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Master's Thesis

Do Central Bank FX Reserves Matter for Inflation?

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Declaration of Authorship

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Prague, July 30th, 2019

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Signature

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Abstract

Foreign exchange reserves are a useful tool and a buffer but maintaining an amount that is too large can be costly to the economy. Recent accumulation of these reserves points to the importance of this topic. This thesis focuses on one specific part of the effect of FX reserves on the economy – the inflation. I use panel data for 74 countries from the year 1996 to the year 2017. There is a certain degree of model uncertainty for which this thesis accounts for by using Bayesian model averaging (BMA) estimation technique. The findings from my model averaging estimations show FX reserves to not be of importance for inflation determination with close to no change when altering lags, variables, when limiting the sample to fixed FX regimes nor when limiting the sample to inflation targeting regimes. The most important variables are estimated to be a central bank financial strength proxy, exchange rate depreciation, money supply, inflation targeting, and capital account openness. These results are robust to lag changes, prior changes, and for the most part remain the same when Pooled OLS is used.

JEL Classification C11, C51, E31, E51, E58, F31

Keywords Model Uncertainty, Bayesian Model Averaging, Price Stability, FX reserves, Inflation rate, Central Banks

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Thesis Proposal

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Motivation

With the widespread implementation of inflation targeting policies as well as the increasing volumes of foreign exchange reserves (FX reserves), especially in emerging economies, a question needs to be posed on whether large reserves are optimal and whether these two phenomena can work together or if they pose a threat or limitations to each other.

Inflation targeting As opposed to exchange rate targeting where the monetary policies are targeted towards pegging the country's currency rate to that of a low-inflation country, inflation targeting aims to maintain price stability by achieving the desired inflation rate using primarily the central banks' main tool – money supply. This enables the country to respond to various shocks with larger degree of freedom. (Sarwat) Evidently, other factors have effect on the interest rate as well as on the level of inflation, one of which are the FX reserves.

Purpose Reserves maintained by the central banks serve several purposes. The role in backing domestic currency is rather significant with gold and foreign currency being the most common reserves. Foreign currency is also required for servicing foreign liabilities and debt obligations when the currency differs from the domestic one. Keeping such reserves tends to be more adequate than attempting to exchange currency when payments are due mainly due to the possibility of worse rates as well as possibly insufficient supply at time of the transaction. Other common uses of reserves include defence against emergencies or an investment fund. The most important role for this thesis is the role as a tool for exchange rate and monetary policy. Specifically, the ability to utilise the FX markets by supplying domestic currency or on the contrary buying domestic currency against foreign currency and with the help of this tool affect the domestic monetary

policy. (Nugée, 2000) In this sense, the non-unity of foreign currency management in some countries due to the asset-based approach often being administered by the central bank while official borrowing is a government's responsibility. In this case of divided management, the incentives of the two organs are not aligned and can cause frictions. Both sides of the balance sheet are managed together in for example the United Kingdom which enables for better focus on net risk and overall results. (Nugée, 2000)

Developing economies Foreign exchange reserves have the potential to contribute to price stability. This affect comes from the changes in interest rate as a result of foreign currency purchases and sale. According to the available literature, the effects of such reserves are considerably higher in developing economies compared to the well-established ones. (Benecká & Komárek, 2014; Cheung & Ito, 2009; Nugée, 2000; Heller H. R., 2015; Disyatat & Galati, 2005; Rodrik, 2006; Aizenman, Hutchison, & Noy, 2008; IMF, 2015) Taking inspiration from Benecká and Komárek (2014), this effect needs to be taken into consideration in the modelling process but data for advanced economies can shed more light on the reason for these differences. On average, the reserves contribute to decreasing the risk of currency crisis in emerging economies while the effect in advanced economies leans towards decreasing the risk of banking crises and market dysfunction. (IMF, 2015)

Exchange rate Due to the large amounts of FX reserves, their role in generating returns should not be overlooked despite it not being the primary goal. For this reason, exchange rate and the monetary policies of each country ought to be taken into consideration as well. Mainly the presence of inflation targeting by the central bank. Existing empirical evidence suggests a noticeable negative relationship between inflation targeting and effectiveness of stabilization of real exchange rates. The given possible explanation for this occurrence is that the two objectives (inflation targeting and exchange rate targeting) do not go particularly hand in hand (Aizenman, Hutchison, & Noy, 2008) which in turn decreases the reserves' ability to affect the price stability that this thesis is examining.

Costs Sterilization is the act of preventing FX operations from affecting the domestic country's monetary base. Intuitively, having large amounts of foreign currency allows for larger impact on the monetary base which in turn requires increased costs of diminishing this effect – sterilization cost. Another useful measure for determining the adequate amount of FX reserves is the opportunity cost of holding them – that is, the difference

between yields on reserves and on alternative opportunities. (IMF, 2013) Such yields can be highly impacted by being invested in a sub-optimal way – for example in too large FX reserves when they are not particularly needed.

Hypotheses

Hypothesis #1: Central Banks that maintain larger FX reserves have an increased capability of maintaining price stability

Hypothesis #2: The size of FX reserves is more influential in emerging economies than in the established economies

Hypothesis #3: Significance of FX reserves is smaller in inflation-targeting economies

Methodology

In my thesis I will be working with panel data most likely obtained from the large credible sources such as International Monetary Fund, The World Bank or Data.gov. Using regressions as well as Bayesian Model Averaging, I will investigate the relationship between price stability and the volume of FX reserves. The tool of choice will be STATA due to its capabilities as well as my previous experience and the measure for FX reserves will be the ratio of FX reserves to total reserves. In the process of modelling, other factors affecting price stability need to be considered. Some of the most notable ones include FX reserves return variance, Real GDP per capita, Trade openness, Capital account openness, FX regime, Exchange rate volatility, Exchange rate depreciation, Inflation targeting and Government debt.

For the second hypothesis, the classification of developing and advanced economies will be inspired by the IMF paper (2015), which uses economic flexibility and external financial flexibility as proxies for flexibility of a country's foreign currency market and the ability to adjust to external shocks respectively. This will enable me to dispute or confirm the current literature based on the latest data. The measurement for inflation targeting will be the amount of diversion from the targeted inflation in each period which will be used as a dependent variable in the third hypothesis that examines the importance of FX reserves for inflation-targeting economies.

Lastly, the robustness of the obtained results will need to be checked using the standard econometric tests to confirm their significance or reveal potential flaws in modelling.

Expected Contribution

Numerous papers have contributed to the topic of FX reserves as well as to inflation targeting. Generally, a common conclusion is that results vary depending on certain factors such as the level of development of the country's economy or other monetary policies. My thesis aims to find the solution to the unanswered question regarding the significance of the relationship between the volume of reserves of foreign currency and price stability of the country. Such information could help in managing reserves by determining the recommended volume to be held or by redirecting the efforts to where they matter the most. The recommended volume has been already addressed by Heller (1966) but with a different approach (in absolute terms rather than with respect to inflation) and the author admitted to several unrealistic assumptions. Benecká et al (2012) also focus on the absolute terms which leaves room for reassessment with a relative view and as the paper mentions: "the determinants of cross-country differences in reserve holdings are far from well understood". By assessing the required amount of FX reserves and finding that the current reserves are excessive especially in inflation-targeting economies, large sums could be saved by investing them into long-term funds instead and so generating income with little to no effort. There is even a possibility that reserves for precautionary purposes are obsolete as advanced economies are able to create assets and swap them into other currencies whenever required. (IMF, 2015)

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Author Supervisor

1 Introduction

Foreign exchange reserves are an important tool of central banks which serves multiple purposes that range from exchange rate manipulation to maintenance of the core function of central banks which is price stability. There is little doubt about the importance of having reserves but in a modern economy and with the current level of transparency, monetary policy needs to be not only helpful but also efficient. Having excessive reserves with little use means that money is not used as efficiently as it could be.

Since the 2000s there has been a surge in foreign exchange reserves. Not only mean but also the median rose noticeable portraying that the trend is widespread. (Benecká & Komárek, 2014) Consequently, concerns whether this enormous reserve accumulation should be limited started arising. Following the global financial crises and depletion of reserves, the positive and significant role of these reserves was reaffirmed, and concerns were mostly dropped. (Benecká & Komárek, 2014) However, with large amounts of reserves that are unlikely to disappear in the near future, their effect on a country's economy needs to be taken into account. These reserves expose economies to further external risk and require additional attention in order to sterilize the local economy from such external effects. Using resources to deal with this issue can not only be costly but may also take away focus from other important factors that play often a more important role meaning that these factors would not receive the attention that is needed to tackle them effectively. Furthermore, reserves that are sitting somewhere without being used are loosely forgone earnings that could be achieved by simply investing the money somewhere else. In this, thesis I will be focusing on one specific possibly adverse effect of foreign exchange reserve accumulation which is its relationship with inflation.

Inflation targeting, being a common topic in economics, has a vast research behind it that mostly supports the framework but is also aware of its limitation. It was first introduced in 1970 and has later been adopted by large number of countries. In addition to that, it has been suggested that in order to be able to fulfil its promises, central bank needs to be separated from political policy so that targets can be set in long term and central banks

can focus on their core objective – price stability. Central bank independence is, however, not clearly defined and, no single measure is available, and some results even incline towards non-importance of central bank independence. (Horváth & Matějů, 2011)

Evidence tends to confirm that inflation targeting is correlated with lower inflation rate but the conclusions are weekend by the fact that in the observations, inflation decreased not only in inflation targeting economies but also in non-targeting. Where literature is lacking is on the co-movements of these two variables in spite of rather persuasive arguments for close relationship between the two. An increase in foreign exchange reserves, unless fully sterilized is also an increase in monetary base of the local economy and so affects the local inflation. (Heller R. H., 1976) Therefore, there is a good reason to expect inflationary pressures as a result of the reserve accumulation and assuming that it is indeed not fully sterilized, an increase in inflation is possible. (Steiner, 2017)

Building on currently available literature, my thesis contributes by investigating the specific effect of foreign exchange reserve accumulation on inflation rate while using relatively new estimation method. Bayesian Model Averaging (BMA) takes advantage of currently available computing power by running iterations of different variable combinations and accounts for model uncertainty in the process. In addition to that, I use updated data, sample limitations for economy regimes, and to my knowledge previously untested combinations of variables data partly based on recent research. These variables include proxies for central bank financial strength introduced in the paper by Benecká et al. (2012), different lags of FX reserves discussed by Steiner (2017), as well as output gap, and money supply.

The thesis is organized as follows. Section 2 reviews the currently available literature on inflation targeting, price stability, foreign exchange reserves and the research done so far on the topics in conjunction. Section 3 describes the data and discusses the methodology used as well as the rationale behind it. Section 4 presents results of the models and their implications. Section 5 contains concluding remarks and recommendations for further work. Following the fifth section, bibliography and appendices are attached that provide regression results and additional details.

2 Literature Review

Inflation and its determinants have been a topic of a large number of papers that provide a deep insight. Foreign exchange reserves are not discussed in such extent but their popularity as a topic has been increasing, especially in the last decade. However, the literature talking about the relationship between these two variables in conjunction is limited. The closest papers that address such topic are by authors Lin, Wang and Steiner. Lin and Wang use data for five East Asian economies making it difficult to apply in other regions. Steiner's approach is wider and comes to a comparable conclusion as that of Lin and Wang. There appears to be a significant positive effect on inflation with reserve accumulation. As per Steiner's article, this effect, however, is not instant and has a lag of two years and is noticeably stronger for countries with fixed exchange rate regimes. Steiner also adds that reserve growth is increasingly less sterilized from the monetary base, possibly due to private capital inflows, and in combination with the accumulation of reserves, the effects on inflation can increase as well. Both papers were written in 2009 which makes the conclusions difficult to be used now and/or in other regions. Lin and Wang argue that the co-movement is present when the exchange rate effect is strong.

2.1 Inflation Targeting

Inflation targeting is a monetary policy first used in 1970 in Germany and Switzerland. (Martínez, 2008) Between 1990s and 2000s, more than 20 countries started using this regime accompanied by high transparency and accountability. (Horváth & Matějů, 2011) Before that, money supply targeting, and exchange rate targeting were practiced but were not successful. (Martínez, 2008) The objective of inflation targeting is to maintain expectations about increasing price levels by setting inflation goals which in turn encourages consumers to spend money as saving purchases for later means they will cost more. The most common inflation target for central banks is 2% and is often measured through Consumer Price Index. Deflation is not a desired option as it motivates consumers

to put off purchases as prices are expected to drop and they will be able to afford more. In this sense, managing low inflation to keep prices stable is preferable to dealing with deflation. When inflation is too high, 'menu' costs and 'shoe-leather' costs increase leading to distortions in economy. Hyperinflation has drastic impact on functions of money as a medium of exchange, store of value and unit of account which consequently has devastating effect on the country's economy. The central bank's main tools for achieving this are interest rates and exchange rates. They also need to maintain trust in their future decisions which affect expectations and consequently price levels. For this reason, central banks that employ inflation targeting regimes state their objectives to the public clearly and periodically.

The ease and precision of measuring interest rate and foreign exchange reserves compared to money supply is one of the main reasons behind inflation targeting's fast growth in popularity. Its function as nominal anchor works well in tying the central bank to focus on long-run policies while not giving in to political pressure. The aim is to anchor expectations and the central bank does that by committing to an inflation rate. So, the expectations are of rate of price increase. (Martínez, 2008)

Empirical evidence supports inflation targeting framework and presents benefits such as lower inflation rate and lower growth volatility. The research was carried out using data from 36 countries that are considered to be emerging economies and the 13 inflation targeting countries were identified using a dummy variable. (Goncalves & Salles, 2008) Having price level increase expectations anchored comes at a cost in the form of decreased ability to accommodate shocks with temporary effects. Such shock would require a short-term change of the target or increase variability interval or tolerance range. This of course would have negative effect on expectations which the central bank with inflation targeting framework relies on. Since normally targets are announced periodically, a temporary change would require an announcement that is out of ordinary making anchoring expectations highly challenging. There is also some doubt about the actual contribution of inflation targeting to the overall decrease in inflation. This doubt stems from the fact that inflation and the expectations of it began to fall not only in inflation targeting but also in nontargeting economies. (Martínez, 2008)

Horváth and Matějů carried out a survey in 2010 to find out what are the most common contributors to setting inflation targets in an attempt to fill in the lack of information on this topic. Expectedly, economic variables play a significant role – mainly domestic and foreign inflation rate, stability of the macroeconomic environment, and the degree of economic activity. The paper then goes on to confirm that inflation does matter for setting future targets. Volatility of the inflation rate also impacts the decision-making process – with higher inflation volatility, inflation targets tend to be set higher, most likely stemming from endeavours to avoid deflation. Furthermore, inflation targets are also influenced by central bank credibility. Intuitively, banks that did not perform well in the past will have difficulties with anchoring public expectations resulting in higher inflation target. (Horváth & Matějů, 2011)

2.2 Price stability

Price stability is the core of monetary economics and is a responsibility of central banks. In the sense that is used nowadays it does not mean that the prices remain constant. Instead, they increase slowly and in an expected manner as a result of inflation targeting policy. Stable prices are important for a healthy functioning of an economy since being able to rely on a constant small growth helps in mitigating risk that arises from unexpected price changes which in turn lowers certain amount of uncertainty that is connected to trade and so the economic activity can be maintained on high level. Decisions under these expectations are well informed and promote efficiency. Furthermore, low inflation expectation result in low real interest rates which contribute to incentives to invest.

According to Goodfriend and King (2001), there are three main reasons for central bank to maintain price stability. Firstly, it enables the real economy to behave in the event of shocks as it would with perfectly flexible prices. Secondly, it contributes to tax smoothing and lastly, price stability or constant mark-up is in line with elimination of the gap between potential and actual output which corresponds to the main focus in macroeconomics. The paper also argues that one of the attributes of price stability is that output is kept at its potential making the policy neutral and that there are two roles to the

mark-up. Firstly, it plays a central role in inflation evolution and so the optimal mark-up is such that maximizes price stability. Secondly, it is a tax on work effort which means that volatility would promote inefficiencies such as unstable unemployment as well as output. When neutral policy is fully credible, expectations can be anchored properly and in return, in the event of a shock to the economy, firms return to zero inflation at a fast rate. In the opposite case, firms would have incentives to prolong the shock to inflation to mitigate the risk that arises from the shock and from monetary policy that lacks in credibility. Returning to price stability in a short amount of time would prove highly costly to the monetary authority.

A tool that can help with maintaining price stability are foreign exchange reserves. Foreign currency purchases and sales affect interest rate which then translates into effect on prices. Such effects are more pronounced in emerging economies which is also why significant portion of literature that talks about foreign exchange reserves focuses on these developing economies.

2.3 Foreign Exchange reserves

Foreign Exchange reserves come from exporters who are paid in foreign currencies that they store in local banks which then transfer the currency to central banks. The exporters exchange the foreign currency for local currency in order to be able to pay their workers as well as their local suppliers.

Central banks are then able to use these reserves for various purposes such as lowering exchange rate risk. By buying a foreign currency (for example US dollar) a central bank increases its reserves of that currency and in the process, the value of the domestic currency in comparison with the foreign currency decreases. This method is used mainly in countries that employ fixed exchange rate. The next use involves buying foreign treasury bills on the foreign exchange market which has essentially the same effect as the previous method which boosts trade by making export relatively cheaper. In return, local economic growth gets boosted. Another very common use is to make sure the country is

able to meet external obligations when needed. Central bank may also need to buy local currency to re-gain confidence of foreign investors. By doing so, it provides foreign currency from its reserves. Confidence of foreign investors can be lost due to local events that triggered fear in said investors followed by sudden deposit withdrawal and drop in the value of local currency. As a result of lower demand imports become more expensive and so inflation increases. Reserves can also be used to diversify investment portfolio and thus contribute to its safety or they can help local banks by recapitalization. Last and perhaps the most important usage of foreign exchange reserves is for liquidity. Having sufficient reserves helps in withstanding unexpected shocks such that affect local exporters and their production. When exports get cut off, the inflow of foreign currency stops and there can be a problem with ability to pay off imports due to the lack of foreign currency. This can be tackled by local central bank through exchanging foreign currency for local.

Data provided by CEIC show that the largest amounts of Foreign Exchange reserves are currently held by China. Their reserves amount to 3,095,591 million USD. Second largest reserves are roughly only a third of that (1,251,522 million USD) and are held by Japan. Russia and India hold similar amounts – 425,577 million USD and 413,015 million USD respectively. European Union as a whole holds 356,163.3 million USD. The Czech Republic then holds 146,180.6 million USD

As previously mentioned, the effect in which Foreign Exchange reserves are intertwined with inflation targeting is through their ability to be used as a tool to manipulate exchange rate, specifically limiting exchange rate fluctuations. To put it simply, through purchases of local currency the central bank can increase demand for local currency and so manipulate the currency's devaluation. Furthermore, unless fully sterilized, reserves are linked with monetary base. Therefore, increase in foreign exchange reserves is also an increase in total amount of money through functioning of money multiplier and eventually also an increase in price level. (Heller R. H., 1976)

Holding foreign exchange reserves brings benefits especially in terms of liquidity and related to it is its feature as a buffer against shocks. Having sufficient reserves has been observed to mitigate crises as well as their impact. This is mainly thanks to the fact that

such buffer can offer liquidity when needed. Of course, there are other reasons for reserve accumulation. The most common ones are smoothing of exchange rate volatility, using the reserves as a tool to manage exchange rate level or to simply store them in a form of savings to build assets for intergenerational purposes. (Intrenational Monetary Fund, 2011; International Monetary Fund, 2015)

Such benefits have diminishing returns when the reserves are becoming increasingly large, as these assets could be used in more effective ways with higher yields and with a higher liquidity meaning that there are foregone earnings. (Benecká & Komárek, 2014) In this sense, holding foreign exchange reserves could be considered as a bad monetary policy. In addition to that, continuous exchange rate interventions in one direction can have negative spill-overs on other countries. (International Monetary Fund, 2015) Overvaluation of real exchange rate accompanied by growth of domestic credit tends to be an effective indicator of currency crisis. (Benecká & Komárek, 2014)

Unfortunately, despite some measures of cost being available, there is no agreement on which are appropriate partly because the focus was previously mainly on the benefits of holding reserves and costs were not discussed as much. (Benecká & Komárek, 2014) Some of the common indicators according to IMF paper (2011), include sterilization costs that come from efforts to avoid adverse effects from foreign exchange interventions, actual or potential exchange rate valuation losses, or the opportunity cost of foregone consumption or investment. This opportunity cost then comes down to the difference between the return on reserves and a borrowing cost of the sovereign. (International Monetary Fund, 2013)

The empirical evidence shows that reserves tend to be smaller the higher the financial development of the economy is. (Benecká & Komárek, 2014; International Monetary Fund, 2013; International Monetary Fund, 2015; Intrenational Monetary Fund, 2011)For emerging markets rules of thumb tend to work well and net financial cost of holding reserves can be assessed by comparing external funding cost and return on resulting liquid foreign assets. The rules of thumb ought to be also accompanied by a more detailed analysis. According to these metrics, most emerging countries hold enough reserves, while some even hold more than it is recommended making the declines in output and

consumption suffered during crisis on average smaller. (Intrenational Monetary Fund, 2011) Mature market economies are recommended to hold reserves mainly for precautionary matters – for instance for cases of sever market dysfunction and for easing of short-term foreign currency funding pressures. This changes when the country itself is an issuer of reserve currency. These economies are able to create assets which then can be swapped into other currencies at virtually any time making them highly liquid. Empirical evidence for such markets is however not fully clear due to the low frequency of currency crises. (International Monetary Fund, 2013)

Considering both sides of the problem, there should be an optimal level of reserves to be held and in fact, there have been numerous attempts to address this. The conclusions tend not to be strong and are often dependent on several factors. There is no single measure available – instead, countries should be assessed individually to account for the small differences between them that together compile into larger effects. (International Monetary Fund, 2013; Intrenational Monetary Fund, 2011; International Monetary Fund, 2015) In the assessment, the economies' maturity, depth, underlying liquidity and economic flexibility should be taken into account. (International Monetary Fund, 2013) According to Benecká and Komárek, the most notable cross-country differences are trade openness, country size and oil exports. To add to the difficulty of determining the adequate amount of foreign exchange reserves, far from trivial policy choices have to be made as some goals are simply not compatible with each other. Benecká and Komárek refer to this as the 'trilemma' which states that from independence, exchange rate stability and financial market openness to the full extent, only two goals can be satisfied. In addition to that, if economy is to diverge from long term reserve accumulation path, structural changes may need to take place in order to provide short-term safety measures. Global financial safety net or a swap line network are possibly feasible alternatives. (Benecká & Komárek, 2014)

The IMF paper from 2013 also discusses a case in which countries are heavily dependent on an imported commodity. For such countries, when the imported commodity is below the estimated long-run level, additional reserves should be held as the price can be expected to rise.

Generally, it is a good idea to address other elements of sovereign risk when foreign exchange reserves reach a certain level. Since early 2000s, the accumulation has been large (Benecká & Komárek, 2014), and some countries also decided not to use these reserves during crisis and turned to foreign currency central bank swap lines or to usage of liquid assets in their sovereign wealth funds. (Intrenational Monetary Fund, 2011) The result is excessive amount of foreign exchange reserves and lack of directive on how to address it.

3 Methodology

This section describes the methodology used to analyse the dependence between foreign exchange reserves in central banks and inflation rate of the country.

3.1 Data description

In this thesis I use data for 74 countries for the period of 1996 – 2017 that from a large part consist of updated data used in the work Benecká and Komárek (2014) that was compiled from various sources. For *Inflation*, World Bank[1] data was used as a source. This data is generated based on Consumer Price Index (CPI) and Laspeyres formula is used for calculation. Laspeyres index uses a basket of goods and services and measures the change in its price relative to a specific base period weighting.

Laspeyres formula:

$$I_L = \left(\frac{\sum Price\ at\ Observation\ Period * Base\ Quantity}{\sum Price\ at\ Base\ Period * Base\ Quantity} \right) x100$$

[1] www.worldbank.org

Table 3.1.1: Descriptive statistics of Inflation and FX reserves

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
Inflation (%)	1626	8.00	3.08	37.70	-11.70	1058.37
FX reserves (ratio to GDP)	1330	56034.03	14450.64	141747.12	17.71	1258172.44

The mean of my dependent variable *inflation* is 8% with a minimum of -11.7% corresponding to Bosnia and Hercegovina in 1996 and a maximum of 1058.37% which corresponds to Bulgaria in 1997. (*Table 3.1.1*). *Inflation* decreased sharply after 1997 which was the peak of hyperinflation in Bulgaria. Following that, the rate is mostly steady with a spike around the Global Financial Crisis of 2008. In *Figure 3.1.2* it can be also seen that during years 1996 and 1997, standard deviation reached the highest numbers. There are 1626 observations for this variable. Details of the remaining independent can be found in appendix. (*A.14*)

Figure 3.1.1: Average inflation rate

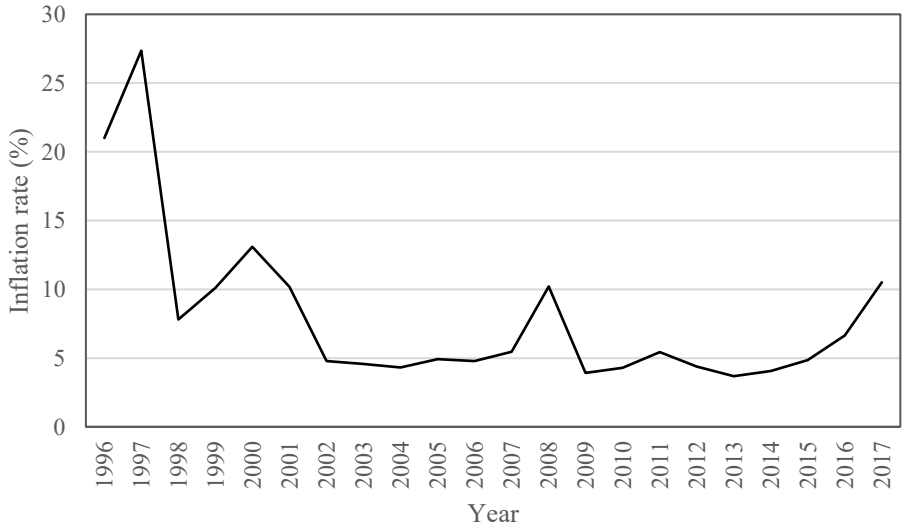
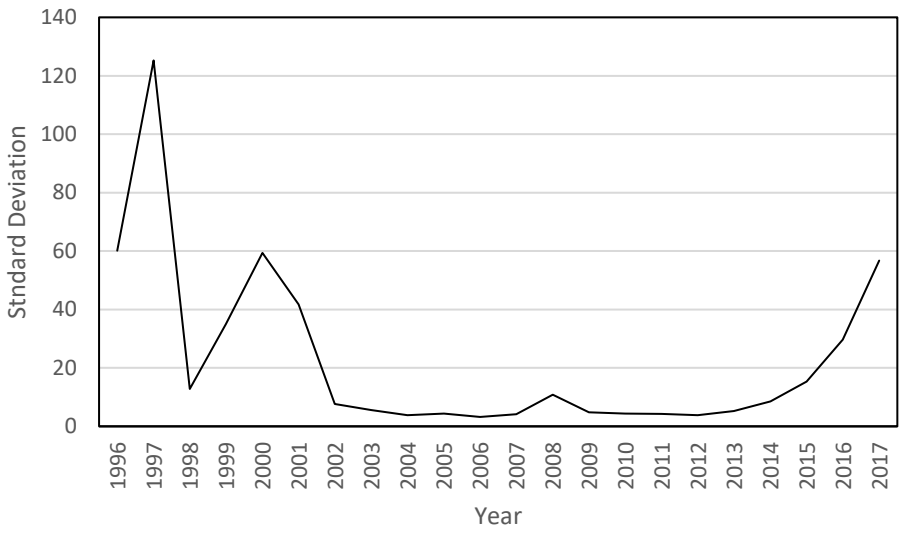
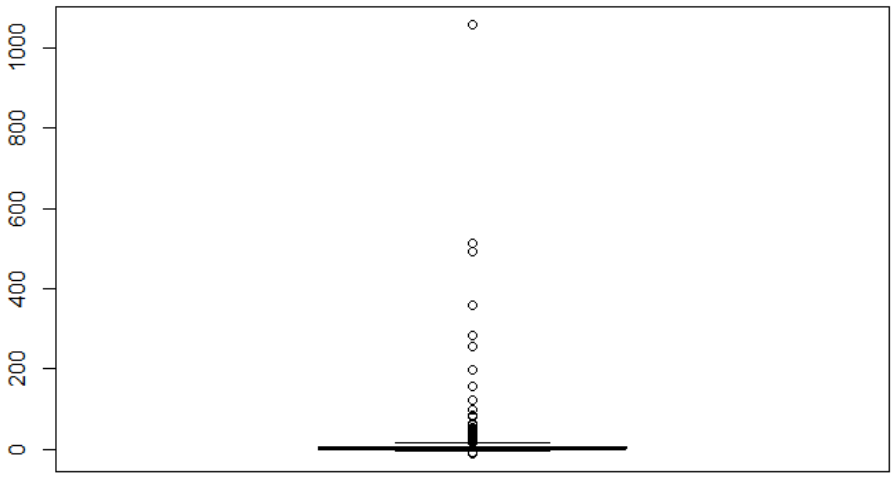


Figure 3.1.2: Inflation rate standard deviation



Some outliers are present in *inflation rate*. However, my method of estimation – Bayesian Model Averaging, is robust to outliers so no further action is needed. (*Figure 3.1.3*)

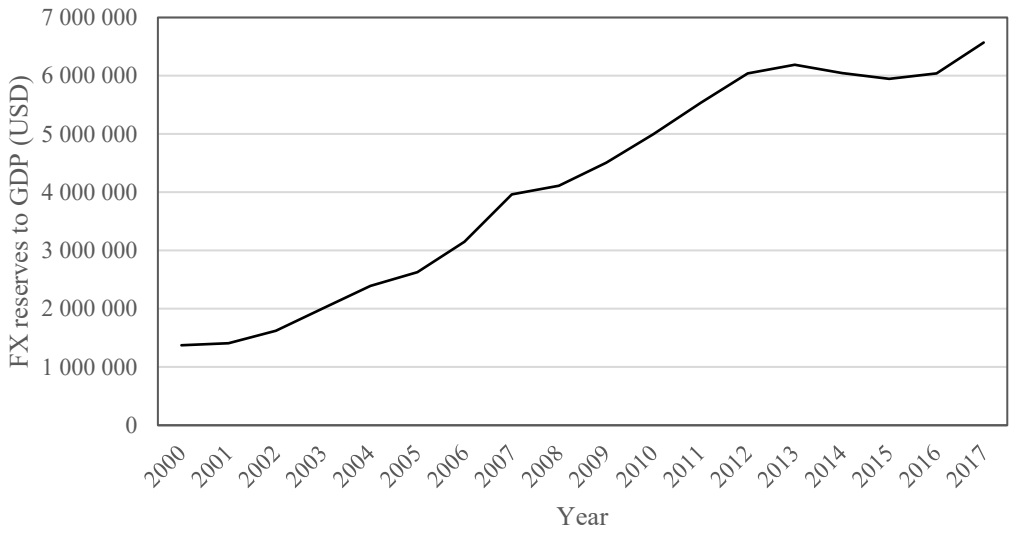
Figure 3.1.3: Inflation rate outliers



FX reserves: The ratio of foreign exchange reserves to GDP. The expected relationship is positive as for fixed exchange rate regimes, maintaining stable FX rate requires issuance of domestic currency, consequently also inflation. Data obtained from IMF[2].

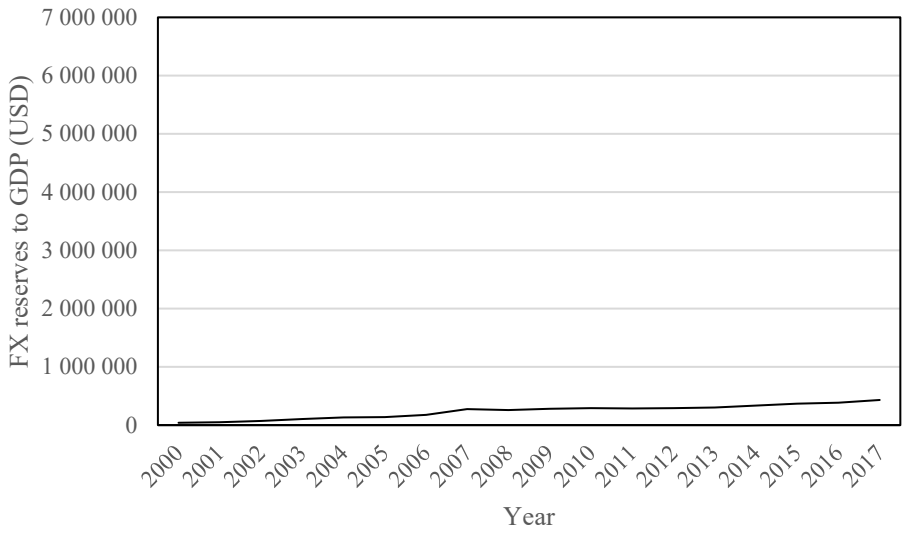
The independent variable of interest, *FX reserves* expressed as a ratio of FX reserves to GDP has a mean of 56034.03 with a minimum of 17.71 and a maximum of 1258172.44. The steady increase in foreign exchange reserves from 2000 to 2017 is consistent with the gathered literature. I also attempted to separate Emerging Economies to observe whether the accumulation is faster in those countries. For definition of Emerging Economies, I took inspiration from Benecká and Komárek (2014), which is a GDP per capita lower than 2000 USD. *Figure 3.1.5* does not indicate any noticeable increase for Emerging Economies in *FX reserves* to GDP compared to the whole sample (*Figure 3.1.4*) which is most likely due to the very limited number of emerging economies in my sample – only 5 countries have a GDP below 2000 USD in my dataset. Compared to *Inflation*, the number of *FX reserves* observations is slightly smaller at 1330 due to shorter time period starting from year 2000.

Figure 3.1.4: FX reserves to GDP



[2]International Monetary Fund: https://www.imf.org/en/Data

Figure 3.1.5: FX reserves to GDP – Emerging Economies only



Inflation targeting: A dummy variable that gains the value of 1 if a country employs an inflation targeting monetary policy regime in a given year. The currently available empirical evidence points to inflation targeting as having a negative impact on inflation. Data was compiled from various sources.

Fixed exchange rate regime: A dummy variable that gains the value of 1 if a country employs a fixed exchange rate regime and 0 otherwise. The IMF data classifies exchange rate regimes into three main categories – pegged (fixed), intermediate and floating. The general consensus seems to be that the category with the highest importance is the fixed regime as it can be used as a means of escaping high inflation. (Benecká & Komárek, 2014; Steiner, 2017)

Out of the 1628 observations, 580 correspond to inflation targeting regimes and 770 to fixed FX regimes. (*Table 3.1.7*) In 2017, 40 out of 74 observed economies employed an inflation targeting regime. That is a large increase compared to 2000 when only 19 economies used inflation targeting. In contrast, economies with fixed FX regime decreased from 42 in 2000 to in 32 2017.

Table 3.1.2: Inflation Targeting and Fixed FX regimes – dummy variables

Dummy variables	Obs	True	False
Inflation Targeting Regime	1628	580	1048
Fixed FX regime	1628	770	858

GDP per capita: Real GDP per capita that serves as a proxy for economic development. Higher economic development is expected to be associated with lower inflation. Data obtained from World Bank.

Corruption: An index of country corruption ranging from 0 to 10. Currently available research finds positive impact of corruption on inflation. (Al-Marhubi, 2000) Data obtained from Transparency International[3].

Debt level: A ratio of public debt to GDP. The expected effect on inflation is positive as increased inflation can aid in servicing debt. Data obtained from IMF.

Output gap: An important link between real side of economy and inflation. Since increase in actual output relative to potential output pushes prices up as a consequence of demand pressure in key markets, the expected effect on inflation is positive. This variable is lagged by one year to cope with simultaneity. Data obtained from OECD and World Bank.

Trade openness: A measure of trade openness that is calculated as the ratio of exports to GDP. The underlying data was downloaded from World Bank. The expected effect on inflation can be either positive as a result of reserve accumulation in response to increased exposure to trade shocks (Benecká & Komárek, 2014) or negative due to its behaviour as a brake on an inflationary surprise by the government. (Romer, 1993)

[3] https://www.transparency.org/en/

Capital account openness: A factor suggested by Chinn and Ito (2008) and used by Benecká et al (2012). It can have a similar effect as trade openness in terms of being the brake on an inflationary surprise by the government.

Exchange rate: Value of a currency relative to USD. Exchange rate affects inflation rate through two channels. Firstly, it directly affects price of imported goods. Secondly, it affects the real exchange rate which in turn affects aggregate demand and output gap.

Exchange rate volatility: Measure of volatility of exchange rate. This measure Benecká and Komárek (2014), was proposed as a possible alternative to exchange rate regime. Data obtained from BIS[4].

For central bank financial strength, Benecká et al. (2012) tested several variables – the ratio of equity to total assets (ETA), central bank financial strength (CBFS), the ratio of non-interest-bearing liabilities (NNIBL), return on average assets (ROAA), and finally return on average equity (ROAE). For my analysis, I chose CBFS and NNIBL based on their favourability in results of the Benecká et al. (2012) paper. These variables can have an endogeneity issue. This endogeneity is in a form of reverse causality meaning that the relationship between central bank financial strength and inflation rate can potentially run in both directions. So, although central bank financial strength can have an effect of decreasing inflation, increase in inflation can also increase central bank's financial strength in a form of seigniorage. To cope with this, although not perfectly, all of these proxies are lagged by one year.

CBFS: Central Bank Financial Strength measured by a ratio of broadly defined capital to total assets used by Benecká et al. in their work. This measure captures apart from equity also other items net (OIN) which reflect specific accounting and reporting practices. Underlying data obtained from IMF.

$$CBFS = \frac{equity + other\ items\ net}{total\ assets}$$

[4] Bank of International Settlements: www.bis.org

NNIBL: Ratio of Non-Interest-Bearing Liabilities to total assets. This measure for central bank financial strength is preferred by Benecká et al. (2012) from economic point of view. This measure also includes issued currency as a non-interest-bearing liability and should capture overall earning potential of central bank. Data is not as complete compared to CBFS. Underlying data obtained from BankFocus.

$$NNIBL = \frac{equity + noninterest\ bearing\ liabilities - nonearning\ assets - fixed\ assets}{total\ assets}$$

CBI: As in Benecká et al. (2012) paper, I also included central bank independence index in my analysis to use in an interaction term with NNIBL. The idea is that increased independence could mitigate political-economy consequences of its financial performance. In return, this could weaken the relationship between inflation and central bank financial strength. Data obtained from Hicks[5].

Exchange rate depreciation: As a tool of central bank, exchange rate depreciation can swiftly improve its finances and so its financial strength, so the expected effect is positive. This variable is lagged by one year to cope with endogeneity. High inflation pushes interest rates up which often has the effect of exchange rate depreciation. Data obtained from BIS.

Transparency: An index of central bank transparency – a measure introduced by Dincer and Eichengreen in their 2014 paper "Central Bank Transparency and Independence: Updates and New Measures" (Dincer & Eichengreen, 2014). Transparency is an important tool in shaping public expectations which affect setting of inflation rate.

Money supply: Broad money as percentage of GDP. According to Steiner (2017), monetary base is becoming increasingly less sterilized from inflation rate. Inclusion of this variable was also mentioned by Heller (1976). Although no strong evidence is available to support it, there is a potential endogeneity issue with this variable. The complications arise from the other information that is contained in the variable –

[5] http://www.columbia.edu/~rh2883/data.html

specifically for example shocks to financial markets such as crises. (Benecká & Komárek, 2014) Data obtained from WorldBank.

3.2 Estimation

In this section, I perform panel data analysis of the relationship between country's inflation and foreign exchange reserves using R. Given the number of variables that I use in my modelling, model uncertainty needs to be taken into account.

Uncertainty is present in most economic models and should be approached appropriately especially in empirical work with multiple explanatory variables. To minimize model uncertainty in modelling, one of two strategies can be chosen. Firstly, model selection which is a method that takes the best model out of all considered based on a criterion. Following the selection of the best model, inference is then conducted, and, in the process, it is assumed that the data was generated by the said model. If the model is indeed a good approximation of the data generating process, it can be generally relied on. Second method of battling model uncertainty is Model Averaging which takes into account all the estimated models and inference is a result of averaging of the said models. The averaging takes advantage of weighting mechanism that can use Bayes' theorem or sampling-theoretic optimality considerations.

3.2.1 Bayesian Model Averaging

This thesis takes advantage of the Bayes' theorem through Bayesian Model Averaging (BMA) as relying on a specific model is often not a safe choice and it was suggested that single model tends to provide worse predictive results. (Ferenández, Ley, & Steel, 2001) Since I am not as much interested in the correct underlying model as in the relationship between foreign exchange reserves Model Selection is not that useful in this case.

In BMA, we assume a model space M and number of explanatory variables K. This gives as 2^K combinations of repressor variables with models indexed by M_k. As a part of the

estimation, BMA iterates through models and variable combinations while searching for the "true model". The main indicators of interest are Posterior Model Probability (PMP), Posterior Mean, and Posterior Inclusion Probability (PIP).

As the name suggests, BMA builds on Bayes theorem which essentially adjusts probability of an event happening, taking into account new evidence. The calculation for event A and event B, occurring with probabilities P(A) and P(B) is as follows:

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$

PIP shows the importance of each predictor and is interpreted as the likelihood of being included in the "true model". For a variable *h* and data *D* the calculation is as follows:

$$PIP = P(B_h \neq 0 \mid D) = \sum_{B_h \neq 0} P(M_k \mid D)$$

Posterior Mean estimates the β coefficients. The calculation where $\hat{\beta}$ is the estimate of coefficient β for model M_k *is:*

$$E\left[\hat{\beta} \mid D\right] = \sum_{k=1}^{2^K} \hat{\beta}\, P(M_k \mid D)$$

Posterior Standard Deviation is then computed as follows:

$$Var\left[\hat{\beta} \mid D\right] = \sum_{k=1}^{2^K} \left(Var\left[\hat{\beta} \mid D, M_k\right] + \hat{\beta}^{\,2}\right) P(M_k \mid D) - E[\beta \mid D]^2$$

PMP is calculated as the ratio of marginal likelihood of an individual model over the sum of marginal likelihoods of the entire model space using the Bayes theorem where $P(M_k)$ is the prior model probability that the model is the "true model:

$$P(M_k \mid D) = \frac{P(D \mid M_k)P(M_k)}{\sum_{j=1}^{2^K} P(D \mid M_k)P\left(M_j\right)}$$

Another important factor are priors that carry information about various distributions of parameters as well as model size. There are two types of priors – parameter prior and prior model size. Parameter prior serves to determine posterior mean of coefficients and prior model size determines averaging weights. These are just the basic values that I will be talking about in this thesis.

3.2.2 Models

For BMA analysis, I use the following base model where the 11th variable is either *NNILB* or *CBFS*:

Base model NNIBL:

$$Inflation_{i,t} = \beta_0 + \beta_1 FX\_Reserves_{i,t} + \beta_2 Inflation\_Targeting_{i,t} + \beta_3 Capital\_Account\_Openness_{i,t} + \beta_4 Exchange\_Rate_{i,t} + \beta_5 Exchange\_Rate\_Depriciation_{i,t-1} + \beta_6 Exchange\_Rate\_Volatility_{i,t-1} + \beta_7 Trade\_Openness_{i,t} + \beta_8 \log(GDP\_per\_capita)_{i,t} + \beta_9 Output\_Gap_{i,t-1} + \beta_{10} Unemployment_{i,t} + \beta_{11} NNIBL_{i,t-1} + \beta_{12} Corruption_{i,t} + + \beta_{13} Transparency_{i,t} + \beta_{14} Debt\_Level_{i,t} + \varepsilon_{i,t}$$

Base model CBFS:

$$Inflation_{i,t} = \beta_0 + \beta_1 FX\_Reserves_{i,t} + \beta_2 Inflation\_Targeting_{i,t} + \beta_3 Capital\_Account\_Openness_{i,t} + \beta_4 Exchange\_Rate_{i,t} + \beta_5 Exchange\_Rate\_Depriciation_{i,t-1} + \beta_6 Debt\_Level_{i,t} + \beta_7 Trade\_Openness_{i,t} + \beta_8 \log(GDP\_per\_capita)_{i,t} + \beta_9 Output\_Gap_{i,t-1} + \beta_{10} Fixed\_FX_{i,t-1} + \beta_{11} CBFS_{i,t-1} + \beta_{12} Corruption_{i,t} + + \beta_{13} Transparency_{i,t} + + \varepsilon_{i,t}$$

The dependent variable is $Inflation_{i,t}$ in each country *i* at time *t*. The explanatory variable $FX\_Reserves_{i,t}$ are foreign exchange reserves and securities in US dollars divided by GDP of each country *i* at time *t*. $Inflation\_Targeting_{i,t}$ is a dummy variable indicating whether country *i* employs inflation targeting regime at time *t*. $Capital\_Account\_Openness_{i,t}$ is an

IMF index portraying country *i*'s Capital Account Openness at time *t*. $Exchange\_Rate_{i,t}$ is the exchange rate of local currency in relation to USD for country *i* at time *t*. $Exchange\_Rate\_Depreciation_{i,t-1}$ is the depreciation of exchange rate of local currency in country *i* at time *t-1*. $Trade\_Openness_{i,t}$ is an index portraying country *i*'s trade openness at time *t* calculated by dividing Imports by GDP. $GDP\_per\_capita_{i,t}$ is the gross domestic product for country *i* at time *t*. $Output\_Gap_{i,t-1}$ is the output gap of country *i* at time *t-1*. $Fixed\_FX_{i,t}$ is a dummy variable which is True if country *i* employs fixed exchange rate regime at time *t*. $NNIBL_{i,t-1}$ are non-interest bearing liabilities in country *i* at time *t*. $CBFS_{i,t-1}$ is central bank financial strength in country *i* at time *t-1*. $Corruption_{it,}$ is corruption in country *i* at time *t*. $Transparency_{i,t}$ is transparency of central bank in country *i* at time *t*.

Taking inspiration from Benecká & Komárek (2014), I will run estimations using 1,000,000 iterations with 500,000 burn ins. Due to lack of prior knowledge, standard uniform prior in combination with benchmark prior (BRIC) is used for estimation. None of the variables have a too high correlation except perhaps for *Transparency* and *Inflation targeting* which have a correlation of 79%. (*Appendix A.15*) I decided to keep both variables.

I will be testing the importance of variables from previous research and also their potential to improve my estimations. Firstly, I will compare the importance of *NNIBL* and *CBFS* and choose the better alternative for further modelling. After that, I will test whether using lags on *FX reserves* proposed by Steiner (2017) and Heller (1976) improves our estimation. Based on newly acquired results I will then see if inclusion of exchange rate volatility provides superior estimation to exchange rate regime.

Throughout the modelling I will be comparing the results of my estimations and I will attempt to choose the most suitable combination of variables for my BMA analysis. When considering determining the importance of variables, any variable with PIP below 50% is considered to be of low importance. Once I select my preferred model, I will repeat my analysis for restricted samples for specific country groups. Firstly, I will test whether the relationship between *FX reserves* and *Inflation* is stronger for inflation targeting economies. Secondly, I will do the same for fixed FX regime economies to compare with

the results of Steiner (2017). Lastly, I will compare the estimations for advanced economies and emerging economies. For the classification of economic development, I will be taking inspiration from Benecká and Komárek (2014) who chose the border for an advanced economy as the level of GDP per capita of 2.000 USD per year. After my estimations, sensitivity checks will be performed by altering prior distributions.

4 Results

4.1 Empirical results

4.1.1 Central Bank Financial Strength

Firstly, I ran the BMA estimation for my two basic models comparing the importance of the two proxies for central bank financial strength – *NNIBL* and *CBFS*. *Table 4.1.1.1* and *Table 4.1.1.2* show the Posterior Model Probabilities (PMP) and variable selections made for each of the top 10 models including the direction of their effect on inflation rate for both estimations.

Detailed results of each estimation are presented in appendix in tables *A.1.1*, and *A2.1*. These tables report the Posterior Inclusion Probability (PIP), Posterior Mean, and the Posterior Standard Deviation for each variable of the two basic models. PIP is a measure that portrays the probability of a coefficient not being equal to zero. In my models specifically, it shows the importance of each included variable in explaining the movements in inflation rate.

Table 4.1.1.1: Posterior Model Probabilities and variable inclusion for the top 10 models of the basic model with NNIBL

Model Ranking	PMP	NNIBL	Capital account openness	GDP per capita	Exchange rate depreciation	Inflation targeting
1	**0.090**	-	-	-		
2	0.071	-	-	-	+	
3	0.048	-		-	+	
4	0.027	-	-			
5	0.025	-		-	+	-
6	0.025	-	-			-
7	0.023	-	-			-
8	0.023	-	-		+	
9	0.020	-	-	-		-
10	0.020	-		-		
Total	**0.372**					

Note: The "+" and "-" signs portray both the inclusion of the particular variable in each model as well as the direction of the effect where "+" stands for positive effect on inflation and "-" stands for negative effect on inflation.

Table 4.1.1.2: Posterior Model Probabilities and variable inclusion for the top 10 models of the basic model with CBFS

Model Ranking	PMP	Capital account openness	Debt level	Exchange rate depreciation	Inflation targeting	Trade openness	Transparency	GDP per capita
1	**0.076**	-	+	+				
2	0.060	-	+	+	-	-		
3	0.051	-	+	+	-			
4	0.050	-	+		-	-		
5	0.037	-	+					
6	0.033	-	+		-			
7	0.032	-	+	+			-	
8	0.026	-	+	+		-		
9	0.022	-	+	+				-
10	0.019	-	+				-	
Total	**0.406**							

Note: The "+" and "-" signs portray both the inclusion of the particular variable in each model as well as the direction of the effect where "+" stands for positive effect on inflation and "-" stands for negative effect on inflation.

From the first two cases, *NNIBL* appears to be the superior variable for my modelling. *CBFS* is not used in any of the top 10 models whereas *NNIBL* is used in all of them showing negative relationship. *NNIBL* also shows a high posterior inclusion probability of 86%. (*Table 4.1.1.3*) Foreign exchange reserves do not seem to be important for my estimations as they do not appear in either of the two cases' top 10 models (*Table 4.1.2*) and the posterior inclusion probability in the *NNIBL* estimation is only 4.8%. From the *NNIBL* estimation, *Capital account openness, GDP per capita, Exchange rate depreciation,* and *Inflation targeting* appear to be the most important determinants of inflation rate. All of these variables have the expected effect direction supporting previous research. (*Table 4.1.1.1*) The total posterior model probabilities for the top 10 models are considerably low in both cases at 37% for *NNIBL* and 41% for *CFBS*.

Table 4.1.1.3: Results for basic BMA estimation that includes NNIBL as a proxy for central bank financial strength. Results reported for the top 100 models.

	PIP	Post Mean	Post SD
NNIBL	0.859	-0.027	0.014
Capital account openness	0.777	-1.146	0.751
GDP per capita	0.599	-1.284	1.220
Exchange rate depreciation (t-1)	0.470	3.461	4.158
Inflation targeting regime	0.379	-1.066	1.549
Trade openness	0.197	-0.611	1.407
Debt level	0.173	0.005	0.012
Transparency	0.130	-0.034	0.106
Exchange rate	0.077	0.000	0.001
Fixed FX regime	0.069	-0.105	0.529
FX reserves	0.048	0.000	0.000
Corruption	0.045	0.004	0.026
Output gap (t-1)	0.036	-0.003	0.035

4.1.2 Monetary base

In the next two cases I added money supply as suggested by Steiner (2017) to check for the sterilization of inflation rate from monetary base. I also checked again for the importance of *CBFS* and *NNIBL*.

NNIBL with Monetary Base:

$$\begin{aligned} Inflation_{i,t} = {} & \beta_0 + \beta_1 FX\_Reserves_{i,t} + \beta_2 Inflation\_Targeting_{i,t} \\ & + \beta_3 Capital\_Account\_Openness_{i,t} + \beta_4 Exchange\_Rate_{i,t} \\ & + \beta_5 Exchange\_Rate\_Depriciation_{i,t-1} \\ & + \beta_6 Exchange\_Rate\_Volatility_{i,t-1} + \beta_7 Trade\_Openness_{i,t} \\ & + \beta_8 \log(GDP\_per\_capita)_{i,t} + \beta_9 Output\_Gap_{i,t-1} \\ & + \beta_{10} Unemployment_{i,t} + \beta_{11} NNIBL_{i,t-1} + \beta_{12} Corruption_{i,t} \\ & + +\beta_{13} Transparency_{i,t} + \beta_{14} Debt\_Level_{i,t} + Money\_Supply_{i,t} + \varepsilon_{i,t} \end{aligned}$$

CBFS with Monetary Base:

$$\begin{aligned} Inflation_{i,t} = {} & \beta_0 + \beta_1 FX\_Reserves_{i,t} + \beta_2 Inflation\_Targeting_{i,t} \\ & + \beta_3 Capital\_Account\_Openness_{i,t} + \beta_4 Exchange\_Rate_{i,t} \\ & + \beta_5 Exchange\_Rate\_Depriciation_{i,t-1} \\ & + \beta_6 Exchange\_Rate\_Volatility_{i,t-1} + \beta_7 Trade\_Openness_{i,t} \\ & + \beta_8 \log(GDP\_per\_capita)_{i,t} + \beta_9 Output\_Gap_{i,t-1} \\ & + \beta_{10} Unemployment_{i,t} + \beta_{11} CBFS_{i,t-1} + \beta_{12} Corruption_{i,t} \\ & + \beta_{13} Transparency_{i,t} + \beta_{14} Debt\_Level_{i,t} + Money\_Supply_{i,t} + \varepsilon_{i,t} \end{aligned}$$

Even after inclusion of money supply into my modelling, *CBFS* does not appear in any of the top 10 models which is why I do not use it in the following estimations and will focus on the estimations using the *NNIBL* variable. (*Table 4.1.2.2*) *NNIBL* also shows similar results to the basic estimation as it appears in all of the top 10 models. (*Table 4.1.2.1*) The importance of *NNIBL* is now even higher with posterior inclusion probability of 100% and a one unit increase in the *NNIBL* ratio corresponds to 0.031 percentage point decrease in inflation rate showing that strength of central bank is important in controlling inflation rate. (*Table 4.1.2.3*) For the *NNIBL* estimation, PMP is also significantly higher with 75.4% for the top 10 models and 16.2% for the best model.

Money supply is estimated to be highly important, being included in all of the top 10 models. The posterior inclusion probability is 100%, same as for *NNIBL* and the posterior mean shows that a one percent increase in *Money supply* leads to a decrease in inflation by 0.036 percentage points. (*Table 4.1.2.3)*

As in the previous case without money supply, the most important variables hold the expected effect direction on inflation rate, confirming previous works. This time the posterior probabilities of inclusion are noticeably higher – 100% for *Exchange rate depreciation*, 99.9% for *Capital account openness*, 99.8% for *Inflation targeting regime* and 87.1% for *GDP per capita*. The PIP for other variables is a lot lower, the highest of them being *Trade openness* which is used in four of the top 10 models (*Table 4.1.2.1*) and with PIP of 37.1%. Similar results were observed for *Output gap* with the difference of magnitude and direction which is positive for this variable. *FX reserves* are also

included in the top 10 models in this estimation – specifically in three of them. The posterior inclusion probability is shown to be 35.1% which is still rather small but a large difference from the previous estimations. The magnitude of the effect was also shown to be negligible – close to zero. *Trade openness'*s PIP is not high at 37.1% but its posterior mean shows a negative effect on inflation, indicating that the prevailing effect is of being a brake on inflationary surprises.

The importance of the remaining variables was estimated to be small. This included *Fixed FX regime*, *Corruption*, *Transparency* and *Exchange rate*. Especially the lack of estimated importance of *Fixed FX regime* is contrary to the conclusions of previous research.

The estimation results indicate that a considerable model uncertainty is present. The posterior model probability (PMP) for the best model accounts only for 16.2% of the total posterior probability while the 10 best models account for 75.4% of the total posterior probability (*Table 4.1.2.1*). Usage of model averaging seems to be adequate in this case as means of tackling this uncertainty.

Following this result, I went on to test whether I the inclusion of exchange rate volatility showed any superior properties as tested in Benecká and Komárek (2014), but it was not used in any of the top 10 models and its posterior probability inclusion was only 3.4% arguing strongly against its inclusion. (*Appendix A.8.1*)

Table 4.1.2.1: Posterior Model Probabilities and variable inclusion for the top 10 models of the basic estimation with NNIBL and Monetary Base

Model Ranking	PMP	Capital account openness	Exchange rate depreciation	NNIBL	Money supply	Inflation targeting	GDP per capita	Trade openness	Output gap	FX Reserves	Debt level
1	**0.162**	-	+	-	-	-	-				
2	0.120	-	+	-	-	-	-			+	
3	0.089	-	+	-	-	-	-	-			
4	0.077	-	+	-	-	-	-		+		
5	0.065	-	+	-	-	-	-	-	+		
6	0.058	-	+	-	-	-	-			+	-
7	0.055	-	+	-	-	-	-		+	+	
8	0.055	-	+	-	-	-		-	+		
9	0.045	-	+	-	-	-	-				-
10	0.027	-	+	-	-	-		-			
Total	**0.754**										

Note: The "+" and "-" signs portray both the inclusion of the particular variable in each model as well as the direction of the effect where "+" stands for positive effect on inflation and "-" stands for negative effect on inflation.

Table 4.1.2.2: Posterior Model Probabilities and variable inclusion for the top 10 models of the basic estimation with CBFS and Monetary Base

Model Ranking	PMP	Inflation targeting	Capital account openness	Exchange rate depreciation	Money supply	Trade openness	FX Reserves	Output gap	Corruption	Debt level	Fixed FX regime
1	**0.090**	-	-	+	-	-					
2	0.071	-	-	+	-	-		+			
3	0.048	-	-	+	-						
4	0.027	-	-	+	-	-	+				
5	0.025	-	-	+	-	-					-
6	0.025	-	-	+	-		+				
7	0.023	-	-	+	-	-			-		
8	0.023	-	-	+	-	-				-	
9	0.020	-	-	+	-	-					
10	0.020	-	-	+	-						
Total	**0.372**										

Note: The "+" and "-" signs portray both the inclusion of the particular variable in each model as well as the direction of the effect where "+" stands for positive effect on inflation and "-" stands for negative effect on inflation.

Table 4.1.2.3 Results for BMA estimation that includes Money Supply, NNIBL as a proxy for central bank financial strength. Results reported for the top 100 models.

	PIP	Post Mean	Post SD
NNIBL	1.000	-0.031	0.003
Money supply	1.000	-0.036	0.007
Exchange rate depreciation (t-1)	1.000	8.047	1.547
Capital account openness	0.999	-0.708	0.165
Inflation targeting regime	0.998	-1.897	0.414
GDP per capita	0.871	-0.756	0.381
Trade openness	0.371	-0.545	0.802
Output gap (t-1)	0.357	0.044	0.066
FX reserves	0.351	0.000	0.000
Debt level	0.182	-0.002	0.005
Fixed FX regime	0.037	0.007	0.073
Corruption	0.036	0.000	0.006
Transparency	0.035	0.000	0.016
Exchange rate	0.034	0.000	0.000

Next, I tested whether the inclusion of *Central bank independence* (*CBI*) as a part of interaction term *NNIBL/CBI* improved the estimation compared to just *NNIBL*.

Table 4.1.2.4: Comparison of Posterior Inclusion Probabilities and Posterior Means of the estimations including NNIBL and NNIBL/CBI

	NNIBL (0.64)		**NNIBL/CBI (0.75)**	
	PIP	**Post Mean**	**PIP**	**Post Mean**
NNIBL(t-1)	1.000	-0.031		
NNIBL(t-1)/CBI			1.000	-0.020
Money supply	1.000	-0.036	1.000	-0.035
Exchange rate depreciation	1.000	8.047	1.000	8.131
Capital account openness	0.999	-0.708	0.999	-0.716
Inflation targeting	0.998	-1.897	0.998	-1.914
GDP per capita	0.871	-0.756	0.840	-0.717
Trade openness	0.371	-0.545	0.414	-0.631
Output gap(t-1)	0.357	0.044	0.401	0.052
FX reserves	**0.351**	**0.000**	**0.326**	**0.000**
Debt level	0.182	-0.002	0.174	-0.002
FX regime fixed	0.037	0.007	0.036	0.006
Corruption	0.036	0.000	0.036	0.000
Transparency	0.035	0.000	0.036	0.001
Exchange rate	0.034	0.000	0.034	0.000

Note: Order of variables in the table corresponds to PIP values of the first case. PMP values for the top 10 models in each case are included in brackets.

The new estimation showed no considerable difference, so I kept the *NNIBL* as my proxy for explaining central bank financial strength. (*Table 4.1.2.4*)

4.1.3 FX reserves lags

For further improvements, I wanted to check another Steiner's (2017) claim – that the effect of *FX reserves* is stronger with a two-year lag. As in his paper, I ran the estimation for zero lag, one lag and two lags using the variables selected by previous models and compared the results.

Table 4.1.3.1: FX reserves lag comparison

	0 (0.75)		1 (0.75)		2 (0.76)	
	PIP	**Post Mean**	**PIP**	**Post Mean**	**PIP**	**Post Mean**
NNIBL(t-1)	1.000	-0.031	1.000	-0.031	1.000	-0.031
Money supply	1.000	-0.036	1.000	-0.035	1.000	-0.035
Exchange rate depreciation	1.000	8.047	1.000	8.050	1.000	8.036
Capital account openness	0.999	-0.708	0.999	-0.710	0.999	-0.712
Inflation targeting	0.998	-1.897	0.998	-1.903	0.998	-1.910
GDP per capita	0.871	-0.756	0.862	-0.744	0.858	-0.738
Trade openness	0.371	-0.545	0.400	-0.593	0.407	-0.606
Output gap(t-1)	0.357	0.044	0.368	0.045	0.368	0.045
FX reserves	**0.351**	**0.000**				
FX reserves(t-1)			**0.291**	**0.000**		
FX reserves(t-2)					**0.265**	**0.000**
Debt level	0.182	-0.002	0.174	-0.002	0.172	-0.002
FX regime fixed	0.037	0.007	0.037	0.007	0.037	0.007
Corruption	0.036	0.000	0.036	0.000	0.036	0.000
Transparency	0.035	0.000	0.036	0.000	0.036	0.000
Exchange rate	0.034	0.000	0.034	0.000	0.034	0.000

Note: Order of variables in the table corresponds to PIP values of the first case. PMP values for the top 10 models in each case are included in brackets.

Neither one nor two lags had any noticeable improvements in the variables' posterior inclusion probabilities (PIPs), posterior mean, or posterior model probabilities. (*Table 4.1.3.1*) Due to the lack of found evidence for lag inclusion, I did not use lags in the following cases and kept the zero lag on *FX reserves*.

4.1.4 Inflation targeting economies

When the sample is limited only to economies employing inflation targeting regime, there are large differences in the estimated effects and importance of certain variables in determining inflation rate. The results are summarised in *Table 4.1.4.1*.

NNIBL no longer holds its previous high importance, instead its posterior inclusion probability is now only 14.6%. Another variable that lost its importance is *GDP per capita*. This seems to indicate that inflation targeting economies are not that far from each other in their *GDP per capita* which appears to be consistent with the posterior standard deviation that is now only 0.063. Exchange rate depreciation dropped to inclusion

probability of 28.5%. This change in conjunction with *NNIBL* could be potentially considered a confirmation of exchange rate being used as tool to affect central bank financial strength. For inflation targeting economies then central bank financial strength is less important and with that also exchange rate depreciation.

Output gap, Transparency, Trade openness, and Corruption are now given a lot higher importance than in previous estimations. Credibility is important for central banks especially in inflation targeting economies. In advanced economies, the emphasis is not only on helpfulness of policy but also its efficiency which is why *Corruption* and *Transparency* have a lot higher posterior inclusion probabilities. *Output gap*'s increase in importance could be a result of increased emphasis in inflation targeting economies on growth stimulation through monetary policy in order to close the output gap or to respond to inflationary pressures caused by positive output gap. *Trade openness's* function as brake on inflationary surprise is now also more pronounced with not only increased posterior inclusion probability but also with a higher posterior mean.

Table 4.1.4.1: Sample limited to inflation targeting economies

	PIP	**Post Mean**	**Post SD**
Output gap (t-1)	1.000	0.214	0.028
Capital account openness	1.000	-0.655	0.095
Money supply	0.983	-0.012	0.004
Trade openness	0.965	-1.306	0.445
Transparency	0.926	-0.157	0.066
Corruption	0.539	-0.031	0.034
Exchange rate depreciation (t-1)	0.285	0.586	1.068
FX reserves	0.257	0.000	0.000
NNIBL	0.146	0.074	0.216
Debt level	0.131	-0.001	0.002
Exchange rate	0.113	0.000	0.000
Fixed FX regime	0.049	0.006	0.064
GDP per capita	0.049	0.002	0.063

4.1.5 Other sample limitations

Next, I limited the sample to economies with fixed exchange rate regime to see if the effect of reserves increases as suggested by Steiner (2017). The results did not show the

mentioned effect – posterior inclusion probability decreased and there was no change in posterior mean. (*Appendix A.13*)

I also wanted to investigate the differences between advanced and emerging economies but my sample only offers 5 emerging economies as per Benecká and Komárek (2014) classification according to which advanced economies are those with GDP per capita above 2000 USD. The results can be found in appendix (*A.10* and *A.11*)

4.2 Robustness Check

For robustness check, I looked at the lags of the included variables as well as a comparison with a simple pooled OLS model.

Adding lags to the model causes only small differences in the results. The most notable differences are for non-interest-bearing liabilities (*NNIBL*), *Trade Openness* and *Transparency. NNIBL* keeps its posterior inclusion probability (PIP) constant at 100% but its Posterior mean increases with each lag. *Transparency*'s effect on inflation also increases with lags but the difference is smaller compared to that of *NNIBL.* In contrast, the importance of this variable increases to 35% with the second lag which is a considerable difference when compared to zero lag (3.5%) but the variable still falls into category of low importance. *Trade Openness* has the highest importance and effect on its first lag by a large margin both in PIP (78%) and posterior mean (-1.56).

Table 4.2.1 One and two period lags for the NNIBL, MB model

	NNIBL, MB		All lagged by 1 period		All lagged by 2 periods	
	PIP	Post Mean	PIP	Post Mean	PIP	Post Mean
NNIBL*	1.000	-0.031	1.000	-0.051	1.000	-0.112
Money supply	1.000	-0.036	0.999	-0.028	0.928	-0.026
Exchange rate depreciation*	1.000	8.047	0.978	6.640	0.117	0.483
Capital account openness	0.999	-0.708	0.998	-0.818	0.997	-1.066
Inflation targeting regime	0.998	-1.897	0.986	-2.160	0.677	-1.425
GDP per capita	0.871	-0.756	0.256	-0.167	0.108	-0.071
Trade openness	0.371	-0.545	0.779	-1.555	0.317	-0.636
Output gap*	0.357	0.044	0.158	0.017	0.033	-0.001
FX reserves	0.351	0.000	0.059	0.000	0.048	0.000
Debt level	0.182	-0.002	0.035	0.000	0.037	0.000
Fixed FX regime	0.037	0.007	0.031	0.001	0.031	0.001
Corruption	0.036	0.000	0.035	0.000	0.056	-0.003
Transparency	0.035	0.000	0.049	-0.005	0.350	-0.087
Exchange rate	0.034	0.000	0.034	0.000	0.036	0.000

Note: Variables marked with "" are lagged (t-1) for the base model (NNIBL, MB)*

There are also only small differences when the results of Pooled OLS and BMA are compared. Out of the top five variables with posterior inclusion probabilities above 99% in BMA, four are also the most statistically significant in Pooled OLS (*NNIBL, Money Supply, Exchange rate depreciation, Inflation targeting*). The differences in effect on inflation are negligible for these variables. *Capital account openness* is shown to not be significant even at 10% with p-value of 0.109. Another noticeable change is for *Debt level* – this variable was shown to be of low importance in BMA with PIP of 18.2% but in Pooled OLS, this variable is statistically significant at 10% significance level with a p-value of 0.088. The differences in the remaining variables are small.

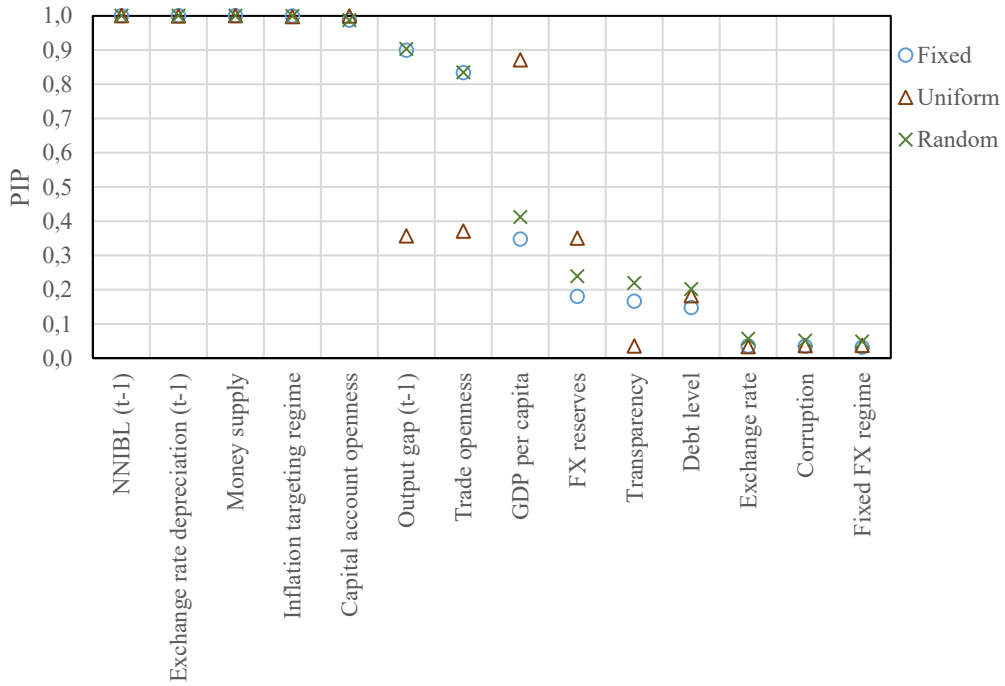
Table 4.2.2: Comparison Pooled OLS and BMA

	Pooled OLS		BMA	
	Estimate	**Pr(>|t|)**	**Post Mean**	**PIP**
(Intercept)	8.357	0.156		
NNIBL (t-1)	-0.031	0.000	-0.031	1.000
Money supply	-0.038	0.002	-0.036	1.000
Exchange rate depreciation (t-1)	8.355	0.001	8.047	1.000
Capital account openness	-0.623	0.109	-0.708	0.999
Inflation targeting regime	-2.052	0.007	-1.897	0.998
GDP per capita	-0.806	0.169	-0.756	0.871
Trade openness	-1.089	0.147	-0.545	0.371
Output gap (t-1)	0.114	0.250	0.044	0.357
FX reserves	0.000	0.104	0.000	0.351
Debt level	-0.010	0.088	-0.002	0.182
Fixed FX regime	0.223	0.624	0.007	0.037
Corruption	-0.020	0.659	0.000	0.036
Transparency	0.055	0.639	0.000	0.035
Exchange rate	0.000	0.601	0.000	0.034

Note: More detailed pooled OLS results can be found in appendix (A.16)

For sensitivity check I used different priors and compared the results for the model with NNIBL and MB. Some sensitivity to prior selection was revealed. The top five variables ranked by their importance are identical across the three models and so are the three variables of least importance. The posterior inclusion probabilities of the variables of medium importance are mostly the same for fixed and random priors but for uniform priors the PIPs are almost in reverse. (*Figure 4.2.1*)

Figure 4.2.1: Sensitivity check – Uniform, Fixed, and Random PMPs for the NNIBL, MB model



5 Conclusion

There is a large reserve accumulation and questions about their appropriateness arise as a consequence. Despite their undoubtable usefulness as a buffer in case of shocks that was tested during the Global Financial Crisis, holding inadequate amount of foreign exchange reserves can be harmful for the country's economy in numerous ways. High reserve accumulation can be taking resources away from other areas where they could be used more effectively, and it also exposes the domestic economy to a higher degree to external risks which can be costly to sterilize.

Maintaining foreign exchange reserves requires drawing on certain resources that have a potential for adverse effects. Issuance of domestic currency is a tool that helps in handling disruptions to these reserves. Usage of this tool can then lead to inflation. This specific

relationship is uncommon for paper titles but has been previously shown to be significant by works such as by Lin and Wang or by Steiner which found a positive effect.

In this work I attempted to find a relationship between foreign exchange reserves and inflation rate. The data used for this estimation were from the period 1996-2017 and involved 74 economies. Inflation was the dependent variable in all my estimations and is measured by Consumer Price Index. The primary independent variable is Foreign Exchange Reserves measured as a ratio to GDP. In my estimation I also dealt with model uncertainty that accompanies larger number of explanatory variables in panel data. Some degree of model uncertainty was revealed so a model averaging technique is the recommendable choice.

I started with a basic Bayesian Model Averaging estimation, choosing between central bank financial strength proxies. The control variables used in all my estimations are *GDP per capita, Inflation targeting regime, Central bank financial strength, Transparency, Exchange rate, Exchange rate depreciation, Capital account openness, Trade openness, Fixed FX regime* and *Output gap*. Other control variables are added and removed as needed. The better fitting proxy for my estimations were Non-Interest-Bearing Liabilities that were predicted to be highly important in estimating inflation rate meaning that central banks need to be strong in order to affect inflation appropriately. I followed up by adding monetary base which again was shown to be highly important and was used in all of the top 10 models, same as *NNIBL*, thus confirming results of previous research by Steiner (2017). Endogeneity is a potential issue for these two variables that I attempted to cope with by employing a one-year lag. I followed up by adding monetary base to my estimations which was shown to be highly important with a small negative effect, implying that monetary base is not sterilized from inflation rate. There is a possible endogeneity issue with this variable caused by the amount of information that is reflected on monetary base.

There are considerable changes in explanatory power of independent variables when sample limitations are applied. For inflation targeting economies Output gap, Transparency, Trade openness and Corruption are considerably more important in

determining inflation rate accentuating the role of policy efficiency in advanced economies.

Throughout my estimations, Foreign exchange reserves remained on a low importance level with posterior inclusion probability below 50%. The posterior mean is approximately zero. The PIP also does not increase with added lags in the case of limiting the sample to inflation targeting economies nor to fixed exchange rate regime economies. Due to the number of effects in economy, general cross-country estimations may not be able to reveal the true relationships and country-specific approach may be needed. Furthermore, data quality and completeness for emerging economies makes these estimations even more challenging and also steers into potential selection bias. The amount of literature on this top leaves a lot of room for future research to explore both in the field of foreign exchange reserves and Bayesian Model Averaging.

In spite of the limitations in this thesis, I believe that this work contributes to the discussion mainly with its usage of the relatively new estimation method, Bayesian Model Averaging that accounts for model, and with its usage of updated data, newly available proxies for central bank financial strength, as well as the usage of money supply in estimations. The thesis showed the importance of central bank financial strength in controlling the inflation rate, and also the importance of money supply, confirming Steiner's (2017) conclusion that inflation rate is far from sterilized from money supply. Furthermore, sample limitations revealed the different importance of certain inflation determinants for inflation targeting economies, supporting previous suggestions that more area-specific approach may be required. Additionally, based on the revealed model uncertainty, I recommend taking advantage of the available computing power and performing estimations using model averaging, especially for models with a high number of explanatory variables, as opposed to using the most common technique – OLS.

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Appendix

A.1.1: Zero FX reserves lags, CBFS

	PIP	Post Mean	Post SD	Cond.Pos.Sign	Idx
Capital account openness	0.991	-1.872	0.489	0.000	4
Debt level	0.987	0.057	0.016	1.000	10
Exchange rate depreciation (t-1)	0.609	5.286	4.861	1.000	6
Inflation targeting regime	0.454	-1.398	1.731	0.000	1
Trade openness	0.376	-1.446	2.094	0.000	3
Transparency	0.170	-0.053	0.136	0.002	8
CBFS (t-1)	0.166	-0.048	0.124	0.000	7
Exchange rate	0.161	0.000	0.001	1.000	5
FX reserves	0.145	0.000	0.000	0.000	9
GDP per capita	0.115	-0.152	0.503	0.001	2
Corruption	0.098	0.015	0.054	0.999	12
Fixed FX regime	0.051	-0.063	0.404	0.092	13
Output gap (t-1)	0.033	-0.002	0.035	0.274	11

Mean no. regressors	**Draws**	**Burnins**	**Time**	**No. models visited**
4.3556	8192	0	0.3171492 secs	8192
Modelspace 2^K	**% visited**	**% Topmodels**	**CorrPMP**	**No. Obs.**
8192	100	1.2	NA	1324
Model Prior	**g-Prior**	**Shrinkage-Stats**		
uniform / 6.5	BRIC	Av=0.9992		

A.1.2: Zero FX reserves lags, CBFS – top 10 models PMPs

Model No.	PMP
1	0.076
2	0.060
3	0.051
4	0.050
5	0.037
6	0.033
7	0.032
8	0.026
9	0.022
10	0.019
Total	**0.406**

A.2.1: Zero FX reserves lags, NNIBL

	PIP	Post Mean	Post SD	Cond.Pos.Sign	Idx
NNIBL (t-1)	0,859	-0,027	0,014	0,000	7
Capital account openness	0,777	-1,146	0,751	0,000	4
GDP per capita	0,599	-1,284	1,220	0,000	2
Exchange rate depreciation (t-1)	0,470	3,461	4,158	1,000	6
Inflation targeting regime	0,379	-1,066	1,549	0,000	1
Trade openness	0,197	-0,611	1,407	0,000	3
Debt level	0,173	0,005	0,012	1,000	10
Transparency	0,130	-0,034	0,106	0,015	8
Exchange rate	0,077	0,000	0,001	1,000	5
Fixed FX regime	0,069	-0,105	0,529	0,078	13
FX reserves	0,048	0,000	0,000	0,000	9
Corruption	0,045	0,004	0,026	0,934	12
Output gap (t-1)	0,036	-0,003	0,035	0,189	11

Mean no. regressors	**Draws**	**Burnins**	**Time**	**No. models visited**
3,8595	8192	0	0,3371298 secs	8192
Modelspace 2^K	**% visited**	**% Topmodels**	**CorrPMP**	**No. Obs.**
8192	100	1,2	NA	1178
Model Prior	**g-Prior**	**Shrinkage-Stats**		
uniform / 6,5	BRIC	Av=0,9992		

A.2.2: Zero FX reserves lags, NNIBL – top 10 models PMPs

Model No.	PMP
1	0,090
2	0,071
3	0,048
4	0,027
5	0,025
6	0,025
7	0,023
8	0,023
9	0,020
10	0,020
Total	**0,372**

A.3.1: Zero FX reserves lags, CBFS, MB

	PIP	Post Mean	Post SD	Cond.Pos.Sign	Idx
Exchange rate depreciation (t-1)	1.000	12.413	1.500	1.000	6
Money supply	1.000	-0.038	0.006	0.000	14
Capital account openness	1.000	-0.958	0.137	0.000	4
Inflation targeting regime	1.000	-2.049	0.411	0.000	1
Trade openness	0.721	-1.224	0.897	0.000	3
FX reserves	0.228	0.000	0.000	1.000	9
Output gap (t-1)	0.165	0.017	0.043	1.000	11
Corruption	0.160	-0.009	0.025	0.000	12
Debt level	0.146	-0.002	0.004	0.000	10
Fixed FX regime	0.119	-0.077	0.246	0.000	13
GDP per capita	0.108	-0.047	0.162	0.000	2
Transparency	0.036	0.001	0.016	0.974	8
Exchange rate	0.034	0.000	0.000	0.000	5
CBFS (t-1)	0.031	0.000	0.009	0.985	7

Mean no. regressors	**Draws**	**Burnins**	**Time**	**No. models visited**
5.7475	16384	0	0.623363 secs	16384
Modelspace 2^K	**% visited**	**% Topmodels**	**CorrPMP**	**No. Obs.**
16384	100	0.61	NA	1149
Model Prior	**g-Prior**	**Shrinkage-Stats**		
uniform / 7	BRIC	Av=0.9991		

A.3.2: Zero FX reserves lags, CBFS, MB – top 10 models PMPs

Model No.	**PMP**
1	0.309
2	0.063
3	0.057
4	0.050
5	0.041
6	0.034
7	0.030
8	0.028
9	0.021
10	0.018
Total	**0.652**

A.4.1: Zero FX reserves lag, NNIBL, MB

	PIP	Post Mean	Post SD	Cond.Pos.Sign	Idx
NNIBL (t-1)	1.000	-0.031	0.003	0.000	7
Money supply	1.000	-0.036	0.007	0.000	13
Exchange rate depreciation (t-1)	1.000	8.047	1.547	1.000	6
Capital account openness	0.999	-0.708	0.165	0.000	4
Inflation targeting regime	0.998	-1.897	0.414	0.000	1
GDP per capita	0.871	-0.756	0.381	0.000	2
Trade openness	0.371	-0.545	0.802	0.000	3
Output gap (t-1)	0.357	0.044	0.066	1.000	11
FX reserves	0.351	0.000	0.000	1.000	9
Debt level	0.182	-0.002	0.005	0.000	10
Fixed FX regime	0.037	0.007	0.073	1.000	14
Corruption	0.036	0.000	0.006	0.391	12
Transparency	0.035	0.000	0.016	0.666	8
Exchange rate	0.034	0.000	0.000	0.049	5

Mean no. regressors	**Draws**	**Burnins**	**Time**	**No. models visited**
7.2704	16384	0	0.6303151 secs	16384
Modelspace 2^K	**% visited**	**% Topmodels**	**CorrPMP**	**No. Obs.**
16384	100	0.61	NA	1015
Model Prior	**g-Prior**	**Shrinkage-Stats**		
uniform / 7	BRIC	Av=0.999		

A.4.2: Zero FX reserves lag, NNIBL, MB – top 10 models PMPs

Model No.	**PMP**
1	0.162
2	0.120
3	0.089
4	0.077
5	0.065
6	0.058
7	0.055
8	0.055
9	0.045
10	0.027
Total	**0.754**

A.5.1: One FX reserves lag NNIBL, MB

	PIP	Post Mean	Post SD	Cond.Pos.Sign	Idx
NNIBL (t-1)	1.000	-0.031	0.003	0.000	7
Money supply	1.000	-0.035	0.006	0.000	13
Exchange rate depreciation (t-1)	1.000	8.050	1.547	1.000	6
Capital account openness	0.999	-0.710	0.165	0.000	4
Inflation targeting regime	0.998	-1.903	0.416	0.000	1
GDP per capita	0.862	-0.744	0.385	0.000	2
Trade openness	0.400	-0.593	0.822	0.000	3
Output gap (t-1)	0.368	0.045	0.067	1.000	11
FX reserves (t-1)	0.291	0.000	0.000	1.000	9
Debt level	0.174	-0.002	0.005	0.000	10
Fixed FX regime	0.037	0.007	0.073	1.000	14
Corruption	0.036	0.000	0.006	0.389	12
Transparency	0.036	0.000	0.016	0.682	8
Exchange rate	0.034	0.000	0.000	0.052	5

Mean no. regressors	**Draws**	**Burnins**	**Time**	**No. models visited**
7.2345	16384	0	0.6263578 secs	16384
Modelspace 2^K	**% visited**	**% Topmodels**	**CorrPMP**	**No. Obs.**
16384	100	0.61	NA	1016
Model Prior	**g-Prior**	**Shrinkage-Stats**		
uniform / 7	BRIC	Av=0.999		

A.5.2: One FX reserves lag NNIBL, MB – top 10 models PMPs

Model No.	**PMP**
1	0.177
2	0.098
3	0.092
4	0.084
5	0.071
6	0.060
7	0.050
8	0.046
9	0.045
10	0.030
Total	**0.752**

A.6.1: Two FX reserves lags NNIBL, MB

	PIP	Post Mean	Post SD	Cond.Pos.Sign	Idx
NNIBL (t-1)	1.000	-0.031	0.003	0.000	7
Money supply	1.000	-0.035	0.006	0.000	13
Exchange rate depreciation (t-1)	1.000	8.036	1.549	1.000	6
Capital account openness	0.999	-0.712	0.165	0.000	4
Inflation targeting regime	0.998	-1.910	0.415	0.000	1
GDP per capita	0.858	-0.738	0.387	0.000	2
Trade openness	0.407	-0.606	0.827	0.000	3
Output gap (t-1)	0.368	0.045	0.067	1.000	11
FX reserves (t-2)	0.265	0.000	0.000	1.000	9
Debt level	0.172	-0.002	0.005	0.000	10
Fixed FX regime	0.037	0.007	0.073	1.000	14
Corruption	0.036	0.000	0.006	0.390	12
Transparency	0.036	0.000	0.016	0.683	8
Exchange rate	0.034	0.000	0.000	0.054	5

Mean no. regressors	**Draws**	**Burnins**	**Time**	**No. models visited**
7.2104	16384	0	0.625385 secs	16384
Modelspace 2^K	**% visited**	**% Topmodels**	**CorrPMP**	**No. Obs.**
16384	100	0.61	NA	1015
Model Prior	**g-Prior**	**Shrinkage-Stats**		
uniform / 7	BRIC	Av=0.999		

A.6.2: Two FX reserves lags NNIBL, MB – top 10 models PMPs

Model No.	**PMP**
1	0.184
2	0.101
3	0.087
4	0.083
5	0.073
6	0.062
7	0.052
8	0.042
9	0.041
10	0.031
Total	**0.755**

A.7.1: Zero FX reserves lags, NNIBL/CBI

	PIP	Post Mean	Post SD	Cond.Pos.Sign	Idx
NNIBL (t-1)/CBI	1.000	-0.020	0.002	0.000	14
Money supply	1.000	-0.035	0.007	0.000	12
Exchange rate depreciation (t-1)	1.000	8.131	1.552	1.000	6
Capital account openness	0.999	-0.716	0.167	0.000	4
Inflation targeting regime	0.998	-1.914	0.420	0.000	1
GDP per capita	0.840	-0.717	0.397	0.000	2
Trade openness	0.414	-0.631	0.849	0.000	3
Output gap (t-1)	0.401	0.052	0.071	1.000	10
FX reserves	0.326	0.000	0.000	1.000	8
Debt level	0.174	-0.002	0.005	0.000	9
Transparency	0.036	0.001	0.017	0.710	7
Corruption	0.036	0.000	0.006	0.361	11
Fixed FX regime	0.036	0.006	0.070	1.000	13
Exchange rate	0.034	0.000	0.000	0.052	5

Mean no. regressors	**Draws**	**Burnins**	**Time**	**No. models visited**
7.2939	16384	0	0.6143548 secs	16384
Modelspace 2^K	**% visited**	**% Topmodels**	**CorrPMP**	**No. Obs.**
16384	100	0.61	NA	1011
Model Prior	**g-Prior**	**Shrinkage-Stats**		
uniform / 7	BRIC	Av=0.999		

A.7.2: Zero FX reserves lags, NNIBL/CBI – top 10 models PMPs

Model No.	**PMP**
1	0.147
2	0.105
3	0.088
4	0.080
5	0.076
6	0.074
7	0.054
8	0.052
9	0.042
10	0.031
Total	**0.749**

A.8.1: Zero FX reserves lags, Exchange rate volatility

	PIP	Post Mean	Post SD	Cond.Pos.Sign	Idx
NNIBL (t-1)	1.000	-0.031	0.003	0.000	8
Money supply	1.000	-0.036	0.007	0.000	14
Exchange rate depreciation (t-1)	1.000	8.047	1.550	1.000	7
Capital account openness	0.999	-0.708	0.165	0.000	4
Inflation targeting regime	0.998	-1.897	0.415	0.000	1
GDP per capita	0.870	-0.755	0.382	0.000	2
Trade openness	0.375	-0.550	0.804	0.000	3
Output gap (t-1)	0.357	0.044	0.066	1.000	12
FX reserves	0.348	0.000	0.000	1.000	10
Debt level	0.181	-0.002	0.005	0.000	11
Fixed FX regime	0.038	0.008	0.074	1.000	15
Corruption	0.037	0.000	0.006	0.379	13
Exchange rate	0.035	0.000	0.000	0.045	6
Exchange rate volatility	0.034	0.000	0.001	0.126	5
Transparency	0.034	0.000	0.016	0.665	9

Mean no. regressors	**Draws**	**Burnins**	**Time**	**No. models visited**
7.3041	1000000	500000	55.18999secs	280957
Modelspace 2^K	**% visited**	**% Topmodels**	**CorrPMP**	**No. Obs.**
32768	857	98	1.000	1015
Model Prior	**g-Prior**	**Shrinkage-Stats**		
uniform / 7.5	BRIC	Av=0.999		

A.8.2: Zero FX reserves lags, Exchange rate volatility – top 10 models PMPs

Model No.	PMP
1	0.157
2	0.116
3	0.086
4	0.074
5	0.062
6	0.056
7	0.054
8	0.053
9	0.044
10	0.026
Total	**0.728**

A.9.1: Zero FX reserves lags, Inflation targeting economies only

	PIP	Post Mean	Post SD	Cond.Pos.Sign	Idx
Output gap (t-1)	1.000	0.214	0.028	1.000	10
Capital account openness	1.000	-0.655	0.095	0.000	3
Money supply	0.983	-0.012	0.004	0.000	13
Trade openness	0.965	-1.306	0.445	0.000	2
Transparency	0.926	-0.157	0.066	0.000	7
Corruption	0.539	-0.031	0.034	0.000	11
Exchange rate depreciation (t-1)	0.285	0.586	1.068	1.000	5
FX reserves	0.257	0.000	0.000	0.996	8
NNIBL (t-1)	0.146	0.074	0.216	1.000	6
Debt level	0.131	-0.001	0.002	0.000	9
Exchange rate	0.113	0.000	0.000	0.000	4
Fixed FX regime	0.049	0.006	0.064	0.997	12
GDP per capita	0.049	0.002	0.063	0.809	1

Mean no. regressors	**Draws**	**Burnins**	**Time**	**No. models visited**
6.4435	8192	0	0.3271248 secs	8192
Modelspace 2^K	**% visited**	**% Topmodels**	**CorrPMP**	**No. Obs.**
8192	100	1.2	NA	483
Model Prior	**g-Prior**	**Shrinkage-Stats**		
uniform / 6.5	BRIC	Av=0.9979		

A.9.2: Zero FX reserves lags, Inflation targeting economies only – top 10 models PMPs

Model No.	**PMP**
1	0.153
2	0.147
3	0.067
4	0.056
5	0.046
6	0.038
7	0.023
8	0.020
9	0.019
10	0.019
Total	**0.588**

A.10.1: Zero FX reserves lags, Advanced economies only

	PIP	Post Mean	Post SD	Cond.Pos.Sign	Idx
NNIBL (t-1)	1.000	-0.031	0.003	0.000	7
Money supply	1.000	-0.035	0.007	0.000	14
Exchange rate depreciation (t-1)	1.000	8.358	1.546	1.000	6
Capital account openness	0.999	-0.719	0.164	0.000	4
Inflation targeting regime	0.998	-1.873	0.418	0.000	1
GDP per capita	0.908	-0.909	0.401	0.000	2
FX reserves	0.383	0.000	0.000	1.000	9
Trade openness	0.356	-0.510	0.776	0.000	3
Debt level	0.301	-0.004	0.006	0.000	10
Output gap (t-1)	0.280	0.033	0.060	1.000	11
Fixed FX regime	0.063	-0.031	0.159	0.001	13
Transparency	0.036	0.001	0.016	0.800	8
Corruption	0.035	0.000	0.006	0.402	12
Exchange rate	0.031	0.000	0.000	0.618	5

Mean no. regressors	**Draws**	**Burnins**	**Time**	**No. models visited**
7.39	16384	0	0.6123621 secs	16384
Modelspace 2^K	**% visited**	**% Topmodels**	**CorrPMP**	**No. Obs.**
16384	100	0.61	NA	989
Model Prior	**g-Prior**	**Shrinkage-Stats**		
uniform / 7	BRIC	Av=0.999		

A.10.2: Zero FX reserves lags, Advanced economies only – top 10 models PMPs

Model No.	**PMP**
1	0.143
2	0.114
3	0.101
4	0.092
5	0.072
6	0.053
7	0.052
8	0.039
9	0.037
10	0.032
Total	**0.734**

A.11.1: Zero FX reserves lags, Emerging economies only

	PIP	Post Mean	Post SD	Cond.Pos.Sign	Idx
GDP per capita	0.332	-3.721	7.081	0.001	1
Money supply	0.286	-0.060	0.136	0.052	13
Output gap (t-1)	0.259	0.461	0.982	1.000	10
Fixed FX regime	0.223	-1.132	2.726	0.000	12
Capital account openness	0.174	0.412	1.250	0.952	3
Corruption	0.173	0.110	0.347	0.874	11
Trade openness	0.149	3.834	16.402	0.838	2
Debt level	0.140	0.004	0.019	0.852	9
FX reserves	0.131	0.000	0.000	0.430	8
Exchange rate	0.125	0.000	0.002	0.480	4
Transparency	0.121	-0.097	0.661	0.391	7
NNIBL (t-1)	0.092	-0.062	1.968	0.641	6
Exchange rate depreciation (t-1)	0.076	0.309	6.242	0.842	5

Mean no. regressors	**Draws**	**Burnins**	**Time**	**No. models visited**
2.2816	8192	0	0.303225 secs	8192
Modelspace 2^K	**% visited**	**% Topmodels**	**CorrPMP**	**No. Obs.**
8192	100	1.2	NA	25
Model Prior	**g-Prior**	**Shrinkage-Stats**		
uniform / 6.5	BRIC	Av=0.9941		

A.11.2: Zero FX reserves lags, Emerging economies only – top 10 models PMPs

Model No.	**PMP**
1	0.131
2	0.05
3	0.029
4	0.029
5	0.022
6	0.02
7	0.02
8	0.017
9	0.015
10	0.015
Total	**0.347**

Table A.12: Posterior Model Probabilities and variable inclusion for the top 10 models of the estimation with NNIBL/CBI and Monetary Base

Model Ranking	PMP	Capital account openness	Exchange rate depreciation	Money supply	NNIBL/CBI	Inflation targeting	GDP per capita	Trade openness	Output gap	FX Reserves	Debt level
1	**0.147**	-	+	-	-	-	-				
2	0.105	-	+	-	-	-	-			+	
3	0.088	-	+	-	-	-	-	-			
4	0.080	-	+	-	-	-	-		+		
5	0.076	-	+	-	-	-	-	-	+		
6	0.074	-	+	-	-	-		-	+		
7	0.054	-	+	-	-	-	-		+	+	
8	0.052	-	+	-	-	-	-			+	-
9	0.042	-	+	-	-	-	-				-
10	0.031	-	+	-	-	-		-			
Total	**0.749**										

Note: The "+" and "-" signs portray both the inclusion of the particular variable in each model as well as the direction of the effect where "+" stands for positive effect on inflation and "-" stands for negative effect on inflation.

A.13.1: Zero FX reserves lags, Fixed exchange rate regime economies only

	PIP	Post Mean	Post SD	Cond.Pos.Sign	Idx
NNIBL (t-1)	1.000	-0.031	0.004	0.000	7
Money supply	1.000	-0.060	0.011	0.000	13
Capital account openness	0.999	-1.166	0.217	0.000	4
Exchange rate depreciation (t-1)	0.711	5.719	4.376	1.000	6
Debt level	0.379	-0.010	0.015	0.000	10
Inflation targeting regime	0.080	-0.078	0.375	0.000	1
FX reserves	0.066	0.000	0.000	1.000	9
Output gap (t-1)	0.064	0.006	0.036	1.000	11
GDP per capita	0.059	-0.019	0.136	0.000	2
Corruption	0.057	-0.001	0.012	0.009	12
Transparency	0.051	0.001	0.026	0.512	8
Trade openness	0.048	-0.013	0.235	0.050	3
Exchange rate	0.047	0.000	0.000	0.994	5

Mean no. regressors	**Draws**	**Burnins**	**Time**	**No. models visited**
4.562	8192	0	0.3146598 secs	8192
Modelspace 2^K	**% visited**	**% Topmodels**	**CorrPMP**	**No. Obs.**
8192	100	1.2	NA	434
Model Prior	**g-Prior**	**Shrinkage-Stats**		
uniform / 6.5	BRIC	Av=0.9977		

A.13.2: Zero FX reserves lags, Fixed exchange rate regime economies only – top 10 models PMPs

Model No.	**PMP**
1	0.286
2	0.156
3	0.094
4	0.079
5	0.023
6	0.022
7	0.021
8	0.015
9	0.014
10	0.014
Total	**0.726**

A.14: Descriptive statistics of Inflation and FX reserves

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
Inflation (%)	1626	8.00	3.08	37.70	-11.70	1058.37
FX reserves (ratio to GDP)	1330	56034.03	14450.64	141747.12	17.71	1258172.44
GDP per capita (USD)	1628	22462.61	19349.08	17425.00	550.39	93905.42
Trade openness (export/GDP)	1625	0.44	0.37	0.33	0.00	2.31
Capital account openness	1628	0.97	1.33	1.49	-1.91	2.36
Transparency	1480	6.93	6.50	3.84	0.00	15.00
Debt level (%)	1598	50.55	44.04	35.90	-15.68	19.90
Output gap (%)	1628	2.13	2.91	3.48	-32.00	43.30
Exchange rate (USD)	1628	95.72	3.23	332.46	0.08	3050.98
Exchange rate depreciation (USD)	1628	1.05	1.00	0.27	-20.70	60.73
Exchange rate volatility (USD)	1156	7.33	0.07	31.44	0.00	350.79
Money supply (ratio M3 to GDP)	1156	64.14	57.19	34.36	0.00	242.38

A.15: Correlation matrix

	Inflation	Inflation targeting	GDP per capita	Trade openess	Capital account openess	Exchange rate	Exchange rate depreciation	NNIBL	Transpa-rency	FX reserves	Debt level	Output gap	Corrup-tion	Money supply	Fixed FX regime
Inflation	1.000	-0.308	-0.382	-0.191	-0.383	0.108	0.227	-0.292	-0.298	-0.088	-0.129	0.218	-0.048	-0.288	-0.013
Inflation targeting	-0.308	1.000	0.383	-0.044	0.359	-0.006	-0.091	0.029	**0.789**	0.004	0.115	-0.395	-0.085	0.096	0.061
GDP per capita	-0.382	0.383	1.000	0.361	0.635	-0.305	-0.082	0.000	0.379	0.168	-0.034	-0.343	0.285	0.340	-0.003
Trade openess	-0.191	-0.044	0.361	1.000	0.234	-0.163	-0.055	0.031	0.067	-0.062	0.047	-0.013	0.177	0.192	0.003
Capital account openess	-0.383	0.359	0.635	0.234	1.000	-0.201	-0.158	0.065	0.380	0.046	0.102	-0.300	0.119	0.167	-0.040
Exchange rate	0.108	-0.006	-0.305	-0.163	-0.201	1.000	0.073	0.008	-0.060	-0.047	-0.010	0.113	-0.080	-0.168	0.089
Exchange rate depreciation	0.227	-0.091	-0.082	-0.055	-0.158	0.073	1.000	-0.120	-0.065	0.012	0.073	-0.028	-0.082	-0.035	-0.005
NNIBL	-0.292	0.029	0.000	0.031	0.065	0.008	-0.120	1.000	0.027	0.011	0.003	0.071	0.071	0.012	0.031
Transparency	-0.298	**0.789**	0.379	0.067	0.380	-0.060	-0.065	0.027	1.000	0.054	0.209	-0.478	-0.158	0.206	0.091
FX reserves	-0.088	0.004	0.168	-0.062	0.046	-0.047	0.012	0.011	0.054	1.000	0.240	-0.053	-0.036	0.570	0.115
Debt level	-0.129	0.115	-0.034	0.047	0.102	-0.010	0.073	0.003	0.209	0.240	1.000	-0.266	-0.391	0.314	0.153
Output gap	0.218	-0.395	-0.343	-0.013	-0.300	0.113	-0.028	0.071	-0.478	-0.053	-0.266	1.000	0.143	-0.142	0.015
Corruption	-0.048	-0.085	0.285	0.177	0.119	-0.080	-0.082	0.071	-0.158	-0.036	-0.391	0.143	1.000	-0.126	-0.019
Money supply	-0.288	0.096	0.340	0.192	0.167	-0.168	-0.035	0.012	0.206	0.570	0.314	-0.142	-0.126	1.000	0.098
Fixed FX regime	-0.013	0.061	-0.003	0.003	-0.040	0.089	-0.005	0.031	0.091	0.115	0.153	0.015	-0.019	0.098	1.000

A.16: Pooled OLS

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	8.357	5.894	1.418	0.156
NNIBL (t-1)	-0.031	0.002	-13.982	0.000
Money supply	-0.038	0.013	-3.034	0.002
Exchange rate depreciation (t-1)	8.355	2.413	3.462	0.001
Capital account openness	-0.623	0.389	-1.601	0.109
Inflation targeting regime	-2.052	0.761	-2.694	0.007
GDP per capita	-0.806	0.585	-1.377	0.169
Trade openness	-1.089	0.752	-1.449	0.147
Output gap (t-1)	0.114	0.099	1.151	0.250
FX reserves	0.000	0.000	1.624	0.104
Debt level	-0.010	0.006	-1.705	0.088
Fixed FX regime	0.223	0.455	0.491	0.624
Corruption	-0.020	0.046	-0.442	0.659
Transparency	0.055	0.117	0.469	0.639
Exchange rate	0.000	0.001	-0.523	0.601

R^2= 0.33727