E_t \lambda_{1(t+1)}\beta_t(c_t, h_t)(1 + q_t r_t) \quad (6)$$

$$\frac{\partial \mathcal{L}}{\partial c_t} = \theta_t U_c(u_t c_t, h_t) - \eta_t \beta_c(c_t, h_t)\theta_t - \lambda_{1t}\theta_t$$

$$\theta_t U_c(u_t c_t, h_t) - \eta_t \beta_c(c_t, h_t)\theta_t - \lambda_{1t}\theta_t = 0$$

$$\Rightarrow U_c(u_t c_t, h_t) - \eta_t \beta_c(c_t, h_t) = \lambda_{1t} \quad (7)$$

$$\frac{\partial \mathcal{L}}{\partial h_t} = \theta_t U_h(u_t c_t, h_t) - \eta_t \beta_h(c_t, h_t)\theta_t - \lambda_{2t}\theta_t A_t F_h(k_t, h_t)$$

$$\theta_t U_h(u_t c_t, h_t) - \eta_t \beta_h(c_t, h_t)\theta_t - \lambda_{2t}\theta_t A_t F_h(k_t, h_t) = 0$$

$$U_h(u_t c_t, h_t) - \eta_t \beta_h(c_t, h_t) - \lambda_{2t} A_t F_h(k_t, h_t) = 0$$

$$\Rightarrow -U_h(u_t c_t, h_t) + \eta_t \beta_h(c_t, h_t) = -\lambda_{2t} A_t F_h(k_t, h_t) \quad (8)$$

$$\frac{\partial \mathcal{L}}{\partial y_t} = \lambda_{1t}\theta_t + \lambda_{2t}\theta_t$$

$$\lambda_{1t}\theta_t + \lambda_{2t}\theta_t = 0$$

$$\Rightarrow \lambda_{1t} = -\lambda_{2t} \quad (9)$$

$$\frac{\partial \mathcal{L}}{\partial i_t} = -\lambda_{1t}\theta_t + \lambda_{3t}\theta_t$$

$$-\lambda_{1t}\theta_t + \lambda_{3t}\theta_t = 0$$

$$\Rightarrow \lambda_{1t} = \lambda_{3t} \quad (10)$$

$$\frac{\partial \mathcal{L}}{\partial k_{t+1}} = -\lambda_{1t}\theta_t \Phi'(k_{t+1} - k_t) - \lambda_{3t}\theta_t + E_t \lambda_{1(t+1)}\theta_{t+1}\Phi'(k_{t+2} - k_{t+1})$$

$$- E_t \lambda_{2(t+1)}\theta_{t+1} A_{t+1} F_k(k_{t+1}, h_{t+1}) + E_t \lambda_{3(t+1)}\theta_{t+1}(1 - \delta)$$

$$\Rightarrow -\lambda_{1t}\theta_t \Phi'(k_{t+1} - k_t) - \lambda_{3t}\theta_t + E_t \lambda_{1(t+1)}\theta_{t+1}\Phi'(k_{t+2} - k_{t+1})$$

$$- E_t \lambda_{2(t+1)}\theta_{t+1} A_{t+1} F_k(k_{t+1}, h_{t+1}) + E_t \lambda_{3(t+1)}\theta_{t+1}(1 - \delta) = 0 \quad (11)$$

Recap of equilibrium equations:

$$\Rightarrow \theta_{t+1} - \beta_t(c_t, h_t)\theta_t = 0 \quad (1)$$

$$\Rightarrow d_t - (1 + q_{t-1} r_{t-1}) d_{t-1} + y_t - c_t - i_t - \Phi(k_{t+1} - k_t) = 0 \quad (2)$$

$$\Rightarrow y_t - A_t F_t = 0 \quad (3)$$

$$\Rightarrow i_t + (1 - \delta)k_t - k_{t+1} = 0 \quad (4)$$

$$\Rightarrow \eta_t = -E_t U_{t+1}(u_{t+1} c_{t+1}, h_{t+1}) + E_t \eta_{t+1} \beta_{t+1}(c_{t+1}, h_{t+1}) \quad (5)$$

$$\Rightarrow \lambda_{1t} = E_t \lambda_{1(t+1)} \beta_t(c_t, h_t)(1 + q_t r_t) \quad (6)$$

$$\Rightarrow U_c(u_t c_t, h_t) - \eta_t \beta_c(c_t, h_t) = \lambda_{1t} \quad (7)$$

$$\Rightarrow -U_h(u_t c_t, h_t) + \eta_t \beta_h(c_t, h_t) = -\lambda_{2t} A_t F_h(k_t, h_t) \quad (8)$$

$$\lambda_{1t} = -\lambda_{2t} \quad (9)$$

$$\lambda_{1t} = \lambda_{3t} \quad (10)$$

$$\Rightarrow -\lambda_{1t}\theta_t \Phi'(k_{t+1} - k_t) - \lambda_{3t}\theta_t + E_t \lambda_{1(t+1)} \theta_{t+1} \Phi'(k_{t+2} - k_{t+1})$$
$$- E_t \lambda_{2(t+1)} \theta_{t+1} A_{t+1} F_k(k_{t+1}, h_{t+1}) + E_t \lambda_{3(t+1)} \theta_{t+1}(1 - \delta) = 0 \quad (11)$$

Let $\lambda_{1t} = \lambda_t$ *so (9) & (10)* $\Rightarrow \lambda_{2t} = -\lambda_t$ *;* $\lambda_{3t} = \lambda_t$

(11)

$$\Rightarrow (11): -\lambda_t \theta_t \Phi'(k_{t+1} - k_t) - \lambda_t \theta_t + E_t \lambda_{t+1} \theta_{t+1} \Phi'(k_{t+2} - k_{t+1})$$
$$+ E_t \lambda_{t+1} \theta_{t+1} A_{t+1} F_k(k_{t+1}, h_{t+1}) + E_t \lambda_{t+1} \theta_{t+1}(1 - \delta) = 0$$

$$-\lambda_t \theta_t [\Phi'(k_{t+1} - k_t) + 1] + E_t \lambda_{t+1} \theta_{t+1} [\Phi'(k_{t+2} - k_{t+1}) + A_{t+1} F_k(k_{t+1}, h_{t+1}) + (1 - \delta)] = 0$$

$$\lambda_t \theta_t [\Phi'(k_{t+1} - k_t) + 1] = E_t \lambda_{t+1} \theta_{t+1} [\Phi'(k_{t+2} - k_{t+1}) + A_{t+1} F_k(k_{t+1}, h_{t+1}) + (1 - \delta)]$$

$$\lambda_t [\Phi'(k_{t+1} - k_t) + 1] = E_t \lambda_{t+1} \frac{\theta_{t+1}}{\theta_t} [\Phi'(k_{t+2} - k_{t+1}) + A_{t+1} F_k(k_{t+1}, h_{t+1}) + (1 - \delta)]$$

$$\lambda_t [\Phi'(k_{t+1} - k_t) + 1] = E_t \lambda_{t+1} \beta_t(c_t, h_t) [\Phi'(k_{t+2} - k_{t+1}) + A_{t+1} F_k(k_{t+1}, h_{t+1}) + (1 - \delta)]$$

Final equilibrium equations:

$$\theta_{t+1} - \beta_t(c_t, h_t)\theta_t = 0 \quad (1)$$

$$d_t - (1 + q_{t-1}r_{t-1})d_{t-1} + y_t - c_t - i_t - \Phi(k_{t+1} - k_t) = 0 \quad (2)$$

$$y_t - A_t F_t = 0 \quad (3)$$

$$i_t + (1 - \delta)k_t - k_{t+1} = 0 \quad (4)$$

$$\eta_t = -E_t U_{t+1}(u_{t+1}c_{t+1}, h_{t+1}) + E_t \eta_{t+1}\beta_{t+1}(c_{t+1}, h_{t+1}) \quad (5)$$

$$\lambda_t = E_t \lambda_{t+1}\beta_t(c_t, h_t)(1 + q_{t-1}r_t) \quad (6)$$

$$U_c(u_t c_t, h_t) - \eta_t \beta_c(c_t, h_t) = \lambda_t \quad (7)$$

$$-U_h(u_t c_t, h_t) + \eta_t \beta_h(c_t, h_t) = \lambda_t A_t F_h(k_t, h_t) \quad (8)$$

$$\lambda_t[\Phi'(k_{t+1} - k_t) + 1] = E_t \lambda_{t+1}\beta_t(c_t, h_t)[\Phi'(k_{t+2} - k_{t+1}) + A_{t+1}F_k(k_{t+1}, h_{t+1}) + (1 - \delta)] \quad (11)$$

Explicit final equilibrium equations:

$$d_t = (1 + q_{t-1}r_{t-1})d_{t-1} - y_t + c_t + i_t + \frac{\Phi}{2}(k_{t+1} - k_t)^2 \quad (2)$$

$$y_t = A_t k_t^{\alpha} h_t^{1-\alpha} \quad (3)$$

$$k_{t+1} = i_t + (1 - \delta)k_t \quad (4)$$

$$\lambda_t = (1 + c_t - \omega^{-1}h_t^{\omega})^{-\psi_1}(1 + q_t r_t)E_t(\lambda_{t+1}) \quad (6)$$

$$\lambda_t = u_t(u_t c_t - \omega^{-1}h_t^{\omega})^{-\gamma} + \eta_t \psi_1(1 + c_t - \omega^{-1}h_t^{\omega})^{-\psi_1 - 1} \quad (7)$$

$$\eta_t = -E_t \frac{(u_{t+1}c_{t+1} - \omega^{-1}h_{t+1}^{\omega})^{1-\gamma} - 1}{1 - \gamma} + E_t \eta_{t+1}(1 + c_{t+1} - \omega^{-1}h_{t+1}^{\omega})^{-\psi_1} \quad (5)$$

$$h_t^{\omega-1}(u_t c_t - \omega^{-1}h_t^{\omega})^{-\gamma} + \eta_t \psi_1 h_t^{\omega-1}(1 + c_t - \omega^{-1}h_t^{\omega})^{-\psi - 1} = \lambda_t A_t (1 - \alpha)k_t^{\alpha} h_t^{-\alpha} \quad (8)$$

$$\lambda_t[1 + \Phi(k_{t+1} - k_t)] = (1 + c_t - \omega^{-1}h_t^{\omega})^{-\psi_1} E_t \lambda_{t+1}[A_{t+1}\alpha k_{t+1}^{\alpha-1}h_t^{1-\alpha} + 1 - \delta + \Phi(k_{t+2} - k_{t+1})] \quad (11)$$

2-Posterior Estimations

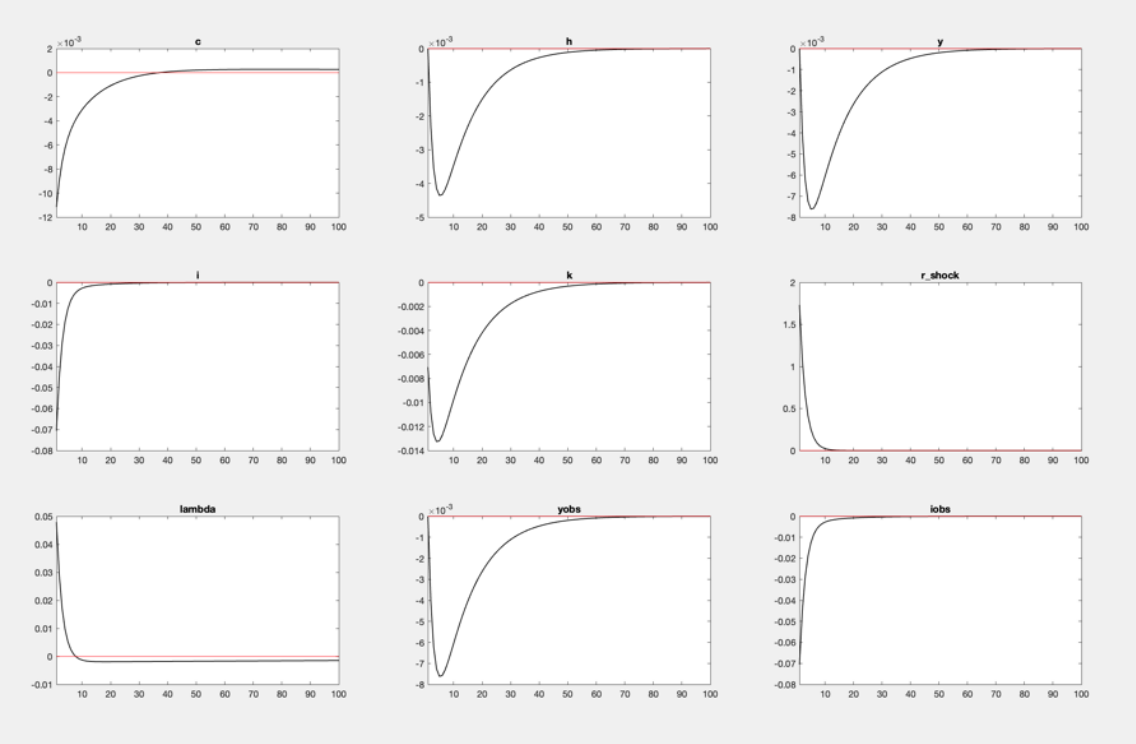
Table A1: Posterior Estimations

parameters

	prior mean	post. mean	90% HPD interval		prior	pstdev
gamma	2.000	2.1570	2.0001	2.3060	invg	0.1000
omega	1.500	1.7490	1.7099	1.7974	norm	0.1000
rho_a	0.800	0.9622	0.9386	0.9787	beta	0.1000
alpha	0.300	0.3663	0.3581	0.3758	beta	0.0100
phi	0.020	0.6213	0.5495	0.6757	norm	0.0700
rho_u	0.600	0.5658	0.5520	0.5835	beta	0.0100
rho_r	0.600	0.6184	0.5968	0.6345	beta	0.0100

3-Bayesian Impulse Responses

Figure A1: Orthogonalized Shock to Interest Rate (complete)



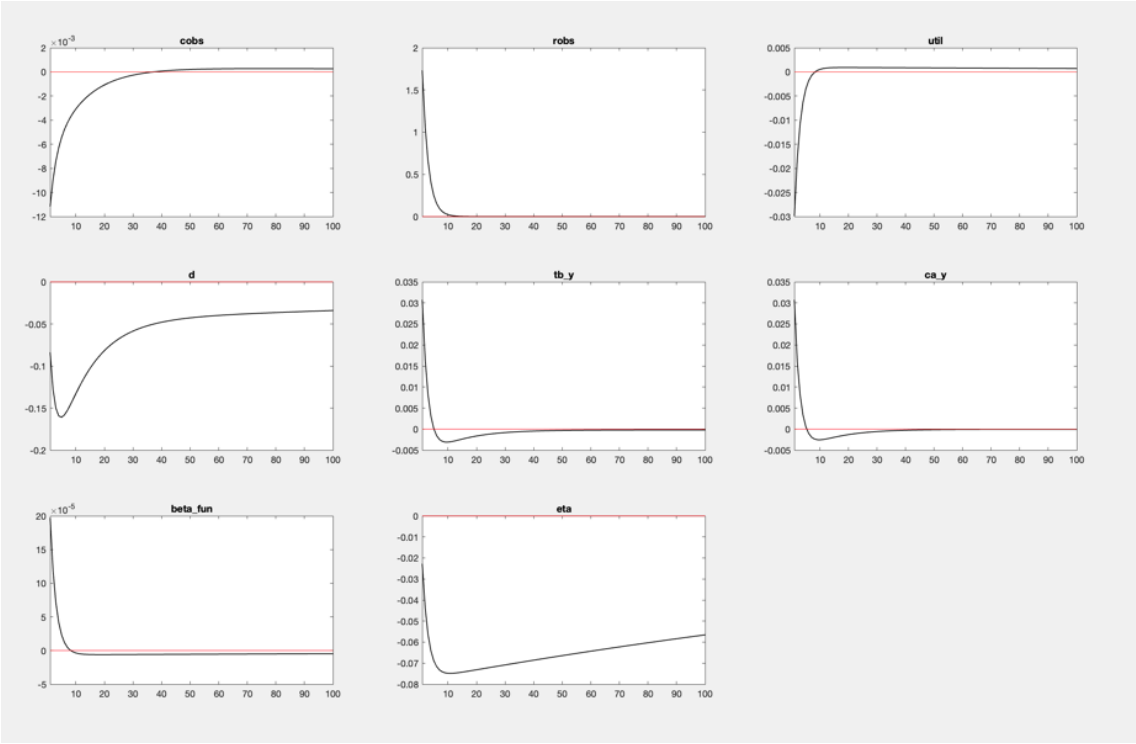
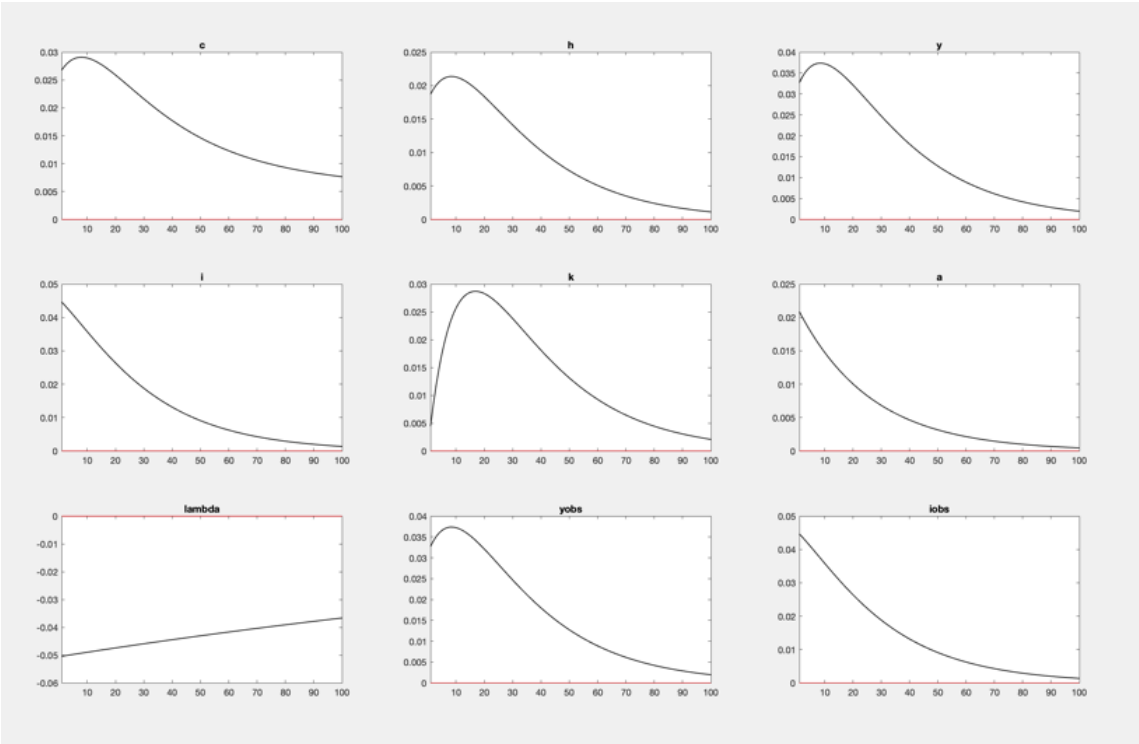


Figure A2: Orthogonalized Shock to Technology (complete)



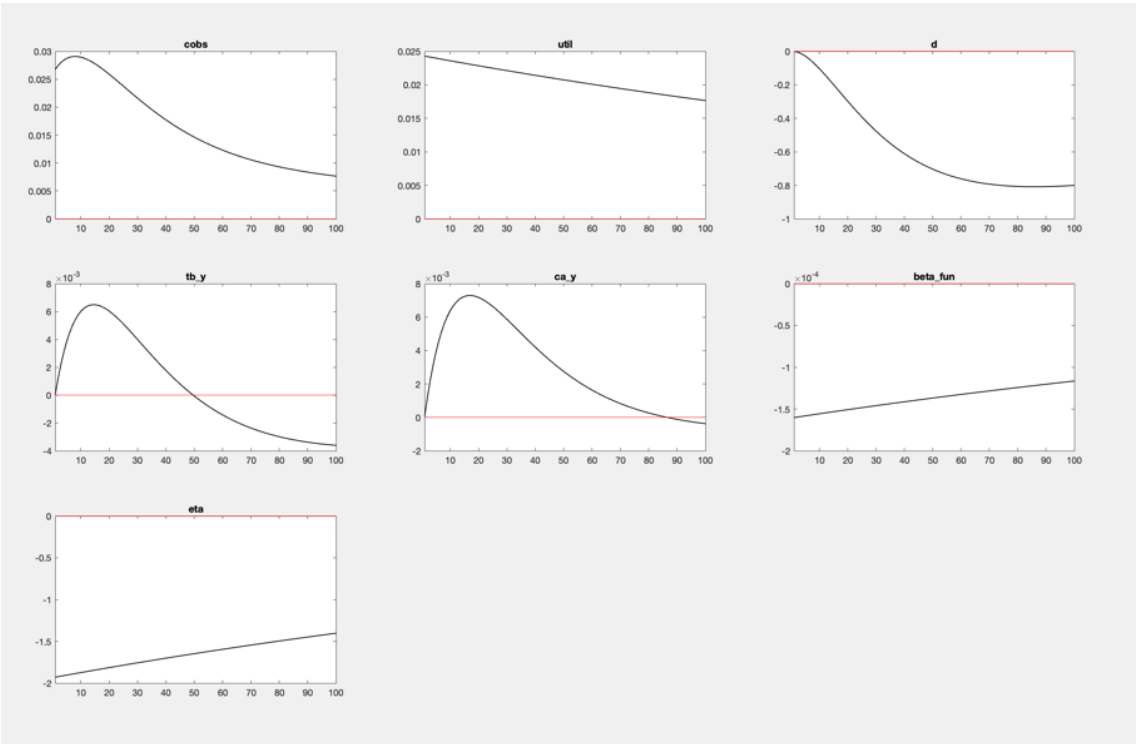


Figure A3: Orthogonalized Shock to Preference (complete)