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MASTER'S THESIS

Gold in Central Bank Reserves and Price Stability

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Declaration of Authorship

The author hereby declares that he compiled this thesis independently, using only the listed resources and literature, and the thesis has not been used to obtain a different or the same degree.

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Prague, January 2, 2019

Signature

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Abstract

There is a traditional view that central banks should hold enough gold in their reserves to be considered financially secure and keep low inflation. However, after the fall of the Bretton-Woods system, many central banks have been decreasing its gold reserves by converting gold into other assets and still they do not experience high inflation. This thesis aims to answer the question if gold reserves of central banks indeed positively affect price stability. We use the panel data for 110 countries for the period from 2000 to 2016. We find that there is a significant negative effect of central banks' gold reserves on inflation but only if we control the proxy variables for the financial strength of central banks. Furthermore, the significance holds only for the inflation-targeting countries, there are no significant effects for the whole data sample.

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Acronyms

CAGR Compounded Annual Growth Rate

CBFS Central Banks Financial Strength

CBI Central Banks Independence

CNB Czech National Bank

EGLS Estimated Generalized Least Squares

FGLS Feasible Generalized Least Squares

LBMA London Bullion Market Association

LM Lagrange Multiplier

LSDV Least Squared Dummy Variables

OECD Organization for Economic Co-operation and Development

OLS Ordinary Least Squares

PCSEs Panel Corrected Standard Errors

ROAA Return On Average Assets

ROAE Return On Average Equity

Master's Thesis Proposal

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Proposed topic	Gold in Central Bank Reserves and Price Stability

Motivation Recently, there have been a lot of discussions of the relationship between price stability and a size of gold reserves in Central Banks. Two main roles of Central Banks are to influence short-term interest rates, debt amount, the supply of money and to regulate and supervise financial markets. Inflation targeting is a monetary policy used by central banks to control the price level. Advocates of inflation targeting claim that it helps to ensure the economic stability and prosperity more than other policies, such as targeting the money supply. As measuring the interest rates by which Central Banks control inflation is easier, faster and more accurate than money supply.

One of the advantages of inflation targeting is that it is the policy of both "the rule" and "the discretion". Central banks set their targets and compare it with the actual inflation rates, in case of discretion they use interest rates and foreign exchange interventions to reach the target. Purchasing and selling of foreign reserves and gold by Central banks from commercial banks influence the interest rates and monetary base. One question that arises is what is the size of foreign reserves and amount of gold that should be held by Central Banks to ensure the price stability. Another question that is often discussed is whether gold is stable enough to hold it as banks reserves and what amount of it would be sufficient.

The role of gold as a part of reserves has been decreasing during last decades after the fall of Bretton-Woods system. Nevertheless, gold is still one of the largest parts of Central Banks' reserves in many countries. Baur (2016) claims that many Central Banks around the world consider gold as a stable asset and therefore are interested in the movements of its prices. Furthermore, they directly and indirectly affect the price of gold. Though, there were signed four Central Bank Gold Agreements during the period of 1999-2012 to diminish their influence on gold prices. Nugee (2000) suggests four main reasons for storing gold as reserves. Firstly, gold is considered as a very stable asset that does not lose value and even appreciates sometimes in times of uncertainty. Secondly, gold is able to keep its value against inflation and serves as a unit of exchange between different countries. Thirdly, credit risk is absent, as there is no counterparty that can default. Last but not least, there is a traditional and historical view that gold can be considered as a stable back up for domestic currency due to its role before and during Bretton-Woods system.

However, Nugee (2000) also describes many disadvantages of gold. The weakness of gold prices during last forty years reduces the demand for it. Also, gold is expensive to store and safeguard. Moreover, Lucey and Li (2015) in their study of whether gold can be considered as safe haven asset conclude that during economic instability gold does not behave as a safe-haven asset, while silver, platinum and palladium do.

The objective of this thesis is to investigate if gold can be considered as a stable enough asset for Central Banks in order to use it as a tool to reach their inflation target. For this purpose, the analysis of the relationship between price stability and a size of gold reserves in Central Banks in the developed countries will be conducted.

Hypotheses

> Hypothesis #1: The policies of Central Banks with a higher proportion of gold in their reserves achieve higher price stability.

Methodology In this thesis, I am going to use the panel data for the countries that have not adopted inflation targeting and the countries that adopted officially inflation targeting policies after 1990 when first three countries – New Zeland, Canada, and the United Kingdom started to use this policy. I will create the model which will analyze the dependence of inflation rate and gold reserves held in central banks. This model should allow me to conclude if gold can be considered as a stable enough asset to be used to achieve the price stability. Additionally, I will create the separate regression to analyze the effects of the gold reserves on the price stability only for the counties that have adopted inflation targeting. As for the dependent variable in this regression, I will use the inflation gap that will show the deviation of real inflation from the target one. Additionally, as one of the independent variables, I will create the dummy variable that will show the years when the policy began to be used due to the fact that the countries implemented it in different years. To test the first hypothesis, I will use the proportion of gold in the reserves of Central Banks, as one of the independent variables. To test the second hypothesis, the ratio of foreign exchange reserves to total reserves will be used. Finally, for the third hypothesis, one of the independent variables will be the proportion of US Dollar reserves in the foreign exchange reserves. The data is expected to be obtained from large data sources, such as WorldBank, European Union Open Data Portal, Data.gov, IMF data source and other big sources. To find other independent variables that can affect my dependent variable, I will review the literature concerning the subject of this thesis before constructing the models. For example, Bleaney (1999) uses such independent variables as – openness, GDP per capita, size of the population, size of the land area, exchange rate regime - to analyze what factors influence the rate of inflation. As I am going to use the panel data, I will find the appropriate model using three econometric tests that allow choosing between fixed, random or pooled OLS models. Finally, after the models will be created and found to be significant, I will check their robustness using standard econometric tests.

Expected Contribution As it is described in the motivation, there is no commonly excepted view on the way how gold reserves affect price stability. Therefore, with this thesis, I am going to find significant evidence if gold can be considered as a stable asset to achieve the price stability and to be used in inflation targeting. This should enable me to conclude whether Central Banks should switch from gold to other foreign currencies, such as for example US dollar, or widen their gold reserves.

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Author Supervisor

Chapter 1

Introduction

Central banks around the world have always been holding a significant part of their reserves in gold. There have been many discussions about the importance of gold reserves held in central banks. The vast majority of economists believe that central banks should keep their reserves in gold because gold is believed to hold its value against inflation. However, more importantly there exists a common belief that if a central bank has more reserves held in gold, then it has more power and it is financially stronger. The high relevance of gold as an asset appeared due to its essential role throughout the history. Since the beginning of time, gold was playing the role of one of the most important and valuable things in people's life. People were building empires and starting wars because of gold. Gold was the most valuable and popular unit of exchange. However, as the societies were developing, the role of gold was declining, as it was replaced by fiat money. Nevertheless, even in the 20th century, the importance of gold was so significant that the whole monetary system of the United States was built on the gold standard.

Despite the fact that gold was considered to be one of the most stable assets in the twentieth century, many central banks have started to decrease their exposure to gold. For example, the Czech National Bank (CNB) has been steadily decreasing its gold reserves during the last eighteen years. As a result, many economists have been criticizing this decrease, as they claim that a sufficient amount of gold is needed to have the price stability in the country. Nevertheless, there are proponents of such a monetary policy that defend the actions of the Czech National Bank. Similar policies can be observed in many other countries, where inflation does not exceed two percent. This may lead to thoughts that the role of gold in the modern world might be overestimated.

Moreover, the fall of the Bretton-Woods system makes the economists doubt if gold still should be considered as a good choice for holding the reserves. Gold is not the only asset that can hold value against inflation but in contrast to many other assets holding gold yields no return. The primary aim of this thesis is to answer the question if there is a significant effect of the amount of gold reserves held in central banks on the price stability.

The thesis contributes to both the researches about the primary factors that affect inflation and tries to find the solution to the debates about the significance of gold reserves. We have found some studies about the dependence of the prices of gold and other precious commodities on inflation rates during small periods of time. Nevertheless, we have not found any studies that concentrate on the efficiency of gold reserves in central banks acting as a hedge against inflation or analyze if there is any dependence of inflation on gold reserves. Furthermore, we are interested to find out if the relationship changes when we control the level of the efficiency of the management of central banks.The results of this analysis can be helpful for the central banks around the world to make the decisions about the sufficient amounts and the compositions of their foreign exchange reserves.

We use the data for 110 countries for the period from 2000 to 2016 to find out if there is the significant relationship between gold reserves of central banks and inflation rate. The main purpose of the estimations of the models constructed in this thesis is to analyze if central banks' gold reserves positively affect the price stability. The dependent variable is the inflation rate and the primary independent variable is the ratio of gold reserves to total reserves. Based on the literature review, we control the variables that are most commonly used in the previous studies of the factors affecting inflation. Furthermore, we include the proxy variables for the performance and the financial strength of central banks to find out if efficiency of the management affects the relationship of gold reserves held in central banks and inflation. After specifying and estimating the models using the whole dataset, we divide the data sample into subsamples to observe the effect of gold reserves on inflation for only those countries that used inflation targeting at least for one year in the analyzed period. Finally, from the results of the regressions of this thesis, we conclude what factors have the most significant effects on the price stability.

The thesis is organized as follows. Chapter two describes the literature review and theoretical framework behind this thesis. We commence the literature review by describing the policy of inflation targeting and the factors that affect the price stability. Then, we describe the usage of foreign reserves by central banks to reach inflation targets. Finally, we discuss the stability and reliability of gold reserves. In the third chapter, we discuss the methodology that is used to specify the model and tests we use to check the robustness. After we check the robustness, we adjust the model to obtain the reliable results. Additionally, the data that is used for the analysis and its sources are described. Chapter four describes the results of the estimations presented in the chapter three, compares them to the literature reviewed in the chapter two and explains the implications of the results for the further research.

Chapter 2

Literature Review

2.1 Inflation Targeting as Policy of Central Banks

The central banks around the world endeavor to control the price levels in their countries efficiently. Before 1990, central banks were trying to control price levels mostly through the money supply targeting. However, then central banks in many countries started to use the new monetary policy – inflation targeting. The advocates of the inflation targeting claim that this policy is better than other less direct monetary policies because it is the policy of both "the rule" and "the discretion".

Central banks set their targets for the yearly inflation rates and try to reach them by using various tools. Usually, central banks set the control dates during the year when they compare the real inflation to the targeted one. In the case of discretion, central banks can either add liquidity or shorten it by using interest rates and foreign exchange interventions. Another advantage of this policy is that it is easier, faster and more precise to measure interest rates and foreign reserves than money supply.

Another reason why more and more countries started to implement this policy is that it works well with consumers. When central banks set their targets high, the consumers begin to buy more now, as they expect the future prices to rise and the actual inflation increases. This policy also works in the opposite case, when the targets that are set are too low, consumers will wait until the prices will decrease and the demand for products will fall that will be followed by the future decrease in prices. Therefore, the policy is the opposite to the policy of "stop-go" used in the past.

Goncalves and Salles (2008) create the research to find out if there is any difference between developing countries that use inflation targeting and those that do not use it. The authors analyze 36 emerging economies. Their results suggest that the countries that use inflation targeting not only, in general, have a lower inflation rate but also higher stability of growth.

Mollick, Torres and Carneiro (2008) conduct the analysis of the effect of the policy of inflation targeting on the output growth of both the developed and the developing economies. The authors' results show the strong significant positive effect of inflation targeting on the real growth of output. For the developed countries the effect is significant for both partial and full inflation targeting regimes. For the developing countries only full inflation targeting regime is found to be significant. Therefore, the authors conclude that the developing countries require strong full inflation targeting regime so that its benefits would be higher than its costs.

Despite the fact that inflation targeting becomes more and more popular around the world, economists argue that if this policy is truly capable of decreasing inflation and reaching the targets or not. For example, Wu (2004) in his analysis of the relationship between inflation targeting policy and inflation finds two different sets of results. From the first set, he concludes that there is a significant adverse effect of the inflation targeting policy on inflation and the countries that adopted that policy have, on average, lower inflation than other ones. Nevertheless, then, the second set shows that he cannot reject the hypothesis that there is no correlation between inflation targeting policy and inflation. Moreover, even though the author controls the effect of levels of real interest rates, there is no significant evidence that inflation targeting results in a more stable level of prices.

Giavazzi and Giovannini (2010) claim that strict inflation targeting monetary policy can increase the probability of the financial crisis. The authors call it the "low-interest-rate-trap" which means that the low interest rates used to reach the inflation targets are one of the driving factors of the financial crises around the world. The primary reason is that the low interest rates enable people to borrow for the risky investments that increase the probability of the financial crisis. Then, after the crisis occurs, the low interest rates are required to survive the crisis. If a financial system is not strong enough, this can result in the movement of the equilibrium to the point where interest rates are minimal. The minimal interest rates will encourage to make the risky investments even more. The authors conclude that the goal of the inflation targeting should not be the main one when an economy is in a week condition and the liquidity is more expensive. Moreover, the deviation from the targeted level of inflation can even help the economy by increasing the price of liquidity and limiting the risky investment.

2.2 Factors that affect the price stability

Usually, economists divide inflation into two types – demand-pull inflation and cost-push inflation. Demand-pull inflation occurs when the demand for products exceeds the supply that leads to an increase in the prices. One possible reason that can lead to this excess is the devaluation of the home currency. The producers find it to be more attractive to export their goods, as for foreigners they become cheaper and more attractive to buy. This causes a decrease in aggregate supply and the increase in aggregate demand for goods and services in the home country.

Another reason that can increase the demand-pull inflation is some expansionary fiscal policy. If the government decides to stimulate spending in the economy, for example, by decreasing the taxes, both producers and consumers have the increase in their budgets. However, though the demand will grow up immediately, the supply will not, as firms will need time to allocate new funds and to produce more goods. Moreover, instead of expanding production, firms can decide to spend more funds on other things, such as new investments or increase in the compensations of their employees. Last but not least, the thing that can rise the demand-pull inflation is the expansionary monetary policy done by the central bank. If central banks decide to provide more or less liquidity to the market by extending the money supply, consumers will get more funds to spend which will increase both spending and the aggregate demand. In case, the supply of goods and services will not adjust by increasing as well, the prices will go up.

As for the cost-push inflation, the increase in prices of final products occurs when the prices of the inputs go up. For example, when there is a low supply of labor, wages increase that makes it more costly to hire a new employee. The production becomes more expensive and this should be reflected in prices.

However, apart from the things described above there are many other factors influencing the prices. Therefore, we review the literature concerning the analysis of the price stability. Bleaney (1999) uses in his analysis of the price stability such explanatory variables as GDP per capita, sizes of area and land, openness and exchange rate regime. These macroeconomics indicators are used in almost all the papers that analyze the inflation. The reason for this is that the actions of central banks and their outcomes are highly dependent on the external conditions of the economies. Benecka et al. (2012) in their analysis of the effect of the financial strength of central banks on inflation use similar independent variables as Bleaney (1999) such as real GDP per capita, trade openness, capital account openness, exchange rate regime and monetary policy regime.

The relationship between the openness of an economy and inflation is not straightforward. Romer (1993) creates a theory that inflation has a negative relationship with openness, as inflation is low in small and open economies. There are many papers that confirm the theory of Romer. Mukhtar (2010) analyzes the effect of openness on inflation on the example of Pakistan in the period of 1960 – 2007. The author confirms that the theory of Romer holds for Pakistan, as the empirical study proves a significant negative relationship. Nevertheless, Terra (1998) claims that Romer's theory holds only for the countries with the high debt amounts and in the period of crisis in the 1980s.

Gruben and McLeod (2004) create the update to the studies done by Romer (1998) and Terra (1998). They claim that the theory presented in Romer (1993) holds not only for low-income countries with high debts but also for high-income countries and not only in the periods of crises. In contrast, Temple (2000) supports the view of Terra and finds that there is no strong correlation between inflation and trade openness. Eijfinger and Schaling (1995) in their analysis show that in times of shocks the higher the degree of openness is – the higher the inflation is and the lower the independence of central banks is.

The effect of the exchange rate regime on inflation has been analyzed in many papers. In general, economists agree that the fixed exchange rate regime should result in lower inflation. For example, Levy-Yeyati and Sturzenegger (2002) analyze the advantages and the disadvantages of the exchange rate regimes and, indeed, confirm that the countries that implement inflation targeting and the fixed exchange rate regime tend to have lower inflation. Collins (1995) argues that the fixed exchange rate regime enables the monetary authority to use the exchange rate as a strong tool to affect the inflation expectations. This is especially useful in the conditions of the hyperinflation. Nevertheless, the author does not think that the exchange rate can decrease the rate of inflation significantly when inflation is low or moderate.

While analyzing the factors influencing the price stability, we cannot but mention its relationship with unemployment. Philips (1958) is the first one who shows the inverse relationship between inflation and unemployment. However, Friedman (1968) is the one who emphasizes the importance of this relationship and introduces the Philips curve to the world. Nevertheless, many researchers that followed the theory of Philips did not confirm that in the long-run the relationship holds. Berentsen et al. (2009) claim that the relationship between inflation and unemployment is dependent on two external factors - the elasticity of money demand and the value of leisure. The authors argue that these factors explain why sometimes in the long-run the relationship is positive.

Alternatively, economists often control political factors to have a robust analysis of price stability. Romer (1993) uses the index of central bank dependence and revolutions and coups to control the political instability. Additionally, Romer (1993) separates the analysis by including and excluding regional and data dummies. Economists often use the independence of a central bank in different papers; however, there is no standard approach on how to evaluate it.

Nevertheless, the most commonly used is Cukierman, Webb, and Neyapti (1992) – (CWN) index. The index is constructed using a large number of variables of formal and informal characteristics that affect central banks. One of the most interesting factors that are taken into account by the authors is the turnover of central banks' governors. The assumption is applied that the more often a governor is replaced, the less independent a central bank is. The authors support their assumption with the idea that if the politicians have the power to choose the governor, they will replace him/her often to find the one who will do their will better. Another impressive set of variables that are included is based on the questionnaire sent to many analysts that work in different central banks around the world.

Garriga (2016) claims that CWN shall be preferred to other alternatives based on the following reasons. Firstly, it is considered as merely replicable and, thus, can be simply applied to other datasets. Secondly, Arnone et al. (2007) show that it is possible to convert CWN index to other indices to analyze more effects using the same questions to central banks. Finally, as it is often used, it is easy to see its significant effects on various variables using different works of other researchers.

Benecka et al. (2012) in their analysis of the relationship between central banks' financial strength and inflation use different indicators that show the performance of central banks. The proxy variables that they use to measure the financial strength of central banks are the following. Firstly, they control the balance sheet measures such as the ratio of equity to total assets (ETA), the ratio of "broadly-defined" capital to total assets ($CBFS_1$) and the ratio of non-interest bearing liabilities to total assets ($NNIBL$).

All these variables allow analyzing of the level of the financial strength or the rate to which central banks are capitalized. However, $NNIBL$ is considered as a more general indicator of the financial strength of central banks, as it includes not only the capital of central banks but also the currency issued. Secondly, the authors control profitability indicators of central banks such as return on average assets ($ROAA$) and return on average equity ($ROAE$). $ROAA$ shows how efficient the management of a firm is, while $ROAE$ shows how profitable the equity of a bank is. Though these indicators are the most popular among the researchers, there are many alternatives to these indicators. For instance, Caruntu and Romanescu (2008) use in their assessment of the performance of banks the ratio of net profits to total income and the ratio of total income to total assets.

2.3 The usage of foreign exchange reserves in Central Banks to reach inflation targets

One of the main reasons why central banks hold different foreign reserves is that it allows them to be less dependent on the specific exchange rate. Thus, their exposure to the exchange rate risk becomes lower. This risk is of high importance in some countries, where the currency value is not stable. There are different reasons why the value of a currency cannot achieve stability. The devaluation can be the result of the political or economic shocks to the countries' economies. Nonetheless, there is a need to find the equilibrium level of the foreign exchange reserves, as especially in emerging markets their cost can be high.

There is a problem that exists in the developing economies and it is called the "liability dollarization". Mishkin (1999) addresses this issue as the one that can start a serious crisis inside a country. The reason is that assets of a country lose value, while their debt in the foreign currency becomes more and more relatively expensive. The problem intensifies due to the fact that moral hazard and adverse selection lead to a dramatical decline in investment and lending in a country. In case that a large part of liabilities of a country is in a foreign currency, the foreign reserves of a central bank can significantly slow down the crisis.

Inflation targeting framework allows central banks to intervene and use different monetary policies to stop a crisis and decrease inflation. One of the most common interventions is the limitation of the currency exchange rate fluctuations. When a central bank holds enough foreign exchange reserves, it can stop the devaluation by increasing the demand for local currency. This increase can be achieved throughout the purchase of local currency and the supply of foreign currencies to the economy. However, a central bank needs to have a sufficient amount of foreign reserves with a stable value in order to succeed in this policy. Furthermore, there are some drawbacks of the limitation of the exchange rate movements.

Mishkin (2004) provides some examples of why using the monetary policy of limiting exchange rate fluctuations might not be the best solution to reach inflation targets. Firstly, as a result of such policy, there is a risk that the exchange rate can become the nominal tool of higher importance than the first one targeted inflation. For instance, in 2003 there was a critical problem in Hungary. In 2001, the government limited the fluctuations of the exchange rate to the deviation of the maximum of fifteen percent. In two years, the Hungarian Central Bank had to intervene, because the forint almost exceeded the border of fifteen percent appreciation. Consequently, the investment in Hungarian businesses became more attractive for foreigners. The Central Bank of Hungary responded to this fast capital inflow by decreasing the interest rates by two percent and buying a significant amount of the foreign currency. Even though the Hungarian Central Bank was trying to stop the supply of liquidity, there was a belief in the market that having the exchange rate within the limits of its policy would be more important for the central bank than the targeted inflation rate. As a result, the inflation rate in Hungary indeed exceeded the targeted one by more than two percent. Secondly and more importantly, Mishkin (2004) claims that the result of using exchange rates to reach the targeted inflation rates depends a lot on the nature of shocks that hit an economy.

2.4 The stability and reliability of gold reserves

After the fall of the Bretton-Woods system, the importance and the amounts of gold reserves have been decreasing. Economists debate if the gold can be considered as the stable enough asset to hold in the reserves of central banks.

However, gold is still one of the largest assets in total reserves of many central banks. Additionally, gold enables central banks to diversify their currency assets and, thus, be less dependent on specific currencies. Nugee (2000) describes four primary reasons for keeping more gold in central banks' reserves.

1. Gold does not lose value and even appreciates sometimes during uncertainty
2. It is often the unit of exchange between different countries because it keeps its value during inflation
3. There is no counterparty that can default, so there is no credit risk.
4. Traditional and historical reliability due to the beliefs that it is a stable asset that occurred before and during the Bretton-Woods system.

Baur (2016) claims that central banks are interested in the prices of gold; therefore, they try to influence directly or indirectly its movements. The reason for this interest is that a lot of central banks around the world still believe that gold is a safe haven. Plender (2016) claims that developing countries should prefer gold to US dollar reserves, as gold would enable them to diversify their portfolio better.

Blose (2010) analyzes how the price of gold varies when the inflation expectations change and concludes that the price of gold does not depend much on the inflation expectations. Chua and Woodward (1982) analyze if gold is the effective hedge against inflation. The authors examine only the period from 1975 to 1980. They conclude that gold indeed acted as an effective hedge against inflation for the investors in the US economy at that time but just for up to six months investment periods.

Worthington and Pahlavani (2006) conduct the analysis of the long-run relationship between the inflation and the monthly prices of gold in the United States. The authors examine two periods from 1945 to 2006 and from 1973 to 2006. The authors conclude that gold can act as an effective hedge against inflation through both direct and indirect investments. Similarly, Ghosh et al. (2001) create the research that focuses on the movements of the prices of gold both in the short-run and the long-run. The authors analyze the monthly prices of gold for the period from 1976 to 1999. The authors argue that in general the price of gold increases at the rate of inflation over time and, thus, gold can be considered as an effective hedge against inflation.

Aye et al. (2015) use the interrupted Markov-Switching cointegration model to analyze if gold is an effective hedge against inflation. The authors use the annual US data for the period from 1983 to 2013. Their results show that the relationship varies depending on what periods are taken into consideration. Nevertheless, the authors conclude that, in general, gold can be considered as an effective hedge against inflation, though its efficiency can decrease due to the shocks to the gold market.

Similarly, Beckman and Czudaj (2012) create the analysis for the relationship of gold and inflation using the Markov-switching vector error correction model. They analyze the monthly data of the price of gold in US Dollar, British Pound, Euro and Japanese Yen for the period from 1970 to 2011. The authors conclude that in the long-run gold is an effective hedge for the inflation but the evidence is stronger for the United States and the United Kingdom than for Euro area and Japan.

Long et al. (2013) investigate the efficiency of gold as a hedge against inflation in Vietnam. They analyze the data for the period from 1980 to 1990. They conclude that gold returns grow at the rate of the expected inflation; therefore, gold is an effective hedge against inflation.

In contrast to the papers described above, there are many studies the authors of which argue with the stability of gold. For instance, Nugee (2000) claims that because of the decreasing pattern of the development of the price of gold during the last decades, it cannot be any longer considered as a stable asset. Moreover, it is likely that if the price of gold increases in the future, the central banks will immediately start selling it, as they will expect it to return to the decreasing pattern. Additionally, all the economists agree that gold is a very expensive asset to store and safeguard. Lucey and Li (2015) make the comparison of gold with other expensive metals and they conclude that gold does not behave as a stable asset, while silver, platinum and palladium do.

Ben-Bassat (1980) constructs the investment model and estimates the efficiency curve for the Central Bank of Israel during the period from 1972 to 1976 and find out that gold had higher returns than other foreign currencies but also much higher standard deviation. The author creates the optimal portfolio for the years of analysis and does not include gold because of too high risk.

Barro and Misra (2013) create the analysis of gold prices and gold returns in the United States for the period from 1836 to 2011. They conclude that the average yearly return of gold is 1.1% and the standard deviation is 13.1%. This means the average real change in price is between 0.1% and 2.1%. Thus, gold yields almost no return on average but the deviation is quite small similar to other risk-free assets. Nevertheless, the author comments that such a small deviation in returns appears because the analyzed period includes the years of gold standard. The deviation is much higher in other periods which can be explained by the changing monetary role of gold.

Joy (2011) conducts the analysis of the efficiency gold as a hedge for US dollar and argues that gold cannot be considered as a safe haven. Guimaraes (2013) creates the research that analyzes if gold can be considered as a safe haven asset and analyzes the correlation between stocks, bonds and gold in the European Union. The author argues that gold is a safe haven for stocks but only in times of small or mild crises. Nevertheless, in case of a strong crisis gold is uncorrelated with stocks movements. Additionally, the author adds that gold is not a safe haven for bonds, as bonds and gold are not correlated. After taking into account all things considered, the author concludes that gold can be considered to be a safe haven for European stocks only in the case when there are extreme conditions on the market.

Chapter 3

Methodology

In this section, we describe the methodology used for the analysis of the dependence between price stability and gold reserves in central banks. We control the most well-known factors influencing inflation in accordance with the literature review.

3.1 Panel data models

This thesis uses the panel data in order to test the hypothesis of the significant effects of gold reserves held in central banks on inflation. Therefore, we begin the methodology with the description of the panel data models. There are three types of the panel data models:

- Pooled OLS
- Random effects model
- Fixed effects model

3.1.1 Pooled OLS

Simple pooled ordinary least squares (OLS) model is used when there is the assumption of no individual effects in the data. The observations in the sample should be independent of others. There are five main assumptions:

1. The data generating process shall be linear implying a linear relationship between dependent and independent variables;
2. The expected value of disturbances shall be zero, or there shall be no correlation between disturbances and independent variables;

3. The dependent variable shall not be stochastic and is assumed to have fixed values in a given sample;

4. The disturbances should have the same variance and there should be no correlation between them;

5. Full rank.

However, if the individual effects are present, the disturbances may not be independent and can vary across the data and/or can be autocorrelated. Then, pooled OLS estimator will not be BLUE (best linear unbiased estimator) and we should choose another model.

3.1.2 Random Effects Model

The random effects model is applied when the individual effects are not correlated to any independent variable and have random distribution across entities and time periods. Under this approach, the individual effects are included in the error term as dummy variables. The intercepts are constant. Then, the random effects model estimates the variance of errors for a given data set. The model is estimated by the generalized least squares (GLS). When the structure of covariance is not known, feasible generalized least squares (FGLS) estimator or estimated generalized least square (EGLS) estimators are used. The model looks as follows:

$$y_{i,t} = \alpha + X'_{i,t}\beta + (u_i + \nu_{i,t}) \tag{3.1}$$

where u is the set of individual effects of some entity in N or time periods in T and $\nu_{i,t}$ is the set of independent identically distributed disturbances.

3.1.3 Fixed effects model

The main difference between the fixed effects and the random effects models is that the fixed effects model assumes that individual effects are constant. The model includes individual effects as dummy variables to the intercept. Therefore, the intercept is not constant. The model looks as follows:

$$y_{i,t} = (\alpha + u_i) + X'_{i,t}\beta + \nu_{i,t} \tag{3.2}$$

where u is the set of individual effects of some entity in N or time periods in T and $\nu_{i,t}$ is the set of independent identically distributed disturbances.

The most common approach is to use the within estimator that uses the deviations from the means (cross-sectional or time-series) when we assume that individual effects are fixed. Nevertheless, the most problematic disadvantage of this estimator is that it excludes all time-invariant variables from the estimation, as they do not deviate from the mean. However, there are other estimators that can be used. The simplest way is to use OLS with the set of dummy variables as the estimator. This method is called the least squares dummy variables (LSDV) regression.

Nevertheless, LSDV can be not efficient when there is a very high number of the cross-sectional units, as too many dummy variables have to be included. The parameters reported by the within and LSDV estimators are identical, but the within estimator gives an accurate value of the sum of squared errors (SSE). There exists another estimator that can be used – "between estimator". It estimates the model by using the mean values of the dependent and the independent variables and completely ignoring time effects.

Three necessary tests are used to determine which panel data model shall be chosen for the analysis. Firstly, the simple F test is used to make a choice between the pooled OLS and the fixed effects models. Secondly, the Breusch-Pagan Lagrange Multiplier test should be applied in order to choose between the random effects and the pooled OLS models. This test uses Lagrange Multiplier (LM) statistics that follows χ^2 distribution to test the null hypothesis of the variance of individual effects to be equal to zero. If the null hypothesis can be rejected, there is the heterogeneity in errors and the random effects model shall be used. Finally, the Hausman test is used to make a choice between the random effects and the fixed effects models. The null hypothesis is that the individual effects are not correlated with the independent variables. If we can reject the null hypothesis, the fixed effects model should be used, as GLS will be biased. The random effects estimator is considered to be more efficient than the fixed effects estimator; however, it can be inconsistent, while fixed effects estimator is always consistent. We apply these tests to find the appropriate model to test the significance of gold reserves.

3.2 Models specification

To test the dependence of inflation on gold reserves, we start with the following model – Model 1:

$$
\begin{aligned}
Inflation_{i,t} = \beta_0 + \beta_1 * Target_{i,t} + \beta_2 * Gold_{i,t} + \beta_2 * log(realGDP)_{i,t} + \\
+ \beta_5 * log(Population)_{i,t} + \beta_6 * Openness_{i,t} + \\
+ \beta_7 * FixedRegime_{i,t} + \beta_8 * FloatingRegime_{i,t} + \epsilon_{i,t} \quad (3.3)
\end{aligned}
$$

where $Inflation_{i,t}$ is inflation in country i t time t, $Gold_{i,t}$ is the ratio of gold reserves to total reserves for country i at time t, $log(GDP)_{i,t}$ is the logarithm of GDP per capita for country i at time t, $log(Population)_{it,t}$ is the logarithm of the population for country i at time t, $Openness_{i,t}$ is the ration of imports to GDP for country i at time t, $FixedRegime_{i,t}$ is the variable indicating the fixed exchange rate regime for country i at time t, $FloatingRegime_{i,t}$ is the variable indicating the floating exchange rate regime for country i at time t, $\epsilon_{i,t}$ is the residual for country i at time t.

Then, following the theory of the Philips Curve, we add the unemployment rate. Additionally, in accordance with the traditional monetarist view, we include the money supply growth.

The model is as follows – Model 2:

$$
\begin{aligned}
Inflation_{i,t} = \beta_0 + \beta_1 * Target_{i,t} + \beta_2 * Gold_{i,t} + \beta_2 * log(realGDP)_{i,t} + \\
+ \beta_5 * log(Population)_{i,t} + \beta_6 * Openness_{i,t} + \beta_7 * FixedRegime_{i,t} + \\
+ \beta_8 * FloatingRegime_{i,t} + \beta_9 * Unemployment_{i,t} + \beta_{10} * MoneySupply_{i,t} + \epsilon_{i,t} \\
(3.4)
\end{aligned}
$$

where $Inflation_{i,t}$ is inflation in country i t time t, $Gold_{i,t}$ is the ratio of gold reserves to total reserves for country i at time t, $log(GDP)_{i,t}$ is the logarithm of GDP per capita for country i at time t, $log(Population)_{it,t}$ is the logarithm of the population for country i at time t, $Openness_{i,t}$ is the ration of imports to GDP for country i at time t, $FixedRegime_{i,t}$ is the variable indicating the fixed exchange rate regime for country i at time t, $FloatingRegime_{i,t}$ is the variable indicating the floating exchange rate regime for country i at time t, $Unemployment_{i,t}$ is the rate of unemployment for country i at time t, $MoneySupply_{i,t}$ is the measure of money supply for country i at time t, $\epsilon_{i,t}$ is the residual for country i at time t.

Finally, we expand the analysis by controlling the effects of the degree of central banks' independence and revolutions by including the index of central banks' independence. Additionally, following Benecka et al. (2012) we control the profitability and the credibility of central banks by including the return on average assets (ROAA) and the ratio of non-interest bearing liabilities to total assets (NNIBL). We estimate the models including these variables separately due to the fact that we expect these variables to be highly correlated. The model that includes is the following – Model 3/4/5:

$$Inflation_{i,t} = \beta_0 + \beta_1 * Target_{i,t} + \beta_2 * Gold_{i,t} + \beta_2 * log(realGDP)_{i,t} + \\ + \beta_5 * log(Population)_{i,t} + \beta_6 * Openness_{i,t} + \beta_7 * FixedRegime_{i,t} + \\ + \beta_8 * FloatingRegime_{i,t} + \beta_9 * Unemployment_{i,t} + \beta_{10} * MoneySupply_{i,t} + \\ + \beta_{11} * ROAA_{i,t} / \beta_{11} * NNIBL_{i,t} / \beta_{11} * Independence_{i,t} + \epsilon_{i,t} \quad (3.5)$$

where $Inflation_{i,t}$ is inflation in country i t time t, $Gold_{i,t}$ is the ratio of gold reserves to total reserves for country i at time t, $log(GDP)_{i,t}$ is the logarithm of GDP per capita for country i at time t, $log(Population)_{it,t}$ is the logarithm of the population for country i at time t, $Openness_{i,t}$ is the ration of imports to GDP for country i at time t, $FixedRegime_{i,t}$ is the variable indicating the fixed exchange rate regime for country i at time t, $FloatingRegime_{i,t}$ is the variable indicating the floating exchange rate regime for country i at time t, $Unemployment_{i,t}$ is the rate of unemployment for country i at time t, $MoneySupply_{i,t}$ is the measure of money supply for country i at time t, $Independence_{i,t}$ is the index of independence of central banks for country i at time t., $ROAA_{i,t}$ is return on average assets for country i at time t. and $NNIBL_{i,t}$ is the ratio of non-interest bearing liabilities to total assets for country i at time t, $\epsilon_{i,t}$ is the residual for country i at time t.

3.3 Robustness check

After we choose the estimator and estimate the models, we check the robustness of the results obtained. Therefore, we start testing our models by the standard panel data robustness tests.

We start with Wooldridge (2002) test for the serial correlation to conclude if there is the first-order autocorrelation. The serial correlation can create biased standard errors and, thus, unreliable results. Wooldridge test uses the regression of the first differences of residuals:

$$y_{it} - y_{it-1} = (X_{it} - X_{it-1}) * \beta + \epsilon_{it} - \epsilon_{it-1} \quad (3.6)$$

$$\delta y_{it} = \delta X_{it} * \beta_1 + \delta\epsilon_{it} \tag{3.7}$$

where Y is the dependent variable, X is the set of independent variables for entity i at time t, β is the set of coefficients, ϵ is the residual at for entity i at time t

If there is no serial correlation, than Corr($\delta\epsilon_{it}; \delta\epsilon_{it-1}$) = -.5
If the serial correlation is present within panel dataset, then clustering is used to adjust the variance.

Then, we use Pesaran (2004) CD test to test the cross-sectional dependence. It is the alternative to Breusch-Pagan test that uses LM statistics. This test shows if the residuals are correlated across the cross-sectional units:

$$CD = \sqrt{\frac{2T}{N * (N-1)}} * \sum_{i=1}^{N-1} * \sum_{j=i+1}^{N} \hat{\rho_{ij}} \tag{3.8}$$

where N is the number of cross-sectional units, T number of year and ρ_{ij} is the estimate of pair-wise correlation of residuals.

If there is no cross-sectional dependence, CD $\rightarrow N(0,1)$ for N$\rightarrow \infty$ when T is sufficiently large.

In order to check for the heteroskedasticity, we use modified Wald test following Greene (2000):

$$W = \sum_{i=1}^{N_g} \frac{(\hat{\sigma_i}^2 - \hat{\sigma}^2)}{V_i} \tag{3.9}$$

where N_g is the number of cross setional units and σ is the variance.

Under no heteroskedasticity, the distribution of W should be $\chi^2[N_g]$. In case heteroskedasticity is present, heteroskedasticity robust standard errors shall be used.

Finally, to complete our check, we test our model by Levin–Lin–Chu (2002) and Im–Pesaran–Shin (2003) tests for the presence of the unit root in the data. If there exists a unit root, then the data is non-stationary. We need to use first-differencing or even higher order-differencing to achieve the stationarity. Levin–Lin–Chu (2002) tests the null hypothesis of $\rho = 0$ in the data generating process:

$$\Delta y_{i,t} = \alpha_i + \rho y_{i,t-1} + \sum_{z=1}^{p_i} \beta_{i,z} \Delta y_{i,t-z} + \epsilon_{i,t}, \tag{3.10}$$

where $i = 1, ..., N$ and $t = 1, ..., T$; $\alpha_i, \beta_i \in \mathbb{R}$ and $-1 < \rho \leq 1$.

The alternative hypothesis is $H_1 : \rho = \rho_i \leq 0$ for $i = 1, ..., N$. The problem of this test is that under the alternative hypothesis it assumes that autoregressive structures are the same across all the panels.

Im–Pesaran–Shin (2003) uses a similar approach as Levin–Lin–Chu but allows for individual specific autoregressive structures. The data generating process is almost the same as under the model (3.6) but ρ is replaced with ρ_i.

$$\Delta y_{i,t} = \alpha_i + \rho_i y_{i,t-1} + \sum_{z=1}^{p_i} \beta_{i,z} \Delta y_{i,t-z} + \epsilon_{i,t}, \tag{3.11}$$

where $i = 1, ..., N$ and $t = 1, ..., T$; $\alpha_i, \beta_i \in \mathbb{R}$ and $-1 < \rho_i \leq 1$. Under the null hypothesis $\rho_i = 0$ for all $i = 1, .., N$. The alternative hypothesis is that $\rho_i < 0$ for all $i = 1, .., N$ and $\rho_i = 0$ for all $i = N_1 + 1, ..., N$. The alternative hypothesis of Im–Pesaran–Shin (2003) test allows for some cross-sectional units to have unit roots in series but not for all.

If we conclude that there are the cross-sectional dependence, the autocorrelation and the heteroskedasticity in our panel data, following Benecka et al. (2012) we cope with these issues using the linear regression with the panel-corrected standard errors (PCSEs) with a common auto-correlative factor. Beck and Katz (1995) explain the main assumptions for "panel errors" in their famous paper – "What to do (and not to do) with Time-Series Cross-Sectional Data". One possible problem with the panel data is the panel heteroskedasticity which means that the variance of the errors is constant within a cluster but is different for different clusters. Another possible problem is when we have contemporaneously correlated errors that mean that error effects are correlated across cross-sectional units. If we have a simple linear model:

$$y_{i,t} = X'_{i,t} \beta + \epsilon_{i,t} \tag{3.12}$$

where $i = 1, ..., m; m$ is a number of cross-sectional units, $t = 1, ..., T_j; T_j$ is a number of time periods, $\epsilon_{i,t}$ is error term that can be correlated across time or contemporaneously correlated across cross-sectional units.

If there is no autocorrelation in our data, then the covariance matrix for this model is

$$E[\epsilon\epsilon'] = \Sigma_{m*m} \otimes I_{T_i*Ti} \tag{3.13}$$

where Σ is the panel by panel covariance matrix and I is an identity matrix; $\otimes$ is a Kronecker Product

There are two ways to estimate this kind of models – panel correlated standard errors (PCSE) or feasible generalized least squares (FGLS). For the first method the OLS estimation is used. PCSEs are computed by taking the square root of the diagonal elements of

$$(X'X)^{-1}X'(\Sigma_{m*m} \otimes I_{T_i*Ti})X(X'X)^{-1} \tag{3.14}$$

If there is the autocorrelation presented in the data, Prais-Winsten estimates are used instead of OLS. Prais-Winsten method estimates the linear regression by generalized least squares (GLS) assuming that the errors follow the first-order autoregressive process.

Some economists believe that FGLS is more efficient than PCSEs. However, Beck and Katz (1995) illustrate that the results of FGLS have the underestimated standard errors and the estimation with PCSEs gives more accurate standards errors and approximately the same efficiency. Usually, there is a small loss in efficiency that is compensated with more accurate standard errors. The authors conclude that FGLS shall be chosen upon PCSEs only if the number of cross-sectional units is two times or more times higher than the number of periods.

Finally, after we check the robustness of the results and change the estimation approach in accordance to the results of the robustness tests, we estimate our models using the subsamples that include only the countries that used inflation targeting for at least one year in the analyzed periods.

3.4 Data description

This thesis uses the fixed and balanced panel data for 110 countries around the world during the period of 2000 – 2016. We use World Bank[1] database as a source for the inflation data. Inflation is measured using consumer price index (CPI) with Laspeyres formula:

$$P_L = \frac{\sum p_c, t_n * q_c, tn}{\sum p_c, t_0 * q_c, t_0}$$

where P_L is the price index between two periods t_0 and t_n, p_c is the price and q_c is the quantity for the product c.

During the analysis of inflation data, we have noticed the presence of the

[1] https://www.worldbank.org/

outliers. Figure 3.1 illustrates that while the mean is 6.16%, minimum and maximum are -8.1% and 513.9% respectively. To cope with the outliers, the dependent variable – inflation – is winsorized. Winsorizing is the statistical technique that enables to diminish the effects of the spurious outliers. This technique sets the value of all the values below the taken percentile equal precisely to the amount of that percentile. Figure 3.1 shows the descriptive statistics of the inflation rate before and after winsorizing.

Table 3.1: Descriptive statistics of inflation rate before and after winsorizing

Variable	Obs	Mean	Std. Dev.	Min	Max
Inflation Rate	1870	6.157256	17.15716	-8.115169	513.9068
InflRate (winsorized)	1870	4.979748	4.449155	-.2173197	16.59537

The data about the amounts of gold reserves are taken from World Gold Council database. Figure 3.2 illustrates the quarterly data of the development of gold reserves in tonnes in the world in the period from 2000 to 2016. It is observable that the amount of gold reserves in the world is stable and is in the range between 30,000 and 33,000 tonnes during the period of analysis. This stability can be partially explained by the fact that the USA, Germany and Italy – the counties with the highest gold reserves in the world – keep their gold reserves stable. Only minor yearly changes of less than 0.5% are observable for these countries. Nevertheless, France which is the fourth country with the highest gold reserves decreased its gold reserves by 19% in 2000 – 2016. Furthermore, countries with smaller amounts of gold reserves tend to have much higher deviation. Figure 3.2 shows the development of gold reserves in US dollars in 2000 – 2016. We can conclude that there is the increasing pattern until 2013 when there is the significant decline. Based on the fact that there is no such decline in tonnes, we can conclude that the price decreased significantly in 2013. Indeed according to the data from CMI Gold Silver Inc.[2], the price of gold decreased by 27.6% in 2013. Figure 3.3 presents the development of the yearly average values of the ratio of gold reserves to total reserves for our data sample. Figure A.1 in Appendix shows historical annual closing gold prices since 1980.

In addition to the development of gold reserves, the data from World Gold Council[3] enabled us to analyze the price stability of gold compared to other

[2] www.cmi-gold-silver.com/
[3] https://www.gold.org/

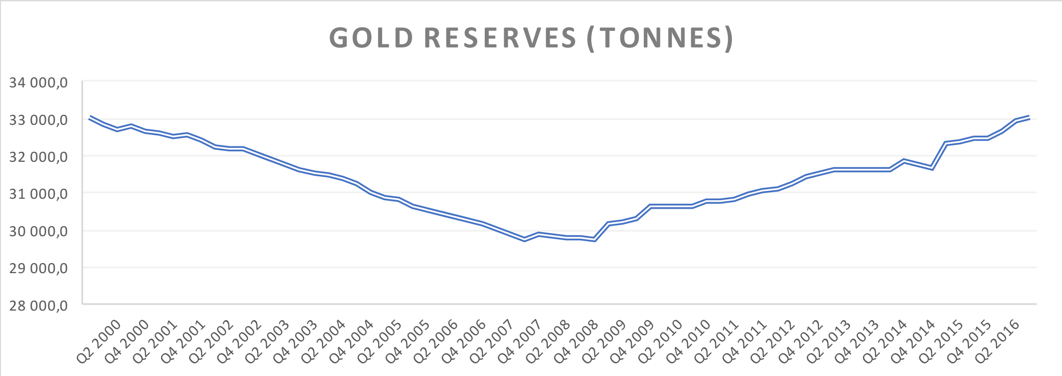

Figure 3.1: Gold Reserves (tonnes)

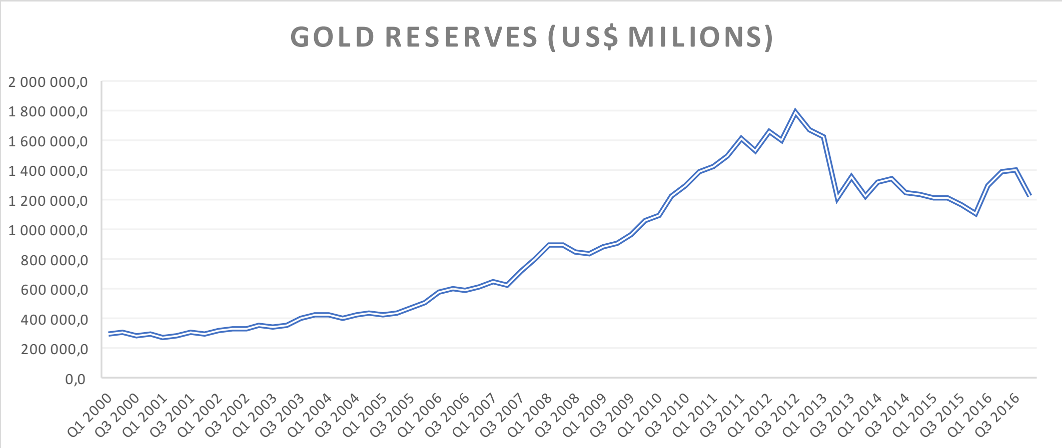

Figure 3.2: Gold Reserves (US dollars)

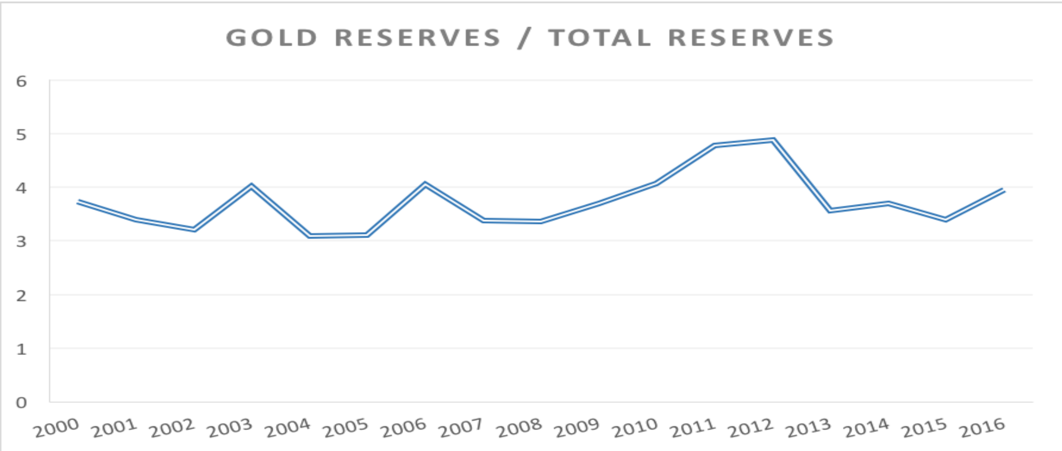

Figure 3.3: The ratio of Gold Reserves to Total Reserves

key currencies in the world. Table 3.1 demonstrates the performance of crucial World currencies in US dollars. We can observe short-term (1-3 months), long-term (1-5 years) and CAGR (compounded annual growth rate – the geometric

Table 3.2: Performance of key currencies in US$ (data ending 31.7.2018)

	Gold (US$/oz)	Euro/US$	Pound/US$	Swiss franc/US$	Yen/US$	Russian rouble/US$	Canadian dollar/US$
1-month	-2.4%	1.1%	0.4%	0.7%	-1.2%	0.3%	1.9%
3-month	-7.0%	-3.2%	-4.6%	0.0%	-2.3%	0.6%	-1.3%
YTD	-5.4%	-2.6%	-2.9%	-1.6%	0.7%	-7.9%	-3.4%
1-Year	-3.7%	-1.3%	-0.7%	-2.4%	-1.4%	-4.5%	-4.1%
3-Year	12.3%	6.9%	-15.9%	-2.1%	11.0%	-4.5%	0.0%
5-Year	-7.1%	-12.1%	-13.7%	-6.5%	-12.5%	-47.4%	-21.0%
3y CAGR	3.9%	2.3%	-5.6%	-0.7%	3.5%	-1.5%	0.0%
5y CAGR	-1.5%	-2.5%	-2.9%	-1.3%	-2.6%	-12.0%	-4.6%

average rate of return over the corresponding period). The returns of Gold are based on LBMA (London Bullion Market Association) gold prices. We can observe that in the short-run the deviation of gold is higher than of other currencies; however, in the long-run the performance of currencies is various and it is not possible to make a general conclusion. Nevertheless, if we compare the 3-year performance, the price of Gold increased the most. If we compare the 5-year performance, all the prices decreased significantly, but the prices of Gold and Swiss Franc declined by the lowest rate.

In Appendix, we also provide the performance of gold in US dollars in comparison to other key precious metals (Table A.1). The development of other commodities is various; therefore, it is hard to make the conclusion if gold is better or worse. However, CAGR clearly illustrates that palladium has the highest return in the 3-year period. Moreover, palladium is the only commodity that has a positive return in the 5-year period.

We use World Bank[4] database as a source for other macroeconomic variables to control the factors that may affect inflation. We follow Bleaney (1999) who in the analysis of the price stability uses such independent variables as – real GDP per capita, sizes of population, exchange rate regime and openness which is the ratio of imports to GDP. Based on the Philips curve, we add the unemployment rate to the analysis. Finally, based on the traditional monetarist view, we include the growth of the measure of the money supply – the ratio of broad money (M3)[5] to GDP. According to the traditional monetarist view, if the economy operates at the full level of employment, the change in the money supply should lead to the changes only in the price level. However, if the unemployment is presented, then changes in the money supply should lead to changes in the level of output and the price level. Nevertheless, the changes

[4]https://www.worldbank.org/

[5]M3 includes currency, short-term deposits (up to 2 years), redeemable deposits (up to three months), debt securities (up to two years), institutional money market funds and other liquid assets

Table 3.3: Descriptive statistics of macroeconomic variables

Variable	Obs	Mean	Std. Dev.	Min	Max
real GDP per Capita	1870	15,612.93	21,935.48	112.85	179,308.10
Population	1870	53,790,232	171,192,933	281,201	1,378,665,00
Openness (Imports to GDP), %	1870	45.53	28.69	0.07	221.01
Unemployment rate, %	1870	7.95	5.72	.14	37.25
Money Supply (M3), ratio to GDP, %	1870	61.83	45.05	0	376.52

in output will not appear immediately and the demand will exceed the supply; therefore, in the short-run the prices will increase. Similar to the inflation rate, we use winsorizing for the openness and our measure of the money supply to diminish the effects of the outliers. For the real GDP per capita and the size of population, logarithms are used.

Additionally, we control the effect of the exchange rate regime. The data about the exchange rate regimes is taken from yearly IMF reports about the exchange rate regimes – "Annual Report on Exchange Arrangements and Exchange Restrictions"[6]. Firstly, we create the index indicating the exchange rate regime:1 – if fixed, 2 – if intermediate, 3 – if floating. Then, we create two dummy variables $FixedRegime_{i,t}$ and $FloatingRegime_{i,t}$ that equal to 1 if a country i at time t has fixed/floating exchange rate regime and, otherwise, they equal to 0. The estimates of these variables show the effect of fixed/floating regime compared to intermediate exchange rate regime assumed by the model when both dummy variables equal to 0.

As we are interested in the effect of the inflation targeting, we include the dummy variable reflecting if a country is inflation targeting is included. The list of countries that use inflation targeting is the specific year is taken from CentralBankNews[7].

To expand the analysis, we further control the indicators measuring the central banks' independence and the effect of revolutions and coups on inflation. The index that measures the degree of central banks' independence is taken from the online appendix of Garrida (2016)[8]. Garrida (2016) constructs her index based on Cukierman, Webb, and Neyapti (1992) index of independence of central banks. Nevertheless, the author applies a much broader dataset that includes the results of the questionnaire sent to the analysts of central banks around the world. The data set of Garrida contains 182 countries for the

[6]https://www.imf.org/en/Publications/Annual-Report-on-Exchange-Arrangements-and-Exchange-Restrictions/

[7]www.CentralBankNews.info

[8]https://sites.google.com/site/carogarriga/cbi-data-1

period of 1970 – 2012. Additionally, the author includes different year dummy variables indicating the occurrence of revolutions and coups and controlling the years of the creation of central banks. The author coded many different factors that can affect the central banks' independence such as, for instance, the characteristics of CEO and legislation laws. The paper describing the construction of this index[9] in details can be found in the references of this Thesis. Figure 3.4 illustrates the development of the yearly average values of Garrida Central Banks' Independence index for the countries divided into five different income groups: low income, lower middle income, upper middle income, high income non-OECD and high income OECD.

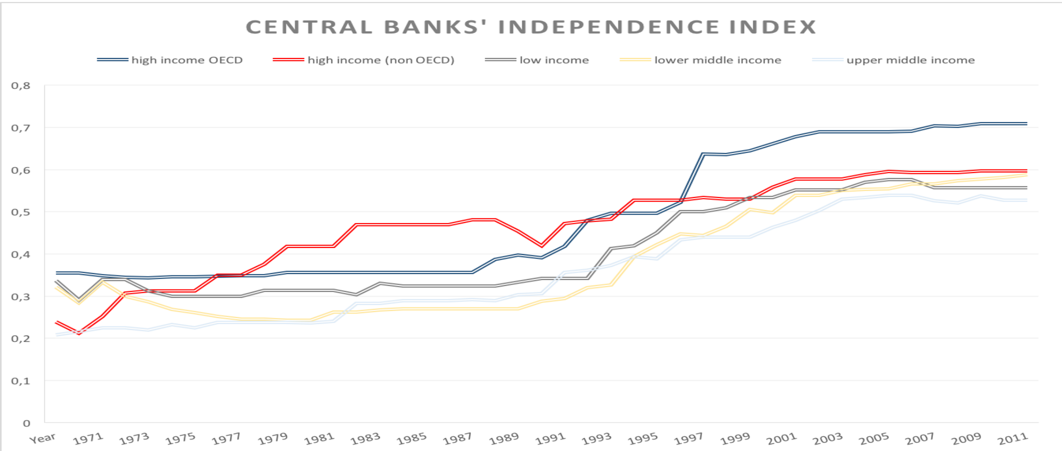

Figure 3.4: Yearly average values of Garrida Central Banks' Independence index

From Figure 3.4 it is observable that high-income countries tend to have higher degrees of the central banks' independence. One thing of interest is that the Organization for Economic Co-operation and Development (OECD) countries' central banks are more independent than central banks of the countries with high income but that are not participants of OECD. The data sample of high-income non-OECD countries includes such countries as Singapore, Qatar, United Arab Emirates, and others. Another interesting finding is that after 1995 the average yearly values of the index are higher for lower middle income than for higher middle income. Furthermore, the average values for low-income countries, in general, exceed the values of middle-income countries. One of the possible reasons for this might be that the high degree of central banks' independence should not necessarily be good for countries with low income. Usually,

[9]Central Bank Independence in the World: A New Data Set". International Interactions

these countries are very corrupted and, therefore, their central banks require much regulation in order to operate efficiently.

We control the performance of Central Banks by including return on average assets (ROAA) as the measure of profitability and the ratio of non-interest bearing liabilities to total assets (NNIBL) as the measure of financial strength.

- $ROAA = \frac{\text{Earnings before taxes}}{\text{Total average assets}}$
- $NNIBL = \frac{\text{equity + Non-interest bearing liabilities - non-earning assets - fixed assets}}{\text{Total assets}}$

The data about the central banks' ROAA and NNIBL for the period from 2012 to 2016 are taken from BankFocus database from Bureau van Dijk[10]. The data for ROAA and NNIBL for the period from 2002 to 2009 have been kindly provided by the authors of the paper "Does Central Bank Financial Strength Matter for Inflation? An Empirical Analysis" (Benecka et al, 2012). We have calculated manually the missing values for ROAA and NNIBL for the period from 2010 to 2012 from the financial statements provided in the annual reports of the central banks. However, for some countries the reports are unavailable and there are missing values in the data taken from BankFocus. Therefore, we have to omit these countries and decrease the data set. For the regressions that include ROAA and NNIBL, we use the data for 65 countries. We estimate the regressions including these variables separately, as we believe that they are highly correlated. Figure 3.5 illustrates the development of yearly average values of ROAA in the World.

We can observe that the most significant decline in the profitability of central banks occurred after 2008. The reason for this must be the occurrence of the global financial crisis. After 2010, the average ROAA has become more stable.

Table 3.4 shows the descriptive statistics of Garrida CBI, ROAA and NNIBL. As there are extreme outliers in the data sample, we apply winsorizing at 5% level to these indicators.

[10]https://www.bvdinfo.com/en-gb

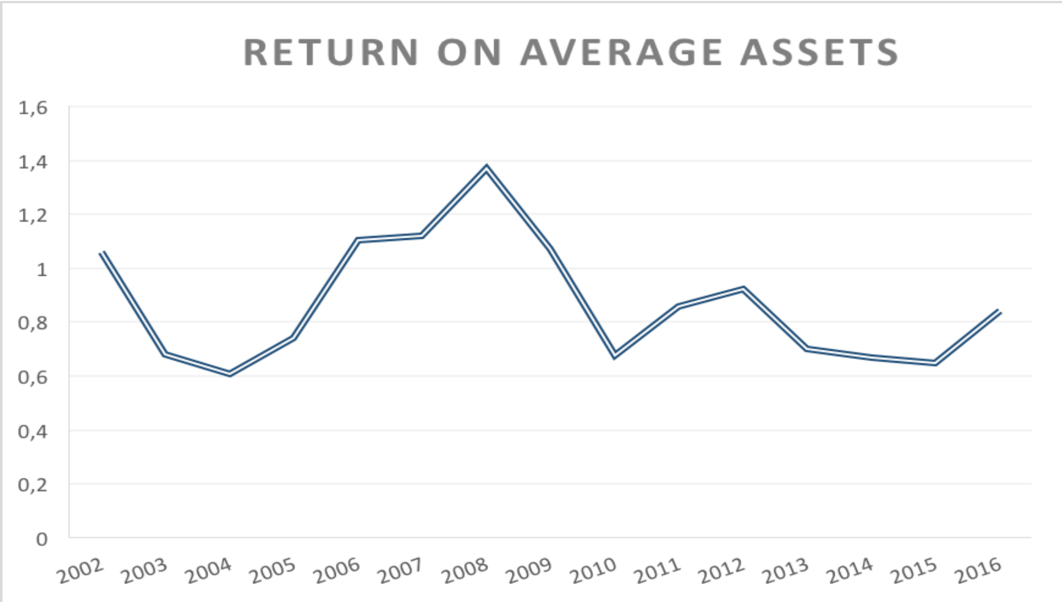

Figure 3.5: Yearly World average values of ROAA of Central Banks

Table 3.4: Descriptive statistics of the proxy variables of the financial strength of central banks

Variable	Obs	Mean	Std. Dev.	Min	Max
ROAA	975	0.9185714	3.25995	-25.02	31.92
NNIBL	975	-2.524033	59.07064	-1662.058	0.9576975
CBI	1430	0.6231969	0.3131438	0	1

Chapter 4

Empirical results

4.1 Results of the regressions

We commence by estimating the first model described in the Methodology – Model 1 (see equation 3.3). Firstly, we test the model using the F-test, the Breusch-Pagan and the Hausman tests to choose the most appropriate model for our estimation. We have to estimate the model using all three panel data models described in the Methodology in order to be able to make the conclusion using these tests. These models are the pooled OLS model, the random effects model and the fixed effects model. Table A2 in Appendix shows the results of all three models.

The result of the F test lets us conclude that the fixed effects model shall be chosen upon pooled OLS. We make this conclusion based on the fact that p-value is equal to zero which enables us to reject the null hypothesis that all dummy variables created in the fixed effects model are equal to zero. The Breusch-Pagan LM test gives us the result that the random effects model shall also be chosen upon the pooled OLS model because the p-value equals zero as well; thus, we can reject the null hypothesis. The null hypothesis is that the variance of individual effects is equal to zero. Finally, we use the Hausman test to make a choice between the fixed effects and the random effects models. We can reject the null hypothesis of no systematic differences at the 0.001 significance level, as p-value is zero.

The random effects model is inconsistent for our analysis. Therefore, for our analysis we choose the fixed effects model. The fixed effects model assumes that the cross-sectional units have different intercepts but have a common set of independent variables. The results of the Hausman and the Breusch-Pagan tests taken to choose the model can be found in Tables A.3 and A.4 in Appendix. Table 4.1 shows the results of the fixed effects estimation of Model 1 (see equation 3.3 in the Methodology).

Table 4.1: The dependence of inflation on gold reserves by fixed effects

(Fixed Effects)

Inflation Rate	Coef.	Std. err.
Target	-0.941**	0.341
Gold	-0.013	0.010
Log real GDP	-0.895***	0.195
Log Population	-0.740	0.798
Openness	0.038***	0.011
Fixed Regime	-0.859***	0.240
Floating Regime	-0.684*	0.272
constant	24.100*	12.237
N. of cases	1870	
Prob > F	0.00	
Standard errors are adjusted for 110 clusters in countries		

(* p<0.05, ** p<0.01, *** p<0.001)

Following the Methodology, we estimate the fixed effects model using the within estimator. We adjust the standard errors by using the clustering for 110 countries in the sample. From the results, we cannot reject the null hypothesis of no effects of gold reserves on the inflation holding everything else constant. In contrast, we can observe that real GDP per capita, openness and the dummy variable indicating fixed exchange rate regime are significant at 0.001 level. The sign of the coefficient of real GDP per capita is negative which implies that a higher real income of a country should decrease the inflation rate. In contrast, the coefficient of openness is positive. If the ratio of imports to GDP increases by 1%, the inflation rate is expected to increase 0.038%. Additionally, from the results we can conclude that the fixed exchange rate regime should lead to lower inflation compared to the intermediate and floating exchange rate regimes. If a country introduces the fixed exchange rate regime, the inflation rate should decrease by 0.859%.

Alternatively, we estimate the model using the between estimator to see what is the difference in the results if we focus only on cross-sectional effects. The Hausman test compares the results of these two estimators in order to test if the random effects model is consistent. Therefore, based on the results of the Hausman test the results should significantly differ. Table 4.2 shows the comparison of the results achieved from the between and the within estimators.

Table 4.2: Comparison of results estimated by the between and the within estimators

Inflation Rate	Between	Within
Target	-1.142	-0.941**
Gold	-0.004	-0.013
Log real GDP	-0.794***	-0.895***
Log Population	0.051	-0.740
Openness	-0.037*	0.038***
Fixed Regime	-3.456**	-0.859***
Floating Regime	-4.294**	-0.684*
_constant	15.757***	24.100*
Prob > F	0.00	0.00

(* p<0.05, ** p<0.01, *** p<0.001)

From the results of the regressions provided in Table 4.2, we can observe that the within estimator finds the dummy variable indicating inflation targeting to be significant at the 0.01 level. The coefficient of the inflation targeting dummy variable is negative that implies that if a country implements inflation targeting, inflation rate should ceteris paribus decrease by -0.941%. The between estimator does not provide the same result. The p-value is not small enough to reject the hypothesis of no significant effects of inflation targeting.

According to the results provided by the within estimator, openness is significant at 0.001 level. The between estimator also finds openness to be significant, though only at the 0.05 level. We cannot but mention that the sign of the coefficient of openness differs if we use different estimators. If we include time effects by using the within estimator, more imports compared to GDP should increase the inflation rate. The model predicts that if a country increases its openness, then its inflation rate should also increase. This relationship is not unexpected; when imports go up, more money flows into an economy which should lead to an increase in the price level. However, our model when estimated by the between estimator predicts that holding everything else equal if a country has a higher rate of openness than another country, then it should have a lower inflation rate.

The results of both the within and the between estimators show that the p-value of log real GDP is small enough to reject the null hypothesis at 0.001 level. This implies the adverse effect of real GDP per capita on the inflation rate. The model predicts that when real GDP per capita increases by 1% inflation rate decreases by 0.895%, holding other variables constant. Our primary variable of interest - gold - is found to be statistically insignificant by both estimators.

Following the theory of the Philips Curve and the traditional monetarist view, we proceed in the analysis with the inclusion of the unemployment rate and the money supply growth to our model – model 2 (see equation 3.4). Table 4.3 demonstrates the results of the fixed effects model estimated including money supply growth and unemployment. However, we expect to have the endogeneity problem with both of these variables; therefore, we include the lagged by one year values of the money supply growth and the unemployment rate.

For the unemployment rate, the endogeneity is very probable, as a higher inflation rate leads to lower labor demand and, as a result, the unemployment rate increases. The money supply growth is also expected to depend on the inflation rate. The major reason for this relationship is that central banks in many countries with low income still often increase the money supply as a short-term solution for how to cope with the increase in the price level. In the end, this leads to even higher inflation. We assume that the values of the unemployment rate and the money supply growth at time t do not depend on the value of inflation rate at time t+1. We understand that a more reliable way to solve the endogeneity problem is to use instrumental variables and two-stage least squares approach. Nevertheless, we believe that we will lose too much efficiency, as we are interested to see if there is any difference in the effects of gold when we include the variables suggested by main economic theories. Moreover, we have also estimated the model including more lags for unemployment and money supply growth, but there are no big differences compared to the estimation with only one lag of both variables.

The money supply is statistically significant at 0.05 level. The increase of 1% in the growth of the money supply is estimated to increase the inflation rate by 2.488% in the following year. In accordance with the traditional monetarist view, we were expecting the relationship to be positive. The unemployment rate is significant at 0.001 level. The increase of 1% in the unemployment rate is predicted to decrease the inflation rate by 0.167%. This result proves the negative relationship suggested by the theory of the Philips curve, as when unemployment rises inflation decreases and when unemployment declines inflation increases.

As we use lags in this regression, the number of observations is decreased

Table 4.3: The dependence of inflation on gold reserves by fixed effects controlling unemployment and money supply

(Fixed Effects)

Inflation Rate	Coef.	Std. err.
Target	-0.916	0.498
Gold	-0.011	0.012
Log real GDP	-0.961*	0.441
Log Population	-1.750	1.159
Openness	0.051*	0.021
Fixed Regime	-0.756	0.403
Floating Regime	-0.524	0.378
Money Supply (t-1)	2.488*	1.095
Unemployment (t-1)	-0.167***	0.042
constant	41.755*	17.164
Within R^2	0.0761	
N. of cases	1760	
N. of groups	110	
Prob > F	0.00	
Standard errors are adjusted for 110 clusters in countries		

(* p<0.05, ** p<0.01, *** p<0.001)

by omitting 2000 year. The new variables included and smaller data set lead to changes in the significance and the coefficients of other independent variables. The most important changes are that the dummy variables indicating the fixed and the floating exchange rate regimes are no longer significant and the dummy variable indicating inflation targeting is not significant as well. Thus, the exchange rate regime and the inflation targeting policy are of lower significance, if we control unemployment and the growth of the money supply. Gold reserves are still statistically insignificant.

Finally, we control the efficiency and the financial strength of central banks by including $ROAA$ as a proxy of the profitability, $NNIBL$ as a proxy of the credibility and CBI as a proxy of the measure of the independence of central banks – Model 3/4/5 (see equation 3.5 in Methodology). However, due to the unavailability of the data, we estimate the regressions controlling these variables using different data sets. All these variables are lagged by one year to cope with the problem of endogeneity. We start by including $ROAA$ into the analysis. The data set includes 65 countries and 15 years (2002 – 2016). The standard errors are adjusted for 65 clusters in countries. Table 4.4 presents the results of the regression including $ROAA$ – model 3 (see equation 3.5 in the Methodology).

Table 4.4: The dependence of inflation on gold reserves by fixed effects controlling the profitability of central banks

(Fixed Effects)

Inflation Rate	Coef.	Std. err.
Target	-0.665	0.645
Gold	0.019	0.013
Log real GDP	-0.281	0.451
Log Population	-3.550	1.931
Openness	0.077***	0.022
Fixed Regime	0.424	0.453
Floating Regime	-0.361	0.445
Money Supply (t-1)	5.081***	1.446
Unemployment (t-1)	-0.212***	0.049
ROAA (t-1)	0.284	0.164
constant	62.634	29.439
Within R^2	0.0962	
N. of observations	910	
N. of groups	65	
Prob > F	0.00	
Standard errors are adjusted for 65 clusters in countries		

(* p<0.05, ** p<0.01, *** p<0.001)

From the results of the model 3, we can observe that the only three variables that are concluded to be statistically significant are money supply, unemployment and openness. For other variables, we cannot reject the hypotheses of no ceteris paribus effects on the inflation rate at the 5% level or lower. According to our model, the money supply growth seems to have a very strong effect on the inflation rate. If there is 1% increase in money supply growth, the inflation rate is expected to increase by 5.1% in the following year. Unemployment and openness have similar coefficients to the ones estimated by previous regressions. The ratio of gold reserves to total reserves is again statistically insignificant. $ROAA$ is found to be insignificant as well at the 5% significance level. However, it is statistically significant at the 10% level, as the p-value is 0.088. This result is consistent with the results of Benecka et al. (2012). When using the fixed effects model, the authors conclude that $ROAA$ is significant at 0.1 level. We were expecting to get similar results to the ones presented in this paper, as approximately half of the data of $ROAA$ we use for this regression was shared with us by them. Thus, our results suggest that the effect holds at the same significance level, even if we completely change the data set. In our case, we increase the number of years but decrease the number of countries in the data set analyzed.

We continue our analysis and estimate the regression that controls the effect of the credibility of central banks on the inflation rate by including $NNIBL$ to the regression. We use the same data set as for the previous estimation. However, we include $NNIBL$ and exclude $ROAA$. We expect $ROAA$ and $NNIBL$ to be strongly correlated, as higher profitability should result in higher credibility and vice versa. Table 4.5 shows the results of the estimation including $NNIBL$ – model 4 (see equation 3.5 in the Methodology). The standard errors are adjusted for 65 clusters in countries.

Table 4.5: The dependence of inflation on gold reserves by fixed effects controlling the credibility of central banks

(Fixed Effects)

Inflation Rate	Coef.	Std. err.
Target	-0.757	0.610
Gold	-0.022	0.014
Log real GDP	0.340	0.505
Log Population	-3.309	1.880
Openness	0.047*	0.022
Fixed Regime	0.092	0.485
Floating Regime	-0.108	0.477
Money Supply (t-1)	4.122**	1.488
Unemployment (t-1)	-0.140***	0.040
NNIBL (t-1)	2.559**	0.792
constant	54.396	28.380
Within R^2	0.0868	
N. of observations	910	
N. of groups	65	
Prob > F	0.00	
Standard errors are adjusted for 65 clusters in countries		

(* p<0.05, ** p<0.01, *** p<0.001)

Similarly to the previous model, the results do not allow us to reject the hypothesis that there are no significant effects of gold reserves on inflation. $NNIBL$ is statistically significant at 1% level. Nevertheless, the positive coefficient is unexpected. We assume that the credibility of central banks should affect the inflation negatively. The possible explanation for the positive relationship might be the presence of the endogeneity, though we use the values of $NNIBL$ lagged by one year. We will check the robustness in the next section and adjust the methodology as necessary. Then, we will compare the results and check if the coefficient becomes negative.

Finally, we estimate the regression that controls the effect of central banks' independence. The data for CBI is available only for the period from 2000 to 2012. Therefore, we use the data set that includes 110 countries and 13 years for this estimation. Table 4.6 shows the results of this regression – model 5 (see equation 3.5 in the Methodology). The standard errors are adjusted for 110 clusters in countries.

Table 4.6: The dependence of inflation on gold reserves by fixed effects controlling independence of central banks

(Fixed Effects)

Inflation Rate	Coef.	Std. err.
Target	-1.215*	0.546
Gold	-0.030*	0.015
Log real GDP	-0.206	0.549
Log Population	-0.040	1.649
Openness	0.072**	0.022
Fixed Regime	-1.019*	0.455
Floating Regime	-0.029	0.426
Money Supply (t-1)	1.970	1.126
Unemployment (t-1)	-0.166**	0.059
CBI (t-1)	-0.661	1.393
constant	6.218	24.757
Within R^2	0.0535	
N. of observations	1320	
N. of groups	110	
Prob > F	0.00	
Standard errors are adjusted for 110 clusters in countries		

(* p<0.05, ** p<0.01, *** p<0.001)

The results provided in Table 4.6 illustrate that though CBI has a negative coefficient, its effect is not strong enough to reject the hypothesis of no effect of CBI on the inflation rate in the following year. However, the variable that is of the highest interest to us – gold – is statistically significant at 0.05 level. The estimated results show that according to our model if a country increases the part of gold reserves in its total reserves, the inflation rate should decrease by 0.03%. Thus, our last model suggests that if we control the effect of the independence of central banks, gold reserves should positively affect the price stability. We did not expect these results, as all that models that were estimated before showed no significant effect of gold reserves. However, this difference might occur due to the fact that we use another data set which does not include 2013 – 2016 years. R^2 is much lower for this model than for the ones estimated before – only 5.35%.

The highest R^2 is achieved when we control the profitability of central banks. Before proceeding to the robustness check, we estimate the fixed effects model controlling ROAA for the subsample of only inflation targeting countries. We include the countries where central banks used inflation targeting at least for one year in the analyzed period. There are 41 countries in our subsample of only inflation-targeting countries. The standard errors are adjusted for 41 clusters in countries.

Table 4.7: The dependence of inflation on gold reserves by fixed effects only for IT countries controlling profitability of central banks

(Fixed Effects)

Inflation Rate	Coef.	Std. err.
Gold	-0.008	0.015
Log real GDP	-1.866**	0.561
Log Population	1.116	5.035
Openness	0.062	0.038
Fixed Regime	-0.507	0.663
Floating Regime	-0.203	0.582
Money Supply (t-1)	4.974**	1.467
Unemployment (t-1)	-0.178***	0.034
ROAA (t-1)	-0.027	0.076
constant	1.498	81.846
Within R^2	0.1245	
N. of observations	574	
N. of groups	41	
Prob > F	0.00	
Standard errors are adjusted for 41 clusters in countries		

(* p<0.05, ** p<0.01, *** p<0.001)

Gold reserves do not become significant if we estimate the fixed effects model only for inflation targeting countries. Based on the results of the estimations, so far we are not able to confirm that there is a significant effect of gold reserves on inflation. Nevertheless, we have to check the robustness of the estimated results of all the models before commenting and explaining the difference between the estimated results.

4.2 Robustness check

In order to check the reliability of the results provided in the previous section, we present the robustness check. Firstly, we check if the data is stationary by using the Levin-Lin-Chu unit root test. We test the robustness of the results of the second, the third, the fourth and the fifth models shown in the previous section. The tests are applied separately, as these models use different data sets. The unit root test is applied to the variables only for the maximum data sets available. Secondly, we test if the cross-sectional dependence is present by the Pesaran CD test for the cross-sectional dependence. Then, we test the presence of the GroupWise heteroskedasticity in the fixed effects regression model using the modified Wald test. Finally, we use the Wooldridge test to determine if there is a serial correlation in our data.

The results of the Levin-Lin-Chu unit root test show that the data we use for this analysis is stationary because we can reject the hypothesis of a unit root for all the variables we include in the estimation. The results of the simple test of Levin-Lin-Chu for CBI show that the data is non-stationary. Nevertheless, if we include a linear time trend to describe the processes that generate the data and control the cross-sectional dependence by removing cross-sectional means from the data, we can reject the hypothesis that panels contain the unit root. The results of Im-Pesaran-Shin (2003) are similar to the results of Levin-Lin-Chu. We can reject the hypothesis of a unit root in our panel data and; therefore, we conclude that our data is stationary. Table A.5 in Appendix illustrates the results of Levin-Lin-Chu test for the data we use for inflation rate, gold reserves, ROAA, NNIBL and CBI.

The results of the Wooldridge test show that we can reject the null hypothesis of no serial correlation for all the models tested. Pesaran CD test for the cross-sectional dependence shows that we can reject the null hypothesis of no cross-sectional dependence in the data. When we use the third test – modified Wald test for GroupWise heteroskedasticity in the fixed effect regression model, we conclude that the p-value is small enough to reject the null hypothesis of the homoskedasticity. Therefore, to cope with all these issues, following Benecka et al. (2012) we decide to use linear regression with panels corrected standard errors (PCSEs). Additionally, we include a common AR(1) to cope with the autocorrelation. We begin by estimating the regression with PCSEs that does not include any proxy for the financial strength of central banks (see model 2 in empirical results). Tables A.6, A.7 and A.8 in Appendix present the results of the Wooldridge test, Pesaran CD test and the modified Wald test respectively.

Table 4.8 represents the results of the model 2 described in the empirical results after the robustness check.

Table 4.8: The dependence of inflation on gold reserves by PCSEs

(PCSEs)		
Inflation Rate	Coef.	Std. err.
Target	-0.159	0.368
Gold	-0.007	0.007
Log real GDP	-1.091***	0.157
Log Population	0.303**	0.107
Openness	0.004	0.013
Fixed Regime	-1.129**	0.377
Floating Regime	-1.015**	0.362
Money Supply (t-1)	-4.904**	1.845
Unemployment (t-1)	-0.023	0.023
constant	10.202*	3.445
R^2	0.1508	
Wald chi2(10)	222.11	
Prob > chi2	0.00	
AR (1)	0.55	
N. of observations	1760	
N. of groups	110	
Estimated covariances	6105	
Estimated autocorrelations	1	
Standard errors are adjusted for 110 clusters in countries		

(* p<0.05, ** p<0.01, *** p<0.001)

Gold reserves are still not statistically significant, as we cannot reject the hypothesis of no effects. One thing of interest is that both dummy variables indicating fixed and floating exchange rate regimes are statistically significant and have negative coefficients. As these variables indicate the strictly fixed or the strictly floating regimes, the significance of both variables implies that these regimes separately are better than the combination of both. However, the coefficients show that if a country introduces the fixed exchange rate, its inflation rate is expected to decrease more than if it introduces the floating regime. Money supply growth is statistically significant as well. The coefficient is very high. According to our model, if a central bank increases the money supply by 1%, its inflation rate should increase by almost 5% in the following year. Finally, the population is significant at 0.01 level and the coefficient is positive that implies a positive relationship between inflation and population size.

We proceed by estimating the regression with PCSEs for the model that controls $ROAA$ (see model 3 in Empirical results). Table 4.9 presents the results of this estimation.

Table 4.9: The dependence of inflation on gold reserves by PCSEs controlling the profitability of central banks

(PCSEs)

Inflation Rate	Coef.	Std. err.
Target	-0.243	0.396
Gold	-0.007	0.009
Log real GDP	-0.624***	0.109
Log Population	0.329**	0.099
Openness	-0.001	0.011
Fixed Regime	-0.899*	0.442
Floating Regime	-1.396**	0.427
Money Supply (t-1)	6.027**	2.113
Unemployment (t-1)	-0.073**	0.024
ROAA (t-1)	0.044	0.157
constant	5.711*	2.632
R^2	0.1626	
Wald chi2(10)	386.7	
AR (1)	0.47	
Prob > chi2	0.00	
N. of observations	910	
N. of groups	65	
Estimated covariances	2145	
Estimated autocorrelations	1	
Standard errors are adjusted for 65 clusters in countries		

(* p<0.05, ** p<0.01, *** p<0.001)

According to this model, gold reserves do not have significant effects on the inflation rate, as we cannot reject the hypothesis of no effects. The proxy variable of the profitability of central banks is not significant. Other signs of the coefficients are stable compared to the previous estimation without $ROAA$. The significance of other variables does not strongly differ.

Alternatively, we estimate the model that controls the credibility of central banks – $NNIBL$ – instead of profitability (see model 4 in Empirical results). Table 4.10 presents the results of this regression.

When we replace $ROAA$ with $NNIBL$, we still do not have significant evidence that gold reserves have an impact on inflation. Additionally, the

Table 4.10: The dependence of inflation on gold reserves by PCSEs controlling the credibility of central banks

(PCSEs)

Inflation Rate	Coef.	Std. err.
Target	-0.364	0.391
Gold	0.005	0.009
Log real GDP	-0.774***	0.167
Log Population	0.270**	0.157
Openness	-0.020	0.011
Fixed Regime	-0.421*	0.381
Floating Regime	-1.396**	0.427
Money Supply (t-1)	5.397**	2.174
Unemployment (t-1)	-0.032**	0.040
NNIBL (t-1)	0.612	1.357
constant	8.512*	4.315
R^2	0.1491	
Wald chi2(10)	144.24	
Prob > chi2	0.00	
AR (1)	0.52	
N. of observations	910	
N. of groups	65	
Estimated covariances	2145	
Estimated autocorrelations	1	
Standard errors are adjusted for 65 clusters in countries		

(* p<0.05, ** p<0.01, *** p<0.001)

significance and the signs of other variables do not change much. Similar to $ROAA$, $NNIBL$ is not significant, as we cannot reject the hypothesis of no effects of $NNIBL$ on the inflation rate in the following year.

Finally, we estimate the model that controls the independence of central banks – CBI (see model 5 in the Empirical results). Table 4.11 represents the results of this regression.

We can reject the hypothesis of no effects of gold reserves on inflation rate at 5% level. The coefficient is negative but very small. If a central bank increases gold reserves by 1%, the inflation rate is expected to decrease by only 0.016%. Central banks' independence is not statistically significant.

According to the results of the last three models estimated, the highest goodness of fit is obtained when we control the proxy variable for the profitability of central banks – $ROAA$. Therefore, we continue the analysis by estimating the model that controls $ROAA$ for the subsample that includes only the countries that use the monetary policy of inflation targeting. We are

Table 4.11: The dependence of inflation on gold reserves by PCSEs controlling the independence of central banks

(PCSEs)

Inflation Rate	Coef.	Std. err.
Target	-0.448	0.452
Gold	-0.016*	0.008
Log real GDP	-0.969***	0.158
Log Population	0.273*	0.118
Openness	0.008	0.014
Fixed Regime	-1.385***	0.441
Floating Regime	-0.920*	0.448
Money Supply (t-1)	4.293*	2.123
Unemployment (t-1)	-0.019	0.026
CBI (t-1)	0.899	0.811
constant	9.540*	3.774
R^2	0.1524	
Wald chi2(10)	264.62	
Prob > chi2	0.00	
AR (1)	0.47	
N. of observations	1320	
N. of groups	110	
Estimated covariances	6105	
Estimated autocorrelations	1	
Standard errors are adjusted for 110 clusters in countries		

(* p<0.05, ** p<0.01, *** p<0.001)

interested if there is any remarkable difference in the significance of the variables if we estimate the model only for the inflation targeting countries. We keep only the countries that used inflation targeting at least for one year in our sample; therefore, we decrease the sample to 41 countries. Table 4.12 shows the results of this regression.

The results change a lot when we include only inflation targeting countries to the sample. The main difference is that gold is now strongly statistically significant at 0.001 level with the negative coefficient. The model estimates that if a central bank increases its gold reserves by 1% compared to its total reserves and it uses inflation targeting, then the inflation rate should ceteris paribus decrease by 0.024%. Another interesting thing is that the proxy of the profitability of central banks is significant at 0.01%. This result is in contrast to all estimations of the regressions using PCSEs that were done before for the samples that include not only inflation targeting countries, as no proxy variable used for controlling the financial strength of central banks was signif-

Table 4.12: The dependence of inflation on gold reserves by PCSEs only for IT countries controlling the profitability of central banks

(PCSEs)		
Inflation Rate	Coef.	Std. err.
Gold	-0.024***	0.006
Log real GDP	-0.783***	0.126
Log Population	0.277**	0.102
Openness	-0.008	0.011
Fixed Regime	-0.638	0.505
Floating Regime	-0.737	0.431
Money Supply (t-1)	6.146***	1.639
Unemployment (t-1)	0.045	0.052
ROAA (t-1)	-0.149**	0.057
constant	7.029*	2.831
R^2	0.2304	
Wald chi2(10)	230.17	
Prob > chi2	0.00	
AR (1)	0.52	
N. of observations	574	
N. of groups	41	
Estimated covariances	861	
Estimated autocorrelations	1	
Standard errors are adjusted for 41 clusters in countries		

(* p<0.05, ** p<0.01, *** p<0.001)

icant before. The coefficient of $ROAA$ is negative. The model estimates that if $ROAA$ of a central bank increases by 1%, the inflation rate in a country should decrease by 0.149%. GDP, population and money supply growth are significant almost in all estimations and it is not the exclusion here. In contrast, the dummy variables indicating the fixed and the floating exchange rate regimes are not statistically significant anymore. Therefore, we can conclude that the exchange rate regime does not have such a strong impact on inflation if a country uses inflation targeting.

The results of the estimation with only inflation targeting countries let us conclude that if a central bank uses the policy of inflation targeting, the effects of its operations and the decisions of its management are stronger on the inflation. We are also interested to see what is the effect of gold on inflation for inflation targeting countries if we control $NNIBL$ and CBI. Therefore, we estimate the regressions with PCSEs that control for these variables only for inflation targeting countries. When we include $NNIBL$ instead of $ROAA$,

R^2 declines, as in contrast to $ROAA$ $NNIBL$ is insignificant. We provide the results of the estimation where $NNIBL$ is included in Table 4.12.

Table 4.13: The dependence of inflation on gold reserves by PCSEs only for IT countries controlling the credibility of central banks

(PCSEs)

Inflation Rate	Coef.	Std. err.
Gold	-0.018**	0.007
Log real GDP	-0.960***	0.157
Log Population	0.239*	0.120
Openness	-0.016	0.012
Fixed Regime	-0.565	0.564
Floating Regime	-0.994**	0.479
Money Supply (t-1)	0.861***	1.028
Unemployment (t-1)	0.035	0.052
NNIBL (t-1)	-0.646	1.027
constant	9.949**	3.367
R^2	0.1985	
Wald chi2(10)	165.87	
Prob > chi2	0.00	
AR (1)	0.53	
N. of observations	476	
N. of groups	34	
Estimated covariances	595	
Estimated autocorrelations	1	
Standard errors are adjusted for 34 clusters in countries		

(* p<0.05, ** p<0.01, *** p<0.001)

Similar to previous regression, gold is significant at 0.01 level. However, in contrast to $ROAA$, $NNIBL$ is not significant, as we cannot reject the hypothesis of no effects on the inflation rate. R^2 is lower than in previous results that implies that the regression controlling $ROAA$ explains more variation in the inflation rate than the regression controlling $NNIBL$.

Finally, we estimate the PCSEs including CBI instead of $NNIBL$ and $ROAA$. Table 4.13 presents the results of this estimation. The results do not strongly differ from the previous two estimations. We can reject the hypothesis of no ceteris paribus effects of gold reserves on the inflation rate at 0.01 level. The coefficient of the ratio of gold reserves to total reserves is negative. If the portion of gold reserves in total reserves of a central bank increases by 1%, the model estimates the inflation rate to decrease by 0.02%. This result is consistent with the previous two regressions that controlled $ROAA$ and $NNIBL$. The

Table 4.14: The dependence of inflation on gold reserves by PCSEs only for IT countries controlling the independence of central banks

(PCSEs)

Inflation Rate	Coef.	Std. err.
Gold	-0.022**	0.006
Log real GDP	-0.684***	0.142
Log Population	0.357*	0.099
Openness	0.013	0.011
Fixed Regime	-0.797	0.417
Floating Regime	-0.722**	0.418
Money Supply (t-1)	3.592***	1.867
Unemployment (t-1)	0.006	0.020
CBI (t-1)	-1.087	1.096
constant	5.502**	2.821
R^2	0.2108	
Wald chi2(10)	144.01	
Prob > chi2	0.00	
AR (1)	0.42	
N. of observations	576	
N. of groups	48	
Estimated covariances	1176	
Estimated autocorrelations	1	
Standard errors are adjusted for 48 clusters in countries		

(* p<0.05, ** p<0.01, *** p<0.001)

proxy of central banks' independence – CBI – is statistically insignificant. R^2 is lower than if we include $ROAA$ instead of CBI. Therefore, $ROAA$ shall be chosen upon $NNIBL$ and CBI in the analyses of inflation.

4.3 Implications

Taking into account all the results that we obtained from the empirical analysis, the main conclusion that we are able to make is that gold reserves are statistically significant only for the inflation targeting countries and only if we control the financial strength of central banks. The results of all three linear regressions estimated with panel corrected standard errors for the countries that used the inflation targeting at least for one year enabled us to reject the hypothesis of no effects of gold on inflation at 0.01 level or lower levels. In contrast, the significance does not hold, if we include the countries that did not use inflation targeting at all in the analyzed period. The only estimation with the panel corrected standard errors for the whole sample that shows the significant effect of gold reserves on inflation is when we include CBI. Nevertheless, R^2 is very low for this estimation.

The significance of gold for the inflation targeting countries implies that according to our model gold reserves can positively affect the price stability only in the case when inflation targeting is or was implemented. Otherwise, the relationship is not proved. This is an important finding in the understanding of the relationship of gold reserves and inflation, as we can argue that central banks that set their targeted values for the inflation rate should take into account the amounts of gold reserves they hold. However, if we analyze the inflation targeting itself, we are not able to confirm that it positively affects the price stability. The dummy variable indicating the usage of the policy of inflation targeting is insignificant almost in all estimations. Another possible reason for the significant effects only for the inflation targeting counties is that these countries might have more accurate and reliable data available.

We cannot but mention another thing of interest – when the panel corrected standard errors are estimated only for the inflation targeting countries, we find only $ROAA$ to be statistically significant among all the proxy variables of the financial strength of central banks. The relationship between gold and inflation is stronger if we control the financial strength of central banks. The highest R^2 of approximately 23% is achieved if we control $ROAA$ compared to the estimations including $NNIBL$ and CBI. The sign of the coefficient of $ROAA$ is negative that implies that the more profitable a central bank is, the more stable a price level is in a country. Nevertheless, the significance holds only for the inflation targeting countries. For the whole sample, neither of the proxy variables for the financial strength of central banks is significant.

We can conclude that for the inflation targeting countries the actions and the performance of central banks are more important than for the non-inflation targeting countries. The fact that the relationship between gold reserves and inflation is stronger when the financial strength is included is not unexpected. If the inflation rate moves away from the targeted value, banks have to be financially strong enough to be able to act accordingly to reach their targeted values. Central banks might choose either inflation rates or foreign exchange interventions to reach their targeted values of the inflation rate. However, if a central bank is unprofitable and has a massive debt amount, it will not be able to intervene effectively.

In contrast, when we include the unemployment rate and the money supply growth lagged by one year to cope with the endogeneity, the p-value of gold does not change much compared to the first model (see model 1 in Methodology). The money supply growth is significant in almost all estimations both for the whole sample and only for the inflation targeting countries. The coefficient is positive and its value is very high that can be explained by the effect of the money multiplier. The unemployment rate is significant in all the fixed effects estimations with the negative sign of the coefficient. Nevertheless, when we estimate the linear regression with the panel corrected standard errors only for the inflation targeting countries, the significance does not hold. We can conclude that for the inflation targeting countries there is no significant evidence that the Philips curve holds. However, as in order to cope with the possible endogeneity we use lagged values of the unemployment rate, we might have lost some efficiency in the estimation. Therefore, we cannot argue that the unemployment rate should not be taken into account by central banks when they need to adjust the inflation rate.

The only variable that is significant in all estimations is real GDP per capita. This significance is consistent with the literature, as almost all papers that investigate different factors affecting inflation control real GDP and the relationship is usually significant. The coefficient is negative that implies that more income of a country implies a more stable price level. Another variable that is significant almost in all regressions is the size of a population. However, the results of the fixed effects model show a negative relationship, while estimation with the panel corrected standard errors shows a positive relationship. Based on the fact that the results of the estimation with the panel corrected standard errors are more reliable, we can conclude that the larger the population of a country is, the higher its inflation rate is.

Additionally, we would like to comment on the significance of the dummy variables indicating the fixed or the floating exchange rate regimes. When we estimate the fixed effects model without controlling the strength of central banks, we can see that both fixed and floating dummy variables are significant and the coefficients are negative. However, then when we include the proxy variables for the strength of central banks, the significance does not hold. At that point of the analysis, we have concluded that the exchange rate regime is not so crucial if we control the financial strength of central banks. Nevertheless, when we estimate PCSEs for both inflation targeting and other countries, we can clearly observe that both dummy variables are strongly significant. Their significance implies that strictly fixed or strictly floating exchange rate regimes are preferable than the regimes that are mixes of both. The sizes of the coefficients differ depending on what are the other variables controlled. However, when we estimate the regressions only for inflation targeting, we can see that only the floating exchange rate regime is significant. Therefore, we can conclude that the floating exchange rate regime shall be preferable to the fixed exchange rate regime in order to have a stable price level in inflation targeting countries.

In view of the fact that gold reserves have significant effects on the inflation rate in the inflation targeting countries, it would be valuable to analyze the effects of other expensive metals. Future studies could fruitfully explore the effects of gold reserves on inflation further by analyzing larger periods of time. Additionally, further work is needed to investigate if other reserves held in expensive metals have stronger effects on inflation than gold. Accordingly to the literature review and the data we possess, gold is not the most stable asset among other precious metals. Silver and palladium if adjusted for inflation are more stable than gold over time. Nevertheless, unfortunately, there is not much data available for other precious metals and, therefore, this analysis is very problematic. Silver and palladium are not as popular as gold among central banks to be used as a hedge against inflation.

Another analysis of interest would be to investigate if there is any difference in the effects of gold on inflation rate if we include into an analysis a much larger time period. Primarily, we would be interested to compare the effects before and after the fall of the Bretton-Woods system. As a consequence of such analysis, we will be able to conclude if the effects of gold on inflation vary over time and depend on the length of period taken into analysis. Currently, this data is not available as well; nonetheless, we believe that finding this data can be a part of very valuable research in the future.

Chapter 5

Conclusion

The importance of central banks' gold reserves has been widely discussed during the last decades. After the fall of the Bretton-Woods system, many economists started to argue that gold cannot be considered as a safe haven, as it is not stable enough to be used as a hedge against inflation and it does not yield any returns. Many central banks around the world have been significantly decreasing its gold reserves since the end of the 20th century and, despite this, they do not experience high inflation. Nevertheless, the majority of central banks still hold large parts of their reserves in gold, as they believe that gold does not lose value when there is high inflation.

Another important reason why many central banks prefer to hold gold in their reserves is that there is a traditional and historical belief in the reliability of gold among the population of the world. Many economists believe that gold reserves can enable central banks to control the inflation expectations of people. Indeed, people tend to consider central banks to be stronger financially if they have enough reserves in gold.

The primary aim of this master thesis is to analyze the relationship between central banks' gold reserves and inflation. For this purpose, we have analyzed the data for 110 countries during the period of 2000 – 2016. The dependent variable is the inflation rate measured by the consumer price index using the Laspeyres formula. The primary independent variable of interest is the ratio of gold reserves to total reserves held in central banks. In accordance with the literature described in the literature review, we determine the main factors that affect inflation. Our analysis controls the following variables: real GDP per capita, the size of population, openness of the economies, the exchange rate regime, the level of unemployment and money supply growth. Additionally, we have included the proxy variables for the profitability, the credibility and the independence of central banks. These variables are included in order to observe if there is a difference in the relationship between central banks' gold reserves and inflation when we control the efficiency of the central banks' management and its actions.

We have estimated the fixed effects model both including the proxy variables of the performance of central banks and without them for the whole sample. The results show that there is no significant evidence of the effects of gold reserves on inflation. After the check of robustness of the results, we conclude that the results of the fixed effects model are not robust due to the presence of the heteroskedasticity, the cross-sectional dependence and the autocorrelation. We cope with these issues by estimating the linear model with panel corrected standard errors (PCSEs). The results of this estimation for the whole sample do not allow us to reject the hypothesis of no effects of central banks' gold reserves on inflation. Nevertheless, after we estimate the model with PCSEs only for the subsample of the inflation targeting countries, we can reject the hypothesis of no significant effects of gold reserves on inflation. Additionally, we can observe that the inclusion of the proxy variable for the financial strength of central banks make the effects of gold reserves on inflation stronger.

All in all, our results demonstrate a strong adverse effect of gold reserves held in central banks on inflation if we include only central banks that set the targets for their inflation and only if we control the financial strength of central banks. In contrast, if we include both the central banks that used inflation targeting for at least one year in the analyzed period and those central banks that did not use it, we do not find any evidence of significant effects of gold reserves on inflation. Furthermore, gold reserves are significant for inflation targeting countries only if we control the financial strength of central banks. Therefore, taking all the findings in the consideration, we can argue that if central banks use the policy of inflation targeting, they should hold sufficient amounts of gold reserves. However, the efficiency of using gold reserves of central banks as a hedge against inflation will depend on the performance and financial strength of central banks.

Though there are many studies of inflation and even there are studies of the effects of inflation on the prices of gold, we have not found any previous researches that analyze the effect of gold reserves held in central banks on inflation. Therefore, our master thesis contributes to the literature about the factors affecting inflation, as it enables us to conclude that gold reserves indeed have significant negative effects on inflation rate but only for the inflation targeting countries.

Based on the fact that we are able to conclude that gold reserves have significant effects on inflation for inflation-targeting countries, we believe that future research is certainly required to explore this topic further. The future research should definitely test if there are significant effects of the reserves of central banks held in other precious commodities, such as silver, platinum etc. The effects might be much stronger, as based on our data we can observe that gold is not the most stable asset among other precious metals. Additionally, though we cannot conclude that gold reserves are significant for all the countries, we believe that further research including the broader data set for the much longer period will be valuable. Primarily, it will be of interest to analyze if the effects were significant before the end of Bretton-Woods system and if the results depend on the length of the time period included.

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Appendix A

Appendix

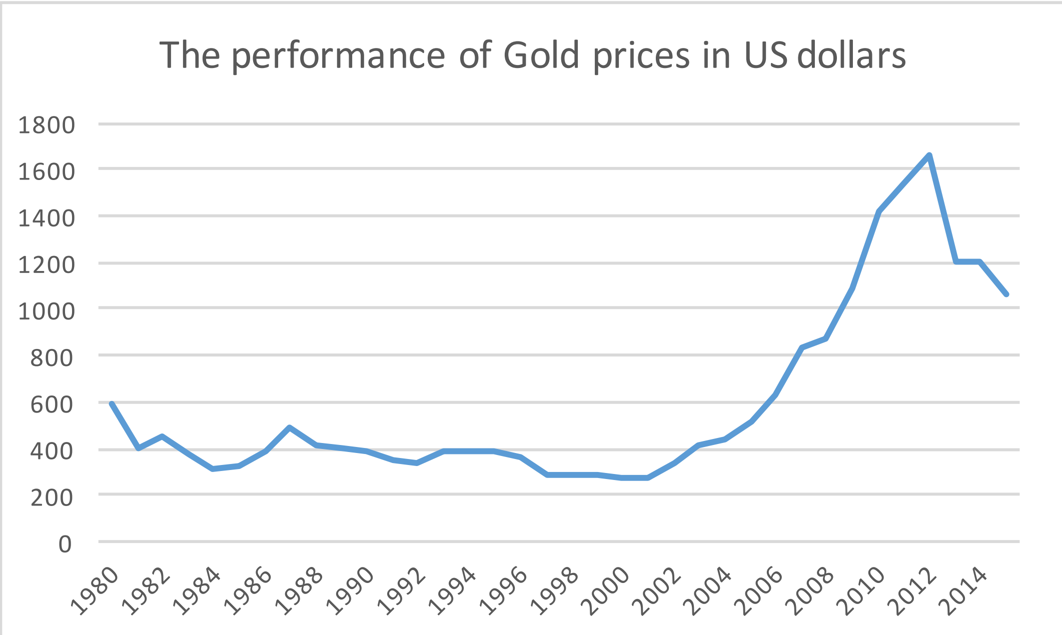

Figure A.1: Historical annual closing Gold prices since 1980

Table A.1: Performance of key commodities in US$ (data ending 31.7.2018)

	Gold (US$/oz)	Silver (US$/oz)	Palladium (US$/oz)	Platinum (US$/oz)
1-month	-2.4%	-4.2%	-1.1%	-1.3%
3-month	-7.0%	-5.8%	-3.4%	-7.3%
YTD	-5.4%	-8.5%	-12.2%	-9.9%
1-Year	-3.7%	-7.9%	5.3%	-10.8%
3-Year	12.3%	5.4%	50.3%	-15.2%
5-Year	-7.1%	-22.6%	28.3%	-41.8%
3y CAGR	3.9%	1.8%	14.5%	-5.3%
5y CAGR	-1.5%	-5.0%	5.1%	-10.2%

Table A.2: Comparison of results of Pooled OLS, Fixed Effects and Random effects models

	Pooled OLS	Fixed Effects	Random Effects
	InflRate	InflRate	InflRate
Target	-1.024***	-0.941**	-0.881**
	(-0.274)	(0.341)	(0.314)
Gold	-0.012*	-0.013	-0.014
	(0.006)	(0.010)	(0.009)
log real GDP	-0.971***	-0.896***	-1.028***
	(0.068)	(0.195)	(0.125)
log Population	0.162*	-0.740	0.368*
	(0.066)	(0.798)	(0.154)
Openness	-0.022***	0.039***	0.015
	(0.005)	(0.011)	(0.009)
Fixed	-1.743***	-0.859***	-0.982***
	(0.249)	(0.240)	(0.234)
Floating	-1.778***	-0.684*	-0.747**
	(0.277)	(0.272)	(0.263)
_cons	13.397***	24.100*	8.289**
	(1.391)	(12.237)	(2.867)
N	1870	1870	1870

Table A.3: Breusch and Pagan Lagrangian multiplier test for random effects

Breusch and Pagan Lagrangian multiplier test for random effects
InflRate[country,t] = Xb + u[country] + e[country,t]
Test: Var(u) = 0
chibar2(01) =2235.42
Prob >chibar2 =0.0000

Table A.4: Hausman test for choosing between Random and Fixed effects mode

Test: Ho difference in coefficients not systematic
chi2(7) = 25.44
Prob>chi2 =0.0006

Table A.5: Levin-Lin-Chu unit-root test

	Obs	**Unadjusted t**	**Adjusted t***	**Adjusted t* p-value**	**Lags in ADF by AIC**
Inflation Rate	1870	-26.4461	-16.6838	0.0000	0.15 lags average
Gold	1870	-39.7714	-29.0149	0.0000	0.30 lags average
ROAA	975	-18.5425	-11.1617	0.0000	0.25 lags average
NNIBL	975	-11.6603	-5.7282	0.0000	0.20 lags average
CBI	1870	-11.0145	1.8775	0.9698	0.70 lags average
CBI (trend and CD)	1430	-76.7450	-69.5252	0.0000	0.14 lags average

Table A.6: Wooldridge test for autocorrelation testing

H_0 – No first-order autocorrelation	
Model 2	
F (1, 109)	69.314
Prob >F	0.0000
Model 3	
F (1, 64)	40.697
Prob >F	0.0000
Model 4	
F (1, 64)	41.056
Prob >F	0.0000
Model 5	
F (1, 109)	57.634
Prob >F	0.0000

Table A.7: Pesaran test of cross sectional independence

H_0 – Cross-sectional independence		
Model 2		
Pesaran's test of cross sectional independence	**=74.025**	Pr = 0.000
Average absolute value of the off-diagonal elements	=0.356	
Model 3		
Pesaran's test of cross sectional independence	**=47.736**	Pr = 0.000
Average absolute value of the off-diagonal elements	=0.377	
Model 4		
Pesaran's test of cross sectional independence	**=49.904**	Pr = 0.000
Average absolute value of the off-diagonal elements	=0.383	
Model 5		
Pesaran's test of cross sectional independence	**=62.817**	Pr = 0.000
Average absolute value of the off-diagonal elements	=0.349	

Table A.8: Modified Wald test

sigma(i)^2 = sigma^2 for all i	
Model 2	
chi2 (110)	19209.10
Prob>chi2	0.0000
Model 3	
chi2 (65)	6007.25
Prob>chi2	0.0000
Model 4	
chi2 (65)	7519.29
Prob>chi2	0.0000
Model 5	
chi2 (110)	42042.02
Prob>chi2	0.0000