Academic year 2017-2018

Master's Degree in Economics of Globalisation and European Integration

The Size of Central Bank Balance Sheet and Interest Rates Before and After the Global Financial Crisis

Master dissertation

Student	Jakub Pešek
Home institution	Vysoká škola ekonomická v Praze
Supervisor	Alfred V. Guender
Submission date	September 2018

Declaration of authorship

I, Jakub Pešek, hereby declare that the thesis "The Size of Central Bank Balance Sheet and Interest Rates Before and After the Global Financial Crisis" was written by myself, and that all presented results are my own, unless stated otherwise. The literature sources are listed in the References section.

Prague, September 29th, 2018

.....

Signature

Acknowledgments

I would like to express my sincere gratitude to my mentor, Professor Alfred Guender, for his time, patience, interest, assistance and valuable recommendations in the writing of this thesis. His guidance and encouragement helped me to give my best.

Furthermore, I would like to thank my parents and my wife Karla, for their unfailing support and continuous encouragement throughout my years of study.

Abstract

This paper investigates changes in the central bank policy interest rate and the size of the central bank balance sheet, in both advanced and developing countries, that occurred after the Global Financial Crisis erupted. It firstly discusses the unconventional monetary policies and the use of the balance sheet as a monetary policy tool. Later, it investigates whether central banks around the world reached the zero lower bound and if they expanded their balance sheets extensively. The objective of this study is two-fold. Firstly, it investigates whether the central bank balance sheet became a policy instrument only in a few countries that had reached the zero lower bound. Secondly, it estimates effects of changes in the size of the balance sheet on the ten-year government bond yield. The linkage between the balance sheet effect and the zero lower bound seems to be present in the data. The results show that the significant inverse effect of the changes in the size of the central bank balance sheet on the ten-year government bond rate occurred in countries which reached the zero lower bound and which expanded their balance sheets extensively. Overall, the comparison between high-income economies and their low-income counterparts shows that the zero lower bound and the expansion of balance sheet were predominantly concerns for high-income countries.

JEL Classification: E43, E52, E58

Keywords: policy interest rate, central bank balance sheet, zero lower bound, long-term interest rate, Global Financial Crisis, Fed, unconventional monetary policy

List of abbreviations

APF1	Asset Purchase Facility 1
APP	Asset Purchase Programme
BIS	Bank for International Settlements
BoE	Bank of England
BoJ	Bank of Japan
BPS	Basis points
BS	Balance sheet
CME+	Comprehensive Monetary Easing (extended)
ECB	European Central Bank
FOMC	Federal Open Market Committee
FRED	Federal Reserve Economic Data
GFC	Global Financial Crisis
IFS	International Financial Statistics
LSAP	Large Scale Asset Purchase
LSAP1	Large Scale Asset Purchases 1
LSAP2	Large Scale Asset Purchases 2
MBS	Mortgage Backed Security
MEP	Maturity Extension Programme
QE	Quantitative easing
QQE	Quantitative and Qualitative Easing
TAF	Term Auction Facility
ZLB	Zero lower bound

List of studied countries and currency unions

ALB	Albania
ARG	Argentina
ARM	Armenia
AUS	Australia
AZE	Azerbaijan
BGD	Bangladesh
BGR	Bulgaria
BHR	Bahrain
BHS	Bahamas
BLR	Belarus
BLZ	Belize
BRA	Brazil
CAN	Canada
CHE	Switzerland
CHL	Chile
CHN	China
COD	Congo
COL	Colombia
CPV	Cabo Verde
CRI	Costa Rica
CZE	Czech Republic
DNK	Denmark
DOM	Dominican Republic
EUR	Euro Area
FJI	Fiji
GBR	United Kingdom
GEO	Georgia
GHA	Ghana
GMB	Gambia
GTM	Guatemala
GUY	Guyana
HKG	Hong Kong
HND	Honduras
HUN	Hungary
IDN	Indonesia
IND	India
IRQ	Iraq
ISL	Iceland
ISR	Israel
JAM	Jamaica
JOR	Jordan
JPN	Japan
KAZ	Kazakhstan
KEN	Kenya
KGZ	Kyrgyz Republic
KOR	South Korea
MDA	Moldova
MEX	Mexico
MKD	Macedonia
MNG	Mongolia
MUS	Mauritius
MYS	Malaysia
NGA	Nigeria
NOR	Norway
NPL	Nepal
NZL	New Zealand
PER	Peru
PHL	Philippines
PNG	Papua New Guinea
POL	Poland
QAT	Qatar
ROU	Romania
RUS	Russia
SAU	Saudi Arabia
SGP	Singapore
SRB	Serbia
STP	São Tomé and Príncipe
SUR	Surinam
SWE	Sweden
THA	Thailand
TUR	Turkey
UEMOA	West African Economic and Monetary Union
URY	Uruguay
US	United States of America
VNM	Vietnam
ZAF	South Africa

Table of content

Introduction

The Global Financial Crisis transformed monetary policy in practice and set a new standard for central banks around the world. When central banks' policy rates reached the zero lower bound (ZLB), and the situation did not seem to subside, they proceeded to use the balance sheet as a monetary policy tool. Not only did central banks employ the balance sheet to provide liquidity support to the system, but also they further extended the use of the policy to flatten the yield curve. Specifically, quantitative easing and forward guidance became tools to reach both goals and consequently to overcome the financial and economic turmoil. Clearly, the Federal Reserve System set the path in fighting the crisis. However, many central banks stayed well above the ZLB. This leads to an attractive question whether central banks used balance sheet policies even though their interest rate could have gone lower or whether balance sheet manipulation was a phenomenon only for those central banks that had exhausted their conventional policies. Moreover, it is still unclear if the effects of unconventional policies on interest rates in the U.S. occurred also somewhere else. A decade after the crisis erupted central banking is slowly returning to normal practice. Now might be the right time to look empirically at the consequences of balance sheet policies around the world and to assess the situation with the benefit of hindsight.

The thesis has two main objectives. Firstly, it aims to show changes in interest rates and balance sheets of central banks around the world and to demonstrate that the balance sheet became a policy instrument only in a few countries which had reached the ZLB. Thus, the hypothesis is that many developed and developing countries did not follow the path set by the Fed, because their interest rates remained well above zero and therefore they did not have to use balance sheet policies. The second and more empirical goal is to see whether there was any effect of balance sheet changes on long-term interest rates in a variety of world economies. The thought is that the expansion of the balance sheet was meant to lower the slope of the yield curve in order to support the economy. I argue that this happened only in countries which had reached the ZLB. Therefore, it estimates the effect of the balance sheet on long-term interest rates of public debt. Overall, the project compares the reaction and changes in high-income economies with their low-income counterparts.

The paper is organised as follows. The theoretical background presents the unconventional policies, the role of the central bank balance sheet and path set by the Fed, which serves as a benchmark for the changes in the balance sheet. The empirical section turns the spotlight on the data to show the interest rates before and after the crisis and to reveal which central bank reached the ZLB. Furthermore, it describes the changes in the size of the central bank balance sheet. It finishes with testing how the change in the size of the balance sheet influenced the long-term interest rate.

The data on both the interest rates and the size of balance sheets are taken from International Financial Statistics (IFS) published by the International Monetary Fund, Thomson Reuters Datastream, Federal Reserve Economic Data (FRED), databases of central banks and Bank for International Settlements (BIS).

1. Theoretical background

1.1. Unconventional policies

When the policy interest rate reaches its minimum, commonly known as zero lower bound, and a central bank thus exhausts its primary monetary policy tool, it might still be able to continue its expansionary policy (Guender, 2018, Mishkin, 2004). However, the possibilities are rather limited and the ZLB forms a restriction of some sort. Firstly, the nominal policy interest rate as a primary tool cannot go significantly below zero (Buiter, 2009). Although some central banks set interest rates below zero, for instance in Sweden, Denmark, Switzerland, Eurozone or Japan, the use was minimal and moderate and there is no evidence of its efficiency in the long run (Bech and Malkhozov, 2016). The reason for the restriction is that even if such policy is used, the transmission mechanism does not function properly. If central banks charge negative interest rates on the liquidity from commercial banks, the latter cannot put the negative interest on its clients because they would simply withdraw the money and hold cash instead (Guender, 2018).

Nevertheless, monetary policy does not have to be entirely toothless (Bernanke and Reinhart, 2004; Borio and Disyatat, 2009). Most recent studies such as Swanson and Williams (2014), Gilchrist et al. (2015), and Gertler and Karadi (2015) conclude that monetary policy

may be effective even at the ZLB. Central banks might still attempt to influence current expectations as well as medium- and long-term interest rates and therefore flatten the yield curve since these borrowing costs influence the investment and purchase of durable goods.

To decrease long-term interest rates, central banks, however, need to purchase assets with longer maturity, which changes the composition or size of the balance sheet. Thus, balance sheets became the main source of unconventional policies during the crisis (Borio and Disyatat, 2009). There are two major balance sheet policies: qualitative and quantitative easing (Woodford, 2012). The policies were described by Bernanke and Reinhart (2004) who commented on the very low-interest rates which occurred at the beginning of the new millennium. Central banks might twist the yield curve by changing the composition of their balance sheet while keeping the size unchanged. Substituting long-term securities for the short-term should lower the yield of targeted long-term assets. The policy is sometimes referred to as qualitative easing (Lenza, Pill and Reichlin, 2010). Moreover, central banks may expand their balance sheets. The sizable increase of the balance sheet happens when a central bank provides liquidity by buying financial assets on a large scale without selling any other assets (Bernanke and Reinhart, 2004). So-called quantitative easing (QE) may work through different transmission mechanisms such as altering expectations, fiscal effects caused by low interest on government bonds or lowering yields on long-term assets as investors are indirectly forced to change the securities they hold on their books. Pure QE should not change the proportion of the assets on the balance sheet and only lead to an expansion of the balance sheet (Lenza, Pill and Reichlin, 2010). Nevertheless, such policy is unlikely feasible in reality and thus the term quantitative easing is commonly used for policies which impact both the size as well as the composition of the balance sheet. This paper uses the term in the same manner. The balance sheet policies might be also supported by enhanced communication of the central bank about its future actions and commitments, so-called forward guidance (Bowdler and Radia, 2012).

Following the introductory remarks about unconventional policies, sections 1.2 – 1.5 discuss diverse causes of changes in the size and the composition of the central bank balance sheet. These sections describe the different reasons for employing particular policies that affected the balance sheet.

1.2. The central bank balance sheet as a monetary policy tool

At the outset of the Global Financial Crisis (GFC), many opposing perspectives and various definitions of the innovative measures of central banks cropped up in monetary policy debates. Central banks started to use the balance sheet in several non-traditional ways. However, as noted by Borio and Disyatat (2009) the balance sheet is used often conventionally through open market operations to influence the market short-term rates and to relieve stress in the financial market. This type of policy should be distinguished from "balance sheet policies" which can be characterised as an extensive use of the balance sheet in order to primarily influence interest rates and financial market prices which do not have short-term character. Similarly, balance sheet policies may also be seen as passive and active policies. To clarify, passive policies are focused on liquidity provision and reassurance to markets as a reaction to financial turmoil (European Central Bank, 2015). Active balance sheet policies are "*…large-scale asset purchases with short-term nominal interest rates at their lower bound"* (European Central Bank, 2015, p. 8). In the same manner, Lenza, Pill and Reichlin (2010) distinguish the non-standard programmes as they were not primarily intended for the provision of liquidity to the banking sector. Liquidity provisions clearly caused a part of the balance sheet changes but that need not imply that the policies were somehow unconventional. Such use happened due to the disruption in financial markets which naturally increased demand for liquidity and that was then met by central banks. Therefore, their balance sheets expanded. However, this expansion of the balance sheet was not as large and lasting as the ensuing intentional policies to lower the interest rates. In contrast, the active policies were developed to accommodate the unusual conditions of the ZLB so that central banks could still fulfil its mandate (European Central Bank, 2015). The main characteristic of the active policy is the immediate, extensive and lasting change in the central bank balance sheet which lowers long-term interest rates. In this thesis, I argue this happened only when the ZLB was reached.

The theoretical concept to employ balance sheet policies even if the ZLB is not reached has been discussed in academic debates as well. For instance, Cúrdia and Woodford (2011) propose that the use of the balance sheet might be completely independent of the policy interest rate and that the extensive use of the balance sheet does not have to be constrained by the level of the interest rate. In this case, the balance sheet would be more likely a complement to policy rates and should enhance the effects of the standard monetary policy measures (Lenza, Pill and

Reichlin, 2010). However, it resembles the passive and conventional use which should not be misinterpreted with balance sheet policies. As they claim such use took place at the outset of the credit turmoil in the middle of 2007. But the monetary policy accommodation provided by central banks at that time was standard, therefore, it only shows the transition from standard policies to balance sheet policies. When short-term interest rates reached their minimum, the motivation naturally changed to substitute balance sheet policies for interest rate policies since the market froze and the low interest rates did not help much to stimulate economic activity (Lenza, Pill and Reichlin, 2010). Also, as Joyce et al. (2012) suggest, the unconventional policies began while the policy rates were still decreasing but the phenomenon lasted only a few weeks. Their charts display that the Fed, BoE and ECB started increasing the size of their balance sheets at the time when the policy rate was on the way down. It was then a form of a transition from one policy to another rather than a thorough use of both at the same time (as complements). The early use enabled a smoother transition between the policies since it was clear that interest rate would hit the zero bound. In addition, a part of the balance sheet expansion happened due to the liquidity provision.

Of course, regardless of the "conventionality", any use of the balance sheet as a policy instrument could affect interest rates even though it might not have been its primary aim. Notwithstanding the effect on the balance sheet, "activity" or "passivity" of the policies could theoretically matter. An active policy is likely to have a stronger influence on the interest rates since the reduction of interest rate is a primary goal and not only a by-product of a policy which had a different purpose. Additionally, a passive policy probably occurred even in countries with policy rates above zero since many countries were impacted by the GFC and had to provide supporting liquidity. Therefore, if the countries had short-term interest rates above zero the effect on long-term rates was probably minimal. On the other hand, it might be rather problematic to distinguish between active and passive policy in practice; hence any differences might not be observable in the data, especially when more than one policy takes place at the same time.

Overall, there might not have been many reasons to use the unconventional policies if countries had interest rates well above zero and could use the traditional measures. There is substantial evidence on the effectiveness of standard interest rate policy and the experience with conventional tools is spread around the world. Meanwhile, the effectiveness of unconventional

policies has not been yet fully confirmed and the results are rather uncertain (Guender, 2018). Thus, to use balance sheet policies without reaching the ZLB would be an uncertain and arguably needless experiment.

Before proceeding to the discussion of empirical evidence on QE it is necessary to look into the channels through which the policy works. Bowdler and Radia (2012) describe transmission mechanisms with the help of three channels – portfolio rebalancing, policy signalling and liquidity. They highlight the importance of portfolio rebalancing. That happens because money and long-term assets are imperfect substitutes so a change in demand for long-term assets leads to portfolio rebalancing and the prices of the assets increase. In other words, as a central bank decides to hold a higher quantity of one type of assets, the private sector has to have less of those assets on its books and substitute it by the other (Woodford, 2012). To maintain the equilibrium asset prices must adjust. The less an asset is a substitute for money, the larger is the effect on its price (Bowdler and Radia, 2012). The critical importance of the portfolio rebalancing might be illustrated by the fact that the majority of the relevant literature focusing on the monetary policy transmission mechanism discusse the effect – European Central Bank, 2015; Hancock and Passmore, 2011; Joyce et al., 2012; Oda and Ueda, 2007; Perera, 2010; Ugai, 2007; Williams, 2011 to name a few. The signalling channel operates through reducing market expectations about the short-term rates to which long-term rates are related (Bauer and Rudebusch, 2013). Therefore, if a central bank announces to continue QE, it will also keep the policy rate close to zero and that affects expectations of future short-term interest rates (Krishnamurthy and Vissing-Jorgensen, 2011). The liquidity channel functions during a disruption in financial markets when higher interest rates are driven by increasing risks (Bowdler and Radia, 2012). If a central bank starts to trade sufficiently to increase the liquidity in markets, the liquidity premium adjusts. Nonetheless, the effects are not likely to be significant if the markets are normally highly liquid.

Krishnamurthy and Vissing-Jorgensen (2011) expand the theory by including additional channels through which QE may work. The authors add to the already mentioned channels (portfolio rebalancing, signalling and liquidity) a duration risk channel, a safety channel, a prepayment risk premium channel, a default risk channel and an inflation channel. Duration risk premium is a basic component of the interest rate and may be lowered when the central bank purchase long-term assets. Next, Krishnamurthy and Vissing-Jorgensen (2012) document

that the safety premium changes with the supply of long-term treasuries. Then, if demand for the treasuries increase, similar outcome should be anticipated. The prepayment risk premium channel is mostly related to mortgage-backed securities (MBS) and large-scale asset purchase (LSAP) (in other words specific to the U.S.). Default risk channel occurs on assets with a higher default risk. QE has the stated aim of boosting the economy and thus lowers the default risk. Lastly, Krishnamurthy and Vissing-Jorgensen (2011, p. 223) comment on the inflation channel: *"To the extent that QE is expansionary, it increases inflation expectations, and this can be expected to have an effect on interest rates"*.

Nevertheless, there are various specific factors which may influence the efficacy of the policy instrument. Firstly, the results might depend on the kind of assets central banks purchased albeit the preferred assets vary over time (Krishnamurthy and Vissing-Jorgensen, 2012). In the pre-crisis period, government bonds rather than private-sector assets were considered for purchase (Bernanke and Reinhart, 2004). Later, central banks purchased private sector securities to affect also other than non-public rates, even though some central banks did not rush with this move (BoE launched the scheme in July 2012 and ECB in September 2014) (European Central Bank, 2015). Also, it is important to distinguish what central banks initially purchased and what they later had on the balance sheet. As Malo de Molina (2013) shows the Fed and BoE mitigated the initial enormous increase of liquidity facilities which were provided for the market. In the two central banks, the liquidity facilities were later reduced almost to zero and securities took up the slack. The ECB, in contrast, continued to provide large amounts of liquidity facilities even later after 2010 which partly happened due to the European Sovereign Debt Crisis and partly by a different approach to monetary policy.

The outcome might also hinge on the counterparties the central banks choose to trade with (Lenza, Pill and Reichlin, 2010). For instance, ECB did not broaden its counterparties in comparison with the Fed, BoJ or BoE (Perera, 2010). ECB cooperated mainly with banks while the Fed and BoE included also the non-banking sector (Lenza, Pill and Reichlin, 2010). This comes from the fact that the main source of funding in the Eurozone are banks, while the non-banking sector dominates in the U.S (European Central Bank, 2009). Lastly, the type of jurisdiction may influence the magnitude of balance sheet policies as it defines the overall financial structure of the market (European Central Bank, 2015). Altogether, the above-

mentioned factors might influence the magnitude of the balance sheet effect; however, the effect should occur regardless of these specifications.

Additionally, the initial size of the balance sheet before the application of unconventional policies may matter. For example, ECB has always had more on its balance sheet than the Fed, proportionally to GDP (Lenza, Pill and Reichlin, 2010). That may not be seen when balance sheet growth is contrasted to its previous size. Alternatively, the balance sheet/GDP ratio could be used to see the changes relative to GDP, which however might not show accurate changes in the balance sheet especially if GDP fluctuates substantially. Another option is to calculate monthly percentage variations of the ratio. All three methods are used at some point in this thesis.

1.3. Lender of last resort

During a severe market panic, central banks assure commercial banks about their statutory role as lender of last resort and if necessary provide emergency liquidity to the affected financial institutions (Perera, 2010). It obviously impacts the balance sheet of a central bank as the reserves rise. However, the lender-of-last-resort role takes on importance when banks are not able to provide good securities as collateral and other banks would not lend liquidity on an unsecured basis under acceptable conditions (Goodhart, 1999). Nevertheless, the function is to a certain degree historical as banks had to fulfil strict reserve-deposit ratios (Bordo, 1990). Then, a bank used to enter the lender-of-last-resort relationship with the central bank, which required special conditions, only if it could not have used other available facilities. Clearly, it is an unsettled question to which degree central banks acted as the lender of last resort during the GFC or whether the provided facilities fulfilled the conditions for obtaining liquid funds in the spirit of Thornton or Bagehot. Fortunately, that is irrelevant for the purpose of the thesis. Whether the changes in balance sheets happened due to the lender-of-last-resort role or other passive facilities barely matters as both have the same impact on the balance sheet of the central bank.

1.4. Foreign exchange interventions

Apart from unconventional and passive policies, there is yet another measure that affects the balance sheet extensively while pursuing the central bank's objective – foreign exchange

interventions. The tool used primarily by central banks in small open economies, may help to steer the inflation and output gap variations (Holub, 2004). When a central bank decides to devaluate the domestic currency and purchases foreign currencies from other financial institutions, its foreign reserves holding increases. The balance sheet of a central bank expands as its foreign reserves increase on the asset side of the balance sheet and the concomitant increase liabilities (Mishkin, 2004). The expansion might be substituted by composition change in the case of sterilised operations. Foreign exchange interventions could be used independently on the policy interest rate as a second monetary policy tool (Borio and Disyatat, 2009). It would happen especially if lowering interest rates would not be bearing fruit. Central banks in a number of countries intervened in the foreign exchange market during the crisis – Australia, Brazil, Colombia, Czech Republic, Chile, Israel, Japan, Mexico, Peru and Switzerland to name a few (Adler and Tovar Mora, 2011; Borio and Disyatat, 2009; Neely, 2011; Reserve Bank of Australia, 2018).

The interventions could affect interest rates since financial institutions were provided with more liquidity (in case of devaluation of domestic currency), which then might have been used for asset purchases. On the other hand, the central bank could partly prevent this from happening by paying interest on reserves (Borio and Disyatat, 2009).

To summarise sections 1.2 – 1.4, the possibility that balance sheet substantially increased, even with the policy rate further from zero, exists in the form of foreign exchange interventions, passive facilities and to a certain degree because of the lender-of-last-resort role. Moreover, such an increase in the balance sheet could have also decreased interest rates even though with lower intensity. Therefore, if the analysis finds any central bank with large variations in its balance sheet size but non-zero interest rate nominee, it need not mean that balance sheet policies were applied.

1.5. Forward guidance and announcement effects

To improve the transmission effects of monetary policy, central banks also used a special strategy of communication about future short-term nominal interest rates to stimulate lending and lower the long-term interest rates – forward guidance (Bowdler and Radia, 2012). Williams (2013) points out that the Fed decided to communicate its expectations about the future path of interest rates as a consequence of the ZLB. Forward guidance was necessary as

the businesses, investors and speculators had a different view about the future monetary policy than the Fed. That influenced market activity. Therefore, clear communication about the future monetary policy helped to align markets' expectations with those of the Fed. Moreover, forward guidance did not remain without adjustments but evolved from relating the policy to dates in the calendar to tying it to economic variables such as the unemployment rate.

However, forward guidance can only be successful if the central bank is perceived as credible (Williams, 2013). If markets do not fully trust released statements about the future, the policy might become completely ineffective. Furthermore, as forward guidance shapes expectation and there are risks with interpretation, central banks must proceed with caution. If done poorly, it may lead to confusion and uncertainty.

Even though explicit forward guidance is sometimes considered as an independent monetary policy tool, in practice, it appears to be a part of a set of unconventional policies rather than an independent measure. For instance, Gertler and Karadi (2015) suggest that forward guidance had a strong supportive role in monetary policy transition.

This thesis measures effects of balance sheet policies. Thus, it is necessary to look closer at effects of the announcements in question. By the very nature of balance sheet policies, central banks needed to enhance the communication in order to ensure the effect would be as intended and to decrease the likelihood of the panic in financial markets (Lenza, Pill and Reichlin, 2010). Gilchrist et al. (2015) testing announcements of Federal Open Market Committee (FOMC) report that, during the conventional period, monetary policy surprises have a larger effect on short-term than long-term interest rates. Exactly the opposite happens during unconventional times when announcements influence more long-term rates. In other words, unanticipated announcements indicating monetary stimulus steepen the yield curve during "normal times" and flatten it when the ZLB is reached. On the other hand, to measure the announcement effects might be beyond the realms of possibility since changes occur only if the announcement is different from markets' expectations (Neely, 2010).

Nonetheless, under the assumption that announcements correspond with actual balance sheet policies, the current study need not include short-term announcement effects of the balance sheet policies in the empirical analysis if it focuses solely on balance sheet policies from a long-term perspective.

1.6. Current empirical evidence

There have been attempts to find empirical evidence for the effect of balance sheet policies; however, the results differ substantially. For instance, Krishnamurthy and Vissing-Jorgensen (2011) provided empirical results suggesting that interest rates in the USA decreased because of QE; but the effects differed depending on the type of bond maturity and phase of QE. Next, evidence given by Pattipeilohy et al. (2013) implies that the programmes had a positive but rather short-lived effect on the level of interest rates. They conclude that only some of the asset purchase programmes worked indicating the strong importance of targeting particular assets.

Several empirical studies attempted to estimate precisely the results of Federal Reserve's LSAP. For instance, Gagnon et al. (2011) estimate that interest rates fell extensively across public and private bonds and securities. The final decrease in the ten-year term premium as a consequence of LSAP1[1] was *"... somewhere between 30 and 100 basis points, with most estimates in the lower and middle thirds of this range"* (Gagnon et al., 2011, p. 38). Similar results are provided by Neely (2010) who conducted an event study for the LSAP1 announcement. He (2010, p. 17) reckoned *"... the U.S. 10-year constant Treasury yield fell by a cumulative total of 107 basis points"*. To see the initial effects D'Amico and King (2010, p. 23) examined the initial Federal Reserve's purchase of $300 billion (i.e. two per cent of U.S. GDP) of U.S. Treasury securities and estimated that*"... the program as a whole shifted the yield curve down by up to 50 basis points"*. Joyce et al. (2011, p. 155) studied the beginning of the QE programme in the United Kingdom (£200 billion i.e. 12 per cent of its GDP) and they *"... found that medium to long-term gilt yields were about 100 basis points lower than they would otherwise have been as a result of QE"*.

The concept that QE could have diminishing returns to scale is supported by evidence from Gertler and Karadi (2015) who compare two waves of LSAP and conclude that LSAP2

[1] LSAP1 had the overall size of 1,725 trillion USD i.e. 12 per cent of U.S. GDP (Neely, 2010).

was less effective than LSAP1. This is also backed by the analysis from Krishnamurthy and Vissing-Jorgensen (2011).

Notably, the majority of studies are focused on the effects in the U.S. There is less evidence about the effects of unconventional policies on interest rates in the Eurozone, Japan or the United Kingdom, let alone other countries. Cecioni, Ferrero and Secchi (2011) list only three studies analysing the effects of the ECB policies on the interest rate during the crisis. The analyses, however, do not focus on long-term rates. Andrade et al. (2016, p. 13) compare empirical studies assessing effects of balance sheet policies on a ten-year government bond in the United Kingdom, U.S., Japan and Eurozone. The impact in basis points (bps) is standardised to a size of purchases equal to ten per cent of GDP of the respective country.

Table 1 Impact of QE programmes on 10-year government bond yields

Central Bank	Programme	Duration	Number of Studies	Reduction	Average	Median
ECB	APP	2015M03-2016M09	4	27-64 bps	44 bps	43 bps
BoE	APF1	2009M3-2010M01	7	31-107 bps	64 bps	62 bps
BoJ	CME+	2008M12-2012M8	2	10-12 bps	11 bps	11 bps
	QQE	2013M4-2014M9	3	14-26 bps	21 bps	22 bps
Fed	LSAP1	2008M12-2010M3	14	32-175 bps	83 bps	75 bps
	LSAP2	2010M11-2011M6	9	33-138 bps	65 bps	48 bps
	MEP	2011M9-2012M12	6	23-175 bps	72 bps	60 bps

Note: Acronyms are explained in the list of abbreviations.

Source: Adapted from Andrade et al. (2016, p. 13, p. 60 and p. 61).

Few facts are observable from the comparison. It is noteworthy to mention that the significant variations correspond with the theory described above. Firstly, lower effects of QE in Eurozone and Japan in contrast to U.S. and the United Kingdom might have happened due to the already larger balance sheet before the policy took place (Japan had performed the policies before the crisis, and the studies for ECB consider programme taking place in 2015). Also, there could have been the pattern of diminishing returns as it is noticeable at the comparison of the two LSAPs of the Fed. Both points may actually refer to the same problem, that balance sheets were already too large proportionally to GDP. Then, the effects might not have been that strong.

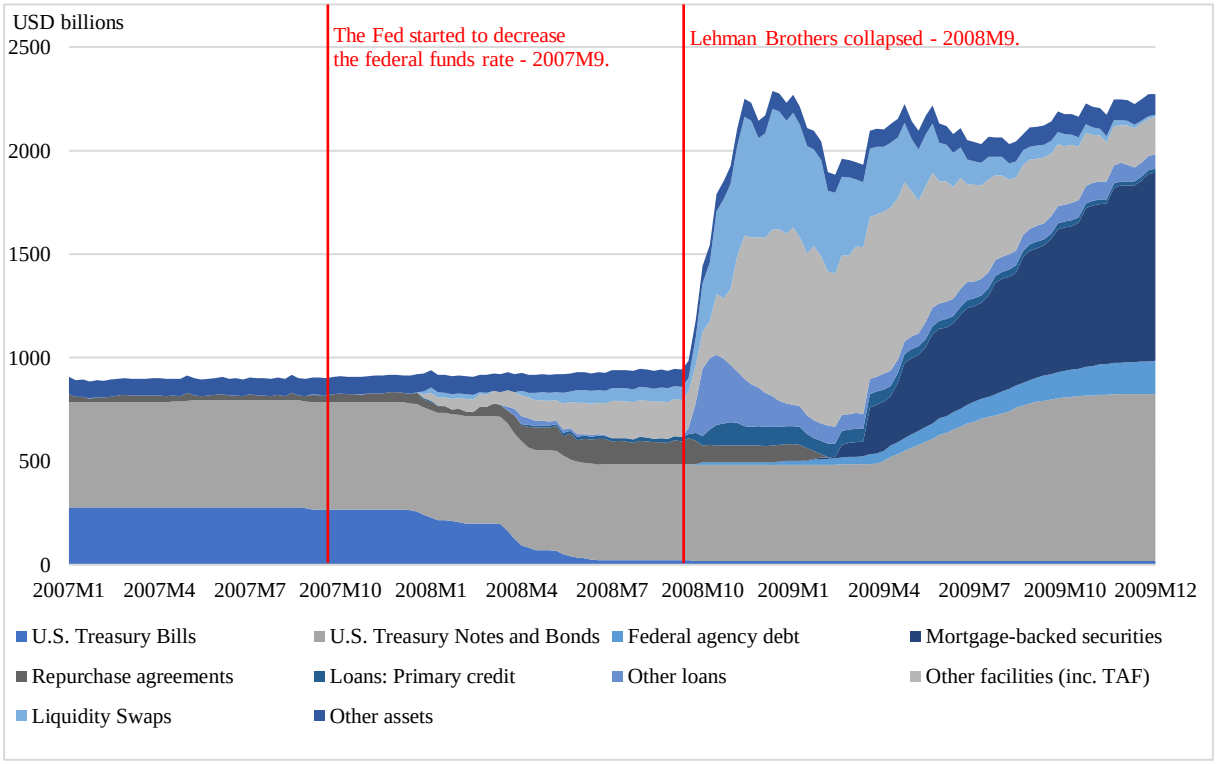
Overall, there is a consensus that the balance sheet policy might lower yields but to what extent seems still rather unclear (Joyce et al., 2012). The studies differ significantly even when the same policy is tested. In other words, it is not clear what the size and duration of the balance

sheet effect are. What is more, all considered studies were focused only on the four major central banks. Little interest has been devoted to studying whether other central banks reached the ZLB and employed balance sheet policies. In conclusion, there is no systematic study of the experience of other central banks and their actions during the GFC.

1.7. The reaction of the Fed to the Global Financial Crisis: the path

The Global Financial Crisis brought the financial system close to collapse. After problems occurred in the subprime mortgage market in the U.S. in early 2007, the signs of forthcoming crisis spread also to Europe when, for instance, a French bank, BNP Paribas, blocked redemptions from three hedge funds or a British bank, Northern Rock, faced a bank run (Brunnermeier, 2009). The main response from U.S. monetary authorities came on September 18, 2007 when the FOMC lowered the target for the federal funds rate from 5.25 to 4.75 percentage points (Federal Reserve Bank of St. Louis, 2018). The Fed then continued to decrease the fed funds rate until the target range became 0 to 0.25 percentage points on December 16, 2008. The primary credit rate, which is used for short-term loans to financial institutions, decreased overall from 6.25 percentage points in August 2007 to 0.50 in December 2008. Moreover, in the attempt to prevent a liquidity crisis, the maximal primary credit borrowing term was raised to 30 days. The financial turmoil fully erupted with the collapse of Lehman Brothers in September 2008 when the fed funds rate was already at two percentage points. The problem was that markets with liquidity froze unexpectedly even though there were enough reserves that, however, banks kept at clearing accounts in the Fed. Also, several emergency programmes to support particular markets or institutions and to provide liquidity were launched by the Fed: Term Auction Facility, Term Securities Lending Facility, Primary Dealer Credit Facility, Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility, Commercial Paper Funding Facility, Money Market Investor Funding Facility, Term Asset-Backed Securities Loan Facility (Butos, 2015; Mishkin and White, 2014). The initial programmes started at the end of 2007 and were mostly used throughout the year 2008. As Lenza, Pill and Reichlin (2010) point, the early policies did not have a quantitative effect on the balance sheet until the fall of Lehman Brothers and firstly resembled qualitative easing policies. Figure 1 illustrates this phenomenon (the area between the two vertical red lines).

Figure 1 The balance sheet of the Federal Reserve: 2007M1-2009M12

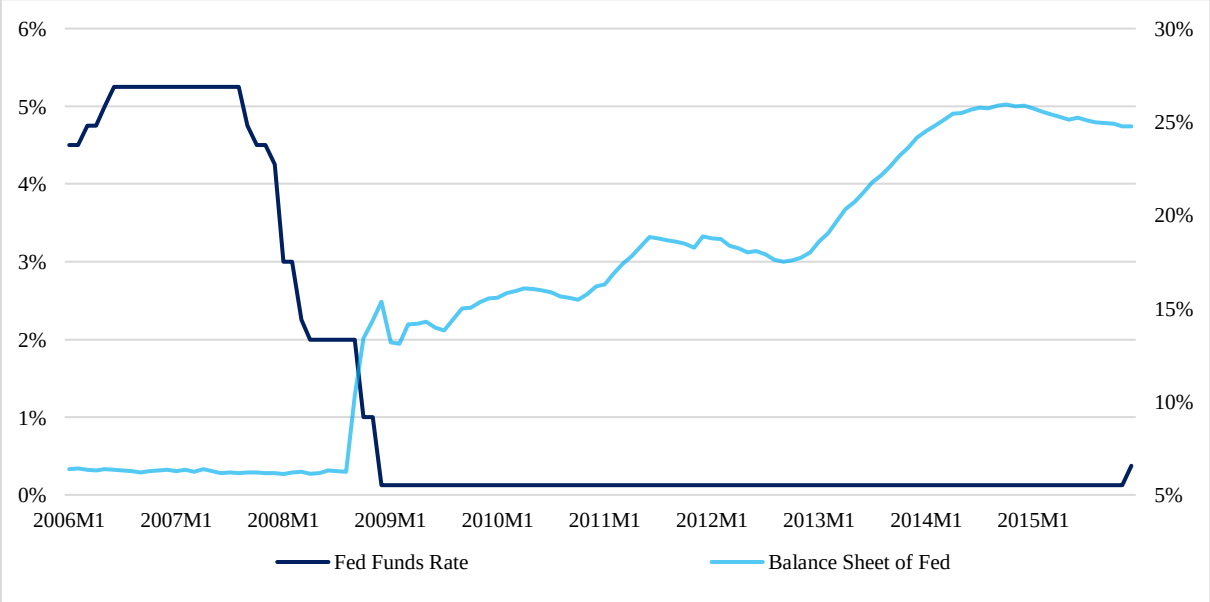


Source: Own compilation based on Lenza, Pill and Reichlin (2010), data from the Federal Reserve.

Neither the low short-term interest rate nor supporting programmes could help the economy to overcome the crisis. Therefore, the Fed started with QE, which was supported by forward guidance. The first LSAP was announced in November 2008 and aimed at lowering long-term interest rates (Chen et al., 2016). The programme ended in November 2010 and among the purchased assets were: agency mortgage-backed securities (MBS), agency debt and longer-term U.S. Treasury securities in overall 1725 billion USD. LSAP2 followed and targeted only longer-term U.S. Treasury securities (600 billion USD, November 2010 – June 2011). QE then continued with LSAP3 (September 2012 – October 2014) when the Fed was purchasing MBS for 40 billion USD and longer-term U.S. Treasury securities (from December 2012) for 45 billion USD each month. At the end of 2013, the Fed started to decrease the purchasing amount. Although the balance sheet has not expanded much further since September 2014, the stable amount of assets held suggests that reinvestment continued. Apart from LSAP, the Fed also used the Maturity Extension Programme (MEP) that aimed to extend the maturity of securities held by the Fed. Short-term securities were sold or redeemed for the overall amount of 667 billion USD which were used to purchase long-term securities (September 2011 – December 2012) (Federal Reserve, 2013).

To summarise, the Fed first substantially decreased interest rates when the primary tensions in the markets occurred. Alongside, it proceeded to qualitative easing policies. The size of the Fed's balance sheet did not change significantly until the fall of Lehman Brothers. Then, the Fed expanded extensively its balance sheets while reaching the ZLB. It also used supporting schemes to provide missing liquidity and calm down panicking financial markets. Later, it moved from supporting schemes to targeting large-scale purchases with the primary aim to lower long-term interest rates. Altogether, the tremendous change in the size of the balance sheet was unique for the Fed since its balance sheet was stable or only moderately growing in the preceding years and variations before the crisis took the value of a few tenths of one percentage point. Furthermore, changes seemed to subside gradually after the jump in September 2008, but many of the initial facilities were provided for a couple of months or few years, which meant that, they had to be renewed to keep providing liquidity. Otherwise the balance sheet would have shrunk. Figure 2 depicts these unprecedented increases in the size of the balance sheet that occurred while the federal funds rate was reaching its respective minimum.

Figure 2 The fed funds rate and the balance sheet of the Federal Reserve: 2006M01-2015M12



Note: Left axis depicts the fed funds rate while the right axis shows the balance sheet/GDP ratio.

Source: Own compilation based on Joyce et al. (2012), data from Federal Reserve.

2. Empirical section

This section covers the response of central banks around the world to the Global Financial Crisis. As the theoretical background showed, the crisis forced the Fed, which I regard as a benchmark, to firstly decrease the policy rate nearly to zero and then to expand its balance sheet. Therefore, this section examines changes in policy rates and the size of balance sheets of the countries in question. Also, it compares and contrasts these responses with that of the Fed. Later, a simple time series analysis is employed to investigate the effect of the balance sheet size on a ten-year rate.

The aim is to examine as many countries with reliable data as possible. The primary source of data is IFS from the International Monetary Fund. I have used all countries on which IFS report a policy interest rate for the sample period (2006M1-2015M12) and added BRICS and OECD countries and central banks tracked by BIS. Policy rates of BRICS and OECD countries which are not observed by BIS and IFS are taken directly from databases of the respective central bank. This forms a dataset of 76 studied central banks (74 countries and two monetary unions – Euro Area (EUR) and West African Economic and Monetary Union (UEMOA)). Besides the two unions, the set covers all five BRICS countries, 19 OECD countries (the rest is in the Euro Area; none of the countries which joined the Euro Area during the sample period is considered independently), two other advanced economies (Hong Kong and Singapore), 16 developing[2] countries, 32 emerging market economies. All economies are listed in the list of countries and currency unions. A further subdivision consists of two groups – low-income and high-income economies (if the country is low-income or high-income is shown in Appendix A). Low-income economies include UEMOA, BRICS, emerging and developing countries while the high-income group includes Euro Area, OECD countries and the two other advanced economies. Additionally, data on the size of the central bank balance sheet, the ten-year government bond rate and GDP was obtained. The data sources are IFS, Thomson Reuters Datastream, FRED, BIS and databases of the central banks. When the data

[2] The differentiation of emerging, developing and advanced countries is used from International Monetary Fund (2017). Euro Area, UEMOA, BRICS and OECD countries are considered separately.

for any of the variables is missing, it is clearly indicated. The summary of available data is in Appendix A.

To examine policy interest rates before, during and after the GFC, I rely on monthly data over a ten-year period from January 2006 until December 2015. The sample period symbolically finishes in December 2015 when the Fed increased its main policy rate for the first time since the outbreak of the GFC. However, the main reason for a decade-long period is that "crises" impacted particular economies at different times. For instance, Europe was later hit by another crisis, the Sovereign Debt Crisis. Generally, the crisis was not spreading around the world evenly and did not end at the same time everywhere. Hence, the period enables a researcher to see the effects of central banks' reactions to subsequent recessions. The pre-crisis period is considered to run from January 2006 to August 2008. Thus, the thesis aligns with the majority of studies and regards the failure of Lehman Brothers in September 2008 as the outbreak of the crisis[3]. Different lengths of the compared periods should not be seen as an issue, because the aim is to capture the state of monetary policy before the crisis. Then, a longer period preceding the crisis would be increasing the number of other effects which affected interest rates and the dataset would not reflect exclusively the pre-crisis situation. As noted earlier, the Fed started to decrease interest rates already in September 2007; however, it would be problematic to take it as the outbreak of the GFC because many central banks (such as ECB, Swiss National Bank, Swedish Riksbank or Reserve Bank of Australia) were still tightening monetary policy. Besides, choosing September 2008 as the beginning of the GFC coincides with the beginning of the expansion of the Fed's balance sheet.

2.1. Policy interest rates before and after the crisis

A large part of the empirical work focuses on the consequences of reaching the ZLB. Because of that, the first step of the analysis is to look at the minimal policy rate of the central banks. Table 2 shows the policy stance in 76 countries before the crisis (2006M1-2008M8) and

[3] There is no real consensus among researches on the beginning of the GFC. Nevertheless, the fall of Lehman Brothers is commonly used as the starting date.

in the period during and after the crisis (2008M9-2015M12)[4]. I distinguish between three threshold values: under 1.01 per cent, under 0.51 per cent and under 0.26 per cent[5].

Table 2 Minimal policy interest rates before and after the crisis

Countries	Under 1.01%		Under 0.51%		Under 0.26%	
	2006M1-2008M8	2008M9-2015M12	2006M1-2008M8	2008M9-2015M12	2006M1-2008M8	2008M9-2015M12
OECD (19 countries)	2	11	1	10	1	8
Other Advanced (2)	1	2	1	2	0	1
BRICS (5)	0	0	0	0	0	0
Emerging (32)	0	4	0	4	0	2
Developing (16)	0	1	0	0	0	0
Euro Area (1)	No	Yes (1)	No	Yes (1)	No	Yes (1)
UEMOA (1)	No	No	No	No	No	No
Total (76)	**3**	**19**	**2**	**17**	**1**	**12**

Note: Euro Area countries are excluded from OECD. As Euro Area and UEMOA have each one central bank for all member countries so they are each considered to represent one "economy" rather than 19 and 8 countries respectively.

Source: Own calculation, data from BIS, IFS and national data.

Notably, there are only 19[6] central banks out of 76 which reached a minimal policy rate lower than one percentage point in the period during and after the crisis. Central banks in 12 countries had a minimal policy rate during the crisis period lower than 26 basis points and only two of them are from the low-income group (BGR and SAU)[7].

Nevertheless, the minimal policy rate does not show the length of the ZLB problem for the central bank. Therefore, it is appropriate to look at a variable showing the size and duration of the policy rate. The average of the monthly policy interest rates should capture both characteristics and illustrate best the value of the policy interest rate for a given period. The following three figures (no. 3, no. 4 and no. 5) show the average[8] rate before and after the outbreak of the crisis. The U.S., as the benchmark, is highlighted in red colour. The majority of the countries are under the 45° line, which is to be expected, as monetary policy substantially

[4] For each central bank, the lowest value of its main policy interest rate in a given period is considered. Then, if that minimal policy interest rate is below the threshold, the country is reported in Table 2.

[5] Each threshold covers all countries below the value. In other words, the group "under 1.01" includes also countries which are "under 0.51" and that covers the group "under 0.26" as well.

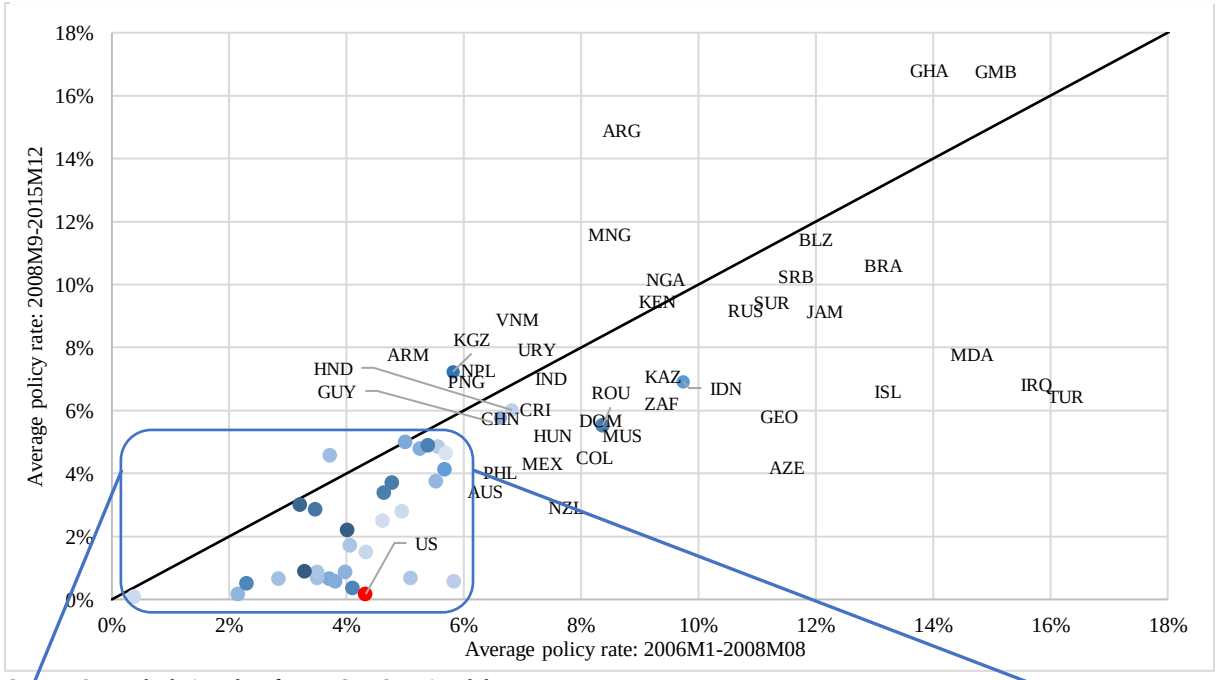
[6] A figure displaying those 19 economies (BGR, BHR, CAN, CHE, CHL, CZE, DNK, EUR, FJI, GBR, HKG, ISR, JPN, KGZ, NOR, SAU, SGP, SWE, US) with their minimal policy values is in Appendix B.

[7] BGR's central bank operates under a currency board (Bulgarian National Bank, 2018) and SAU's currency is pegged to dollar (Arab Monetary Fund & BIS, 2015).

[8] The average policy rate is calculated as a weighted average from end-of-month values.

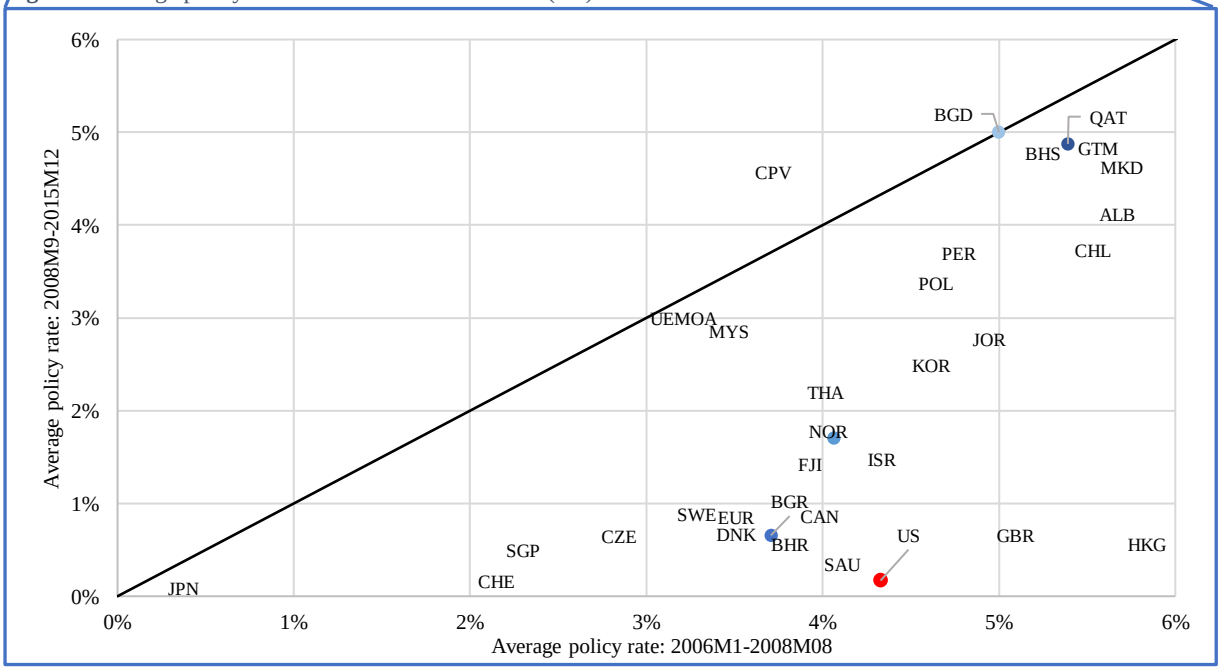
eased during the crisis the world over. Importantly, Figure 5 displays that central banks in high-income countries carried out more significant cuts in the policy rate than low-income countries. The trend line of low-income countries is relatively close to 45° line (slope ~3/4) while the one of high-income countries has slope ~1/2. It demonstrates that a majority of low-income countries did not experience such significant differences in interest rates before and after the outbreak of GFC as high-income countries.

Figure 4 Average policy rates before and after the GFC (1/3)



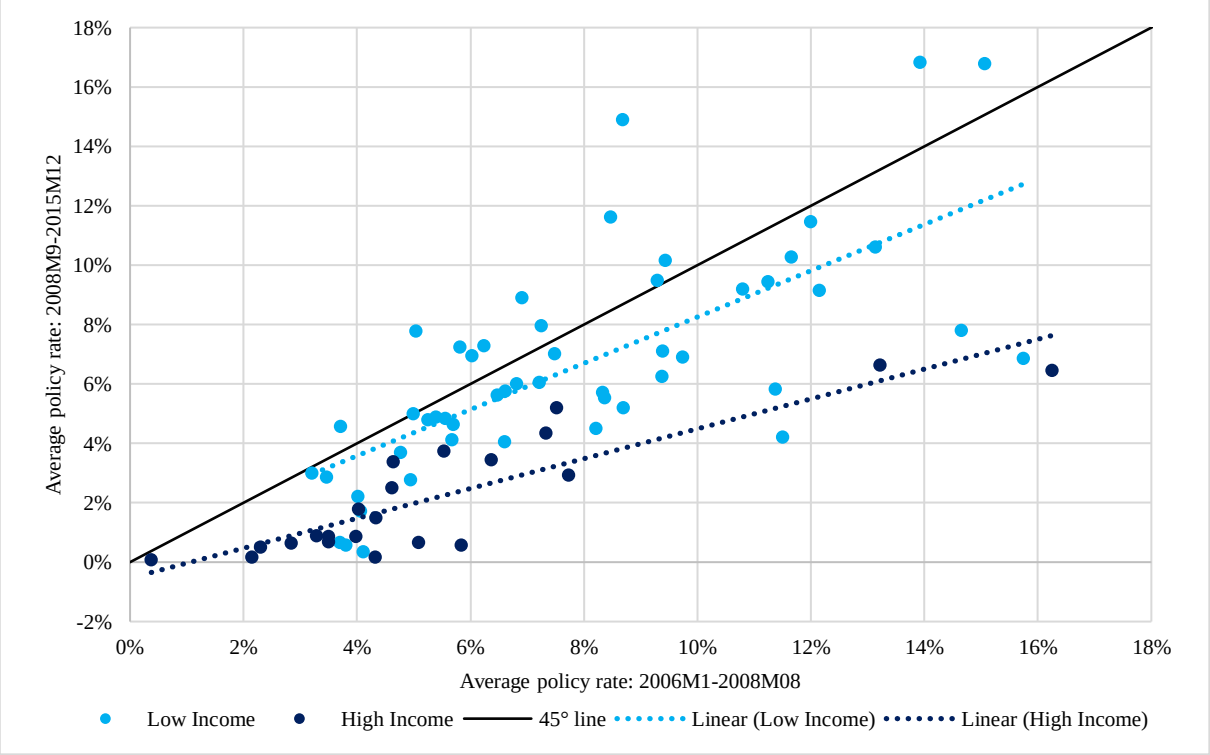
Source: Own calculation, data from BIS, IFS, national data.

Figure 4 Average policy rates before and after the GFC (2/3)



Source: Own calculation, data from BIS, IFS, national data.

Figure 5 Average policy rates before and after the GFC (3/3)



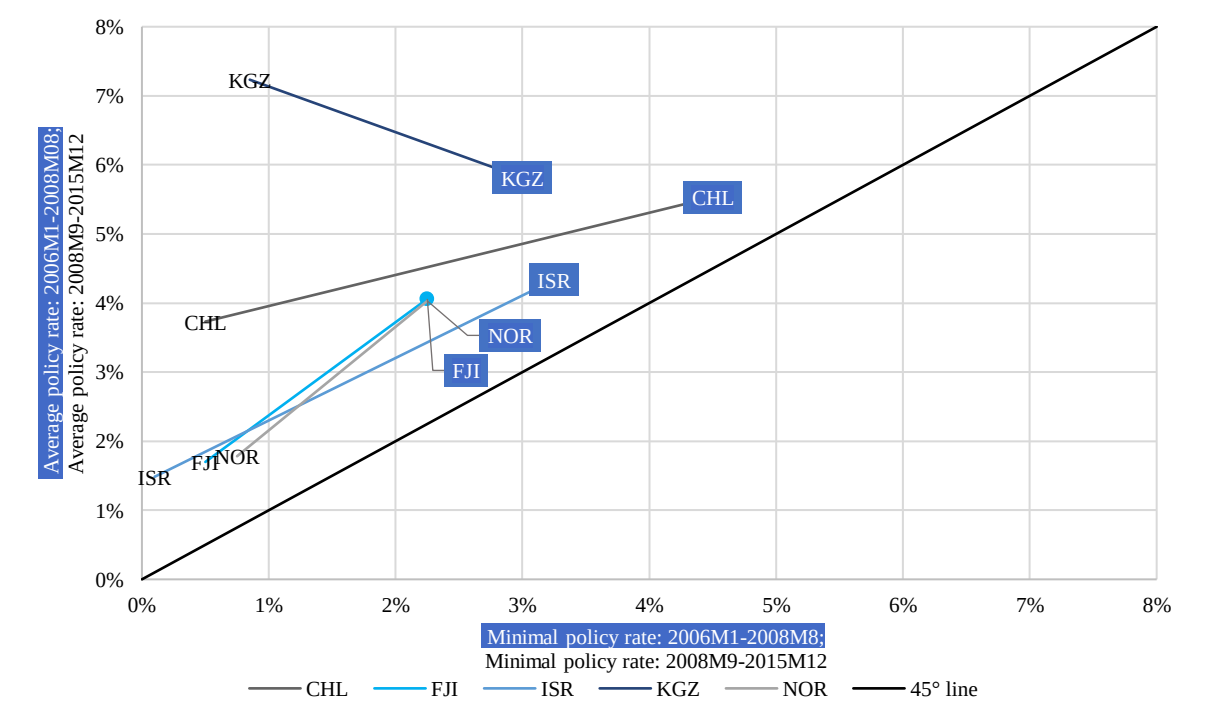
Source: Own calculation, data from BIS, IFS, national data.

In connection with the ZLB, if Figure 3 is combined with the previous information on the minimal policy interest rate, it is possible to determine which countries indeed faced the ZLB. Figures 6 and 7 show the minimal and average policy rates before and after the outbreak of the GFC for the 19 economies identified in the first part of the analysis as those which might have experienced the ZLB. The name of the country highlighted in blue shows the values of the minimal and the average policy rate before the GFC (2006M1-2008M8) while the other (in black) depicts values after the outbreak of the crisis (2008M9-2015M12). Therefore, the figures flow from the right upper corner (before the crisis) to the lower left corner (after the crisis). The vertical axis contains the values of the average policy interest rate for both periods while the horizontal axis shows the minimum policy rate for the same periods. For instance, before the crisis, the average policy rate for GBR was 5.09 percentage points and the minimum rate was 4.50 percentage points. During the crisis, the average policy rate fell to 0.66 percent points while the minimum rate fell to 0.50 percentage points. The length of the line indicates the extent to which policy eased during the crisis period (the size of the cut in the interest rate). The closer the observations are to the 45° line, the closer the average is to the minimum, hence, more sustained the easing (the duration of the cut in the interest rate). Nevertheless, no country can lie below the 45° line because the average policy rate cannot be lower than the minimum rate.

Figure 6 depicts five economies where the minimum policy rate was below one percentage point but their average rate was above this threshold, implying that they have not suffered much from the ZLB and the decrease in the rates was probably sufficient to boost the economy. Also, the crisis values are far from the 45° line which indicates that the easing was not sustained. Figure 7 displays 14 central banks which might have suffered from the ZLB as not only the minimal rate was below one percentage point, but also the average rate for the period decreased below the threshold.

To summarise, there are only 14 economies of 76 studied which could have faced the ZLB problem[9] and only three of them represent low-income economies (BGR, BHR, SAU).

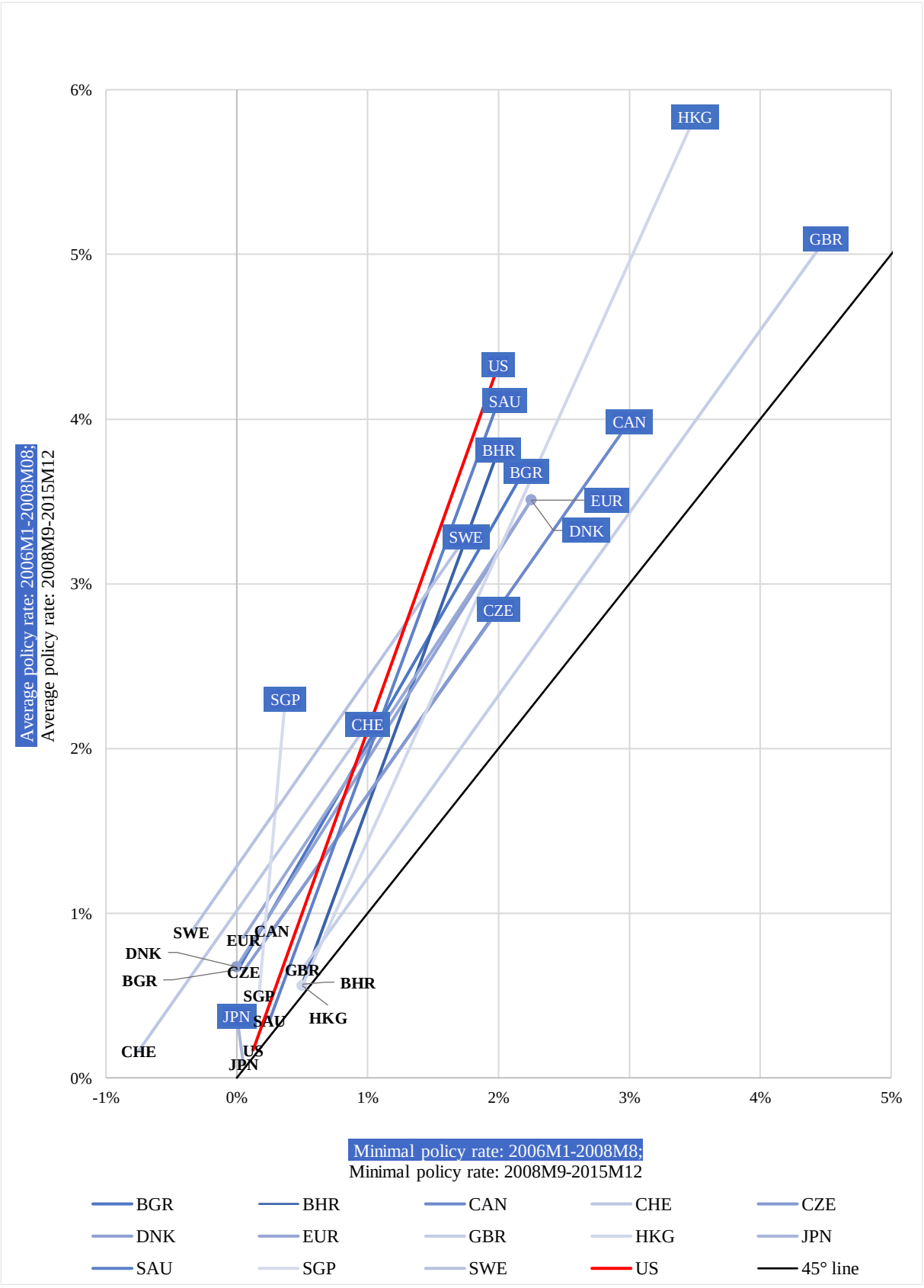
Figure 6 Average and minimal policy rates before and after the GFC (1/2)



Source: Own calculation, data from BIS, IFS, national data.

[9] The 14 economies (BGR, BHR, CAN, CHE, CZE, DNK, EUR, GBR, HKG, JPN, SAU, SGP, SWE, US) are identified as such because they had the average policy rate (calculated as a weighted average from end-of-month values) below one percentage point in the period after the outbreak of the GFC (2008M9-2015M12). Moreover, all of them had the minimal policy interest rate lower than 0.51 per cent. Five other countries (CHL, FJI, ISR, KGZ, NOR) which were previously considered in the analysis as those which could have experienced the ZLB problem (based on minimal policy rate), are eliminated because their average policy rate is well above the one-percentage-point threshold.

Figure 7 Average and minimal policy rates before and after the GFC (2/2)



Source: Own calculation, data from BIS, IFS, national data.

2.2. The size of the balance sheet before and after the crisis

Having discussed interest rates, I can now proceed to the second part of the analysis related to the size of the balance sheet. Firstly, an index is constructed to show how the balance sheet of the respective central bank changed relative to the balance sheet of the Fed. Balance sheets of central banks are set to 100 per cent for July 2007, to mark the period before the rapid expansion of the Fed's balance sheet. The indices are captured in the following figures (no. 8 – no. 73) which show the relation of the Fed's balance sheet and the balance sheet of other central banks at a point in time from July 2007 until December 2015[10]. Economies that have been identified previously as having a potential problem with the ZLB are distinguished by a red frame. Also, it was previously suggested in the theoretical section to use the balance sheet to nominal GDP ratio (BS/GDP ratio). This would have certain advantages and disadvantages. Firstly, it brings another variable into play, thus, it might not clearly depict changes of the balance sheet but rather show the variation in GDP. Secondly, the balance sheet might be deflated by nominal GDP. Nonetheless, it would eliminate changes in the balance sheet caused by increasing nominal GDP, which might be the case of developing and emerging countries. In any case, the indices for the BS/GDP[11] ratio are presented in Appendix C. The differences between the figures are not substantial albeit BS/GDP ratio eliminates the balance sheet changes which are due to economic growth.

Also, to see whether the difference between the changes in the balance sheet (BS) of the U.S. and a given country is statistically significant, I conduct a simple t-test of the difference in means[12]. The test statistics is displayed in the note to the figure. The null and alternative hypotheses of the test are:

$$H_0: \overline{BS}_{US} = \overline{BS}_k;\ H_a: \overline{BS}_{US} \neq \overline{BS}_k;$$

$$where\ US\ stands\ for\ the\ United\ States\ and\ k\ is\ a\ given\ country.$$

[10] If otherwise, it is specified in a note of the figure.

[11] Monthly values for the annual GDP were converted from quarterly data. The quarterly GDP was divided by three to obtain the monthly GDP. Then, values for the monthly GDP for the last 12 months were used to acquire the monthly value of the annual GDP. For instance, the annual GDP for October 2008 is formed from the summary of the monthly GDP for the period 2007M11-2008M10.

[12] The mean $\overline{BS}$ is based on index values. It is calculated from the balance sheet size in a given month relative to the base period (2007M7) and averaged over a sample period. For instance, $\overline{BS}_{US} = 321\%$ which means that the average size of the Fed's balance sheet is 321% of the size in 2007M7.

$$t \approx \frac{\overline{BS}_{US} - \overline{BS}_k}{\sqrt{\frac{\sigma_{US}^2}{n} + \frac{\sigma_k^2}{n}}}$$

However, the difference in means might not be very informative if there is a lag in changes in the balance sheet size. This is likely because the crisis did not affect all countries equally at the same time. Therefore, it is also tested whether the regression line of changes in the balance sheet size of the particular central bank relative to the Fed's balance sheet size differ from one with statistical significance. If the regression line has a slope equal to one, it means that the balance sheet of the respective central bank grows equally as the Fed's balance sheet at a given point of time.

$$H_0: \beta_1 = 1;\ H_a: \beta_1 \neq 1; on\ the\ regression\ line\ BS_k = \beta_0 + \beta_1 BS_{US} + u$$

$$t \approx \frac{\hat{\beta}_1 - 1}{se(\hat{\beta}_1)}$$

The results of both tests and $\hat{\beta}_1$ are displayed in the note of the figure only if the p-value is at least 0.01.

Notably, apart from the time before the crisis, the size of the Fed's balance sheet became almost constant in two spans in the sample period. The first one lasted 19 months (2011M6-2012M12) when the size of the balance sheet was oscillating around 325 per cent of the original size in 2007M7. The second period occurred at the end of the sample (2014M9-2015M12) after reaching 505 per cent of the base value. During the interims, balance sheets of many other central banks were still expanding. In such cases, the periods are depicted in red ovals. Other noteworthy periods are circled in blue. The dotted line represents the linear trend. If the trend line is above the 45° line it means that the other country expanded the balance sheet faster than the U.S. (such as GBR). There are also regional patterns in the indices; therefore, the comparisons of major economies in each region are attached in Appendix D. The patterns show the course of the crisis around the world and the similar reaction of central banks to local conditions.

Figure 8 Index of BS: ALB to US

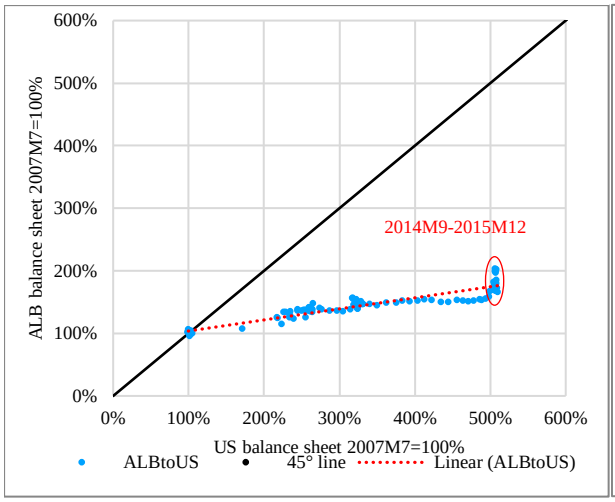
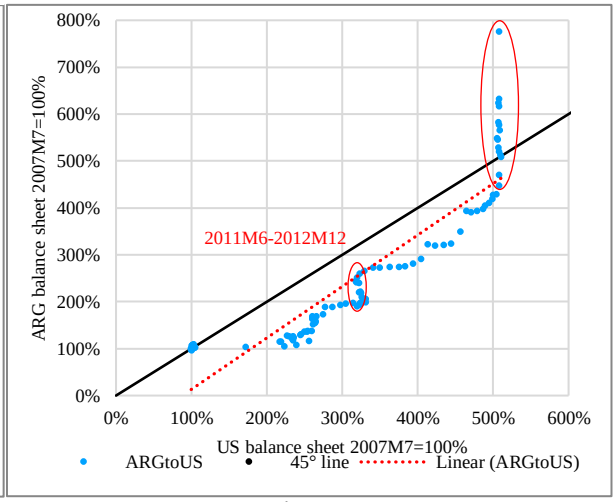


Figure 9 Index of BS: ARG to US



Note: $H_0: \beta_1 = 1$; *p-value: 0.07;* $\hat{\beta}_1 = 1.096$

Figure 10 Index of BS: ARM to US

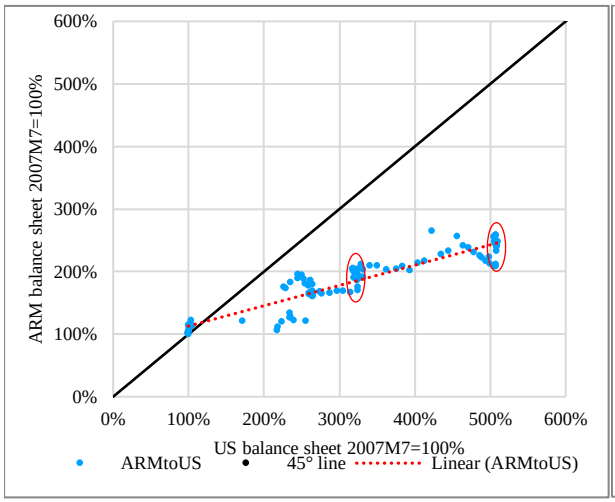


Figure 11 Index of BS: AUS to US

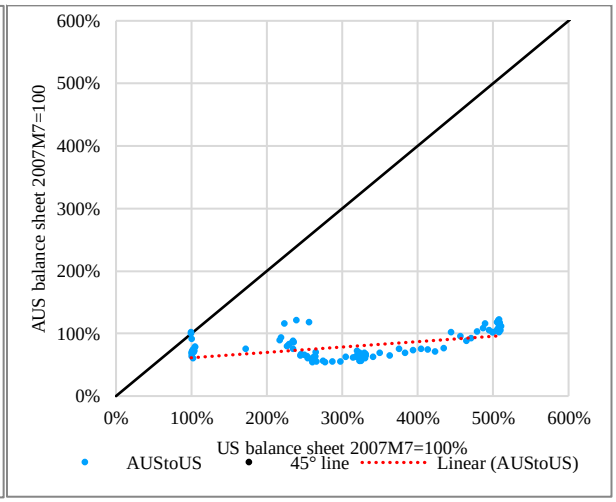


Figure 12 Index of BS: AZE to US

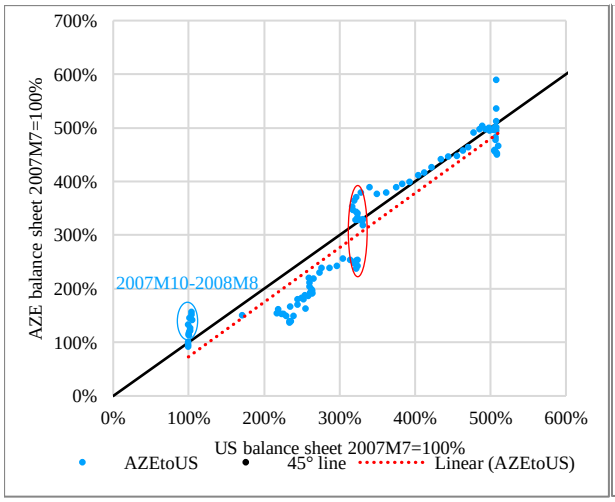
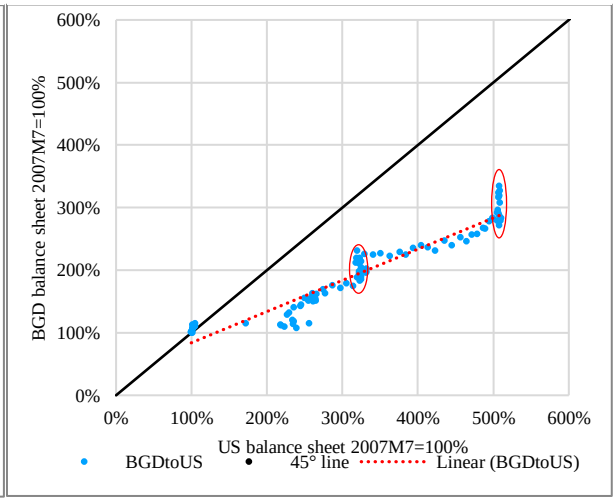


Figure 13 Index of BS: BGD to US



Note: $H_0: \overline{BS}_{US} = \overline{BS}_{AZE}$; *p-value: 0.22*
$H_0: \beta_1 = 1$; *p-value: 0.62;* $\hat{\beta}_1 = 1.017$

Figure 14 Index of BS: BLR to US

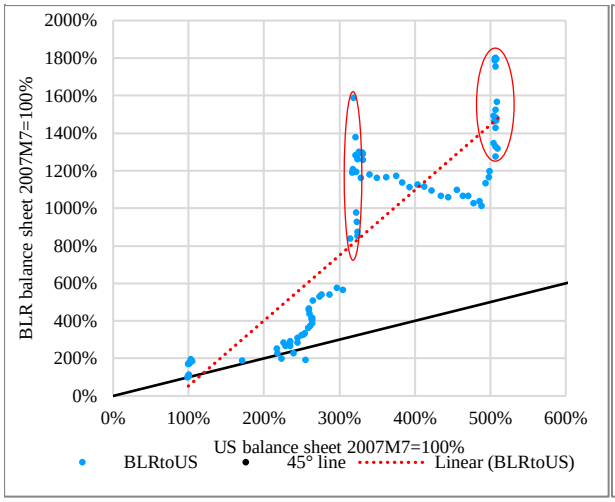


Figure 15 Index of BS: BLZ to US

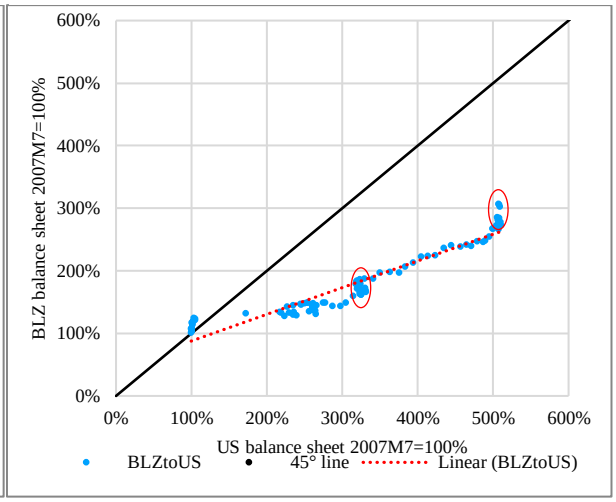


Figure 16 Index of BS: BRA to US

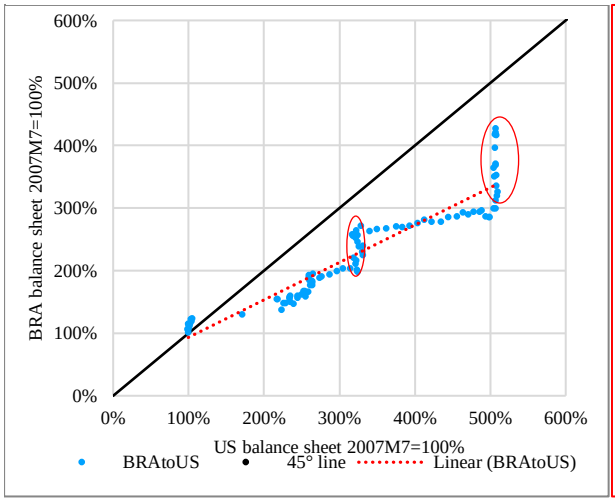


Figure 17 Index of BS: CAN to US

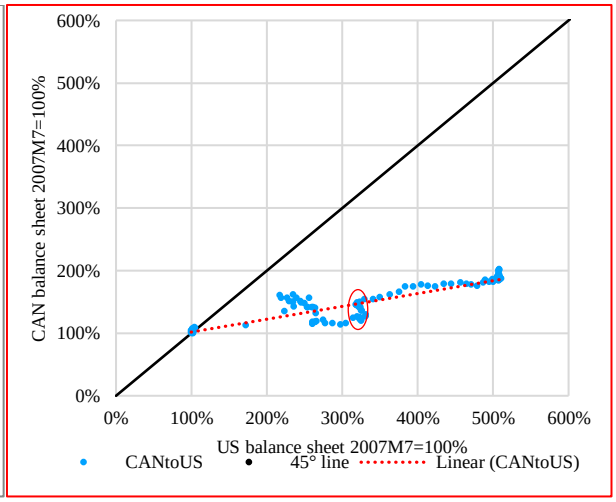


Figure 18 Index of BS: CHE to US

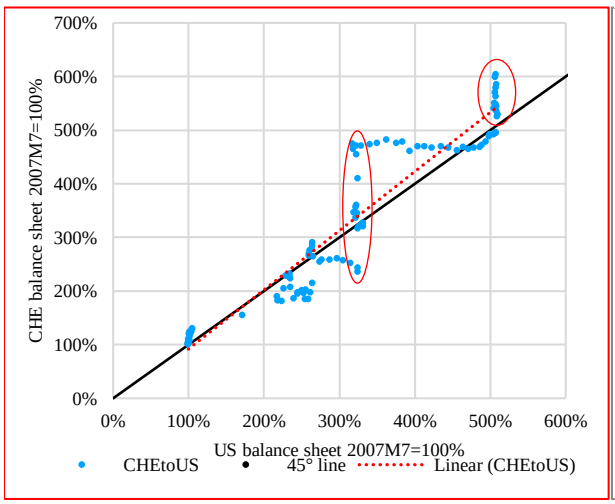
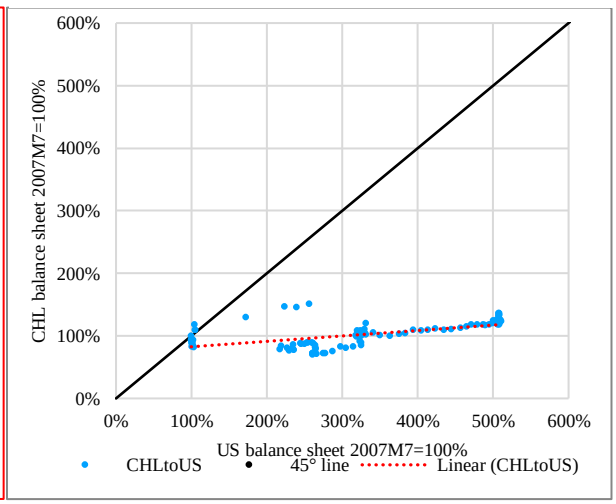


Figure 19 Index of BS: CHL to US



Note: $H_0: \overline{BS}_{US} = \overline{BS}_{CHE}$; *p-value: 0.46*
$H_0: \beta_1 = 1$; *p-value: 0.01;* $\hat{\beta}_1 = 1.103$

Figure 20 Index of BS: CHN to US

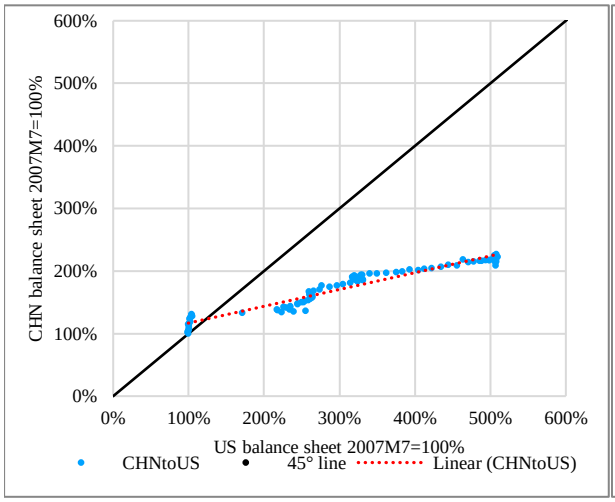


Figure 21 Index of BS: COD to US

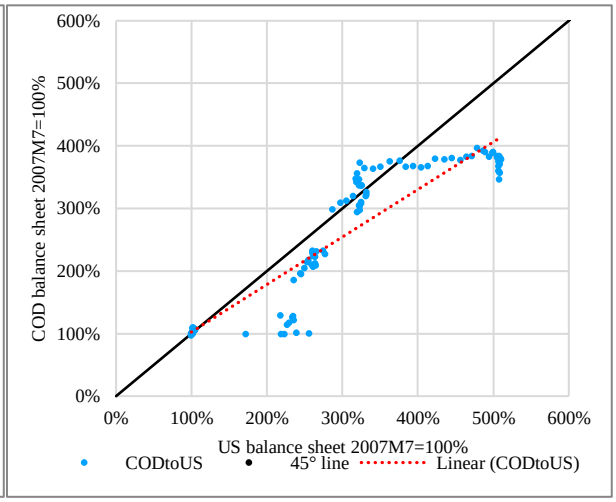


Figure 22 Index of BS: COL to US

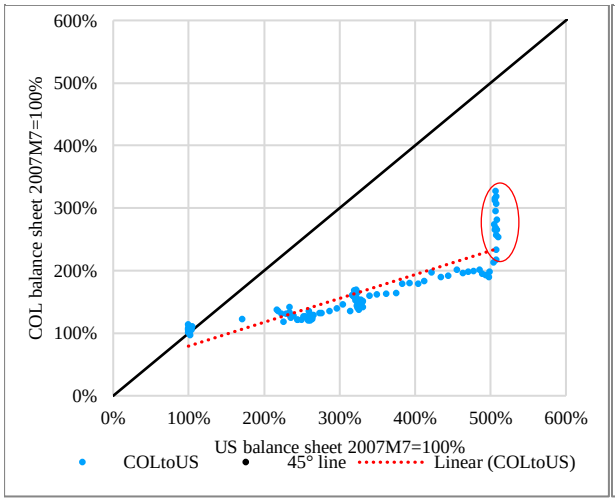


Figure 23 Index of BS: CPV to US

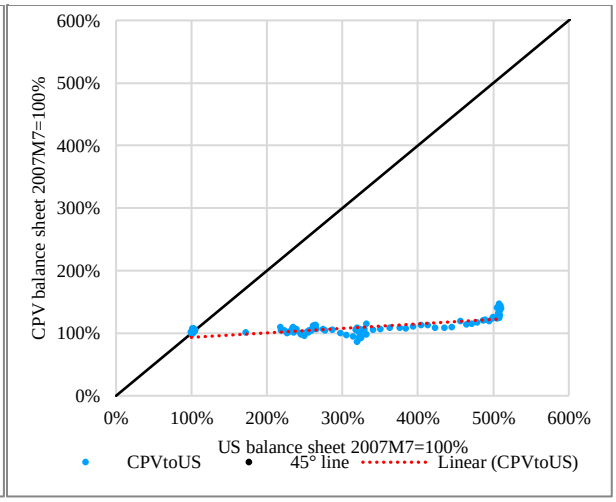


Figure 24 Index of BS: CRI to US

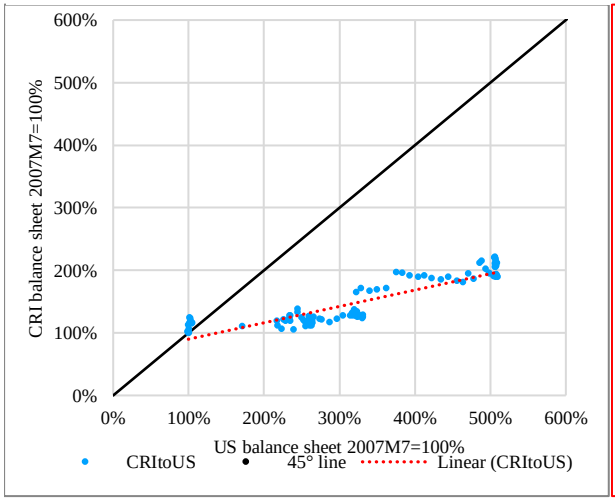


Figure 25 Index of BS: CZE to US

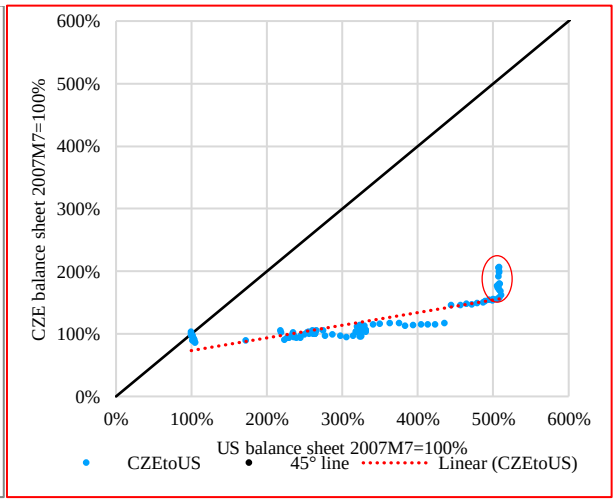


Figure 26 Index of BS: DNK to US

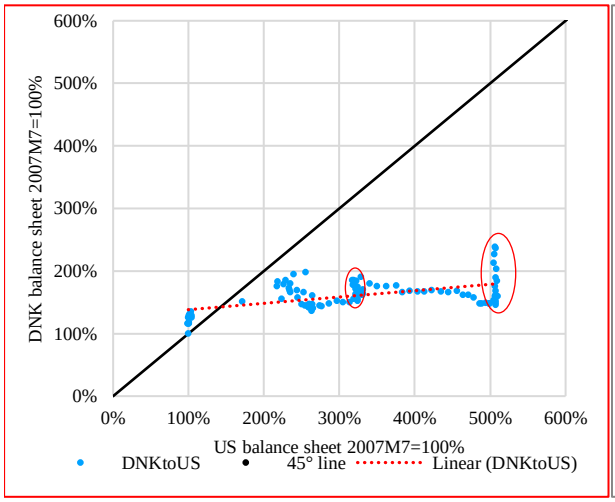


Figure 27 Index of BS: DOM to US

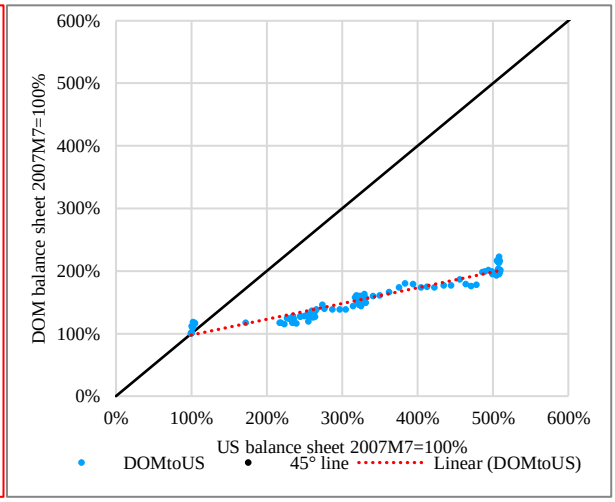


Figure 28 Index of BS: EUR to US

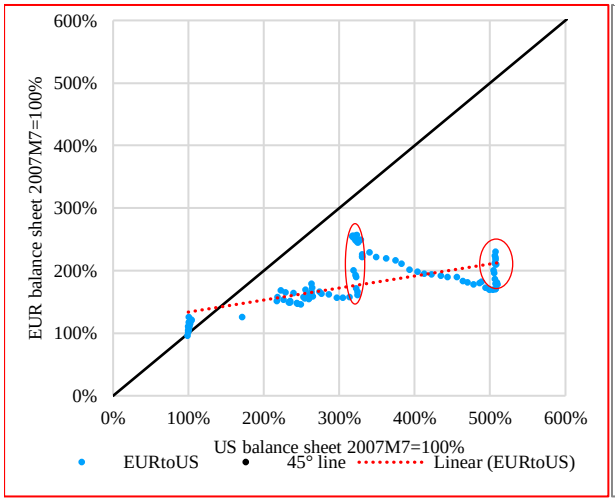


Figure 29 Index of BS: FJI to US

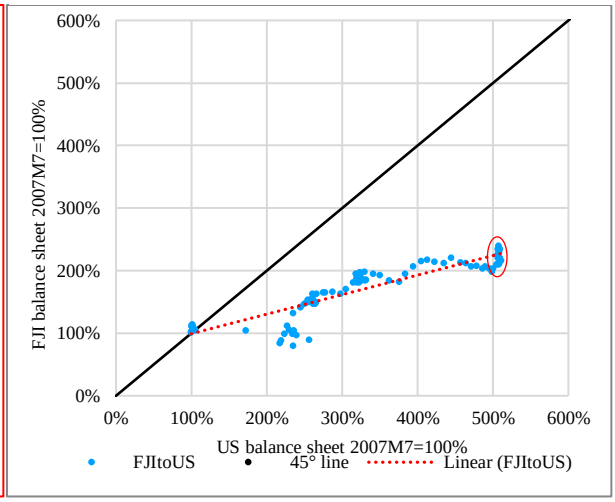


Figure 30 Index of BS: GBR to US

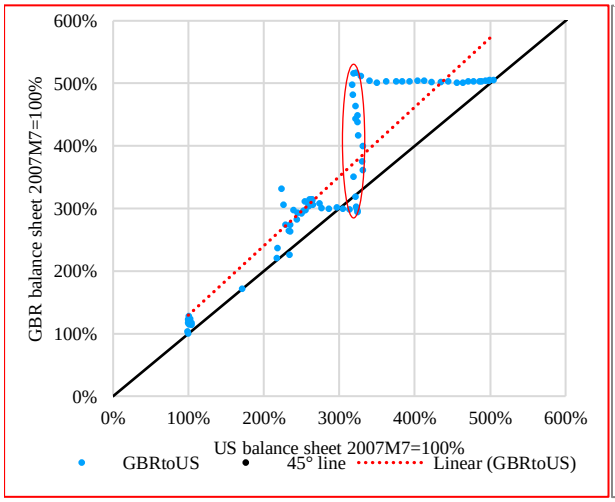
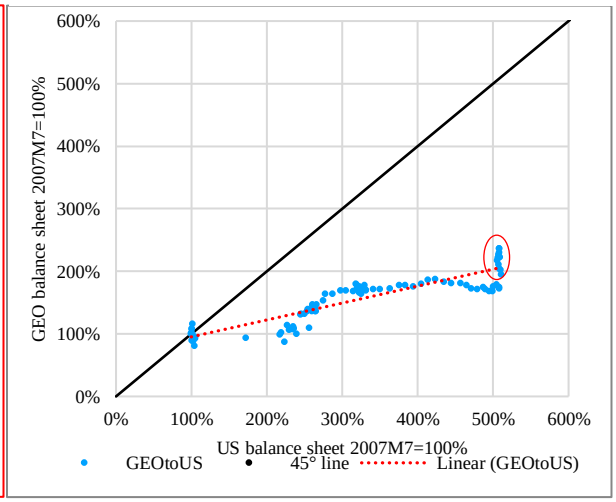
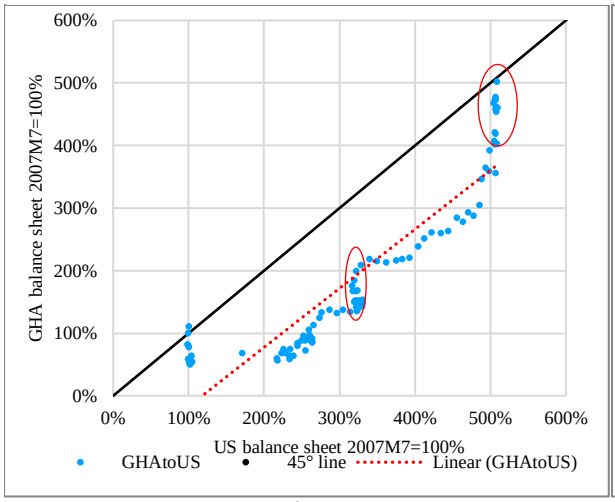


Figure 31 Index of BS: GEO to US



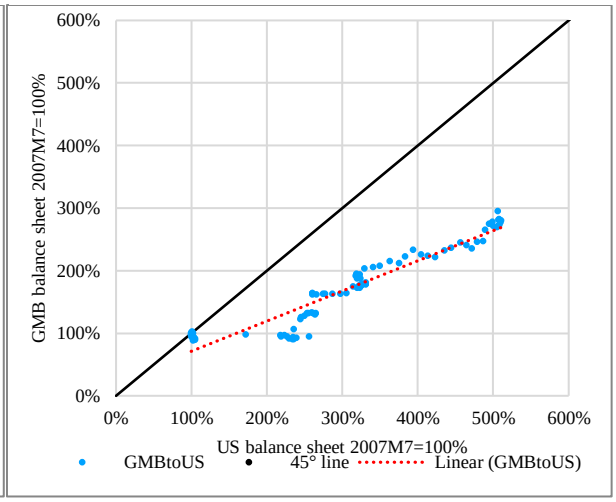
Note: Period 2006M5 – 2014M9;
H_0: β_1 =1; p-value: 0.04; $\hat{\beta}_1$ =1.108

Figure 32 Index of BS: GHA to US



Note: $H_0: \beta_1 = 1$; *p-value: 0.20;* $\hat{\beta}_1 = 0.944$

Figure 33 Index of BS: GMB to US



Note: Period 2006M1 – 2015M4

Figure 34 Index of BS: GTM to US

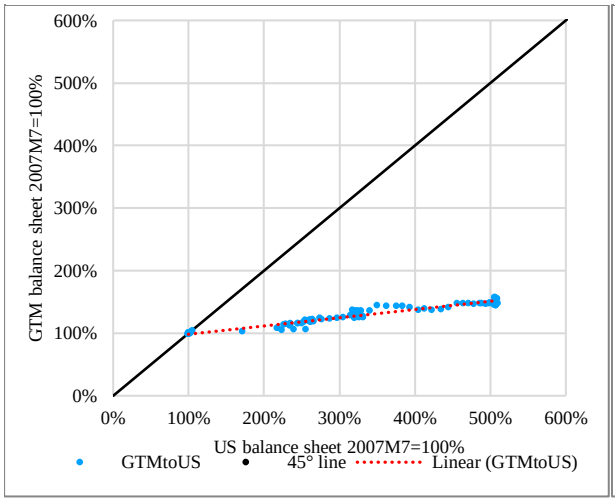


Figure 35 Index of BS: GUY to US

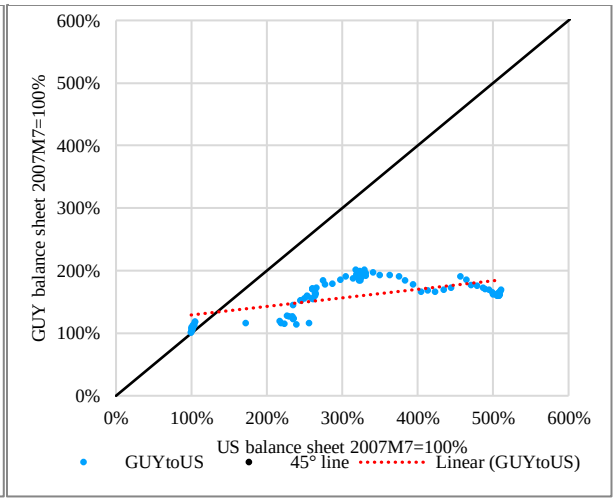


Figure 36 Index of BS: HND to US

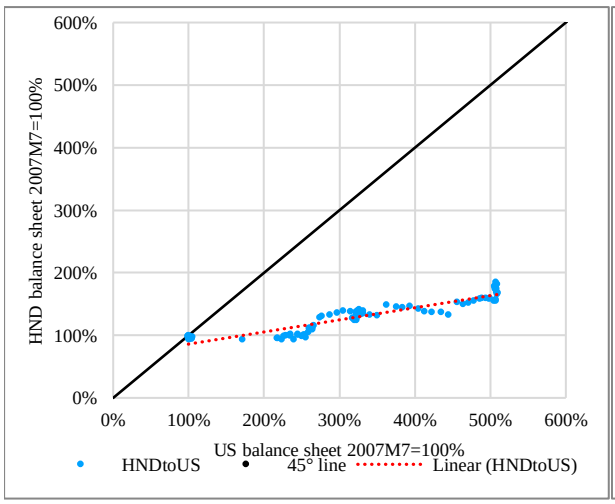


Figure 37 Index of BS: HUN to US

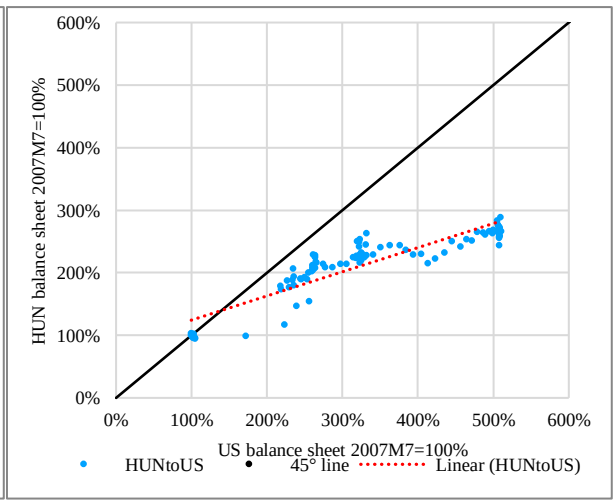


Figure 38 Index of BS: IDN to US

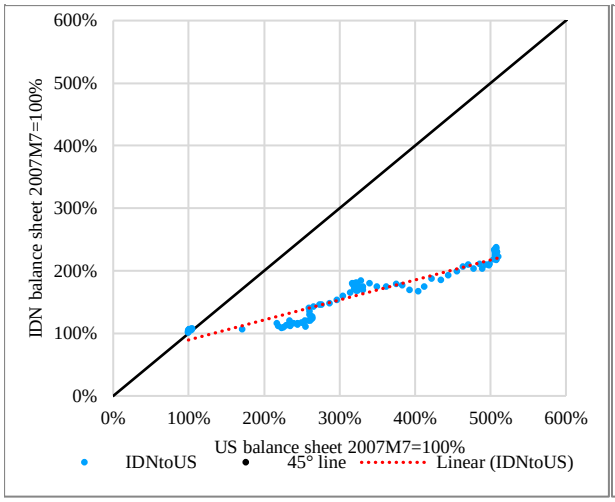


Figure 39 Index of BS: IND to US

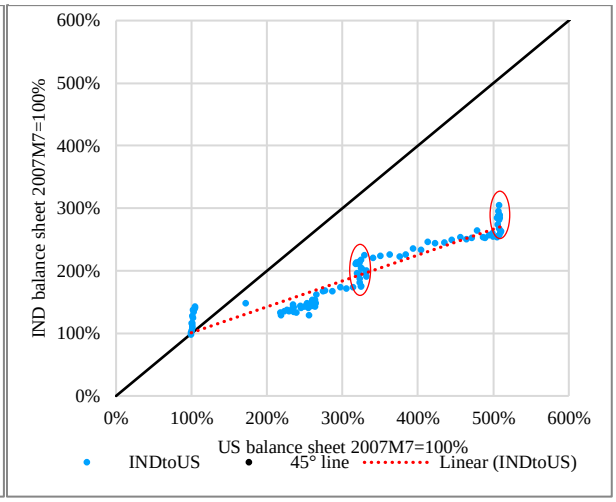


Figure 40 Index of BS: ISL to US

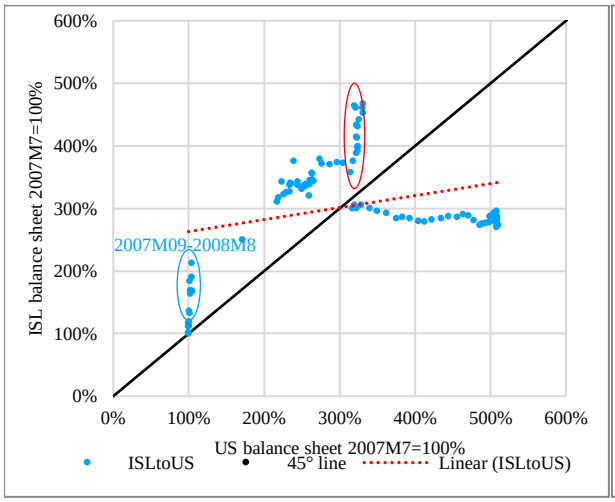
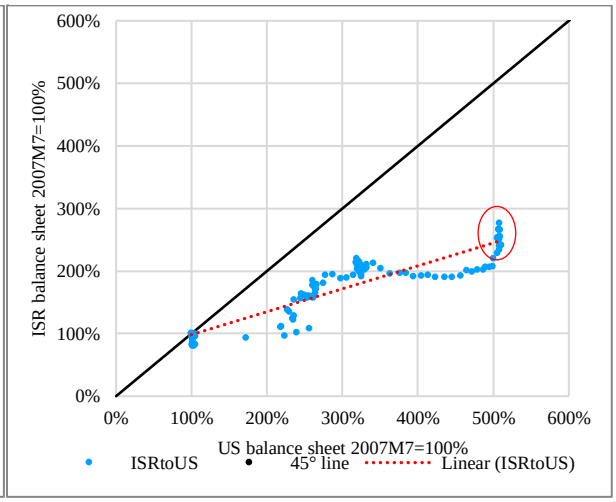


Figure 41 Index of BS: ISR to US



Note: $H_0: \overline{BS}_{US} = \overline{BS}_{ISL}$; *p-value: 0.31*

Figure 42 Index of BS: IRQ to US

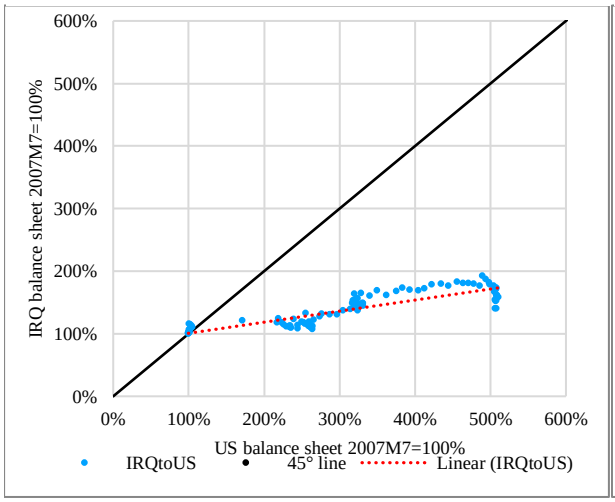


Figure 43 Index of BS: JAM to US

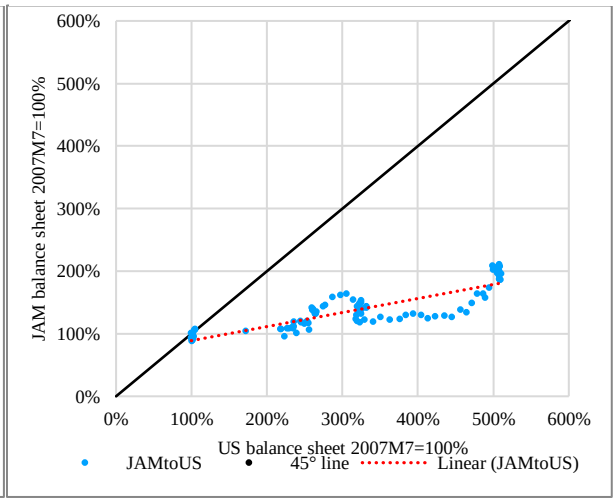
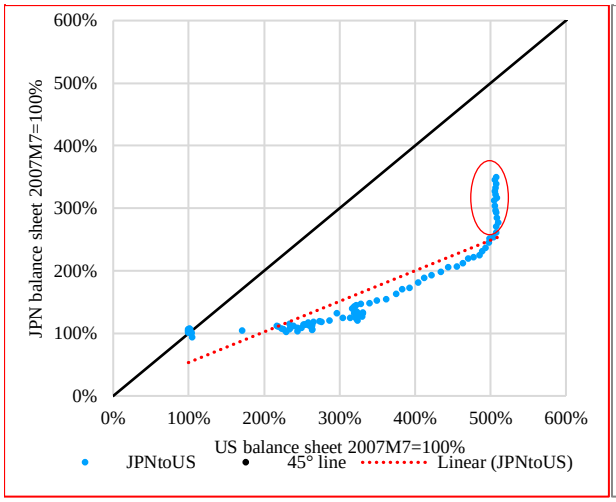


Figure 44 Index of BS: JPN to US



Note: Japan had already massively expanded its balance sheet before the sample period started.

Figure 45 Index of BS: KAZ to US

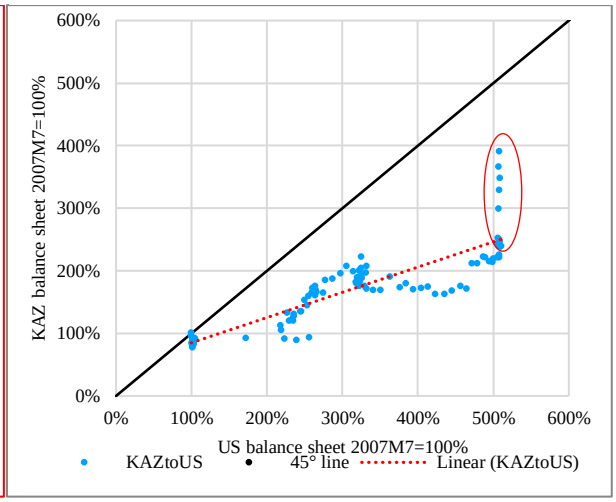


Figure 46 Index of BS: KEN to US

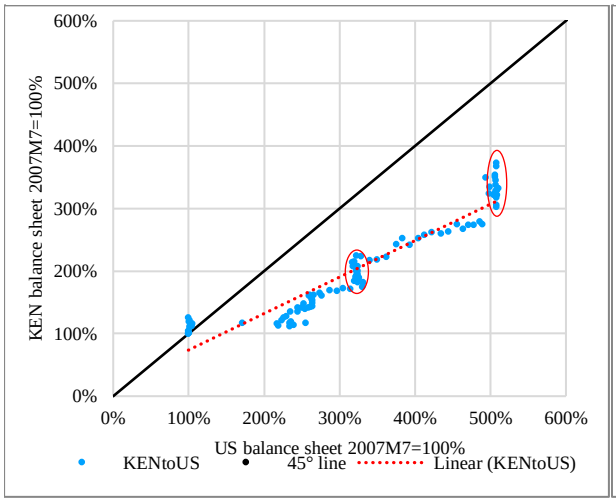


Figure 47 Index of BS: KGZ to US

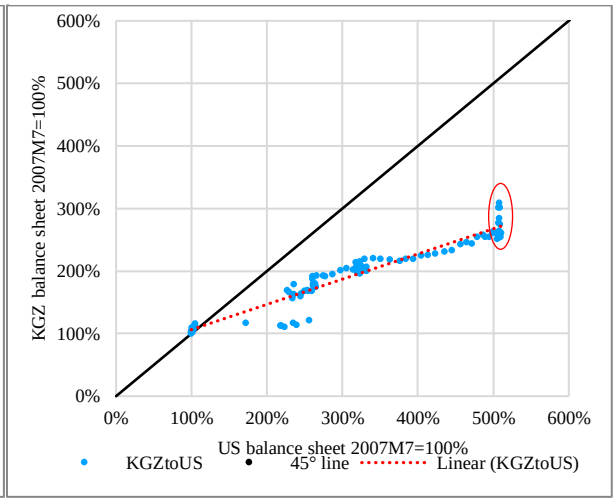


Figure 48 Index of BS: KOR to US

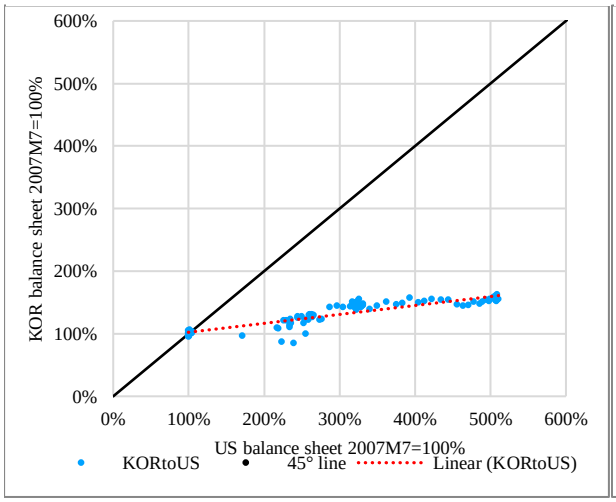


Figure 49 Index of BS: MDA to US

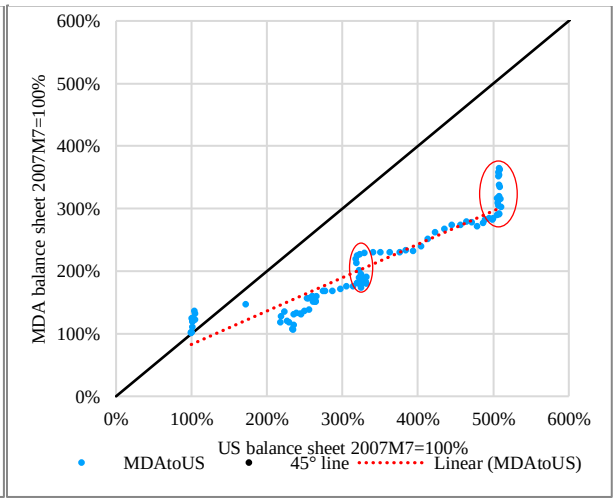


Figure 50 Index of BS: MEX to US

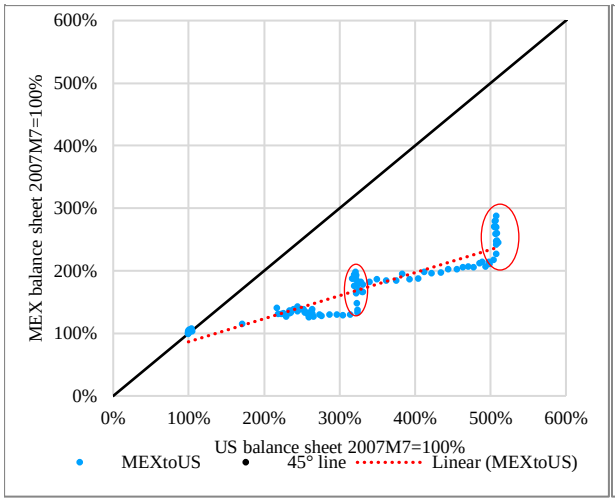


Figure 51 Index of BS: MKD to US

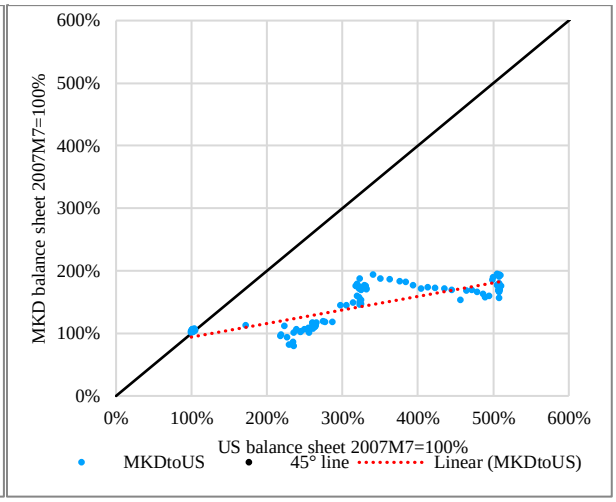


Figure 52 Index of BS: MNG to US

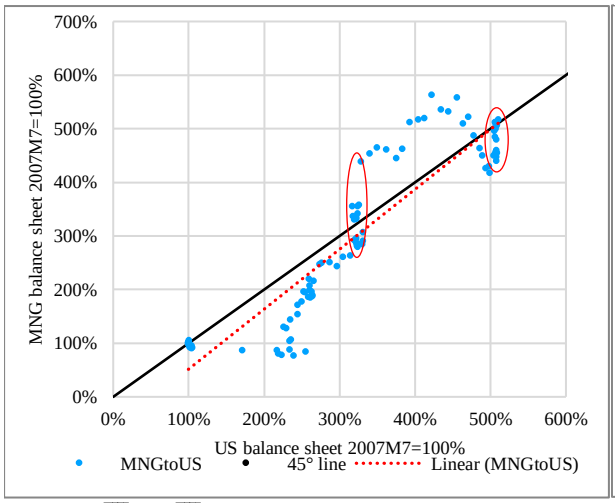
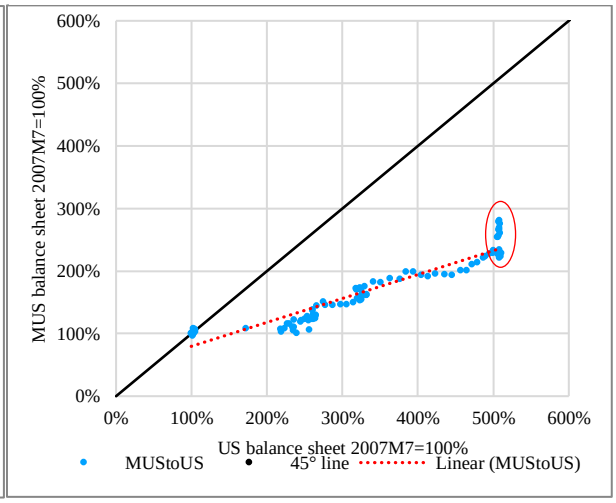


Figure 53 Index of BS: MUS to US



Note: $H_0: \overline{BS}_{US} = \overline{BS}_{MNG}$; *p-value: 0.28*
$H_0: \beta_1 = 1$; *p-value: 0.02;* $\hat{\beta}_1 = 1.118$

Figure 54 Index of BS: MYS to US

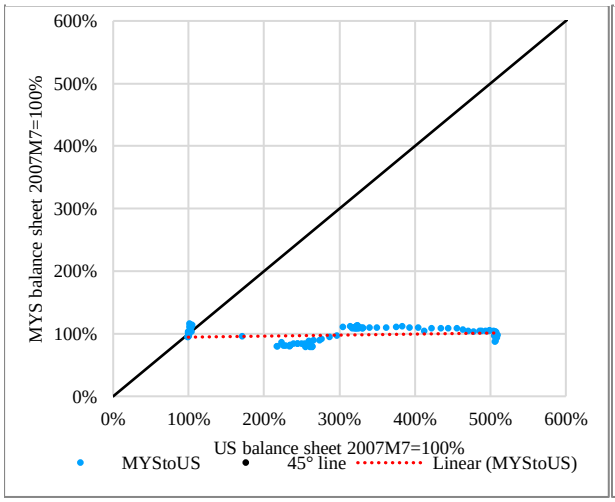
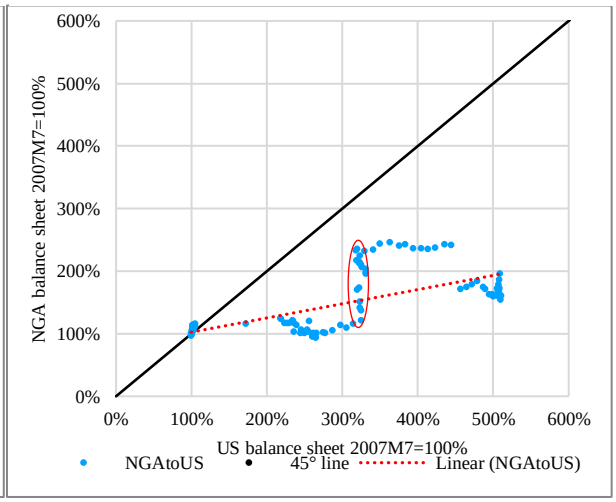


Figure 55 Index of BS: NGA to US



Note: $\hat{\beta}_1$ *is statistically insignificant at the 5% significance level:*
$H_0: \beta_1 = 0$; *p-value: 0.07*

Figure 56 Index of BS: NOR to US

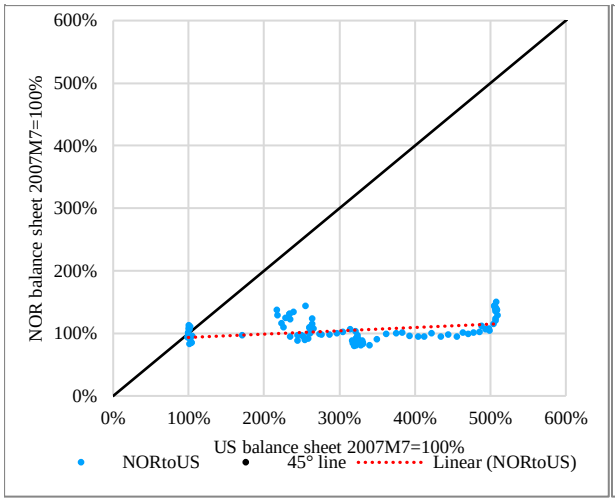


Figure 57 Index of BS: NPL to US

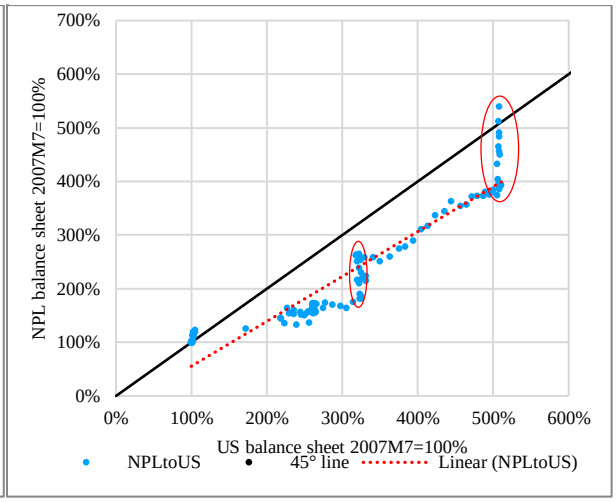


Figure 58 Index of BS: NZL to US

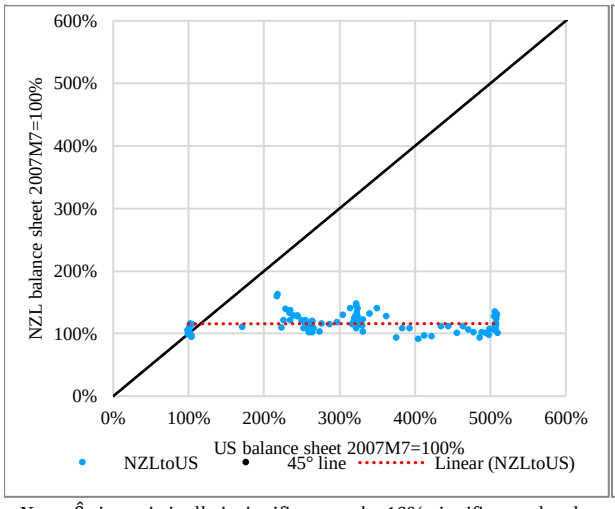
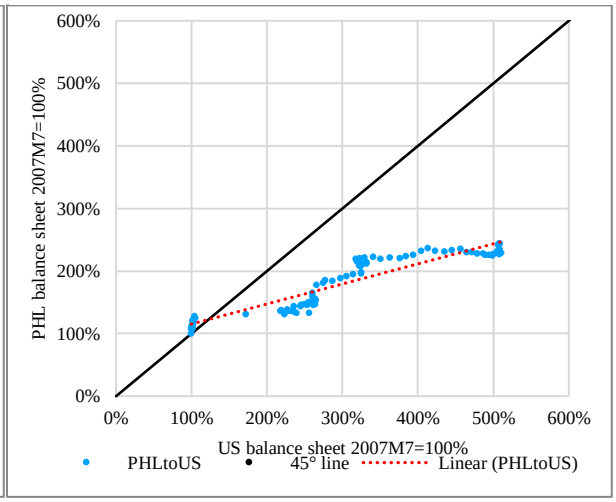


Figure 59 Index of BS: PHL to US



Note: $\hat{\beta}_1$ is statistically insignificant at the 10% significance level: H_0: β_1 =0; p-value: 0.91

Figure 60 Index of BS: PNG to US

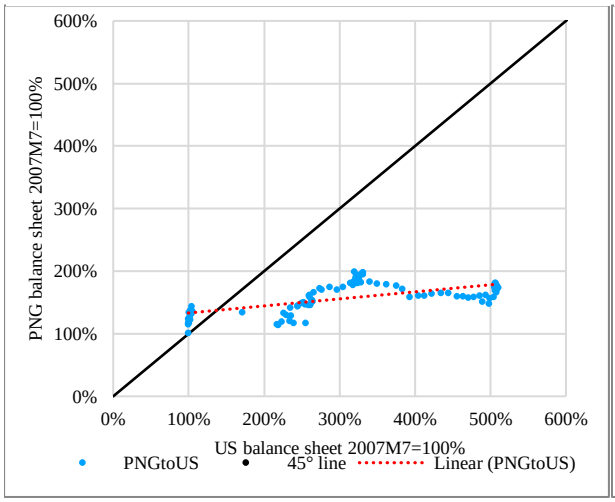


Figure 61 Index of BS: POL to US

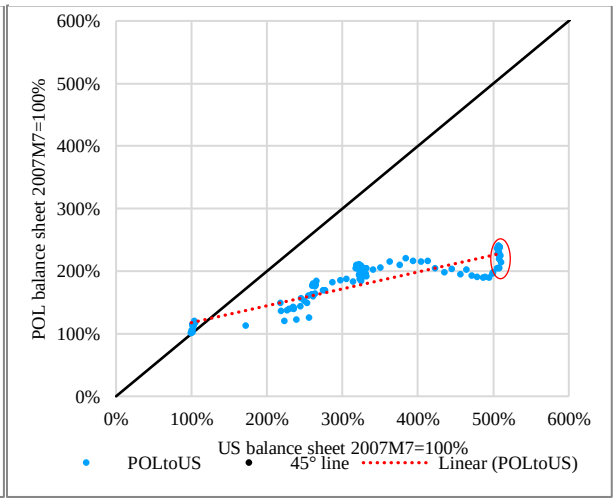


Figure 62 Index of BS: QAT to US

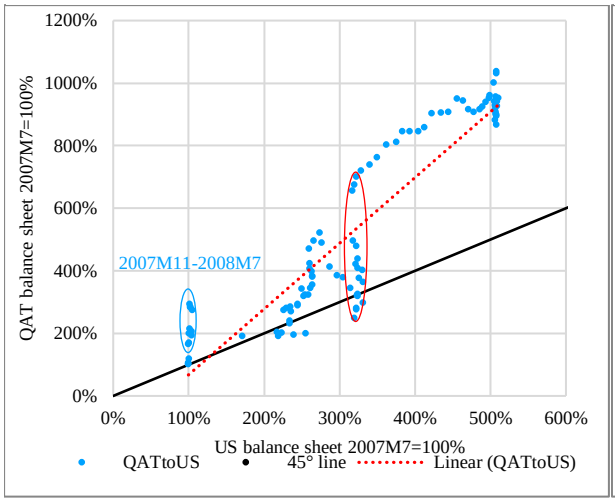


Figure 63 Index of BS: ROU to US

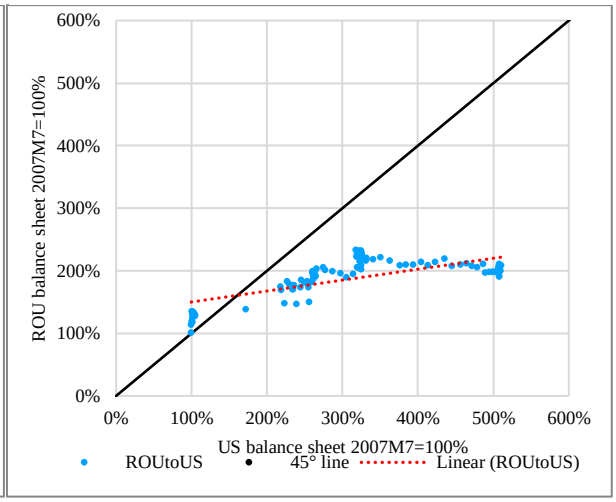


Figure 64 Index of BS: RUS to US

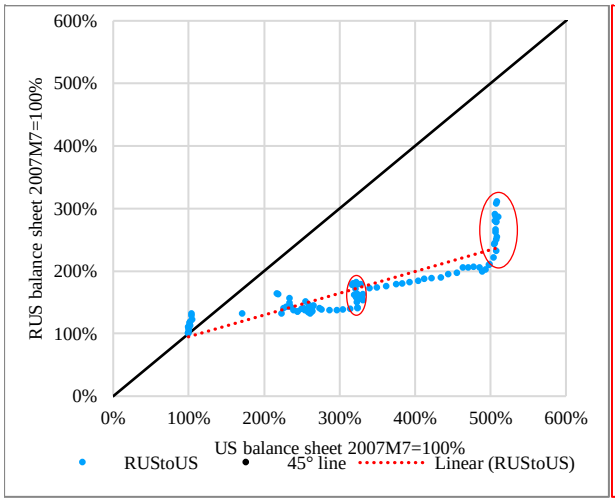


Figure 65 Index of BS: SAU to US

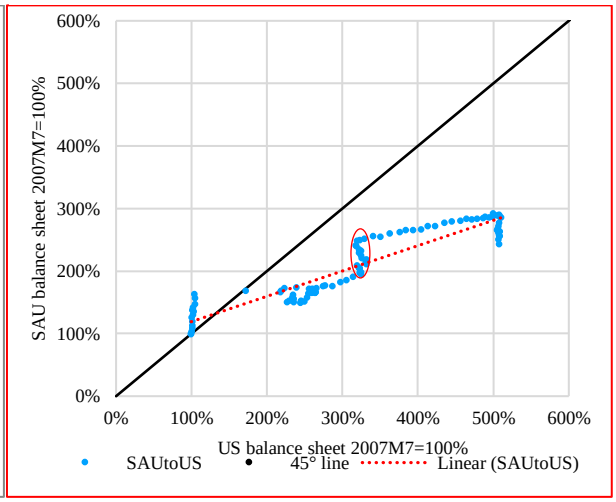


Figure 66 Index of BS: SGP to US

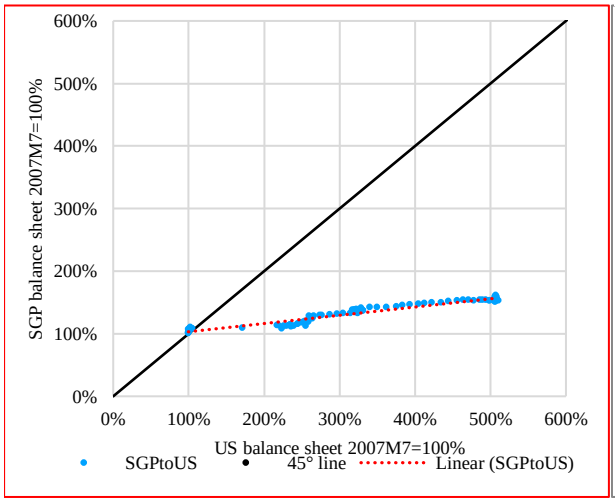


Figure 67 Index of BS: SRB to US

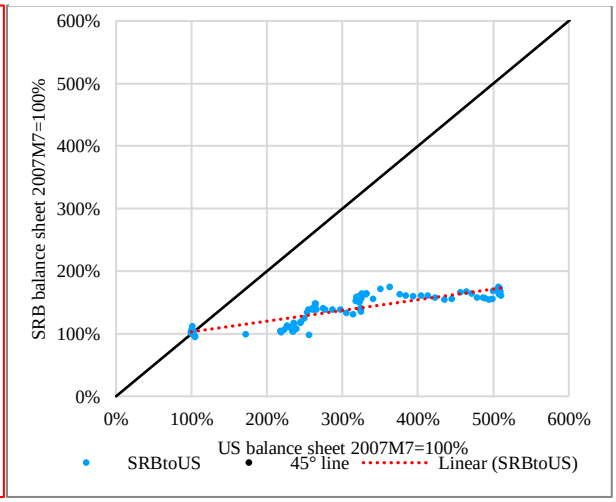


Figure 68 Index of BS: STP to US

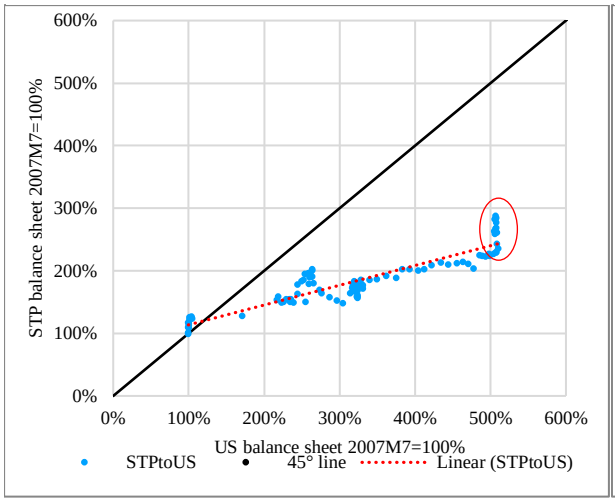


Figure 69 Index of BS: SUR to US

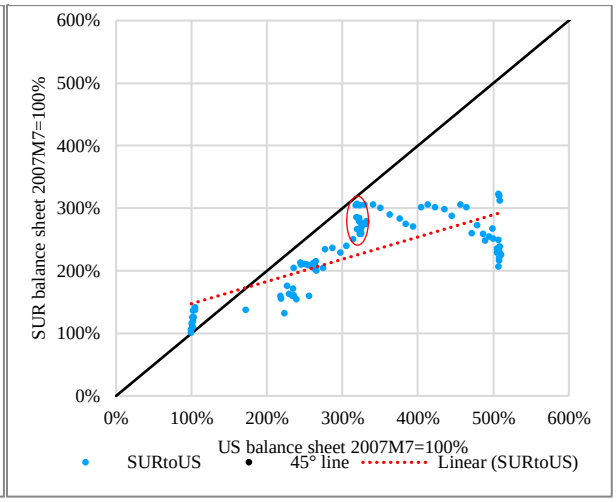


Figure 70 Index of BS: SWE to US

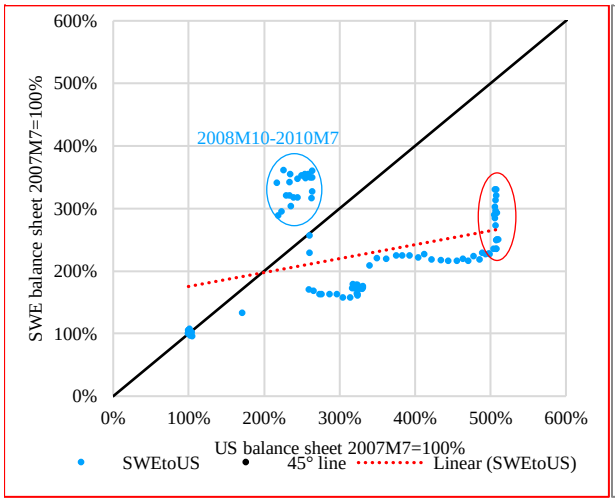


Figure 71 Index of BS: THA to US

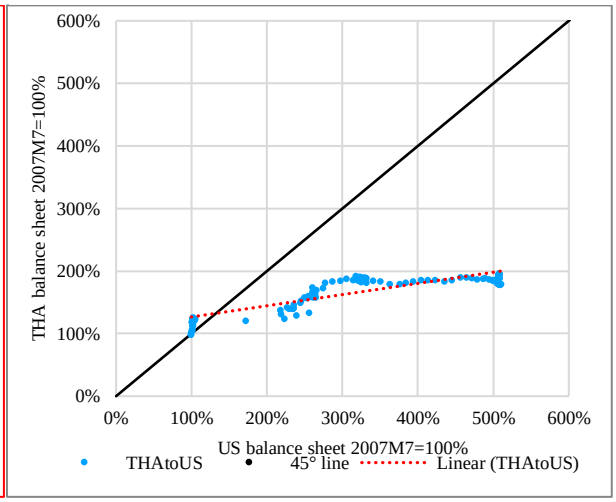


Figure 72 Index of BS: TUR to US

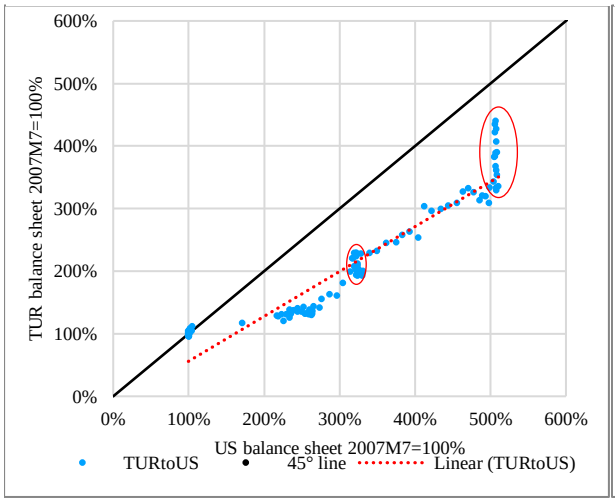


Figure 73 Index of BS: UEMOA to US

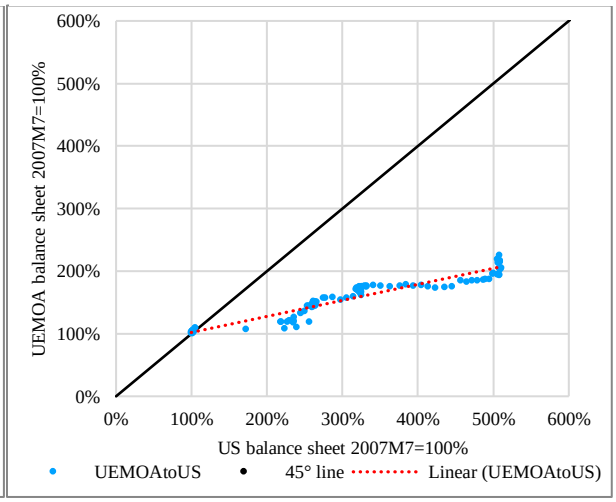


Figure 74 Index of BS: URY to US

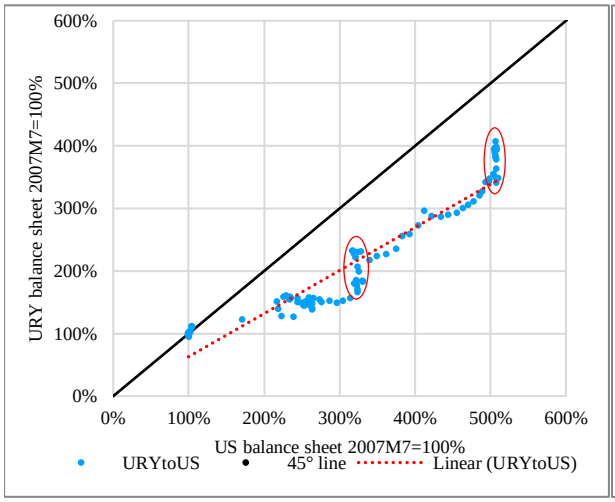
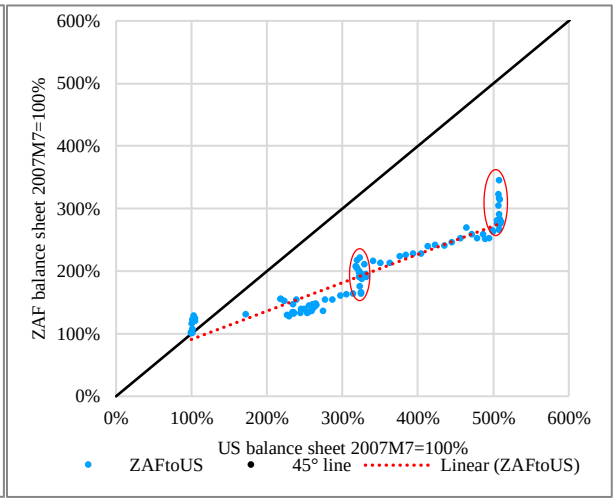


Figure 75 Index of BS: ZAF to US



Sources for figures no. 8 – no. 75: Own calculations, data from FRED, IFS, national data.

To sum up, the hypothesis of equality of the means of balance sheet changes is not rejected at 1% level for AZE, CHE, ISL, MNG while the null hypothesis that the regression coefficient equals one is not rejected at 1% level for ARG, AZE, CHE, GBR, GHA, MNG. Out of those economies, CHE and GBR belong among the ZLB-nominees.

In connection with the preceding figures, Table 3 summarises changes in the size of the balance sheet for 69 studied central banks. The data is missing for seven countries from the original set. It shows how many countries reached the particular threshold during the sample period (2007M7-2015M12). The maximum size of the balance sheet is considered as the determinative value. The base value is 100 per cent in July 2007 as in the figures above. Notably, a majority of central banks (54) increased their balance sheets at least moderately (over 200 per cent), whilst, only ten of them expanded the balance sheet by more than 500 per cent. The phenomenon of large balance sheet changes is not restricted only to countries facing the ZLB but occurred also in other countries including developing and emerging economies. However, some of the changes in the balance sheet size might have happened due to nominal GDP growth. The same indices for BS/GDP ratio (reported in Appendix C) imply that many of the changes in low-income countries were caused by growing nominal GDP. 12 economies crossed the threshold of 200 per cent of the base value of BS/GDP ratio in 2007M7, seven of them are ZLB-nominees (CHE, DNK, EUR, GBR, JPN, SWE, US) and only three belong to the low-income group (Table C1 in Appendix C).

Table 3 The balance sheet expansion relative to the base period: summary of the maximum

Countries	Over 200% of BS in 2007M7	Over 300% of BS in 2007M7	Over 400% of BS in 2007M7	Over 500% of BS in 2007M7
OECD (19 countries)	14	7	5	3
Other Advanced (1)	0	0	0	0
BRICS (5)	5	4	1	0
Emerging (27)	20	8	5	4
Developing (15)	13	9	3	3
Euro Area (1)	Yes (1)	No	No	No
UEMOA (1)	Yes (1)	No	No	No
Total (69)	**54**	**28**	**14**	**10**

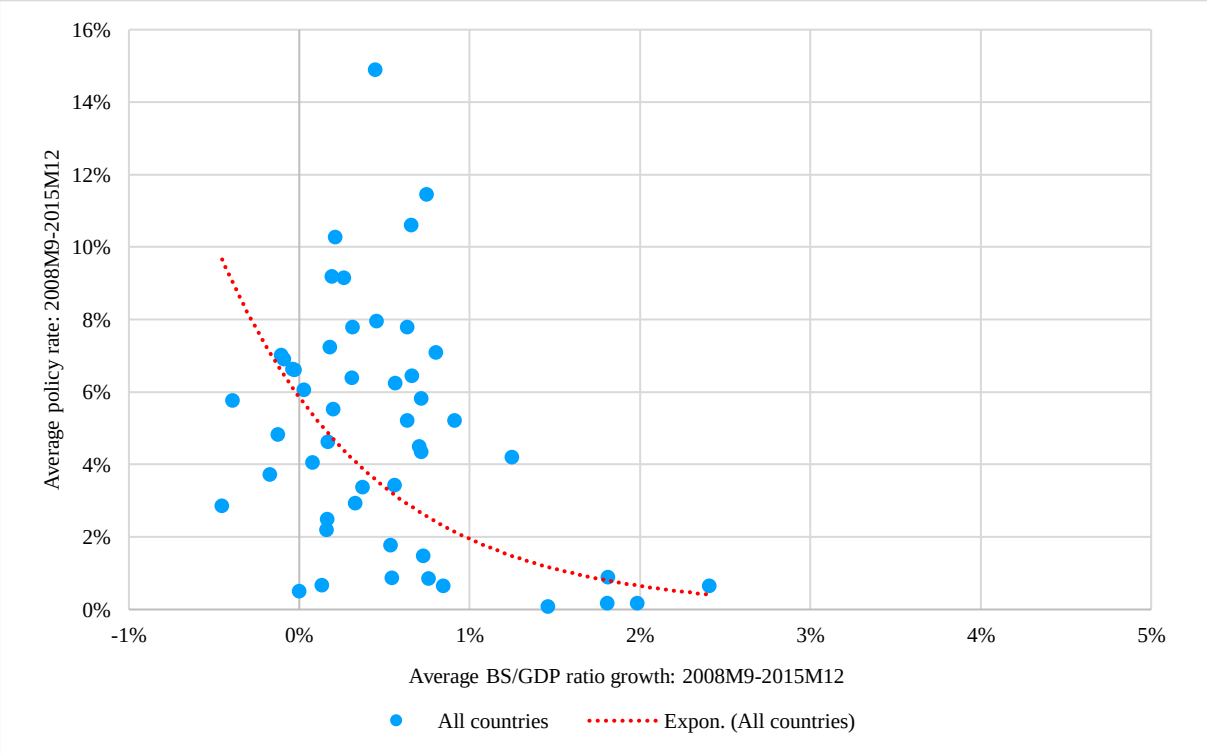
Source: Own calculation, data from IFS, national data.

Secondly, Figure 76 shows the relationship between the average policy rate and average changes in the BS/GDP ratio during and after the crisis (2008M9-2015M12). The BS/GDP-ratio growth is constructed as a percentage monthly change in the size of the ratio. Mathematically speaking, the monthly changes are calculated as $\frac{(BS_t/GDP_t)-(BS_{t-1}/GDP_{t-1})}{(BS_{t-1}/GDP_{t-1})}$. Then, a simple average is calculated from those values. The BS/GDP ratio is used in order to naturally eliminate countries where the increasing balance sheet might reflect the increasing nominal GDP and high inflation[13]. The data is available for 48 countries. The period examined starts in September 2008 to compare the same time span for changes in policy rates as well as balance sheets. Therefore, it aligns with the crisis period used earlier in the analysis. Notably, exponential trendline[14] suggests that there might be a linkage between the average policy rate and average BS/GDP ratio growth for the period since the failure of Lehman Brothers. Figure 77 displays, not only the lower policy rates of high-income economies showed earlier in the analysis, but also higher average BS/GDP-ratio growth of these economies. A figure distinguishing the countries in figures no. 76 and no. 77 is in Appendix B. The five countries the most on the left in Figure 77 (countries with largest average BS/GDP-ratio growth) are GBR, CHE, US, SWE, JAP; thus countries which indeed reached the ZLB.

[13] The continuous growth of the nominal balance sheet in some countries only mirrored the nominal GDP growth and inflation. Then, using the BS/GDP ratio leads to real values and the countries with a high nominal balance sheet growth are eliminated. On the other hand, the drawback is that the balance sheet in other countries might then be deflated by the nominal GDP.

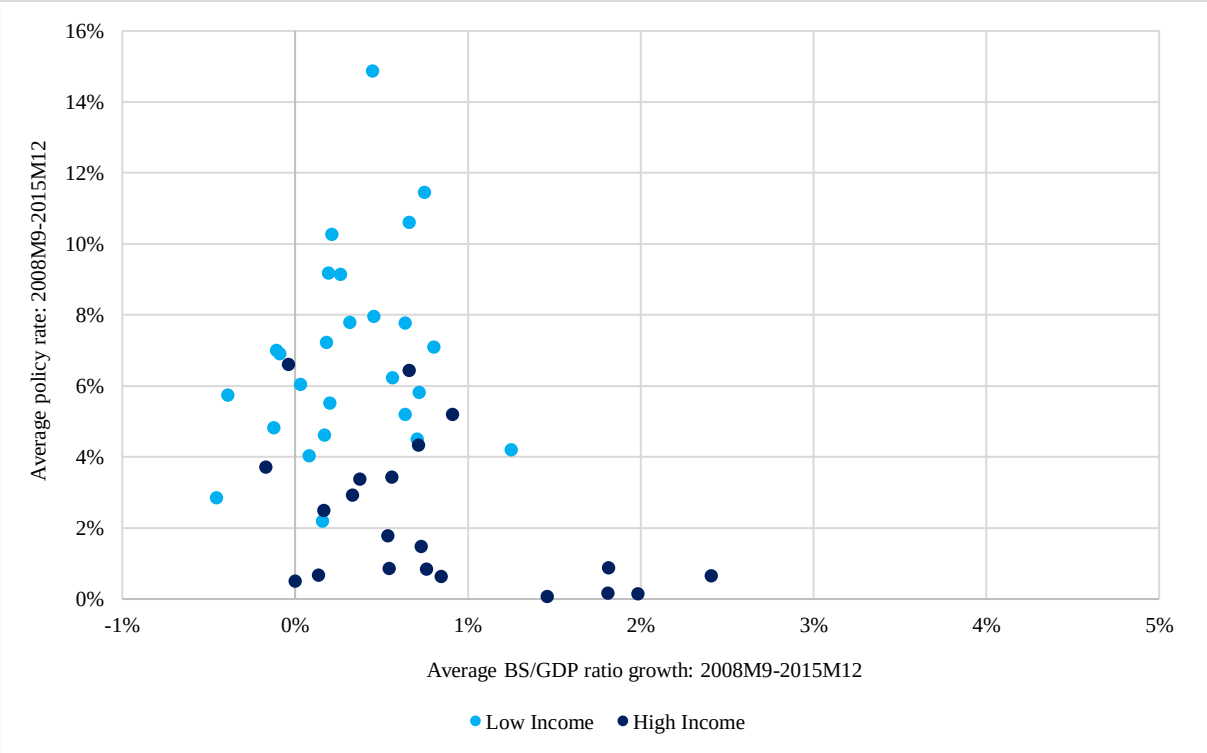
[14] The trendline is specified as $y = \beta_0 \cdot e^{\beta_1 x} + \varepsilon_t$; *where* y *stands for an average policy rate and* x *is an average* $\frac{BS}{GDP}$ *ratio growth.*

Figure 76 The average policy rate and average BS/GDP growth: 2008M9-2015M12 (1/2)



Source: Own calculation, data from BIS, FRED, IFS, national data.

Figure 77 The average policy rate and average BS/GDP growth: 2008M9-2015M12 (2/2)



Source: Own calculation, data from BIS, FRED, IFS, national data.

2.3. Central banks at the zero lower bound

As previously mentioned in section 2.1, 14 central banks out of 76 examined are identified to have reached the ZLB. Affected economies are BGR, BHR, CAN, CHE, CZE, DNK, EUR, GBR, HKG, JPN, SAU, SGP, SWE and US. Balance sheets in 11 of those economies (data on BGR, BHR and HKG are missing) are examined to see their expansion. Ten of them showed moderate or strong changes in the balance sheet size (reaching maximum values over 200 per cent of the balance sheet size in July 2007) and therefore they are nominees for the significant results of the changes in balance sheet on the long-term interest rate. This is valid especially for CHE GBR, JPN, SWE, US which experienced a strong expansion (over 300 per cent). The balance sheet of SGP's central bank remained almost unchanged (under 200 per cent). Looking at the course of the balance sheet changes, CAN and CZE do not seem to use balance sheet much either as their balance sheets were mostly stable and moderately growing. Moreover, they both barely crossed the 200 per cent threshold (CAN: 201 per cent and CZE: 207 per cent) and did so only in the last months of the sample period.

2.4. Empirical model

Apart from the cross-section data analysis of policy interest rates and changes in the size of the balance sheet of central banks, the paper also examines the effects of the change in the size of the balance sheet on a long-term interest rate during the crisis from a time series perspective. I verify in this section the existence of a potential linkage between long-term interest rates and balance sheet changes in 32 countries[15]. The time series analysis presumes persistence in the movement of interest rates and examines whether there is an inverse relationship between the changes in the size of the central bank balance sheet and the long-term interest rate (a ten-year government bond rate):

$$\Delta i_t^l = \alpha_0 + \alpha_1 \Delta i_{t-1}^l + \alpha_2 \Delta i_t^{pr} + \beta_1 \Delta bs_t + \varepsilon_t$$

[15] Data for the rest of the countries from the original dataset was not available.

The dependent variable:

Δi_t^l is the monthly change in the ten-year government bond rate (in basis points)

The explanatory variables:

Δi_{t-1}^l is the lag of the dependent variable Δi_t^l (in basis points)

Δi_t^{pr} is the change in the main central bank policy interest rate (in basis points)

Δbs_t is the change in the size of the central bank balance sheet (in billions and in some cases trillions[16] of a domestic currency)

Nominal data is used for the estimation as it gives the opportunity to examine a large set of countries and it does not face the data on inflation, which is not often available or reliable in less developed countries. Due to the nature of the data and serial correlation, first differencing is used for the variables (unit root tests were run to examine the non-stationarity of the data)[17]. The regression is run over the 2008M10–2015M12 period to capture the crisis[18]. That gives 86 observations[19] for each regression after first differencing.

2.5. Empirical results based on time series data

The effects of changes in the size of the balance sheet on the ten-year government bond rate are presented in Table 4. Full results with estimates for the other coefficients are available in Appendix E. The estimates of Δbs_t determine the change in the long-term rate caused by a

[16] Billions of a domestic currency are used for the vast majority of countries with three exceptions for which trillions are considered: IDN, JPN and KOR.
[17] Economic theory assumes a causal relation between Δbs_t and Δi_t^l in the sense that Δbs_t represents a shift in policy thereby leading to a potential change in Δi_t^l, as it was described in the theoretical section. Nevertheless, I cannot rule out an endogeneity bias in the regressions since the current change in the balance sheet (independent variable) and the current change in the interest rate (dependent variable) are used.
[18] Also, the first QE programme in the U.S. was announced in November 2008 (Chen et al., 2016) which aligns with the period examined.
[19] Countries with shorter sample periods or few missing variables are: GBR, ROU, SGP.

rise in the size of the central bank balance sheet by one billion (one trillion for IDN, JPN, KOR) of a domestic currency. For instance, if the balance sheet of ECB rose by 100 billion euros, the long-term interest rate fell by 4.8 basis points in a given month. However, this is difficult to understand as each currency has different purchasing power. Therefore, the coefficient was standardised into a change in the balance sheet size equal to ten per cent of the annual GDP (the value of GDP in 2007 is used). In other words, the forth column shows the change in the long-term rate caused by a rise in the size of the central bank balance sheet by a value equal to ten per cent of annual GDP. For example, when the balance sheet size of Swiss National Bank increased by a value equal to ten per cent of Swiss annual GDP (i.e. 57 billion Swiss francs[20]), the estimated reduction in the rate of the ten-year government bond was eight basis points.

The balance sheet effect on the ten-year government bond rate (Table 4) was examined for 32 countries of which 10 were previously identified as those which reached ZLB. The objective was to see if the balance sheet (Δbs_t) would have a statistically and economically significant effect on the long-term interest rate (Δi_t^l) during the GFC only for ZLB countries. Seven economies show statistically significant inverse effect of changes in the balance sheet size on the long-term rate and six of them are ZLB nominees (CHE, DNK, EUR, GBR, SWE and US). NOR is the only non-ZLB-nominee pointing towards such result. The Norwegian central bank also reached very low policy interest rates (below one percentage point at the end of the sample period). However, it cannot be described as ZLB-nominee because its average policy rate after the outbreak of the crisis was 1.78 percentage points (Figure 7). In addition, variations in the size of the balance sheet were rather limited in contrast to others, not reaching more than 150 per cent of the 2007M7 value (Figure 56). Overall, the Norwegian central bank balance sheet increased twice, for the first time in the period following the outbreak of the crisis (2008M10-2009M6) and then at the end of the sample period (since 2014M9). The remaining six countries (CHE, DNK, EUR, GBR, SWE and US) with significant results were previously identified as ZLB-nominees. The balance sheet of each central bank at least doubled. EUR, GBR, SWE and US each implemented certain forms of QE which caused the shifts in the size of the balance sheet and then could have affected the interest rates. The balance sheet expansion of Swiss National Bank happened due to the foreign exchange interventions and DNK is in the

[20] Data on GDP comes from IFS.

European Exchange Rate Mechanism II, therefore, applies the fixed-exchange-rate policy and basically follows the ECB. JPN, which is another country known to use the QE, did not show any significant result. JPN has been the only country using a form of QE before the GFC, therefore, the conjecture is that the policy might have been already exhausted and markets did not further respond to monetary easing.

Although it was not the primary aim to estimate the size of the balance sheet effect due to the simplicity of the analysis, the results correspond with previous studies investigating effects of QE on the ten-year government bond rate in EUR, GBR and US. The studies were summarised by Andrade et al. (2016). Their paper is mentioned earlier in this thesis and the results are shown in Table 1. They also report the effects standardised to a change in balance sheet size equal to ten per cent of GDP[21] so a comparison is possible even though they review studies on specific QE programmes and not the overall crisis period. Importantly, the resulting effects are alike. For GBR (2009M3-2010M01), they report a range of reduction in the rate of the ten-year government bond as 31-107 bps with the average of 64 bps, while my result indicates a decrease by 75 bps (2008M10-2015M12). The stated impact of ECB's balance sheet expansion is between -27 and -64 bps with -44 bps as the average (2015M03-2016M09) which also tallies with my result (-45 bps for 2008M10-2015M12). I estimate a higher reduction in the ten-year interest rate for the Fed (-125 bps for 2008M10-2015M12) than the averages for previous studies (-83 bps for 2008M12-2010M3; -65 bps for 2010M11-2011M6 and -72 bps for 2011M9-2012M12) nevertheless it is still with the range of estimated effects (from -23 bps to -175 bps).

Table 4 Effects of the size of the central bank balance sheet on a long-term rate

Dependent variable: 10-year government bond rate (basis points)					
Country	ZLB	Δbs_t (bps)	Impact of Δbs_t standardised to a change in BS equal to 10% of annual GDP in 2007 (bps)	p-value (Δbs_t)	n R^2
AUS		-0.19 (0.33)	-22	0.56	86 0.07
CAN	Yes	-0.80 (0.93)	-126	0.39	86 0.06
CHE	Yes	-0.14 (0.07)	-8	0.05+	86 0.23
CHL		0.0012 (0.0013)	11	0.37	86 0.17

[21] For GDP, I use the value from 2007. Although they use GDP values from the year when the QE programme started, the results might be compared because the differences in GDP would lead to an impact not reaching more than a few basis points.

CHN		-0.0006 (0.0048)	-2	0.91	86 0.03
COL		0.0031 (0.0011)	134	0.01**	86 0.12
CZE	Yes	-0.045 (0.099)	-17	0.65	86 0.01
DNK	Yes	-0.19 (0.05)	-33	0.00***	86 0.22
EUR	Yes	-0.048 (0.028)	-45	0.09+	86 0.06
GBR	Yes	-0.49 (0.29)	-75	0.10+	71 0.19
HUN		0.017 (0.010)	44	0.10+	86 0.20
IDN		0.23 (0.22)	99	0.31	86 0.06
IND		0.010 0.007	50	0.12	86 0.15
ISL		-0.061 (0.039)	-8	0.12	86 0.15
ISR		-0.29 (0.27)	-21	0.29	86 0.12
JPN	Yes	0.00 (0.17)	0	0.99	86 0.05
KEN		0.22 (0.43)	47	0.61	86 0.08
KOR		-0.20 (0.17)	-21	0.25	86 0.15
MEX		0.14 (0.04)	157	0.01**	86 0.13
MYS		0.00 (0.13)	0	0.99	86 0.02
NGA		0.005 (0.012)	16	0.69	86 0.22
NOR		-0.15 (0.07)	-35	0.03*	86 0.11
NZL		-1.4 (1.0)	-26	0.16	86 0.08
PHL		-0.065 (0.074)	-45	0.38	86 0.07
POL		0.17 (0.21)	20	0.41	86 0.10
ROU		-0.9 (1.2)	-39	0.46	83 0.08
RUS		0.016 (0.005)	57	0.00*	86 0.21
SGP	Yes	-0.10 0.79	-3	0.90	84 0.01
SWE	Yes	-0.18 (0.08)	-36	0.03*	86 0.11
THA		-0.016 (0.027)	-15	0.54	86 0.04
USA	Yes	-0.086 0.049	-125	0.09+	86 0.11
ZAF		0.39 (0.17)	129	0.03*	86 0.08

*Note: Δbs_t determines the change in the long-term rate caused by a rise of the central bank balance sheet by one billion (one trillion for IDN, JPN, KOR) of a domestic currency, while the forth column shows the change in the long-term rate caused by a rise of the central bank balance sheet size by a value equal to 10% of annual GDP (the value of GDP in 2007 is used). Resulting effects are determined in basis points. Standard errors are in parentheses. Significance codes: '***' for p<0.001; '**' for p<0.01; '*' for p<0.05' and '+' for p<0.1. The results with statistical significance 10% and the correct expected sign (-) are highlighted in blue. Different period for: GBR (2008M10-2014M9).*

Source: Own calculation, data from BIS, Datastream, FRED, IFS, national data.

2.6. Implications

A few main points should be highlighted to draw possible implications of the findings. Firstly, only 14 out of 76 economies were identified as ZLB-nominees and three of them represented the low-income countries. Not all of them expanded their central bank balance sheets extensively; thus, the cut in the rates might have been enough to boost the economy. Similar situation seems to have happened to some other countries which experienced policy rates close to zero, however, were not classified as ZLB-nominees because the easing did not last long. On the other hand, there were countries that extensively increased the size of their central bank balance sheets but were not among the ZLB-nominees. In those economies, the significant inverse effect of the balance sheet expansion on the long-term interest rate did not materialise. Nevertheless, all countries that belonged to the ZLB group and expanded substantially their balance sheet, except Japan, produce the significant negative effect of changes in the size of balance sheet on the long-term rate for the crisis period. This seems to imply that balance sheet policies might have an impact on interest rates only once the ZLB is reached. In the opposite case, the expanding balance sheet does not seem to influence the long-term rate.

Moreover, the results also demonstrate that the ZLB and QE were phenomena predominantly for high-income countries. The vast majority of the low-income economies left the policy rate well above zero. Indeed, none of the low-income economies seems to provide the evidence for the inverse significant effect of the balance sheet expansion on the long-term interest rate. This contrasts sharply with the experience of seven high-income economies. A number of central banks in low-income economies increased the size of their balance sheets; however, changes in the size of the balance sheet do not seem to have influenced the long-term interest rates and therefore flattened the yield curve.

Conclusion

The common view on monetary policy during the GFC is that once central banks' policy rates reached the ZLB, the central banks proceeded to use the balance sheet as a monetary policy tool. Central banks were supposed to decrease medium- and long-term interest rates by purchasing assets with longer maturity and therefore to flatten the yield curve. Such unconventional policy would then expand the size of the central bank balance sheet. However, I argue that this happened only in a few high-income countries as others stayed above the ZLB and did not need to use the unconventional policies. Furthermore, I propose that the expansion of central bank balance sheet lowered the long-term interest rates only in countries which had reached the ZLB. Overall, the thesis provides a systematic evaluation of balance sheet effects for diverse economies around the world.

To investigate the hypotheses, the paper firstly discusses the need of unconventional policies and the role of the central bank balance sheet as a passive and active tool in influencing the aggregate demand economy. These sections present causes of particular policies and their potential impact. It also described the linkage between changes in the size of the balance sheet and changes in and long-term interest rates. The literature review then focused on the empirical findings on the role of the balance sheet and presented evidence on the existence and the size of the balance sheet effect on interest rates. The U.S. was chosen as a benchmark for the balance sheet changes so the analysis of the Fed's path in fighting the crisis ended the theoretical background. On these foundations, the paper investigated how much each country cut its policy rate and whether it could possibly suffer from the ZLB. Then, changes in the size of the balance sheet were examined as well as its influence on the ten-year government bond rate.

After studying policy interest rates in 76 economies and identifying a small group of ZLB-nominees, the study indicates that the ZLB was more an exception rather than a rule. It also infers that the vast majority of low-income countries left interest rates well above zero. On the other hand, large changes in the size of the balance sheet were not as rare as the ZLB problem. Neither did balance sheet changes occur only in high-income countries. Therefore, the paper could not establish a linkage between changes in the balance sheet and the ZLB. Nevertheless, the relationship between ZLB and balance sheet variations was clearer when the changes which occurred due to economic growth were eliminated by means of the BS/GDP

ratio. The possible linkage was also apparent in the comparison of the average BS/GDP-ratio growth and the average policy rate. Moreover, five central banks with the highest BS/GDP growth were ZLB nominees. Nevertheless, not many central banks followed the size or course of the changes in the US, albeit certain tendencies did occur, for instance in CHE and GBR. Noteworthy, the regional pattern seems to be a strong part of balance sheet changes, as central banks might have reacted to local conditions in similar fashion. Other reasons for changes in the balance sheet were discussed in the theoretical part: the passive use of the balance sheet, the lender-of-last-resort role and foreign market interventions. Passive policies and the role of lender of last resort should have happened around the peak of the crisis and would have to be identified by examining the composition of the balance sheet. Foreign exchange innervations remain the only other active policy apart from QE which should create such substantial changes in the balance sheet. However, there is no reason to believe that the devaluation of domestic currency would have no effect on interest rates as it created an excess of domestic liquidity.

Nonetheless, when effects of changes in the size of the balance sheet on long-term interest rates were investigated, a link between the effects and ZLB seems to be present. It appears that only ZLB-nominees with considerable changes in the balance sheet would experience a significant inverse effect of the balance sheet expansion on long-term interest rates. For these countries, the effect occurs regardless of whether the source of changes in the balance sheet was QE or foreign exchange interventions. The condition for the existence of the effect seems to be the ZLB. Despite the simplicity of the time series model, it looks that the size of the effect is in agreement with the previous studies on the topic, which, however, were limited only to the four major central banks. My study finds the significant inverse effect of the change in the size of the balance sheet on long-term rates for six ZLB-nominees (CHE, DNK, EUR, GBR, SWE and US) and NOR, which neither reached the ZLB nor expanded its balance sheet extensively.

Overall, I propose the linkage that extensive changes in the size of the balance sheet have an opposite effect on long-term interest rates only once ZLB is reached. Further research should investigate the composition of the balance sheet for those economies where central bank's assets and liabilities expanded massively, even with respect to GDP, but did not reach the ZLB. More work is needed to understand the linkage between the ZLB, central bank balance sheet management and its effects on long-term interest rates.

References

Adler, G. & Tovar Mora, E. C. (2011). Foreign exchange intervention: a shield against appreciation winds? *IMF Working Paper*, WP/11/165.

Andrade, P., Breckenfelder, J. H., De Fiore, F., Karadi, P. & Tristani, O. (2016). The ECB's asset purchase programme: an early assessment. *ECB Working Paper Series*, No 1956.

Arab Monetary Fund & BIS (2015). Central Bank Papers on Monetary Policy Frameworks in the Arab Countries. *AMF-BIS Working Party Meeting on Monetary Policy in the Arab Region.*

Bauer, M. D. & Rudebusch, G. D. (2013). The signaling channel for Federal Reserve bond purchases. *Federal Reserve Bank of San Francisco Working Paper Series*, Working Paper 2011-21

Bech, M. & Malkhozov, A. (2016). How have central banks implemented negative policy rates? *BIS Quarterly Review*, March 2016.

Bernanke, B. S. & Reinhart, V. R. (2004), Conducting Monetary Policy at Very Low Short-Term Interest Rates. *The American Economic Review*. *94*(2), 85-90.

Bordo, M. D. (1990). The lender of last resort: alternative views and historical experience. *FRB Richmond Economic Review, 76*(1), 18-29.

Borio, C. & Disyatat, P. (2009). Unconventional monetary policies - An appraisal. *BIS Working Paper Series*, No 292.

Bowdler, Ch. & Radia, A. (2012). Unconventional monetary policy: the assessment. *Oxford Review of Economic Policy, 28*(4), 603–621.

Brunnermeier, M. K. (2009). Deciphering the 2007-08 Liquidity and Credit Crunch. *Journal of Economic Perspectives*. *23*(1), 77-100.

Buiter, W. H. (2009). Negative nominal interest rates: Three ways to overcome the zero lower bound. *The North American Journal of Economics and Finance, 20*(3), 213-238.

Bulgarian Nartional Bank (2018). *About BNB: Mission* [online]. Retrieved August 19, 2018, from: http://www.bnb.bg/AboutUs/AUMission/index.htm

Butos, W. N. (2015). The Bernanke Fed and Credit Easing Policies, 2008-2014. *Journal of Private Enterprise*, *30*(4), 1-15.

Cecioni, M., Ferrero, G. & Secchi, A. (2011). Unconventional monetary policy in theory and in practice. *Bank of Italy Occasional Papers*, 102.

Chen, Q., Filardo, A., He, D. & Zhu, F. (2016). Financial crisis, US unconventional monetary policy and international spillovers. *Journal of International Money and Finance*, 67, 62-81.

Cúrdia, V. & Woodford, M. (2011), The central-bank balance sheet as an instrument of monetary policy. *Journal of Monetary Economics 58*(1), 54-79.

D'Amico, S. & King, T. B. (2010). Flow and Stock Effects of Large-Scale Treasury Purchases. *Finance and Economics Discussion Series* 2010-52.

European Central Bank. (2009), The external financing of households and non-financial corporations: a comparison of the euro area and the United States, *ECB Economic Bulletin*. (4), 69-84.

European Central Bank. (2015), The role of the central bank balance sheet in monetary policy. *ECB Economic Bulletin*. (4), 61-77.

Federal Reserve Bank of St. Louis (2018). *Financial Crisis: Full Timeline* [online]. Retrieved May 18, 2018, from: https://www.stlouisfed.org/financial-crisis/full-timeline

Federal Reserve (2013). *Maturity Extension Program and Reinvestment Policy* [online]. Retrieved May 18, 2018, from: https://www.federalreserve.gov/monetarypolicy/maturityextensionprogram.htm

Gagnon, J., Raskin, M., Remache, J. & Sack, B. (2011). The Financial Market Effects of the Federal Reserve's Large-Scale Asset Purchases. *International Journal of Central Banking*, *7*(1), 3-43.

Gertler, M. & Karadi, P. (2015). Monetary policy surprises, credit costs, and economic activity. *American Economic Journal: Macroeconomics*, *7*(1), 44-76.

Gilchrist, S., López-Salido, D. & Zakrajšek, E. (2015). Monetary policy and real borrowing costs at the zero lower bound. *American Economic Journal: Macroeconomics*, *7*(1), 77-109.

Goodhart, C. A. E. (1999). Myths about the lender of last resort. *International Finance*, *2*(3), 339-360.

Guender, A. V. (2018). *Optimal Monetary Policy Under Uncertainty.* Manuscript.

Hancock, D. & Passmore, W. (2011). Did the Federal Reserve's MBS purchase program lower mortgage rates? *Journal of Monetary Economics*, *58*(5), 498-514.

Holub, T. (2004).Foreign Exchange Interventions Under Inflation Targeting: the Czech Experience. *Deutsche Bank Research Notes,* No. 17.

International Monetary Fund. (2017). World economic outlook - Seeking Sustainable Growth: Short-Term Recovery, Long-Term Challenge. *World economic and financial surveys.* October 2017.

Joyce, M., Lasaosa, A., Stevens, I., & Tong, M. (2011). The financial market impact of quantitative easing in the United Kingdom. *International Journal of Central Banking, 7*(3), 113-161.

Joyce, M., Myles, D., Scott A. & Vayanos, D. (2012). Quantitative Easing and Unconventional Monetary Policy: An Introduction. *Economic Journal, 122*(564), F271-F288.

Krishnamurthy, A. & Vissing-Jorgensen, A. (2011) The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy. *Brookings Papers on Economic Activity, 43*(2) 215–287.

Krishnamurthy, A. & Vissing-Jorgensen, A. (2012). The aggregate demand for treasury debt. *Journal of Political Economy, 120*(2), 233-267.

Lenza, M., Pill H. & Reichlin, L. (2010), Monetary policy in exceptional times. *ECB Working Paper Series*. No 1253/ October.

Malo de Molina, J. L. (2013). The European Central Bank's Response to the Crisis. *Banco de España Monthly Bulletin*, (July-August), 37-45.

Mishkin, F. S. (2004). *The Economics of Money, Banking and Financial Markets* (11th ed.). London: Pearson.

Mishkin, F. S. & White, E. N. (2014). Unprecedented actions: the Federal Reserve's response to the global financial crisis in historical perspective. *NBER Working Paper Series*, No. 20737.

Neely, C. J. (2010). The Large-Scale Asset Purchases Had Large International Effects. *Federal Reserve Bank of St. Louis Working Paper* No. 2010-018.

Neely, C. J. (2011). A Foreign Exchange Intervention in an Era of Restraint. *Federal Reserve Bank of St. Louis Review, 93*(5), 303-24.

Oda, N. & Ueda, K. (2007). The Effects of the Bank of Japan's Zero Interest Rate Commitment and Quantitative Monetary Easing on the Yield Curve: A Macro-Finance Approach. *The Japanese Economic Review, 58*(3), 303-328.

Pattipeilohy, C., van den End, J. W., Tabbae, M. & de Haan, J. (2013) Unconventional Monetary Policy of the ECB during the Financial Crisis: An Assessment and New Evidence. *DNB Working Paper*, No 381.

Perera, A. (2010). *Monetary Policy in Turbulent Times: Impact of Unconventional Monetary Policies*. Paper presented at the Central Bank of Sri Lanka International Research Conference, 23 November 2010.

Reserve Bank of Australia (2018). *The Exchange Rate and the Reserve Bank's Role in the Foreign Exchange Market* [online]. Retrieved July 12, 2018, from: https://www.rba.gov.au/mkt-operations/ex-rate-rba-role-fx-mkt.html

Swanson, E. T. & Williams, J. C. (2014). Measuring the effect of the zero lower bound on medium-and longer-term interest rates. *American Economic Review, 104*(10), 3154-3185.

Ugai, H. (2007). Effects of the quantitative easing policy: A survey of empirical analyses. *Monetary and Economic Studies-Bank of Japan, 25*(1), 1.

Williams, J. C. (2011) Unconventional monetary policy: Lessons from the Past Three Years. *FRBSF Economic Letters*, 2011-31.

Williams, J. C. (2013) Will Unconventional Policy Be the New Normal? *FRBSF Economic Letters*, 2013-29.

Woodford, M. (2012). Methods of policy accommodation at the interest-rate lower bound. *Jackson Hole Symposium - The Changing Policy Landscape*, 185-288.

List of tables

List of figures

Appendices

Appendix A – Summary results of the studied countries

Table A1 Overview of available data and low-income/high-income countries

Country	Group		Available data			
	Low-income	High-income	Policy interest rate	Balance sheet	BS/GDP ratio	10-year bond rate
ALB	✓		✓	✓		
ARG	✓		✓	✓	✓	
ARM	✓		✓	✓	✓	
AUS		✓	✓	✓	✓	✓
AZE	✓		✓	✓	✓	
BGD	✓		✓	✓		
BGR	✓		✓			
BHR	✓		✓			
BHS	✓		✓			
BLR	✓		✓	✓	✓	
BLZ	✓		✓	✓	✓	
BRA	✓		✓	✓	✓	
CAN		✓	✓	✓	✓	✓
CHE		✓	✓	✓	✓	✓
CHL		✓	✓	✓	✓	✓
CHN	✓		✓	✓	✓	✓
COD	✓		✓	✓		
COL	✓		✓	✓	✓	✓
CPV	✓		✓	✓		
CRI	✓		✓	✓	✓	
CZE		✓	✓	✓	✓	✓
DNK		✓	✓	✓	✓	✓
DOM	✓		✓	✓		
EUR		✓	✓	✓	✓	✓
FJI	✓		✓	✓		
GBR		✓	✓	✓	✓	✓
GEO	✓		✓	✓	✓	
GHA	✓		✓	✓		
GMB	✓		✓	✓		
GTM	✓		✓	✓	✓	
GUY	✓		✓	✓		
HKG		✓	✓			
HND	✓		✓	✓		
HUN		✓	✓	✓	✓	✓
IDN	✓		✓	✓	✓	✓
IND	✓		✓	✓	✓	✓
IRQ	✓		✓	✓		
ISL		✓	✓	✓	✓	✓
ISR		✓	✓	✓	✓	✓

JAM	✓		✓	✓	✓	
JOR	✓		✓			
JPN		✓	✓	✓	✓	✓
KAZ	✓		✓	✓	✓	
KEN	✓		✓	✓		✓
KGZ	✓		✓	✓	✓	
KOR		✓	✓	✓	✓	✓
MDA	✓		✓	✓	✓	
MEX		✓	✓	✓	✓	✓
MKD	✓		✓	✓	✓	
MNG	✓		✓	✓		
MUS	✓		✓	✓	✓	
MYS	✓		✓	✓	✓	✓
NGA	✓		✓	✓		✓
NOR		✓	✓	✓	✓	✓
NPL	✓		✓	✓		
NZL		✓	✓	✓	✓	✓
PER	✓		✓			
PHL	✓		✓	✓	✓	✓
PNG	✓		✓	✓		
POL		✓	✓	✓	✓	✓
QAT	✓		✓	✓		
ROU	✓		✓	✓	✓	✓
RUS	✓		✓	✓	✓	✓
SAU	✓		✓	✓		
SGP		✓	✓	✓	✓	✓
SRB	✓		✓	✓	✓	
STP	✓		✓	✓		
SUR	✓		✓	✓		
SWE		✓	✓	✓	✓	✓
THA	✓		✓	✓	✓	✓
TUR		✓	✓	✓	✓	
UEMOA	✓		✓	✓		
URY	✓		✓	✓	✓	
US		✓	✓	✓	✓	✓
VNM	✓		✓			
ZAF	✓		✓	✓	✓	✓
Total (76)	**54**	**22**	**76**	**69**	**48**	**32**

Note: Table A1 shows whether the country belonged to the high-income or low-income group. It also depicts if the particular data was available for each country and therefore if it was considered for the respective test.

Data: Policy Interest Rate – BIS, IFS, national data; Balance Sheet – IFS, national data; GDP – FRED, IFS; 10-Year Bond Rate – Datastream, FRED, IFS.

Table A2 Overview of changes in the policy interest rate and the balance sheet

Country	Minimal policy rate below 1%	Average policy rate below 1%	Max size of BS (% of 2007M7 value)	Max BS/GDP ratio (% of 2007M7 value)	Inverse significant effect of BS expansion on 10-year rate
ALB			200%-300%		
ARG			>500%	100%-200%	
ARM			200%-300%	100%-200%	
AUS			100%-200%	100%-200%	
AZE			>500%	200%-300%	
BGD			300%-400%		
BGR	✓	✓			
BHR	✓	✓			
BHS					
BLR			>500%	400%-500%	
BLZ			300%-400%	200%-300%	
BRA			400%-500%	100%-200%	
CAN	✓	✓	200%-300%	100%-200%	
CHE	✓	✓	>500%	>500%	✓
CHL	✓		100%-200%	100%-200%	
CHN			200%-300%	100%-200%	
COD			300%-400%		
COL			300%-400%	100%-200%	
CPV			100%-200%		
CRI			200%-300%	100%-200%	
CZE	✓	✓	200%-300%	100%-200%	
DNK	✓	✓	200%-300%	200%-300%	✓
DOM			200%-300%		
EUR	✓	✓	200%-300%	200%-300%	✓
FJI	✓		200%-300%		
GBR	✓	✓	>500%	400%-500%	✓
GEO			200%-300%	100%-200%	
GHA			>500%		
GMB			200%-300%		
GTM			100%-200%	100%-200%	
GUY			200%-300%		
HKG	✓	✓			
HND			100%-200%		
HUN			200%-300%	200%-300%	
IDN			200%-300%	100%-200%	
IND			300%-400%	100%-200%	
IRQ			100%-200%		
ISL	✓		400%-500%	300%-400%	
ISR			200%-300%	100%-200%	
JAM			200%-300%	100%-200%	
JOR					
JPN	✓	✓	300%-400%	300%-400%	
KAZ			300%-400%	100%-200%	
KEN			300%-400%		
KGZ	✓		300%-400%	100%-200%	
KOR			100%-200%	100%-200%	
MDA			300%-400%	100%-200%	
MEX			200%-300%	100%-200%	
MKD			100%-200%	100%-200%	
MNG			>500%		

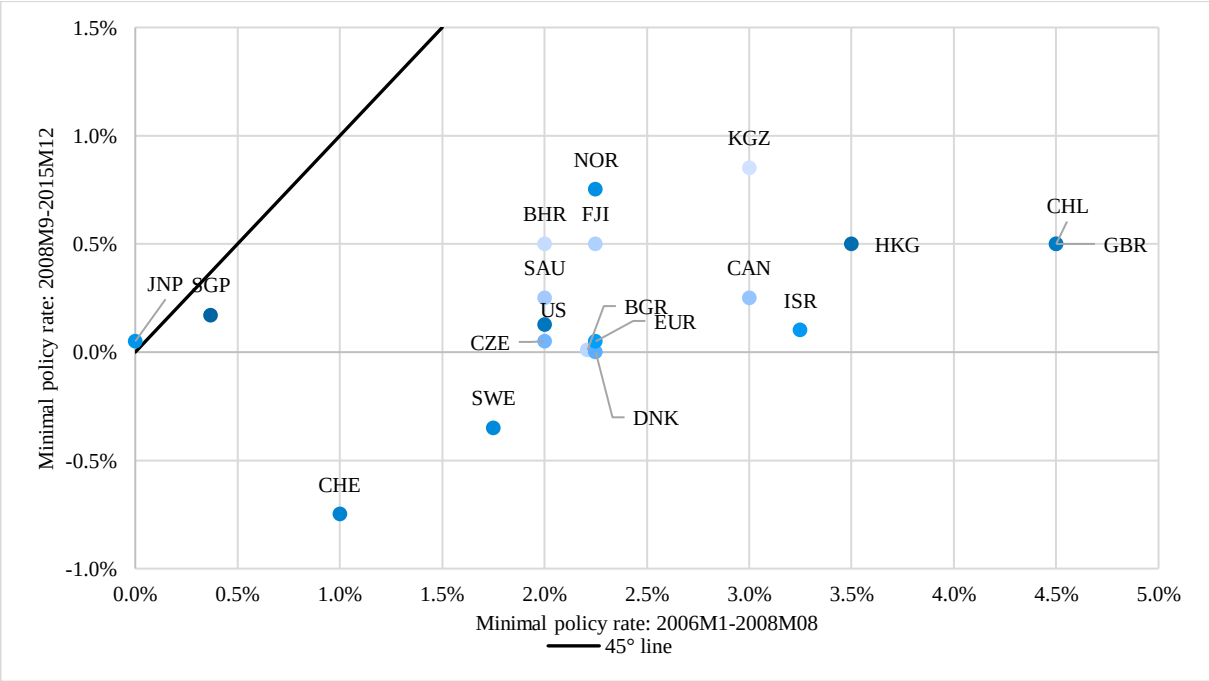
MUS			200%-300%	100%-200%	
MYS			100%-200%	100%-200%	
NGA			200%-300%		
NOR	✓		100%-200%	100%-200%	✓
NPL			>500%		
NZL			100%-200%	100%-200%	
PER					
PHL			200%-300%	100%-200%	
PNG			100%-200%		
POL			200%-300%	100%-200%	
QAT			>500%		
ROU			200%-300%	100%-200%	
RUS			300%-400%	100%-200%	
SAU	✓	✓	200%-300%		
SGP	✓	✓	100%-200%	100%-200%	
SRB			100%-200%	100%-200%	
STP			200%-300%		
SUR			300%-400%		
SWE	✓	✓	300%-400%	300%-400%	✓
THA			100%-200%	100%-200%	
TUR			400%-500%	100%-200%	
UEMOA			200%-300%		
URY			400%-500%	100%-200%	
US	✓	✓	>500%	400%-500%	✓
VNM					
ZAF			300%-400%	100%-200%	
Total (76)	**19/76**	**14/76**	**69**	**48**	**7/32**

Note: Table A2 summarises the results for tests run in the paper. Thus, it shows whether the minimal policy interest rate and the average policy interest rate went below one percentage point. Also, it depicts how much the size of the balance sheet and BS/GDP ratio expanded in contrast to the base value and if there was a significant inverse effect of the change in the size of the balance sheet on the 10-year interest rate. Highlighted countries are ZLB-nominees with the statistically significant inverse effect of the balance sheet expansion on the 10-year interest rate

Source: Own calculation, data from BIS, Datastream, FRED, IFS, national data.

Appendix B – Supplementary figures on minimal and average policy interest rates

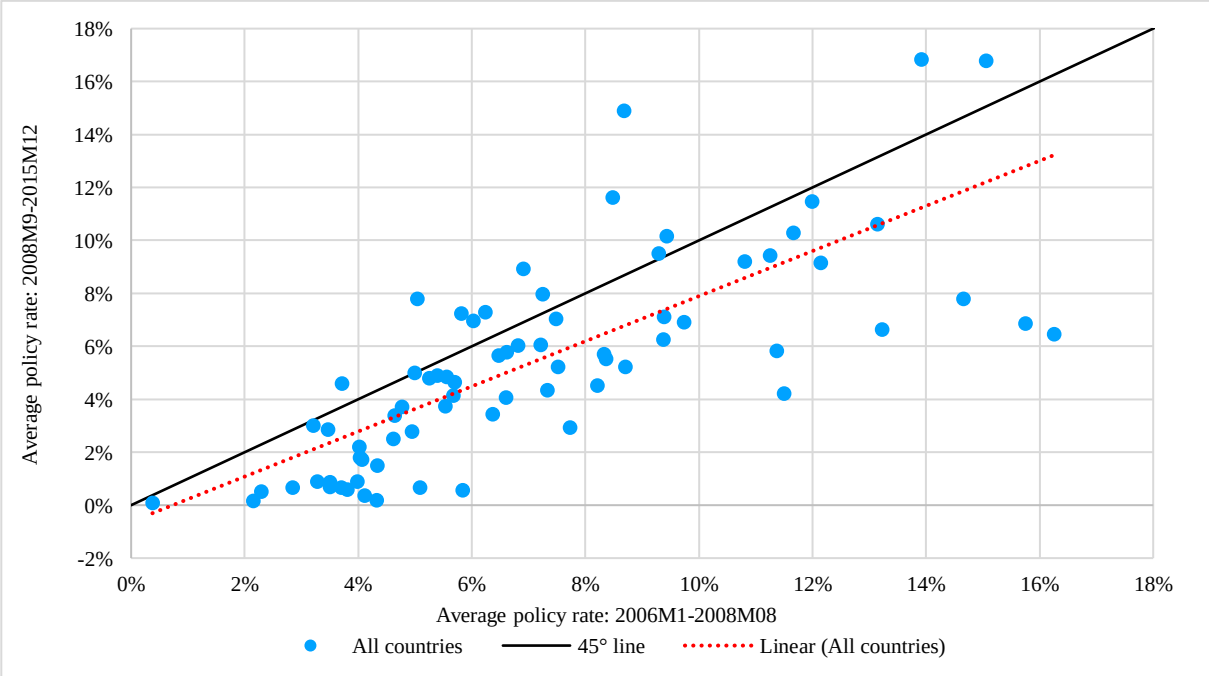
Figure B1 Minimal and average policy interest rates: economies below 1%



Note: Figure B1 depicts countries where the main policy interest rate decreased below one percentage point during the crisis: 2008M9-2015M12.

Source: Own calculation, data from BIS, IFS, national data.

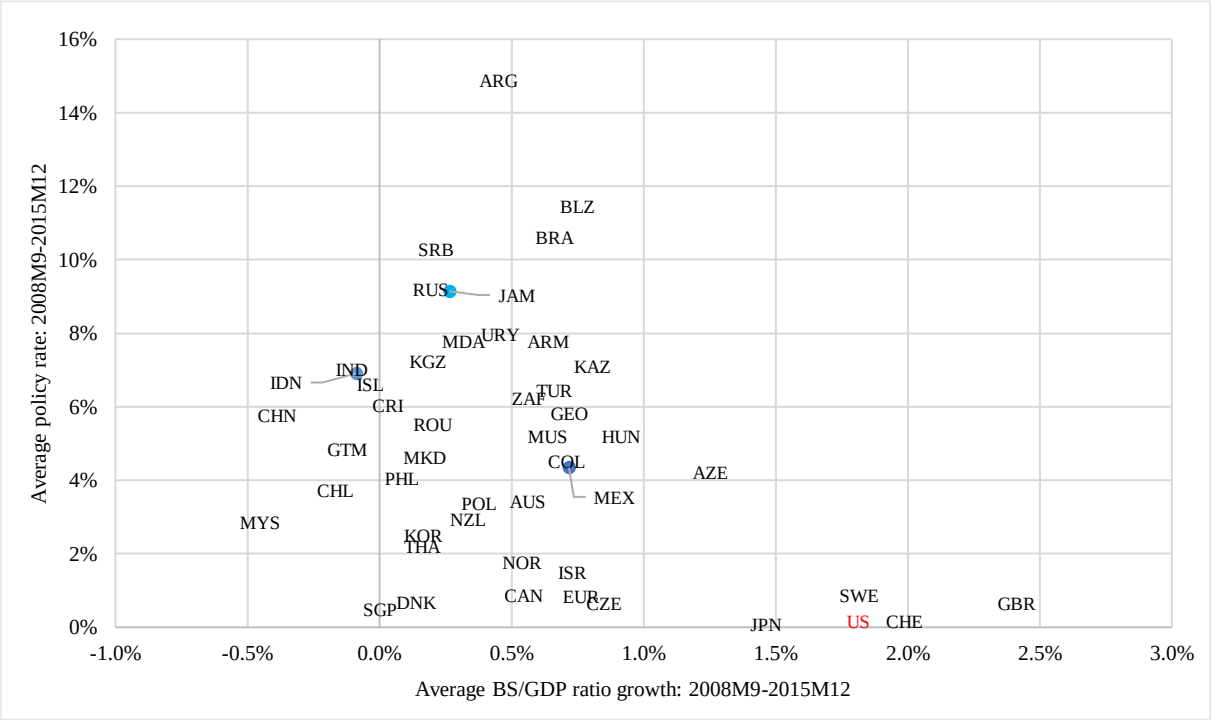
Figure B2 Average policy interest rates



Note: Figure B2 shows the average policy interest rate for the periods before and after the GFC. The trendline is moderately below the 45°line, which could be expected because before the crisis central banks were mostly tightening monetary policy while after the crisis monetary policy was eased.

Source: Own calculation, data from BIS, IFS, national data.

Figure B3 The average policy rate and average BS/GDP growth: 2008M9-2015M12



Note: Figure B3 captures the possible linkage between the average policy rate and the average BS/GDP-ratio growth. Noteworthy, five countries with largest BS/GDP-ratio growth (JPN, SWE, US, CHE, GBR) are ZLB-nominees. Monthly data on annual GDP was extrapolated from quarterly data.

Source: Own calculation, data from BIS, FRED, IFS, national data.

Appendix C – Indices of BS/GDP ratio with respect to the U.S.: 2007M7-2015M12

Figure C1 Index of BS/GDP ratio: ARG to US

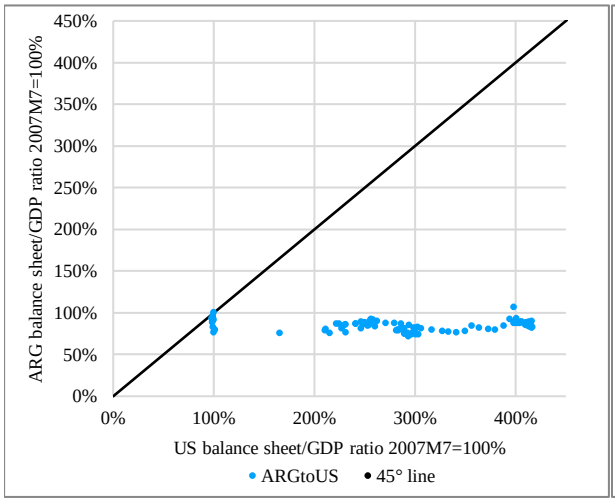


Figure C2 Index of BS/GDP ratio: ARM to US

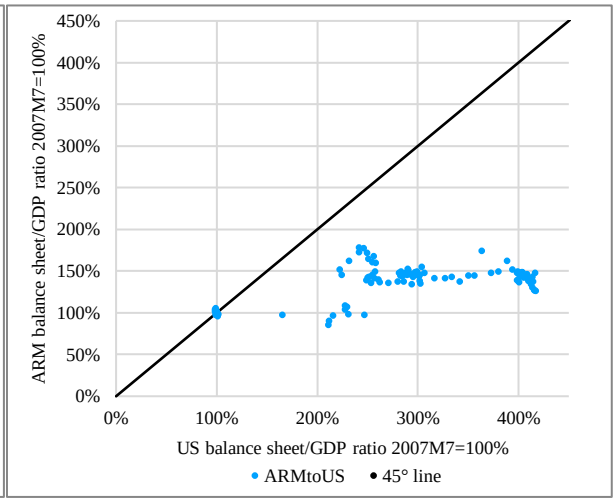


Figure C3 Index of BS/GDP ratio: AUS to US

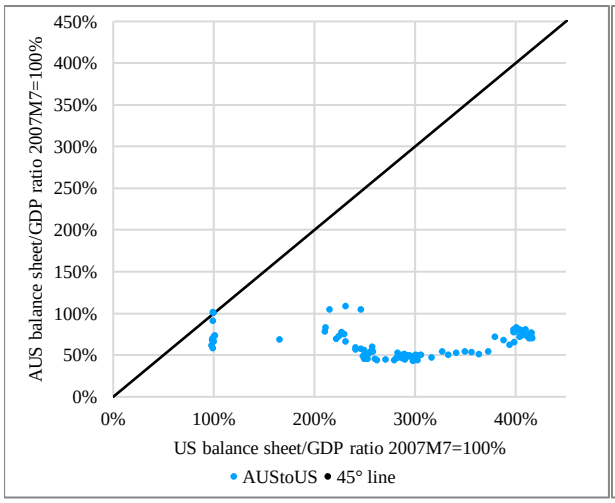


Figure C4 Index of BS/GDP ratio: AZE to US

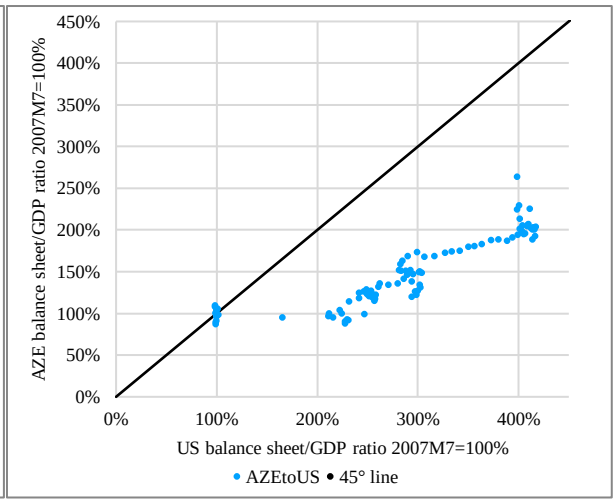


Figure C5 Index of BS/GDP ratio: BLR to US

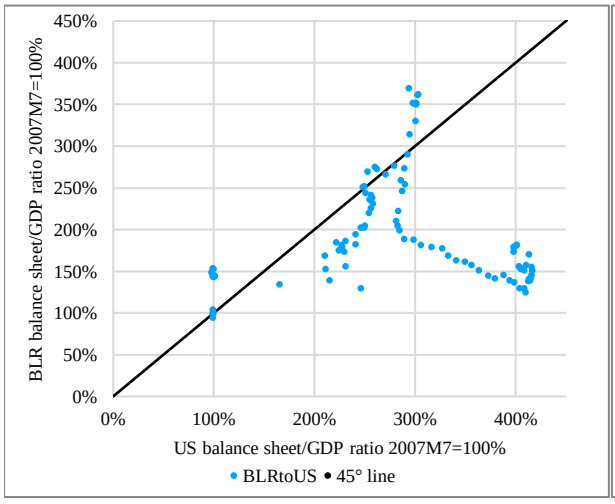


Figure C6 Index of BS/GDP ratio: BLZ to US

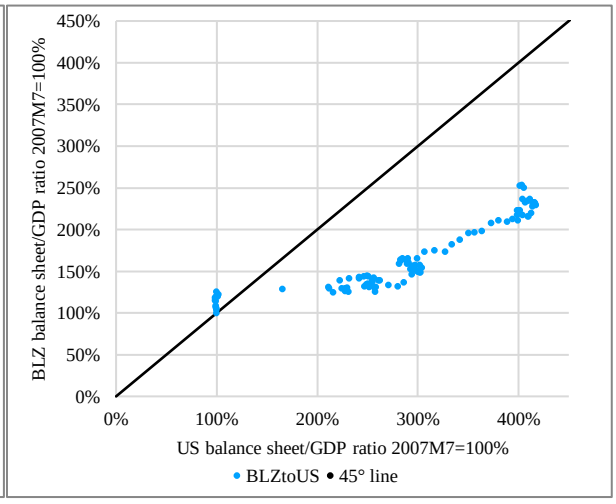


Figure C7 Index of BS/GDP ratio: BRA to US

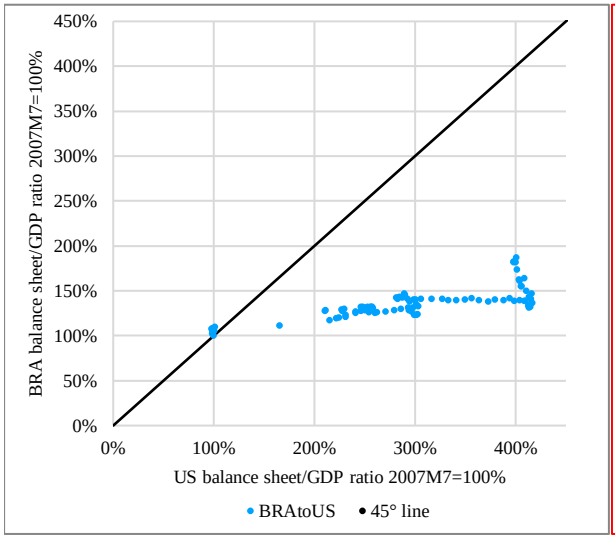


Figure C8 Index of BS/GDP ratio: CAN to US

Figure C9 Index of BS/GDP ratio: CHE to US

Figure C10 Index of BS/GDP ratio: CHL to US

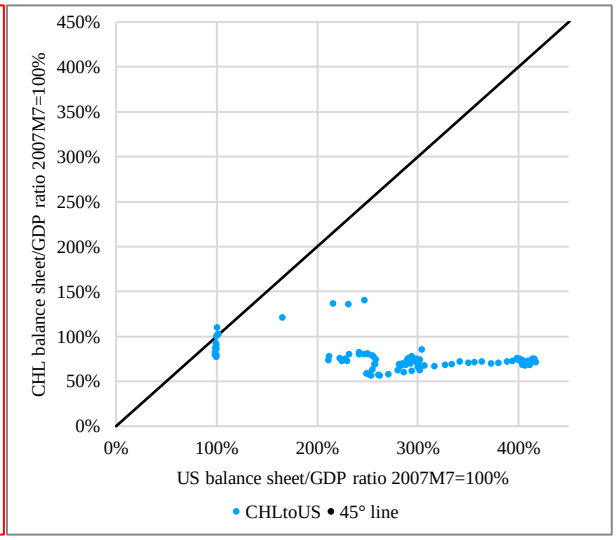


Figure C11 Index of BS/GDP ratio: CHN to US

Figure C12 Index of BS/GDP ratio: COL to US

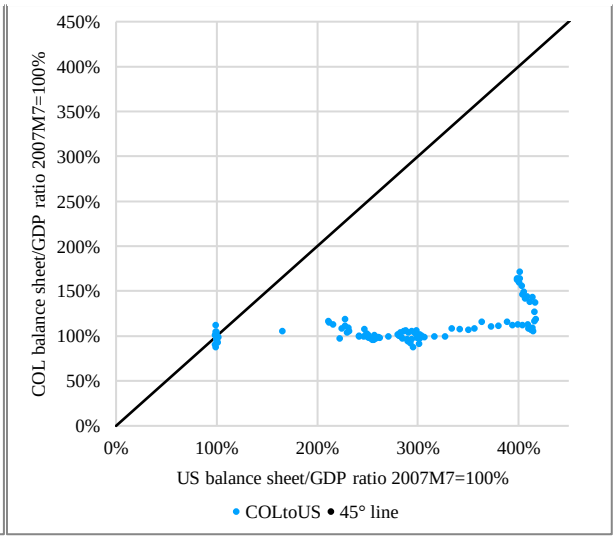


Figure C13 Index of BS/GDP ratio: CRI to US

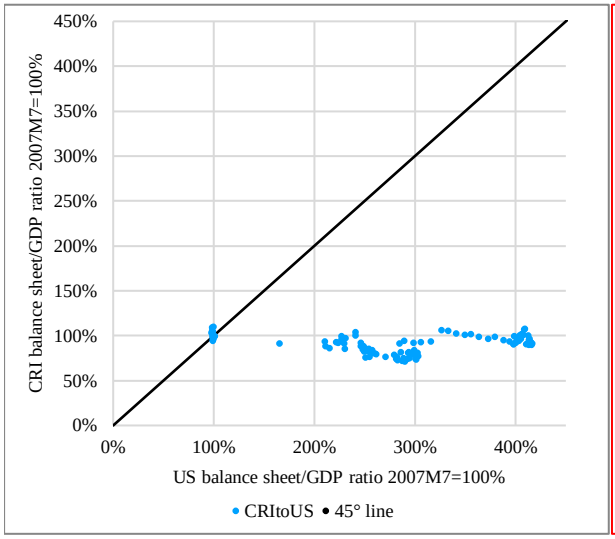


Figure C14 Index of BS/GDP ratio: CZE to US

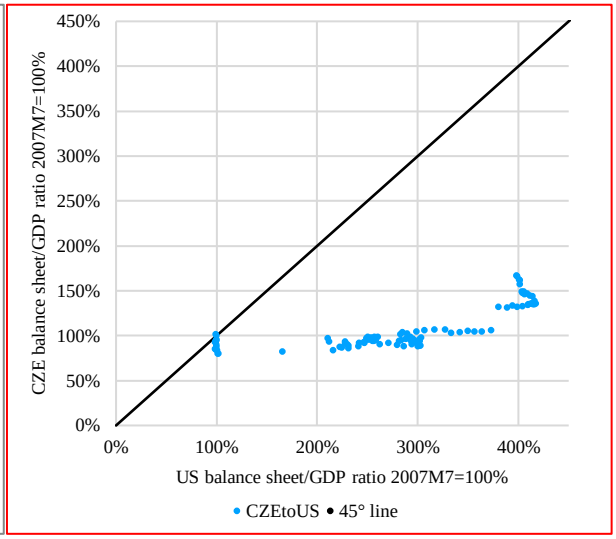


Figure C15 Index of BS/GDP ratio: DNK to US

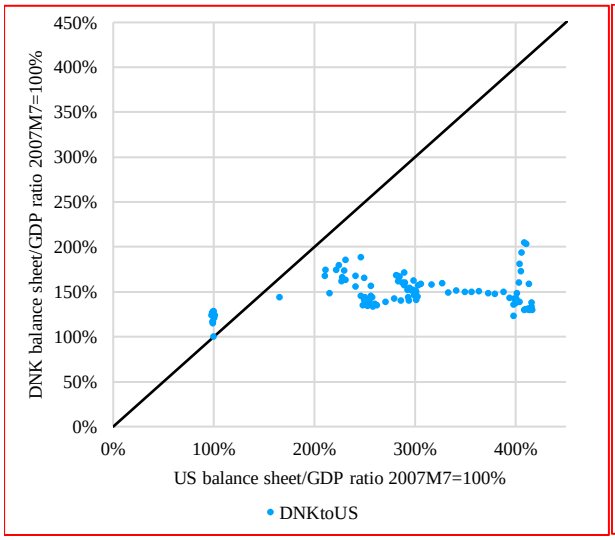


Figure C16 Index of BS/GDP ratio: EUR to US

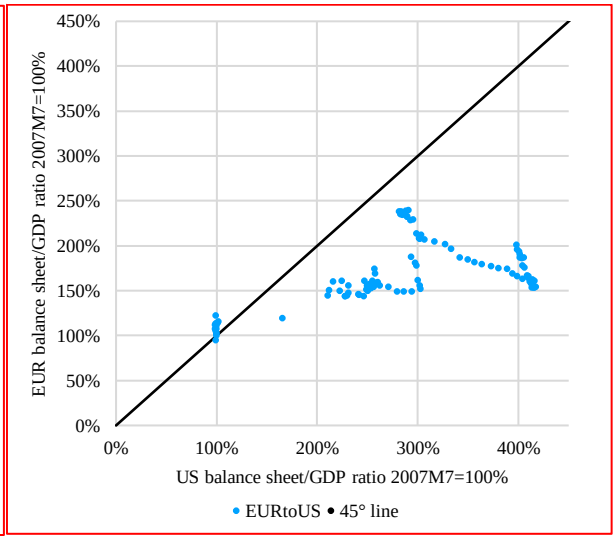
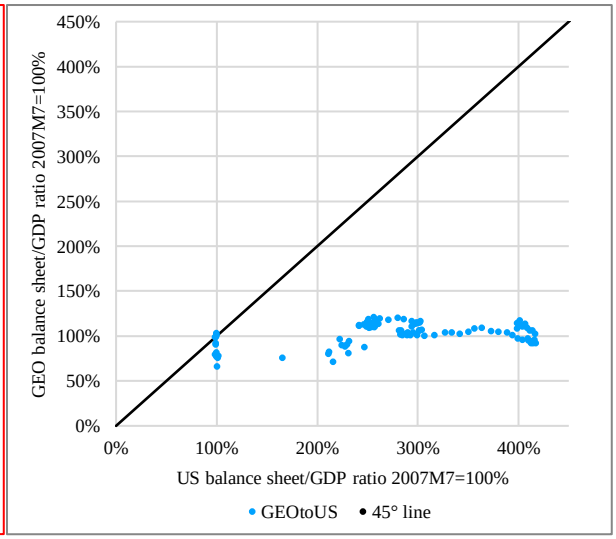


Figure C17 Index of BS/GDP ratio: GBR to US

Figure C18 Index of BS/GDP ratio: GEO to US



Note: Period 2006M5 – 2014M9.

Figure C19 Index of BS/GDP ratio: GTM to US

Figure C20 Index of BS/GDP ratio: HUN to US

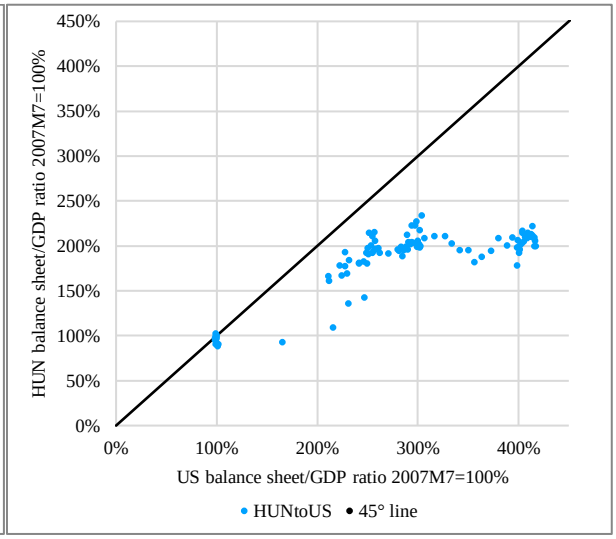


Figure C21 Index of BS/GDP ratio: IDN to US

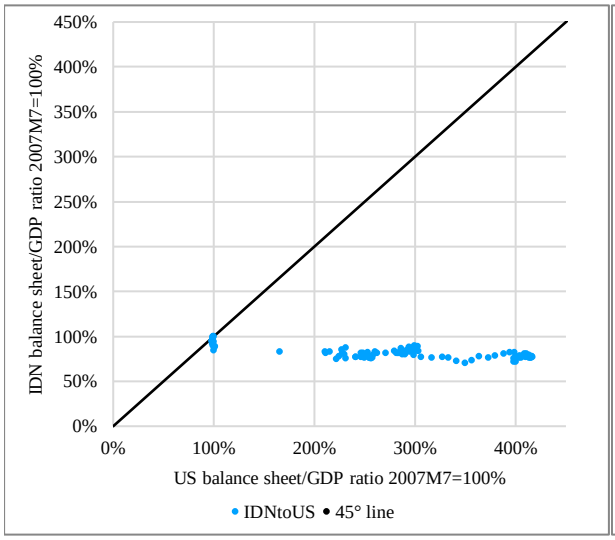


Figure C22 Index of BS/GDP ratio: IND to US

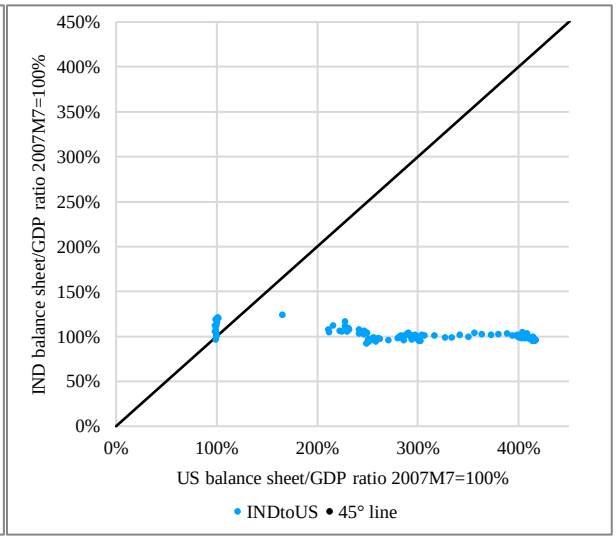


Figure C23 Index of BS/GDP ratio: ISL to US

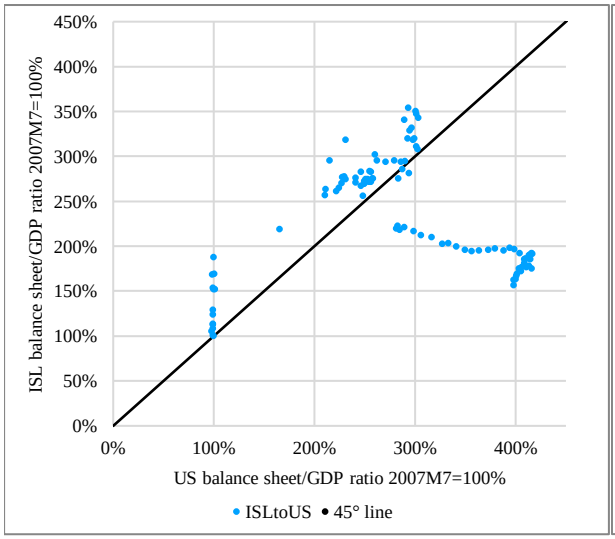


Figure C24 Index of BS/GDP ratio: ISR to US

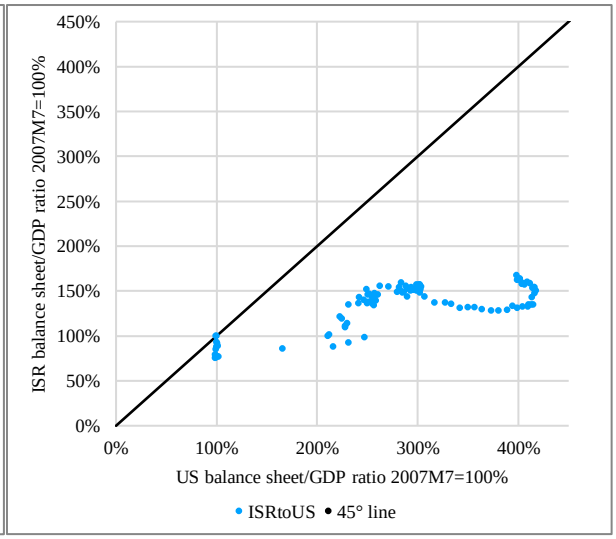


Figure C25 Index of BS/GDP ratio: JAM to US

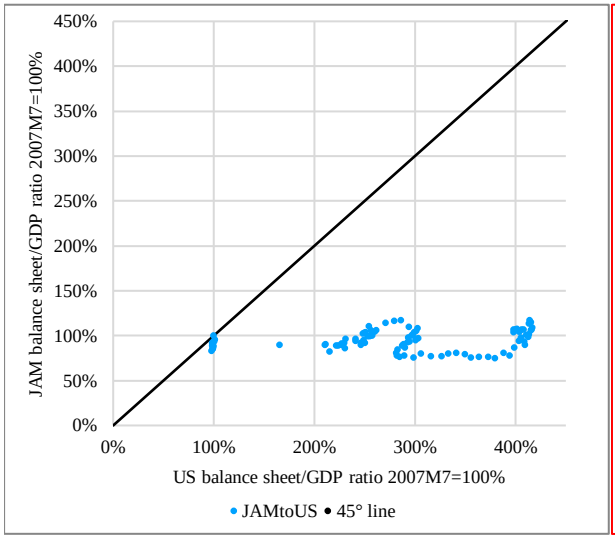


Figure C26 Index of BS/GDP ratio: JPN to US

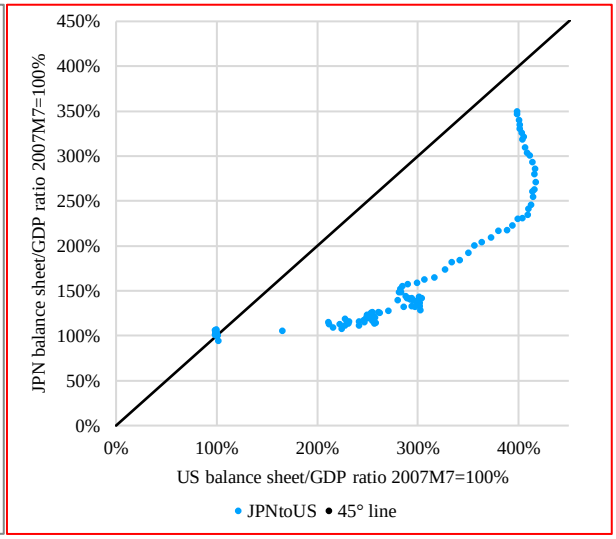


Figure C27 Index of BS/GDP ratio: KAZ to US

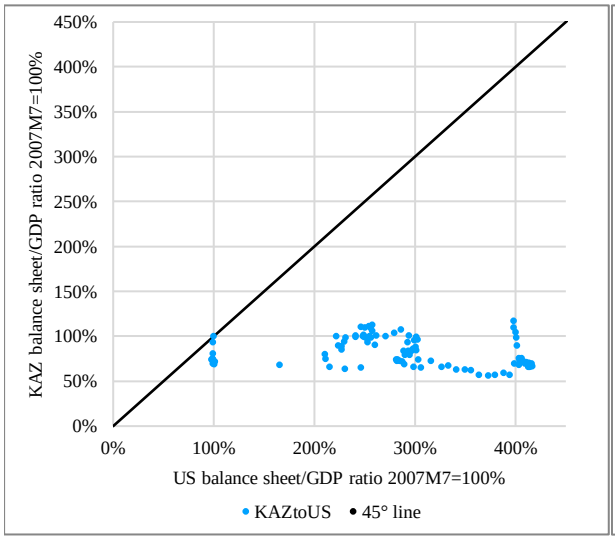


Figure C28 Index of BS/GDP ratio: KGZ to US

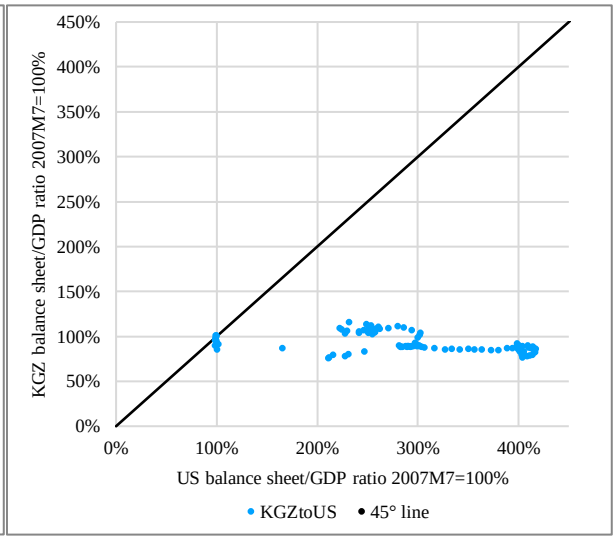


Figure C29 Index of BS/GDP ratio: KOR to US

Figure C30 Index of BS/GDP ratio: MDA to US

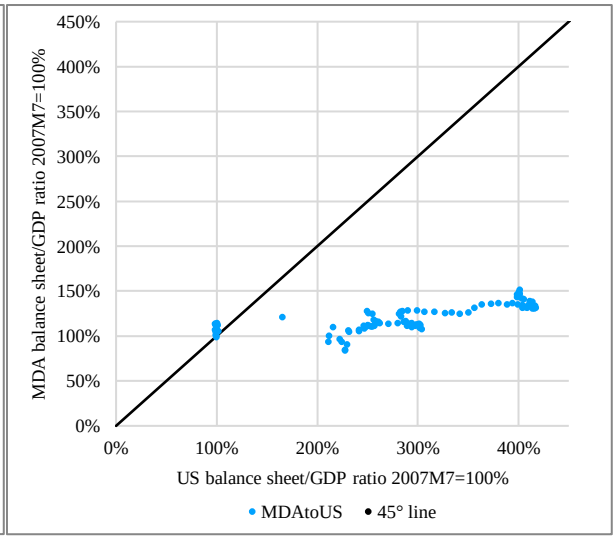


Figure C31 Index of BS/GDP ratio: MEX to US

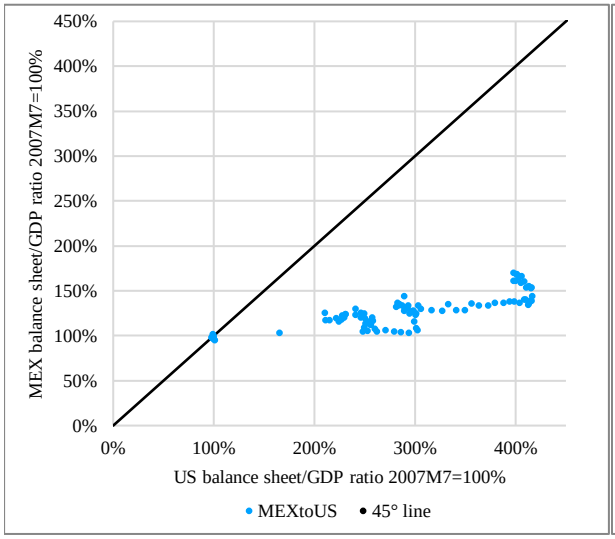


Figure C32 Index of BS/GDP ratio: MKD to US

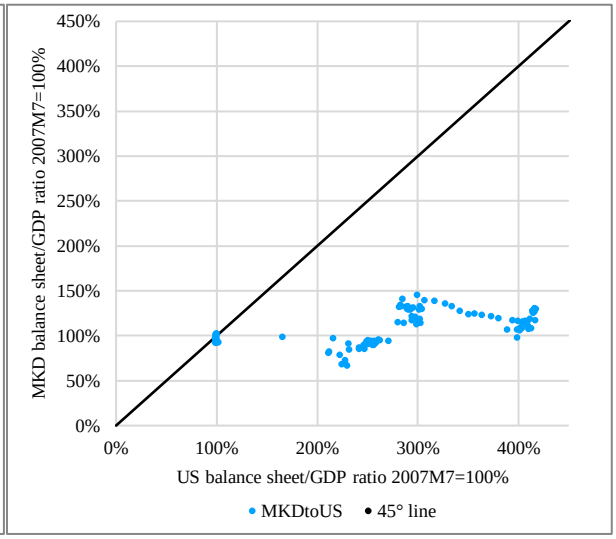


Figure C33 Index of BS/GDP ratio: MUS to US

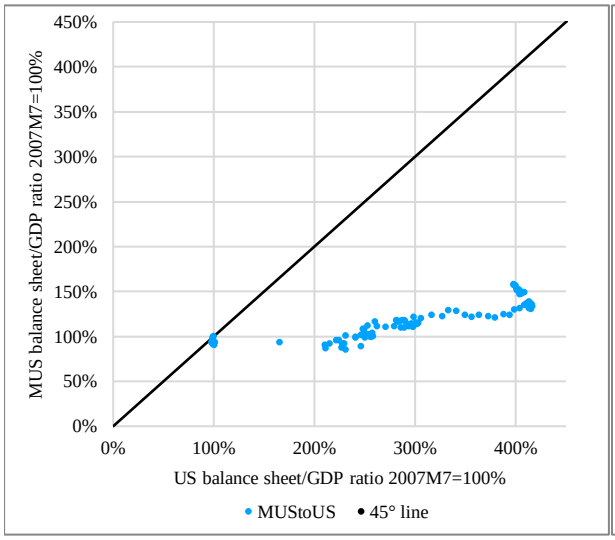


Figure C34 Index of BS/GDP ratio: MYS to US

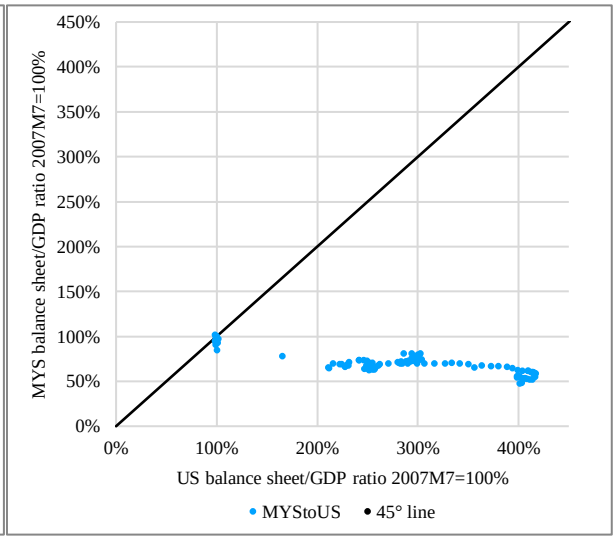


Figure C35 Index of BS/GDP ratio: NOR to US

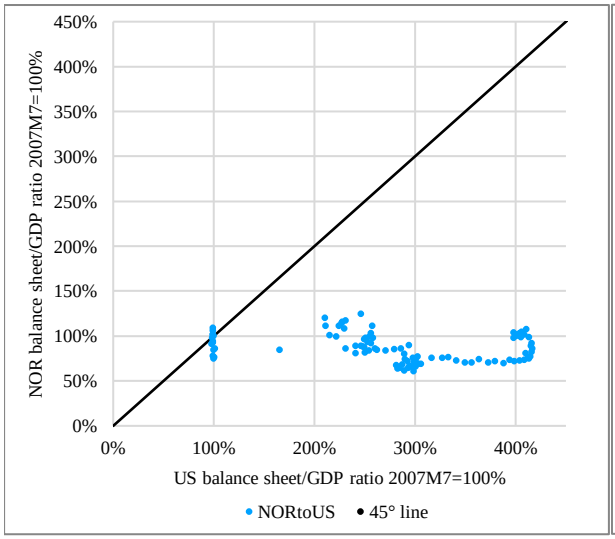


Figure C36 Index of BS/GDP ratio: NZL to US

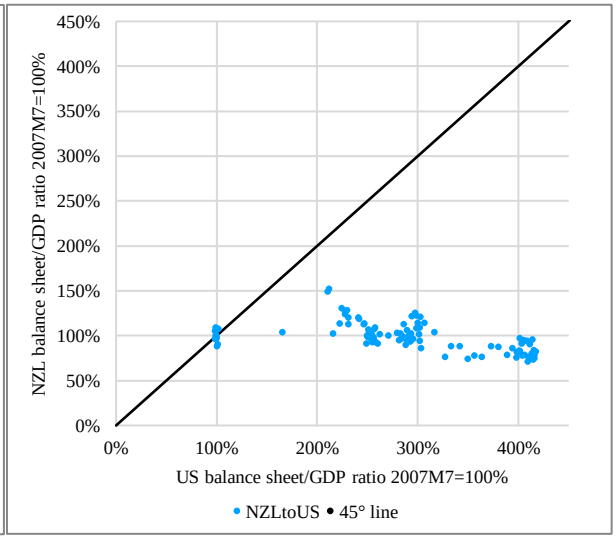


Figure C37 Index of BS/GDP ratio: PHL to US

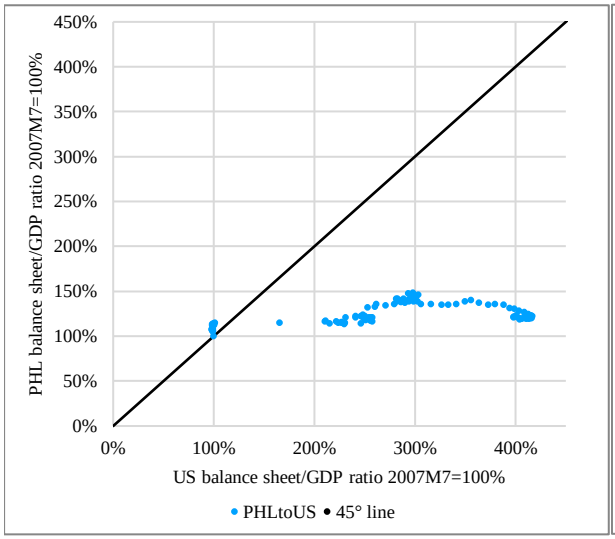


Figure C38 Index of BS/GDP ratio: POL to US

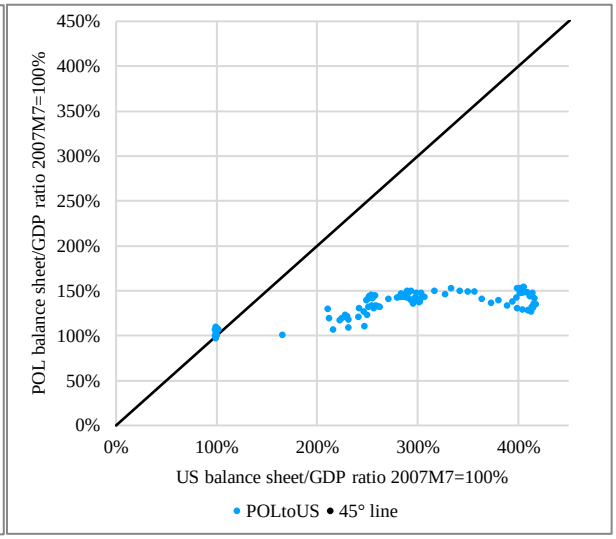


Figure C39 Index of BS/GDP ratio: ROU to US

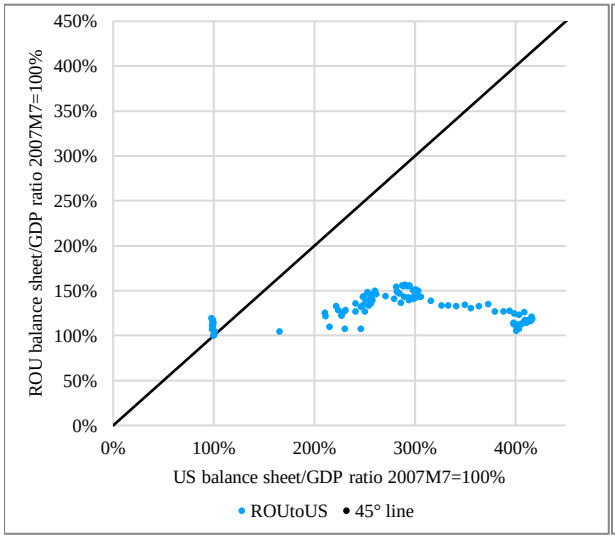


Figure C40 Index of BS/GDP ratio: RUS to US

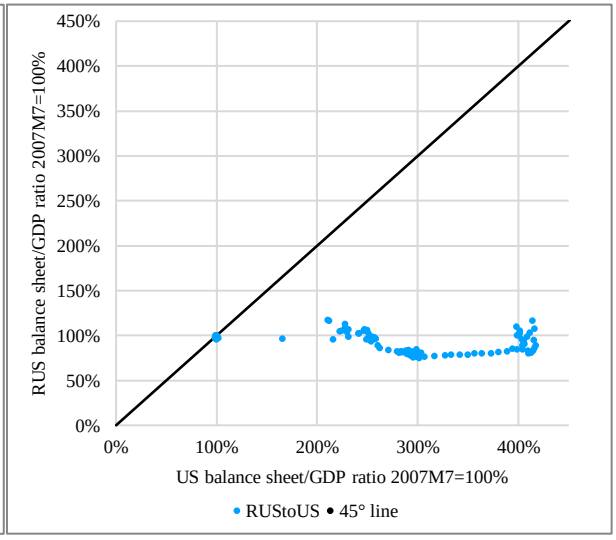


Figure C41 Index of BS/GDP ratio: SGP to US

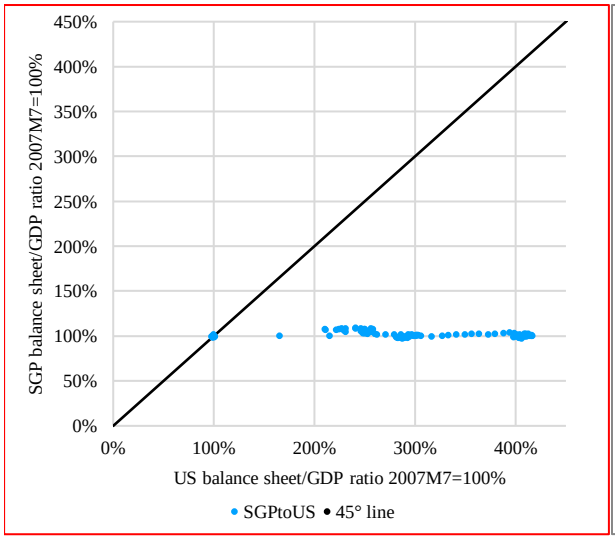


Figure C42 Index of BS/GDP ratio: SRB to US

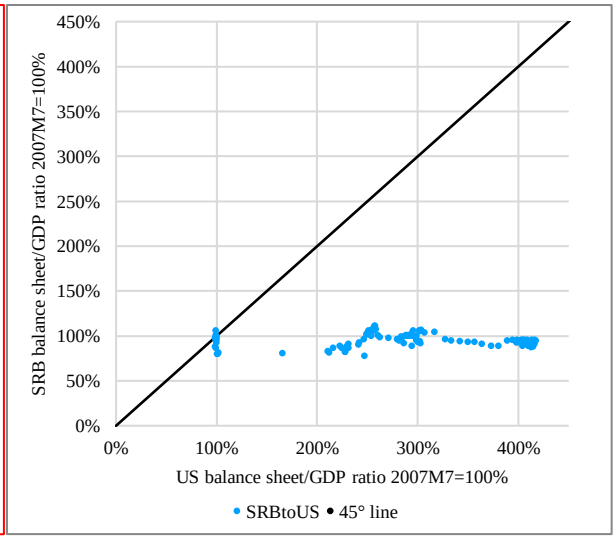


Figure C43 Index of BS/GDP ratio: SWE to US

Figure C44 Index of BS/GDP ratio: THA to US

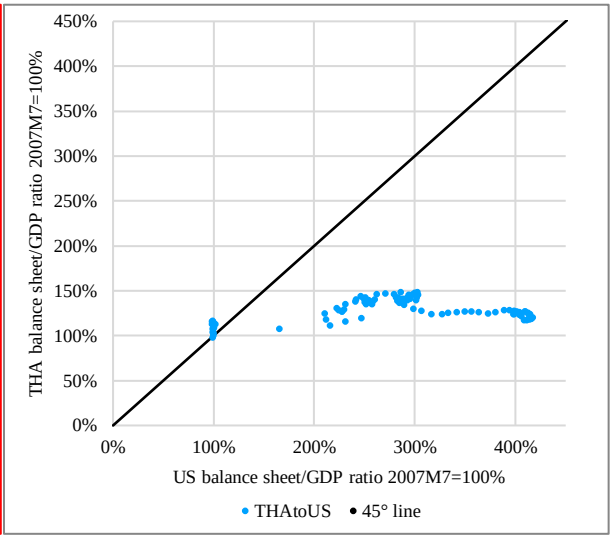


Figure C45 Index of BS/GDP ratio: TUR to US

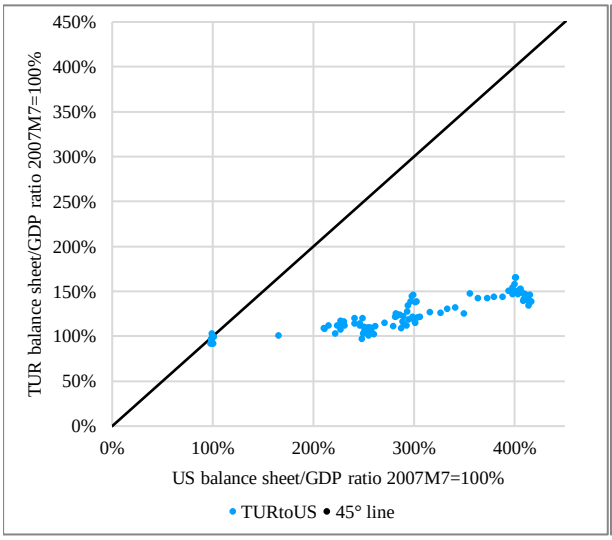


Figure C46 Index of BS/GDP ratio: URY to US

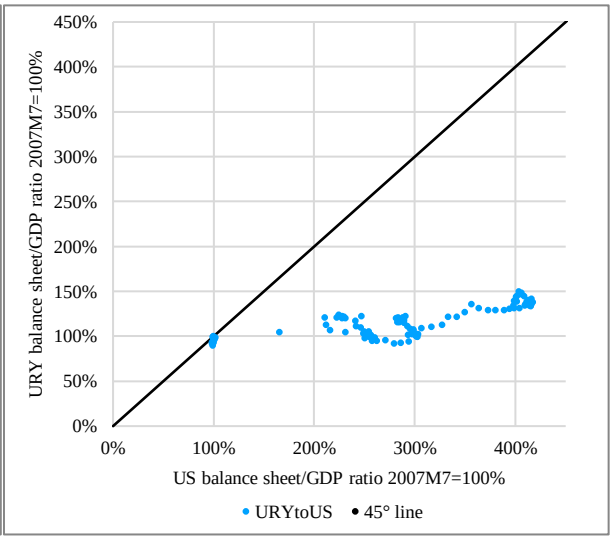
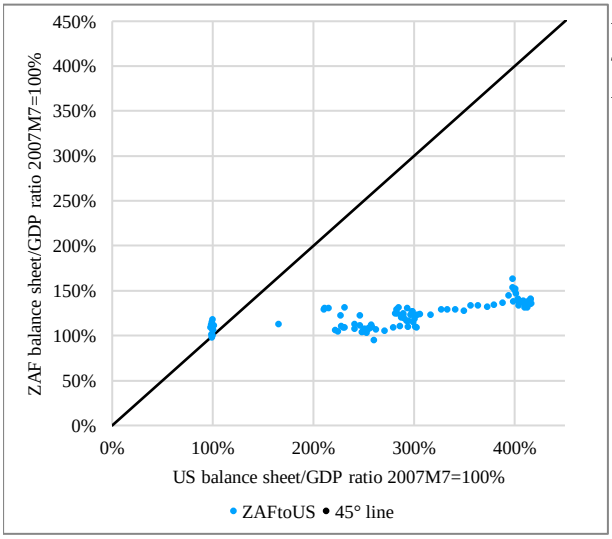


Figure C47 Index of BS/GDP ratio: ZAF to US



Note: ZLB-nominees are distinguished by a red frame.

Sources for figures B1 – B47: Own calculations, data from FRED, IFS, national data.

Table C1 The maximum size of BS/GDP: summary

Countries	Over 200% of BS/GDP ratio in 2007M7	Over 300% of BS/GDP ratio in 2007M7	Over 400% of BS/GDP ratio in 2007M7
OECD (19 countries)	8	6	3
Other Advanced (1)	0	0	0
BRICS (5)	0	0	0
Emerging (19)	3	1	1
Developing (3)	0	0	0
Euro Area (1)	Yes (1)	No	No
Total (48)	**12**	**7**	**4**

Note: Table C1 summarises the changes in the BS/GDP ratio. It shows how many countries reached particular threshold of the BS/GDP ratio. Maximum values are considered.

Source: Own calculation, data from FRED, IFS, national data.

Appendix D – Regional patterns in the size of the balance sheet

Figure D1 Index of BS: selected African economies

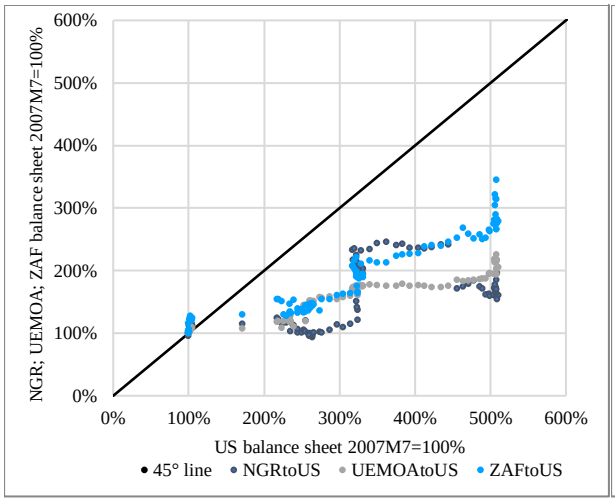


Figure D2 Index of BS: selected Asian economies

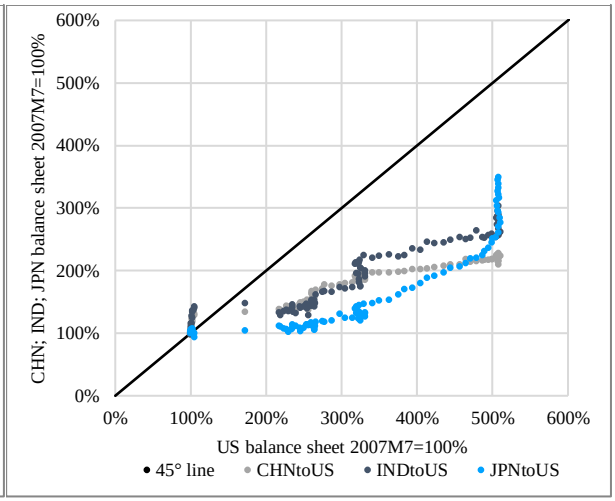


Figure D3 Index of BS: selected European economies

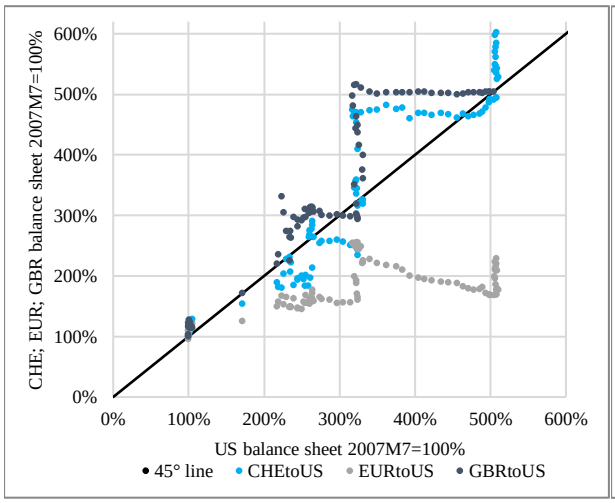
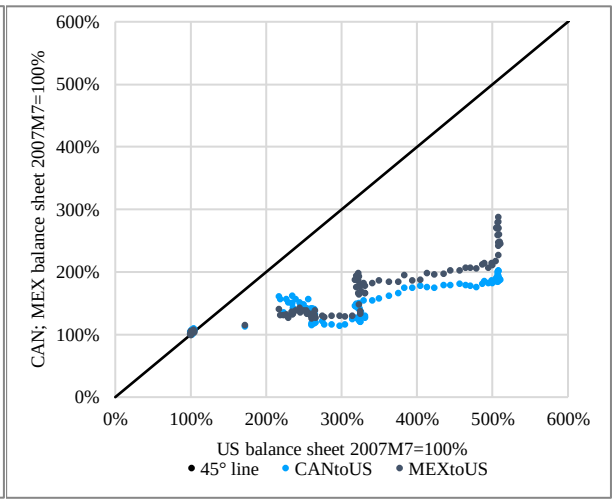


Figure D4 Index of BS: selected North American economies



Note: Period for GBR: 2006M5 – 2014M9.

Figure D5 Index of BS: selected Oceanic economies

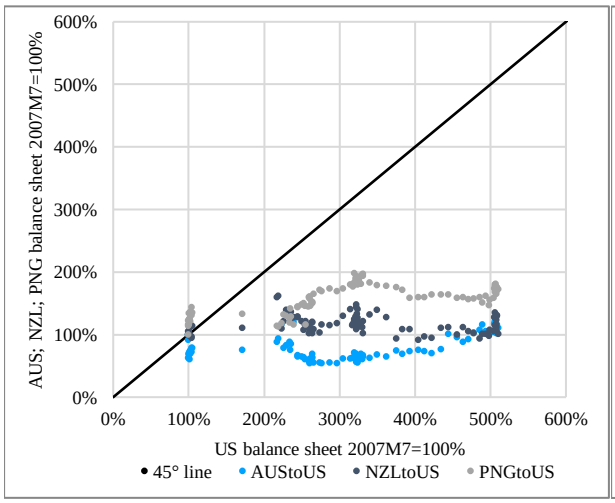
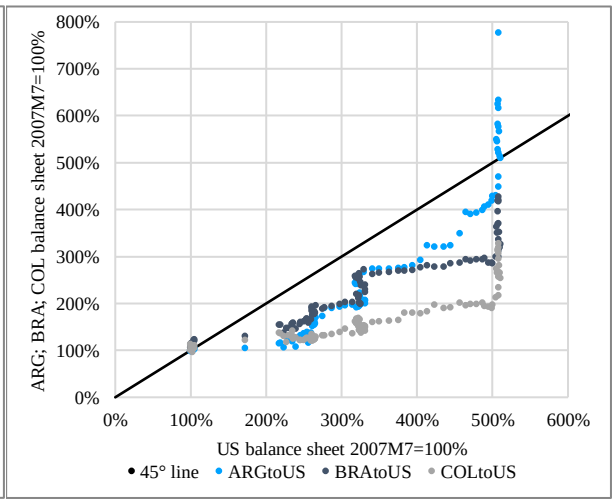


Figure D6 Index of BS: selected South American economies



Sources for figures C1 – C6: Own calculations, data from FRED, IFS, national data.

Appendix E – Full results of the empirical model

Table E1 Results of the empirical model

Dependent variable: 10-year government bond rate (basis points)							
Country	ZLB	constant	Δi^{l}_{t-1}	Δi^{pr}_{t}	Δbs_t	F test (p-value)	n R^2
AUS		-0.01 (0.03)	0.13 (0.11)	0.24+ (0.13)	-0.19 (0.33)	0.13	86 0.07
CAN	Yes	-0.02 (0.02)	-0.04 (0.11)	0.34+ (0.18)	-0.80 (0.93)	0.19	86 0.06
CHE	Yes	-0.01 (0.02)	-0.04 (0.10)	0.35*** (0.08)	-0.14+ (0.07)	0.00	86 0.23
CHL		-0.01 (0.02)	0.35*** (0.10)	0.01 (0.05)	0.0012 (0.0013)	0.00	86 0.17
CHN		0.00 (0.02)	-0.16 (0.11)	0.14 (0.12)	-0.0006 (0.0048)	0.48	86 0.03
COL		-0.08+ (0.05)	0.19+ (0.10)	0.04 (0.13)	0.0031** (0.0011)	0.01	86 0.12
CZE	Yes	-0.04 (0.04)	0.05 (0.11)	0.17 (0.26)	-0.045 (0.099)	0.82	86 0.01
DNK	Yes	-0.02 (0.02)	0.19+ (0.10)	0.18 (0.12)	-0.19*** (0.05)	0.00	86 0.22
EUR	Yes	-0.02 (0.03)	0.10 (0.11)	-0.19 (0.17)	-0.048+ (0.028)	0.18	86 0.06
GBR	Yes	0.01 (0.03)	-0.07 (0.11)	0.55*** (0.14)	-0.49+ (0.29)	0.00	71 0.19
HUN		0.02 (0.05)	0.04 (0.10)	0.88 (0.21)	0.017+ (0.010)	0.00	86 0.20
IDN		-0.11 (0.08)	-0.13 (0.10)	0.98+ (0.50)	0.00023 (0.00022)	0.14	86 0.06
IND		-0.01 (0.04)	-0.34** (0.11)	0.49** (0.17)	0.010 0.007	0.00	86 0.15
ISL		0.00 (0.02)	-0.13 (0.10)	0.11** (0.04)	-0.061 (0.039)	0.00	86 0.15
ISR		-0.02 (0.03)	0.08 (0.11)	0.29* (0.11)	-0.29 (0.27)	0.01	86 0.12
JPN	Yes	-0.01 (0.01)	-0.13 (0.11)	0.66+ (0.37)	0.00000 (0.00017)	0.23	86 0.05
KEN		-0.01 (0.13)	-0.19+ (0.11)	0.34* (0.14)	0.22 (0.43)	0.09	86 0.08
KOR		-0.03 (0.02)	-0.19+ (0.10)	0.43** (0.15)	-0.00020 (0.00017)	0.00	86 0.15
MEX		-0.07+ (0.04)	-0.07 (0.10)	-0.04 (0.20)	0.14** (0.04)	0.01	86 0.13
MYS		-0.01 (0.02)	0.15 (0.12)	-0.02 (0.14)	0.00 (0.13)	0.64	86 0.02
NGA		-0.03 (0.10)	-0.15 (0.10)	0.98*** (0.22)	0.005 (0.012)	0.00	86 0.22
NOR		-0.02 (0.02)	0.24* (0.10)	-0.02 (0.10)	-0.15* (0.07)	0.02	86 0.11
NZL		-0.02 (0.03)	0.21+ (0.11)	0.02 (0.11)	-1.4 (1.0)	0.09	86 0.08

PHL		-0.03 (0.04)	-0.01 (0.10)	0.78* (0.34)	-0.065 (0.074)	0.12	86 0.07
POL		-0.03 (0.02)	0.29** (0.11)	0.11 (0.13)	0.17 (0.21)	0.04	86 0.10
ROU		0.00 (0.07)	0.00 (0.11)	0.90* (0.38)	-0.9 (1.2)	0.10	83 0.08
RUS		-0.01 (0.05)	0.10 (0.10)	0.07 (0.05)	0.016* (0.005)	0.00	86 0.21
SGP	Yes	-0.01 (0.03)	0.08 (0.11)	0.07 (0.11)	-0.10 0.79	0.83	84 0.01
SWE	Yes	-0.01 (0.03)	0.01 (0.11)	0.22 (0.15)	-0.18* (0.08)	0.02	86 0.11
THA		-0.01 (0.03)	0.04 (0.12)	0.22 (0.14)	-0.016 (0.027)	0.32	86 0.04
USA	Yes	0.01 (0.03)	-0.01 (0.12)	0.65+ (0.33)	-0.086+ 0.049	0.02	86 0.11
ZAF		-0.02 (0.03)	0.17 (0.11)	-0.01 (0.10)	0.39* (0.17)	0.07	86 0.08

*Note: Δi_{t-1}^{l} and Δi_{t}^{pr} show the impact of a one-basis-point increase in the respective variable on the long-term rate (in basis points) while Δbs_t determines the change in the long-term rate caused by a rise of the central bank balance sheet by one billion (one trillion for IDN, JPN, KOR) of a domestic currency. Resulting effects are determined in basis points. Standard errors are in parentheses. Significance codes: '***' for p<0.001; '**' for p<0.01; '*' for p<0.05' and '+' for p<0.1. The results with statistical significance 10% and the correct expected sign (-) are highlighted in blue. Different periods for: GBR (2008M10-2014M9)*

Source: Own calculation, data from BIS, Datastream, FRED, IFS, national data.