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Selected Aspects of Negative Interest Rates

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Abstract

Developed economies have been severely hurt over the last decade. Low inflation and unbalanced growth forced authorities to implement unconventional measures like negative interest rates. The unbalanced environment in financial markets is also visible on the commodity market. The prices of commodities have already experienced second contraction over the last decade. However, according to Frankel (2012) the changes in prices of commodities are heavily determined by real interest rates. This thesis summarizes implications resulting from negative nominal interest rates and then takes a closer look on the connections between changes in interest rates and the movements in commodity market. We use vector *error correction model* to investigate impact of nominal macroeconomic factors on the set of 16 commodities of different types (metal, energy and industrial commodities). As expected, our findings confirmed that the price changes in the commodity market are in the long run significantly linked with inflation as well as with nominal interest rates. The analysis also supports the claims of considerable correlation among prices themselves but provides no evidence of negative interest rate policy impact on the commodity market.

Abstrakt

Rozvinuté ekonomiky boli v poslednom desaťročí výrazne zasiahnuté. Nízka inflácia a nevyvážený rast viedli k implementácii nekonvenčných opatrení ako napríklad negatívne úrokové sadzby. Nestabilné prostredie na finančných trhoch je tiež viditeľné v prípade komoditného trhu. Ceny komodít zaznamenali už druhý pokles za posledné desaťročie. Avšak, podľa J. Frankela (2012) sú zmeny cien komodít výrazne určované reálnymi úrokovými sadzbami. Táto práca sumarizuje dôsledky vyplývajúce z negatívnych nominálnych úrokových sadzieb a následne bližšie skúma prepojenie medzi zmenami úrokových sadzieb a pohybmi na komoditnom trhu. Na preskúmanie vplyvu nominálnych makroekonomických faktorov na množinu 16 komodít rôzneho druhu (kovy, energetické a priemyselné komodity) používame vektorový model korekcie chýb. Naše zistenia potvrdili očakávanie, že zmeny cien na komoditnom trhu sú v dlhodobom horizonte významne spojené ako s infláciou, tak aj s nominálnymi úrokovými sadzbami. Analýza tiež podporuje tvrdenia týkajúce sa značnej korelácie medzi samotnými cenami, ale neposkytuje žiadne dôkazy o vplyve politiky negatívnych úrokových mier na trh komodít.

Kľúčové slová

Negatívny, nominálny, úrok, úroková sadzba, komodity

Keywords

Negative, nominal, interest, interest rate, commodity, co-movement

Declaration of Authorship

1. The author hereby declares that he compiled this thesis independently, using only the listed resources and literature.

2. The author hereby declares that all the sources and literature used have been properly cited.

3. The author hereby declares that the thesis has not been used to obtain a different or the same degree.

Prague, May 19, 2017 Šimon Repko

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Bachelor's Thesis Proposal

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Proposed Topic:

Selected Aspects of Negative Interest Rates

Preliminary scope of work:

Research question and motivation

The steady decline in the global commodity prices reflects slowing demand as markets did not fully recover from the recession and it seems like majority of subjects in the market are rather risk-averse. This development leaves the governments and the economists despair as they are gradually exhausting their options to effectively and successfully fight against the deflation. In recent years, we are witnesses of the unconventional monetary policies practiced by several central banks and I want to study how and why they implemented policy of the negative interest rates and its influence on the commodity market. Regarding financial crisis in 2007-2008 and its causes, being skeptical about unorthodox movement of interest rates is justified, as lowering interest rates stimulates the market and encourages people to invest less "expensively" but afterwards it can find its limitations.

Recent price shocks in the commodities like crude oil, gold or silver on the one hand and phenomena of the risk-averse people and the bull markets on the other can also significantly shake with this interest-sensitive market. Nevertheless, there are some people betting more on commodities due to situation in China and its resemblance with real estate market in US in years 2007-2008. Regarding some other current events such as "Brexit" together with this modern policy of NIR, examination of the connection between macroeconomic factors and the movement of the prices on the commodity market will be the core of this paper.

Contribution

In the last decade there have been studies about causes and consequences of loose monetary policy and unconventional measures, but mostly regarding quantitative easing. So this paper will study reaction of interest-sensitive commodity market on macroeconomic indicators and will discuss, in detail, the impact and the implications of negative interest rates policy. Moreover, the analysis will be aimed at the factors in the nominal terms rather than in the real ones to investigate the potential information it possesses.

Methodology

Analyzing the behavior of the commodity prices according to changes in the interest rates and inflation. Regressing prices of base commodities like gold and crude oil on the interest rate and determining the correlations inside the commodity market.

Outline

1. Abstract
2. Introduction
3. Influence of negative interest rates on commodity

4. Interpretation of regression outcomes
5. Conclusion
6. Appendix

List of academic literature:

1 *Akram, Q. F. (2009). Commodity prices, interest rates and the dollar. Energy Economics, 31(6):838–851.*

2 *Bech, M. L. and Malkhozov, A. (2016). How have central banks implemented negative policy rates? resreport.*

3 *Brunnermeier, M. K. and Koby, Y. (In Preparation). The Reversal Interest Rate: The Effective Lower Bound of Monetary Policy.*

4 *Denizer, C. (1989). Primary commodity prices and macroeconomic variables: A long run relationship. resreport, Center for Economics and Econometrics; World Bank*

5 *Rogoff, K. (2014). Costs and benefits to phasing out paper currency. resreport, Harvard University*

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Author	**Supervisor**

List of Acronyms

BoJ	Bank of Japan
CBPR	Central Bank Policy Rate
DNB	Denmark National Bank
ECB	European Central Bank
FED	Federal Reserve System
GDP	Gross Domestic Product
IMF	International Monetary Fund
LIBOR	London Interbank Offered Rate
NIR	Negative Interest Rates
NIRP	Negative Interest Rates Policy
OECD	Organization for Economic Co-operation and Development
QE	Quantitative Easing
QQE	Quantitative and Qualitative Easing
SNB	Swiss National Bank
VAR	Vector AutoRegression
VECM	Vector Error Correction Model
WEO	World Economic Outlook

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1 Introduction

"That doesn't mean I think it's the end of the world when it ends, but I don't think anybody knows exactly what the full implications" of negative rates will be. I hope to live long enough to find out," – Warren Buffet

Initiated by a strong development of China's market and followed by a steady growth and expansionary macroeconomic environment around the world, the prices of all commodities skyrocketed and reached their peak in July 2008, especially the prices of metals and energy which were twice as higher as in 2003. This boom showed two similarities with previous price explosions of commodities[1] according to J.Baffes and T.Haniotis (2010) – firstly, all took place in the shadow of a high and strong economic growth and all were followed by a serious depression. In contrast with the other however, this expansion was accompanied by a steep growth in real estate and equity markets and was the only one where all three main types of commodities – energy, metals and agriculture – grew simultaneously. The sudden blast of the real-estate bubble plummeted the prices, sometimes to the levels from 2003. Nobody had foreseen such a drop.

In addition, during the financial crisis of 2008, the use of traditional measures was found inadequate and the use of unorthodox tools was now considered. *"There is a consensus that central banks require additional tools to address the problems that can occur in financial markets and that inflation targeting was an insufficient policy tool in the past."* (Bruce V. Rauner, 2009) Several states started injecting money into the market in the form of quantitative easing. However, the recession stroke really hard and the first recovery in 2011/2012 failed which lead the system into another collapse. The system struggled with deflation, interest rates had been pushed to zero along with huge money injections and the market was teeming with idle risk-averse people.

As nominal interest rates of more countries crossed 1% level, the financial instruments started becoming unworthy to be invested in as they yielded almost nothing. It was fairly expected that investors would somehow react to these significant shocks in financial markets and consequently they adjusted their portfolios. It was just a matter of the time till the commodity market experienced the inflow of funds again. Hence

[1] There were two major commodity booms in the post-WWII period (during the Korean War) and the early 1970s energy crisis

commodities encountered a comeback in their value and rose back to the pre-crisis altitudes. Certain studies have pointed out that there is correlation between prices of commodities and the real interest rate (Frankel, 2012). Therefore, it could have been expected to see that as nominal interest rates were reaching zero bound and the majority of developed countries suffered from deflation, the commodities were becoming more valuable. This prevailing unfavorable economic situation in the world and growing distrust for conventional investments and counter measures yield its fruits.

Consequently, after the introduction of quantitative easing by several countries, another unorthodox measure was presented - negative interest rates, previously regarded as an impossible event. The theory tells us that by decreasing the interest rate, the incentive to lend also diminishes. If we set negative interest rates then even the principal is not fully returned. This should therefore never happen by simple math and consideration.

It was considered as a non-existing event a few years ago according to the member of the Executive Board of the ECB L.B. Smaghi: *"...the economic shock is so powerful that the nominal interest rate needs to be brought down to zero. At that level, cutting policy rates further is not possible, so any additional monetary stimulus can be undertaken only by resorting to unconventional monetary policy tools."* It would be appropriate to clarify what this ground-breaking policy exactly means. According to the definition by Investopedia, the negative interest rate policy (NIRP) is an unconventional monetary policy tool whereby nominal target interest rates are set with a negative value, below the theoretical lower bound of zero percent.

This thesis will be structured in the following manner. In chapter 2, we will describe the theory behind interest rates in detail and uncover their influential flows to the economy. Moreover, the phenomenon of negative interest rates will be introduced, its implications and impossibility in theory. Also there will be a briefly described phenomenon of zero lower bound. In chapter 3 we will provide details about history and development of the NIR. In fact, there are only five central banks which introduced this unconventional policy – the SNB, DNB, Sveriges Riksbank, ECB and BoJ. (Hungary also adopted the NIR, but only on the deposit rate which is not its CBPR). In chapter 4, the situation on the commodity market in the last decade and then the connection with interest rates will be explained. Chapter 5 then focuses on data including description of source dataset and issues that had to be resolved during its gathering and manipulation. Furthermore, variables that are controlled for in our analysis are also explained. Chapter

6 describes the used methodology and all encountered issues related to it. Chapter 7 summarizes the results and provides some information about possible improvements applicable in the future analysis. The last chapter contains the findings and recapitulates their implications.

2 What are negative interest rates?

The phenomenon of negative interest rate is aptly described by Matthew Campbell and Peter Levring (2016):

"A monetary policy tool once viewed by mainstream economists as approaching apostasy, if not a virtual impossibility."

Prior to a closer look at the implications of negative interest rates and the phenomenon preceding it, we should clarify what are interest rates in general.

2.1 What is the interest rate?

The interest rate is a fee charged by a lender to a borrower expressed as a percentage of the principal.

This borrowed asset can have different forms, i.e. cash, consumer goods, large assets like cars or buildings, land etc. It is a rent that we pay for an apartment or land or a lease on the car. To some extent, the interest is included in the majority of transactions we do. The interest rate is mostly associated with deposits, loans, mortgages, pension funds, bonds, stocks and other securities. The level of interest is linked with risks of lending – if it is more likely that we will get back assets we lent when the rate of interest is lower and vice versa. Therefore, the interest rates on deposits and government bonds are very low while the interest rates on loan, mortgages and stocks tend to be higher.

However, it is a great difference between nominal interest rate and real interest rate. Interest rates of common use are called "nominal". If we adjust it for the inflation, we get the "real" interest rate. In practice we subtract inflation from the nominal interest rate. The real interest rate measures a value in purchasing power – that means if the amount of goods that we can buy after some period (with principal plus interest) is the same as the amount affordable before that period (with the principal only).

There are numerous types of interest rates on the market:

- Discount rate – the rate at which eligible institutions can borrow some liquidity from the central bank (the term usually linked with the FED)
- Refinancing rate – or minimum bid, is the interest rate at which other banks can borrow some liquidity from central bank (the term usually linked with the ECB)
- Repo rate – the discount rate at which government bonds are repurchased by the central bank from commercial banks

- Deposit rate – the interest rate that is paid by financial institutions to deposit account holders
- Lending rate – the interest rate that banks charge on money that they lend
- Interbank rate – the interest rate charged among commercial banks on short-term loans. This rate is usually differentiated according to creditworthiness of the borrower or the objective of financing.

Another type of interest rate, at first glance not as specific, is the Central Bank policy rate (CBPR) or the key interest rate. The central bank uses this interest rate to enact or signal its monetary policy heading. The central banks' policy making committees (e.g. Fed Open Market Committee) are usually authorized to make decisions over this rate. Since the underlying financial instrument of the CBPR is selected by the banks themselves, it can differ from country to country. For instance, the Governing Council of the ECB sets these three key interest rates for the Eurozone: the interest rate on the main refinancing operations, the rate on the deposit facility and the rate on the marginal lending facility. In some other countries the CBPR is the discount rate (e.g. Denmark, Japan) while it is a repurchase agreement rate in the others (e.g. Sweden, Singapore)

The short term interest rate is one of the main instruments of a monetary policy. In addition, interest rate, inflation, exchange rate and money base create group of nominal anchors for monetary policy. Nominal anchor is usually one of these variables that is selected by the central bank to pin down expectations of private agents about development of nominal prices and other important factors. Tools used to control these monetary targets can be divided into two groups. Traditional tools, the first group, are used commonly by the central banks to drive economy to expand or to contract. There are three - open market operations, the discount rate and the reserve requirements.

The second group is called "unconventional" monetary tools. These measures are used in the case of very low nominal interest rates where the deflation is threatening or is already occurring. In this group we find credit easing, quantitative easing, forward guidance and signaling

2.2 The interest rates in theory

It is known that commercial banks are paid by central banks to hold money in their deposits in order to secure liquidity. Households and firms are receiving payments for entrusting and lending (i.e. storing) their savings to bank facilities. Loan and mortgage rates depend on the level of interest, too. Thus the influence of interest rates is significant on the market. The theory/system is based on logical assumptions that banks yield the profit when borrowing and/or that households and firms are better off when storing their money to banks.

The aforementioned theory is well-described by IS-LM model, where the IS curve (Investments - Savings) defines balance on the capital market and, similarly, on the market of goods and services. On the other hand, the LM curve (Liquidity preference - Money supply) defines balance on the money market and the likewise balance on the bond market. (Cahlík, Hlaváček & Seidler, 2010) Main endogenous variables in this model are interest rate (depicted on the vertical axis) and output (i.e. income, depicted on the horizontal axis). According to nature of the IS curve, investments and consumption are discouraged by higher real interest rate, therefore the IS curve is downward sloping while the LM curve represents an opposite effect here. If the output increases, households react to the rise in demand for money by selling the securities. Consequently, the bond market is hit by excess supply and that pushes the interest rates up – hence upward slope of the curve.

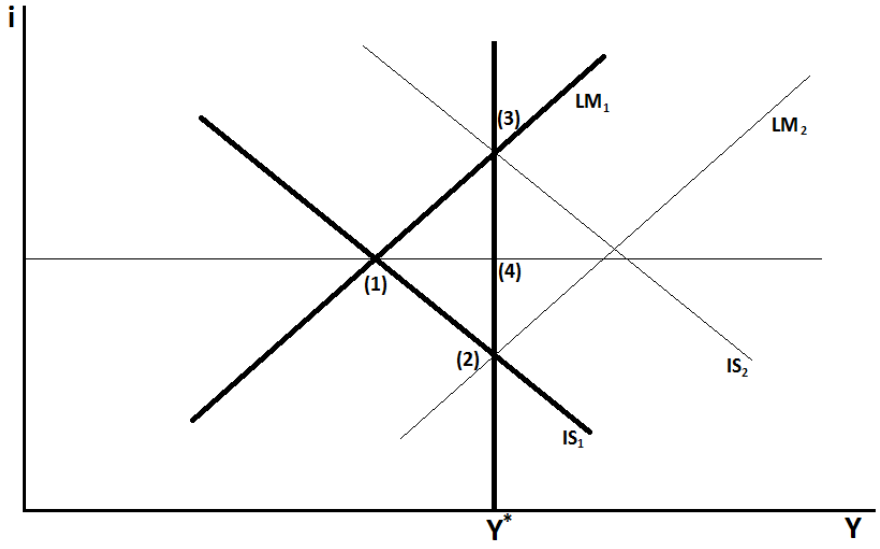


Figure 1- Fiscal and Monetary policy in IS-LM model
Source: Macroeconomics (Cahlík et al.,2010)

Figure 1 depicts a situation in which economic authorities – government and central bank – aim to boost the economy and increase output. Sole expansive monetary policy, e.g. money injections, shifts in the LM curve to the right (point 2). Sole expansive fiscal policy shifts the IS curve to the right (point 3). Both cases are followed by a growth in output, but expensive monetary intervention decreases interest rate and increases investment whereas expansive fiscal policy increases interest rate and decreases investment. The need of government or central bank to change the level of output or interest rate can be achieved by an appropriate combination of fiscal and monetary policies (either expansive or restrictive). As pointed out, the character of expansive monetary policy is employed during economic downturns to boost the economy, but it definitely has its limits.

Theory of the IS-LM model considers the minimum output of zero and the same holds for interest rate – in the case of output, the association is straightforward as there is no possibility of having negative production.

The position of interest rate is slightly different but clearly nobody is willing to pay for the service when it is provided by themselves. (e.g. to lend €1000 without getting back at least €1000) Therefore, the zero interest rate is considered to be an effective lower bound of interest rates.

2.3 Paradox of the thrift

In The General Theory of Employment, Interest and Money (1936), Keynes claims that one effective tool against a recessed economy is more spending, more risk-taking, and less saving. Market with living subjects and many streams of funds is boosting itself and through the "centrifugal forces", it should eventually recover back to growth – which Keynes called "circular flow". Essentially, it is in contradicting the typical behavior in the market/economy little bit as people tend to reduce their expenses as much as possible during the tough times and save for the possible worse ones. However, this approach of preparing for "the worse" may actually bury the system in the end and drag it into a vicious circle, illustrated by Figure 2. The decline in demand implies cost-cutting by companies (higher unemployment and/or lower wages), followed by a decrease in spending and investing leading to a further reduction in demand and so on – so-called deflationary spiral.

Figure 2 - Deflationary spiral, whose elements circularly reinforce each other
Source: snbchf.com

This phenomenon is identified as "Paradox of the Thrift", or Paradox of Savings, whose first conceptual description was probably mentioned first in The Fable of the Bees (1732) by Bernard Mandeville. Nevertheless, this theory has its drawbacks which are frequently criticized. Firstly, it overlooks Say's Law message according to which the decline in demand implies lowering of prices by producers and hence people will continue their spending. This point is still a subject of debates as New Keynesian economists reject Say's law and argue against this argument by "rigidity of prices" – stating that prices are unable to respond fast enough. Secondly, people's unwillingness to spend increases their saving rate and subsequently the amount of loanable funds (assuming that they do not squirrel cash away into a mattress). That allows banks to make lending more attractive by lowering the lending rate in order to stimulate investments and spending. Some comments[2] to this argument have been raised stating the fact that banks themselves may sit on these extra funds to cover deposits (the growth in excessive reserves). This line of thoughts is leading to a phenomenon known as "liquidity trap". For these reasons, the phenomenon is frequently a subject of debates among economic society.

2.4 Negative interest rates. Why negative?

After the financial crisis of 2007/2008, economies all around the world went into recession for a decent couple of years and adopted several fiscal or monetary policies to overcome it. Stagnation in demand pushed the levels of inflation down, growth was

[2] However, if people choose to hold cash rather than to deposit them than there will be no growth in loanable funds. More about this topic can be found in paper by R.W.Garrison (2005)

unconvincing, time of price stability was still behind the horizon and thus in line with common standards, central authorities responded by cutting interest rates.

During deepening of the crisis, authorities all around the world were fighting with the recession by making money more attractive as can be observed on Figure 3. Many of them squeezed their interest rates under the 1% rate already in 2010, slowly approaching zero and almost exhausting the firepower of interest rate. Surely, interest rate setup is not the only instrument used by central authorities. Several central banks decided to initiate huge money injections known as "quantitative easing"[3]. This bond-buying program is based on purchasing government bonds or financial assets of private banks in order to stimulate spending and investments by increasing money supply. The difference between QE and other classic bond-buying monetary tools is that standard central bank monetary policies are aimed at short-run interest rate and if contraction is long enough to withstand lowering interest rate to zero, the central bank has to stop with these actions and use other tools. Only then the implementation of unconventional techniques may be the next step made by the central bank since QE influences the long-term interest rate. Thus main aim of this policy is to increase money supply and also to handle the inflation by keeping it boosted up over the target[4].

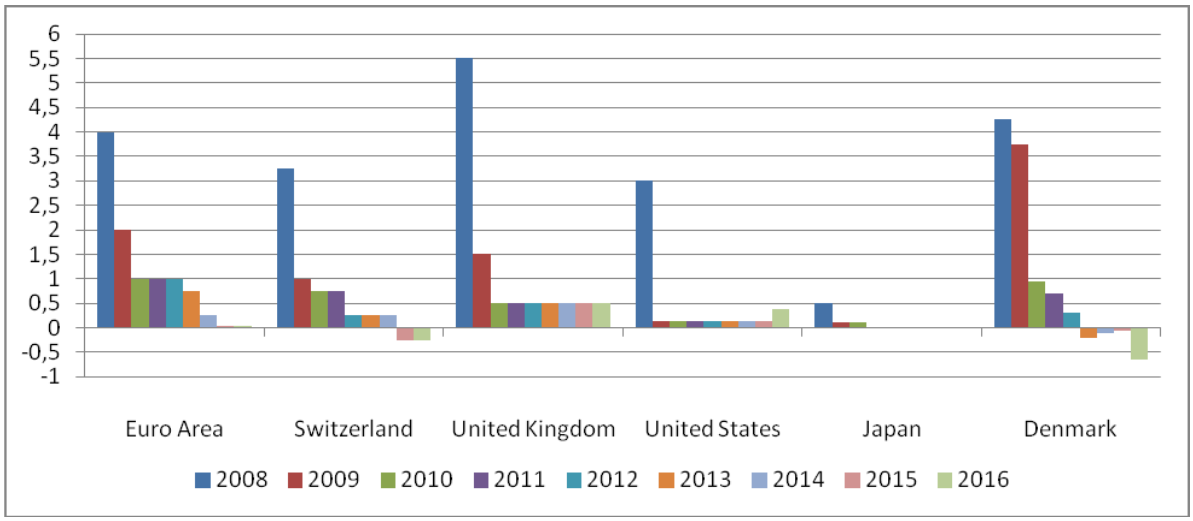


Figure 3 - Development of the nominal Central Bank policy rates in developed countries

[3] This term was firstly used by Bank of Japan when struggling with deflation in early 2000's
[4] Risky because if is not balanced out, the cash inflow can shoot inflation too high, or can be ignored by the banks unwilling to lend it out

To sum up, in cases where the potential of classic economic tools is limited, there is a place for unusual ones such as quantitative easing. Similarly, another even more unorthodox measure knocked on the doors/crossed minds – negative interest rates and matter of zero lower bound.

Zero lower bound is a subject to many discussions when it comes to monetary policy or interest rates. Zero-bound interest rate is described by Investopedia as *"The lowest percentage of owed principal that a central bank can set. In monetary policy, the use of a 0% nominal interest rate means that the central bank can no longer reduce the interest rate to encourage economic growth. As the interest rate approaches the zero bound, the effectiveness of monetary policy is reduced as a macroeconomic tool."* However, the relevance of this phenomenon was not very often taken seriously before 2008 despite several encounters mainly related to the Great Depression in the US (1929-30s) and Switzerland during the late 1970s[5].

Zero lower bound is generally considered as effective lower bound, as was mentioned in subchapter 2.1. Yet, it can be suggested that under specific circumstances, the effective lower bound can be actually somewhere in negative region because investors are willing to pay in certain situations to keep their funds safe. Brunnermeier and Koby (2016) argue in their study that so-called "reversal rate" exists which marks the line/point at which "accommodative monetary policy "reverses" its effect and becomes contractionary for lending. The level of this rate is not clearly stated as it is determined by economic environment and financial sector's balance variables and zero may thus not be strictly binding – *"…there is room to go negative up to that point, provided that financial stability is secured."* Judging by the events of the last couple of years, it can be said that this myth is refuted/severely fractured. Negative interest rates are the reality at this moment and there are a couple of unanswered questions arising. What implications does the NIR have? Can a system withstand this measure or it is the beginning of the end?

This potential zero limit is pulling the break on monetary interventions as explained above. As the face value of fiat money does not change over time, the option of households to hoard cash is quite compelling reason why rates are not expected to fall below zero. However, if all means are drained then even the unthinkable is reconsidered and the central banks would eventually announce setting key rates of

[5] Japan was taken as special case despite wrestling with ZLB for decades

negative sign. This key rate is represented in different countries by different financial instruments regarding the explanation in the previous chapter, but the overall transmission mechanism (from implementing new policy to actually influence common life of households) is actually quite complicated and sluggish. The policy adopted by the central bank directly influences commercial banks which than implement these changes, in their own way, into the life of people. Thus central bankers set the negative rates and leave all decisions on commercial banks. As already mentioned, the zero-interest yield of cash argument does effectively impede (well, under specific conditions have been negative deposit rates experienced in practice[6]) banks to directly set negative deposit rates. Therefore, the decision is met either with keeping no excessive reserves as the negative interest is imposed only on reserves over some limit or with compensating the negative yield via squeezing discount or other rates.

According to Mercein et al. (2016) there are three main channels by which policy objectives are reached through lower or negative interest rates.

- The spending channel – stimulating spending of consumers by lowering earnings from deposits. This intrusion into profits should discourage saving, motivate to spend and consequently, impale economic production stagnation/spark the economic production, and generate inflation.
- The exchange rate channel – steering flows of money out of country by creating unpleasant business environment in order to depreciate currency. Weaker currency makes domestic goods cheaper compared with the one produced abroad hence stimulating exports, driving growth, and subsequent inflation.
- The asset valuation channel – decreasing discount rate on securities and removing obstacles for investments to some extent. Promoting better financial support to companies can drive their investments and boost economic growth as well as inflation of asset prices.

On the other hand, there are also other reasons to lower interest rate aside from driving inflation – protecting the exchange rate and thus avoiding the currency to be overvalued. Obviously, it is the logic of the second channel but against a different foe – excessive money inflow and subsequent currency appreciation. Clearly, if interest rates

[6]There are several central banks that adapted negative deposit rates – ECB, SNB,MNB (Hungary), Norges Bank (Norway) and Sveriges Riksbank (Sweden)

cross the zero line and follow a negative trend then these processes and outcomes are augmented.

2.5 How to overcome zero lower bound?

We will look into the issue of the ZLB from the previous subchapter. Several suggestions have been made by economists on how to circumvent the zero line and sustain the power of the central banks.

One of the first suggestions was made by Silvio Gesell in the 19th century when he proposed a tax on holding cash - a thought also cited and approved by John Maynard Keynes. In 2009, Greg Mankiw mentioned a serial number lottery in which bank notes with specific ending digit were randomly chosen to be declared worthless so that people would be gambling if they were to hold on to cash.

If there is an interest levied on financial instruments, then why not introducing an interest on physical currency as well? This would probably solve the problem of hoarding cash as the most liquid asset would have lost its "zero loss, zero gain" status. Let's break it down. All financial instruments can be split into two categories: registered instruments and bearer instruments. Registered ones are those where identity of the owner is known and their record exists in some publicly available database. Therefore, the issuer knows the owner's identity. For instance, common stocks and bank accounts are among registered instruments. Imposing negative interest rates on bank accounts can be put into practice as easily as positive interest rates – just a change in inputs in ledger. To "pay up" negative dividends is technically possible but illegal in most jurisdictions. However, it can be stated that stocks are able to yield negative nominal value in the end due to volatility in their market value. On the other hand, main attribute of bearer instruments is an unknown identity of the owner. Therefore, the issuer does not possess any knowledge about the holder's identity. This aspect makes it difficult to pay even a positive interest as it has to be dealt with multiple-payment-on-the-one-instrument issue. An attempt to claim a negative interest rate on bearer instrument is even harder – how can people be forced to reveal their identity and pay? Thus in the fashion of Buiter (2009): *"The reason no interest, at a positive or at a negative rate, is paid on currency is that it is costly and administratively awkward and intrusive to do so."*

According to suggestions made by Kenneth Rogoff (2014), the consideration to phase out fiat money would be a constructive approach to how to eliminate the last

alternative to avoid paying negative interest rate on bonds and bank deposits. Likewise, there are also other proposals.[7]

[7] Buiter (2009) suggests also to separate numéraire from currency and establish an adjustable exchange rate between them to be able to control for changes in monetary policy – e.g. introduction of negative nominal interest rates

3 Brief history and development of the NIRP

As stated before, the phenomenon of negative interest rates is not very well explored as it is considered as impossible in theory. Nonetheless, there are studies dealing with the implementation of these controversial policies by several central banks. To be more precise, there are only five authorities that have ventured into the once-uncharted territory of this policy in the recent years – the ECB (European Central Bank), the BoJ (Bank of Japan), the DNB (Denmark National Bank), the SNB (Swiss National Bank) and the Swedish Riksbank. In the next paragraphs, we will briefly describe how this adaptation was managed and the reasons why the NIRP was the favored option.

3.1 The first experience

Struggles with inconveniently strong exchange rate have a rich history in Switzerland. It can be pointed out that there is a connection between these monetary decisions and the break-up of Breton-Woods system of fixed exchange rates. Moreover, we should not leave aside an effect of the prevailing monetary situation in Europe back then. In the 1970s, Switzerland used negative interest rates (the NIR) to counter their currency appreciation due to a wave of investors fleeing inflation in other parts of the world. They imposed the NIR on deposits of non-residents, from 2% in 1972 up to 10% in 1978. Surely, intentions of the SNB were not to fight the deflation but the actual results spoke for themselves – *"This policy lasted only until 1982, when the Swiss realized that inflation was too high a price to pay for a weak currency" (Paul Meggyesi, 2010)*

3.2 The second wave of implementation

From 2012, all four above mentioned European authorities crossed zero bound led by the DNB. In order to answer the question why Denmark played the role of Columbus in this scenario and for proper understanding of influential flows and consequent effects, we should briefly describe the situation in Europe.

Part of the EMS (European Monetary System) introduced by the EEC (European Economic Community) in 1979 was the ERM I (Exchange Rate Mechanism) whose main purpose was to reduce exchange rate variability and achieve monetary stability in Europe in preparation for a new single currency – the euro. Therefore, European

currencies were pegged to the ECU (European Currency Unit). The 1st January 1999 marks a replacement of the ECU by euro and the adaptation of this new currency by several European states. The referendum in Denmark closely rejected the acceptation of euro but entered the ERM II where it is currently its only member. The ERM I & II allow fluctuation in the exchange rate and in the case of Danish krone, the deviance is very little also in the ERM II – only 2.25%. Therefore, the DNB has a sole role in maintaining the peg. Thus when European debt crisis reached its periodic peak in 2012, risk-averse investors saw krone as a stable port and exchange rate margins were threatened. A counter move of the DNB was a decrease in interest rate in order to stem hot money inflow but at that time, the country was already wrestling with a very low interest rate so there was no other choice than to go down and push away speculators (Matthew Campbell and Peter Levring, 2016).

"There's no sharp, disruptive movement when you pass below zero. It's just working like very low interest rates," said Denmark's National Governor Lars Rohde.

This implies that Denmark obliged large and medium-sized companies to pay lenders (individuals are free of duty for now) and also gave a chance to some fortunate homeowners to actually yield a profit on the mortgages. Looking at the theoretical consequences of the NIR, some dovish economists do expect hard hit on economy in the future although there is no empirical evidence of any distortions like asset bubbles, capital flight etc. yet. However, Denmark managed to get back to the zero level, as can be seen on Figure 4 but only for a couple of months as they were forced to react to the prevailing situation at the end of 2014.

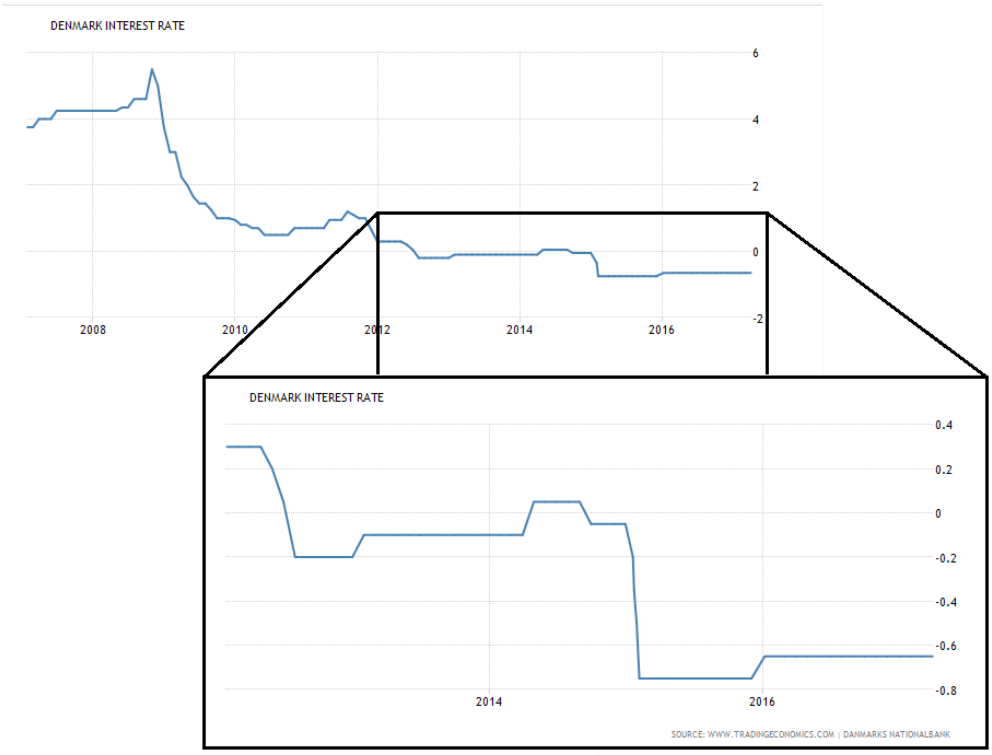
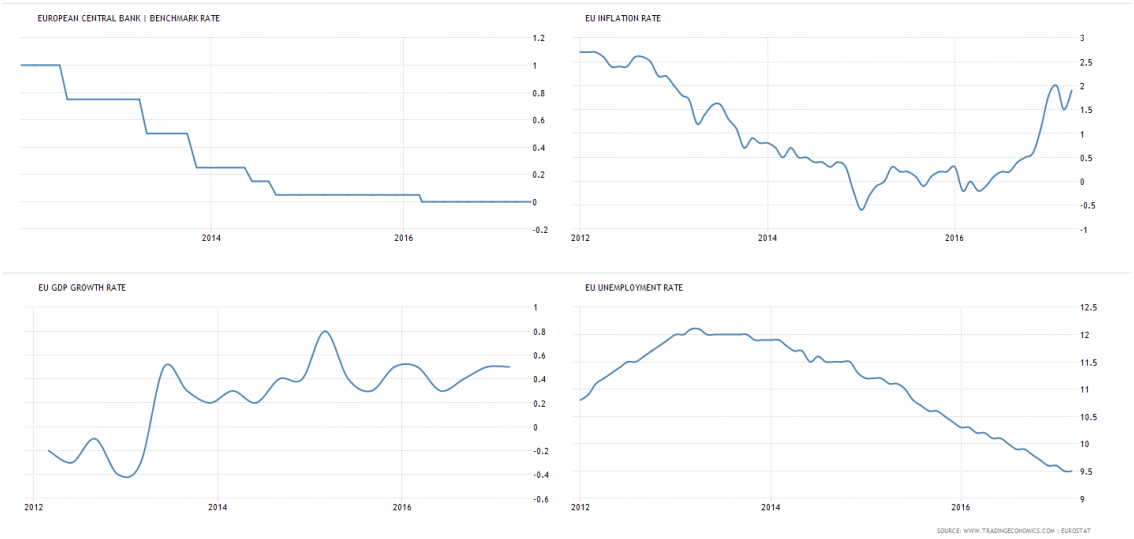


Figure 4 - Denmark temporarily retrieved to positive interest rates for several months during the year 2014 (from July to September)
Source: www.tradingeconomics.com

3.3 Role of the European Central Bank

These several ventures with sub-zero interest rates widened thinking of central authorities when it comes to economic stagnation. Unceasing increase of unemployment across whole the Eurozone, unpersuasive growth rate floating just above zero line, and inflation already on the way back threatening to cross the zero line (see Box 1) compelled bankers to consider an unorthodox solution. In the mid-2014, the ECB as the first major monetary institution agreed to move deposit rates into the negative territory in order to prevent falling into a deflationary spiral and *"to underpin the firm anchoring of medium to long- term inflation expectations"* (Draghi, 2014).

"Negative interest rates aren't an irrational concept. I'm not sure, though, whether in the case of the ECB it will have the desired effect," (Christoph Kind, 2012).



Box 1 - Set of economic indicators for Eurozone for period 2012-2017[8]
Source: www.tradingeconomics.com

3.4 Connection with SNB, Riksbank and DNB

At the turn of 2015, the Swedish Riksbank accommodated the NIR policy with the mandate of *"safeguarding the role of the inflation target as a nominal anchor for price setting and wage formation"* (Sveriges Riksbank, 2015)). Both authorities (Riksbank and ECB) faced the same concerns and used this unconventional measure together with other intervention instruments. The ECB continued with quantitative easing and proceeded with purchasing of covered bonds, asset-backed securities and funding banks by targeted longer-term refinancing operations while the Riksbank initiated a purchase of bonds and interventions on the foreign exchange market by January 2016 (BIS Quarterly Review, March 2016).

According to BIS Quarterly Review (March 2016), the ECB's initiation of monetary easing resulted in money inflow to European countries outside the Eurozone. Since Denmark and Switzerland did not accept euro, Danish krone and Swiss franc got under the appreciation pressure and in order to cease the surge of liquidity, the central banks either introduced negative interest rates on deposits (SNB) or reduced key interest rate to negative levels (DNB) alongside other measures. In the case of the SNB, the main aim was identified as unaccomplished during 2015 as capital inflow did not vanish and pressure on the currency persisted.

"The negative deposit rate, still at 0.75 percent, and the SNB's proven willingness to sell francs even after removing the cap will help weaken the Swiss

[8] Long-term development of these macroeconomic indicators can be found in Appendix 3

currency over time. That can only help the economy, as would healthier growth in the euro region" said Thomas Jordan, president of the SNB (2016).

On the other hand, the combination of the NIR and heavy interventions on the FX market field utilized by the DNB yields fruit, situation normalized, money inflow had stemmed and at the beginning of 2016, the rates actually moved back a little closer from zero to -0,65 (BIS Quarterly Review, March 2016).

3.5 The last current member of the NIRP – the Bank of Japan

The last follower of this strategy is Japan in which the Bank of Japan (BoJ) executed negative rates in January 2016. A week later, for the first time ever, the yield on 10-year government bonds briefly turned negative and benchmarks of lending and mortgage rates were falling. *"The effects (of negative rates) will eventually spread to the real economy and consumer prices, and people will see the policy in a positive light,"* said the BoJ governor Haruhiko Kuroda (2016).

The decline on the market reached its peak in the mid-2016 when even yield on 15Y government bond went negative. This might be considered as a result of Japan's hopeless long-lasting fight against deflation and a desperate attempt/step of the BoJ after executing numerous monetary tools including not very successful/ineffective bond-buying programs of the QQE (Qualitative and quantitative easing) set off in April 2014 and a couple of the QE's (Quantitative Easing) tryouts initiated in 1997 (the second one in 2001). The main aim of these policies was to achieve a sustainable level inflation of 2% within a period of two years. The QQE strategy failed to achieve this goal but Hiroshi Fujiki and Hajime Tomura (2015) argue that it would be significantly expensive for the BoJ to exit the QQE program. In their study, they considered *"simple macroeconomic scenarios to run simulations under transparent assumptions. Thus, the simulation results in this paper should be taken as ballpark figures of the BoJ's future profit based on one of a number of possible scenarios, rather than a point estimate of the BoJ's future profit based on macroeconomic projections."* Huge public debt, stagnation in inflation, depreciated yen – all of this contributed to negative interest rates to incur a failure in Japan.

3.6 The current situation

"Lowering the rate further into negative territory was seen as an effective tool for providing additional monetary easing, which also reinforced the impact of the other

monetary policy measures in place by stimulating the "velocity of reserves", as written in the minutes from the 2016 April's meeting of the European Central Bank's Governing Council

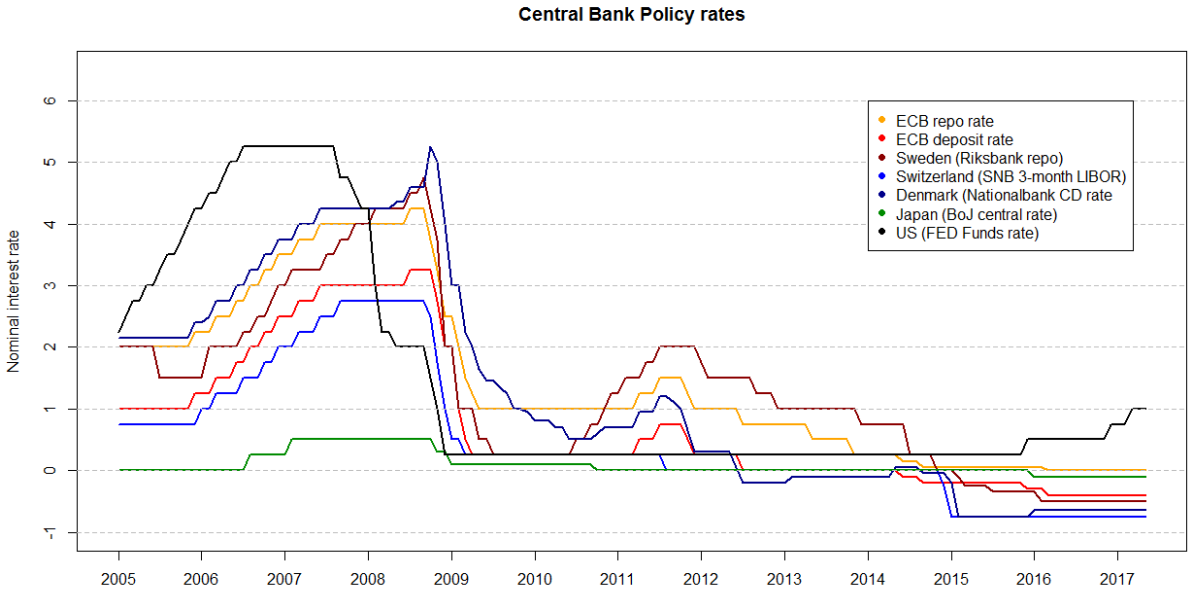


Figure 5 - Central Bank Policy rates of countries with introduced negative interest rates (except US)

The development of the interest rates in advanced countries has experienced almost no change in the course of last year (depicted in Figure 5). The institution in the role of the US central bank, the FED, has been of opinion that it is time to leave zero rates and thus it raised interest rates to the current level of 1%. It had done so only for the third time since 2007. However, the US inflation overstepped targeted limit of 2% but as we saw in the past, the FED is willing to let inflation float over this limit in order to let the monetary policy accommodate. Although quantitative easing has not been a monetary instrument used by the FED for quite some time, the decision to reduce its balance sheet has not been taken yet. On the other hand, the ECB and BoJ are still carrying on with their monetary injections of estimated $200 billion of purchases per month. The perspective development of inflation across the currency block and the current plan of the ECB to maintain its bond-buying program until December 2017 form a very important thought in people's minds - when and how will the ECB end monetary easing? Main point of concern is that abandoning it too early can jeopardize all the effort done so far to stabilize the price and on the other hand getting out too late can drive the inflation excessively high. Nevertheless, *"the withdrawal of QE is sending a signal of confidence that central banks have in growth,"* as said by Peter Oppenheimer,

the member of Board of Directors of Goldman Sachs. In addition, all three key interest rates of the Eurozone (the interest rate on the main refinancing operations, the rate on the deposit facility and the rate on the marginal lending facility) are consistently falling, as we can see in Figure 6. Despite the current zero level of refinancing rate and deposit rate being pushed even deeper below zero at the rate of -0.40%, there was no further decreasing during the last year.

Date		Deposit facility	Main refinancing operations		Marginal lending facility
			Fixed rate tenders Fixed rate	Variable rate tenders Minimum bid rate	
With effect from					
2016	16 Mar.	−0.40	0.00	-	0.25
2015	9 Dec.	−0.30	0.05	-	0.30
2014	10 Sep.	−0.20	0.05	-	0.30
	11 Jun.	−0.10	0.15	-	0.40
2013	13 Nov.	0.00	0.25	-	0.75
	8 May.	0.00	0.50	-	1.00
2012	11 Jul.	0.00	0.75	-	1.50
2011	14 Dec.	0.25	1.00	-	1.75
	9 Nov.	0.50	1.25	-	2.00
	13 Jul.	0.75	1.50	-	2.25

Figure 6 - ECB key interest rates in percentages per annum[9]
Source: www.ecb.europa.eu

In Sweden, the policy of negative interest rate is still kept associated with the description of "had the intended effect". Furthermore, The Riksbank gave some suggestions about going further down with the interest rates. Inflation is slowly approaching expected 2% level, economic growth is strong enough and at the end of year 2016 the bank announced another purchase of government bonds in the nominal value of SEK 275 billion. But there are concerns about overheating housing market as prices are rapidly rising. Swiss SNB also has no plans to make any changes in their monetary policy and it keeps its 3-month LIBOR rate at -0.75% since January 2015. Likewise, Demark is currently in a similar situation as there is no reconsideration of the monetary policy on the table.

[9] New row represents change in at least one of the rates

4 Commodity market

In this chapter, we will summarize the events of last few years that occurred on the commodity market and afterwards we will inspect the connection with interest rates.

4.1 Progress and fall

The steady decline in global commodity prices in the last few years has reflected the slowing demand and decrease in investments. Furthermore, some have stressed the similarities in these economic issues and the ones during 2008. Nine years ago we were dealing with financial crisis generated by massive disruptions in the financial services industry caused by inconsistent handling of mortgages by the banks but current situation has certainly its roots in this financial crisis.

"With such enormous bucks devoted to trading in oil and other commodities, the distortions that they cause have been exacerbated" – Gary Weiss, American investigative journalist

Disturbances in the consumption and investments during economic crisis decreased the amount of imports into Europe and the United States, lowering sales revenues of export-oriented countries and thus damaging their economies. China, the second largest economy in the world, was particularly hit by these events. Right at the time of a slow-down by structural reasons, the combination of these two components highlighted unsustainability of its economic growth. Such a hit on world's engine of industrial growth had a tremendous impact on the commodity market. George Friedman (2016) stated that the excess supply was created by an overestimation of the development on the market. Firstly, a disproportionate expected demand, created mainly by China, boosted the extraction of commodities. Primary signs of the downturn were then ignored and prices maintained due to the massive demand from China based on the assumed comeback of growth. Moreover, the reliance on cyclical behavior kept prices up even after a decline in China's imports[10]. Therefore, the hardest impact of this collapse in investing was on commodity-exporting emerging and developing economies (Special Focus, World Bank / Commodity Market). In addition, also countries exporting manufactured goods were hurt. Thus it can be believed that economies mostly hit were China (manufactured goods), Russia (energy commodities), Saudi Arabia (crude oil),

[10] It was believed that decline in consumption is just temporary/seasonal and that there is no need to slow the production down

South Korea (manufacture goods from cars to electronics), Australia (industrial commodities, particularly iron ore and copper) etc. Therefore, the theory of international trade and its benefits is being tested by these events.[11]

Although the decline in export market affected almost all commodities, particularly mineral exporters and oil producers suffered enormously. "*Energy makes up such a tremendous part of the economic landscape that any time you have a downward price pressure it's like a gift to the entire economy"* – Joel Kurtzman (2012). As can be seen in Box 3 (see Appendix 4), majority of commodities were falling down till the end of 2015 but it seems like there are signs of a recovery. *"Prices for most commodities appear to have bottomed out last year and are on track to climb in 2017,"* said John Baffes, Senior Economist and lead author of the Commodity Markets Outlook. "*However, changes in policies could alter this path."*

4.2 Is there a connection between prices of commodities and interest rates?

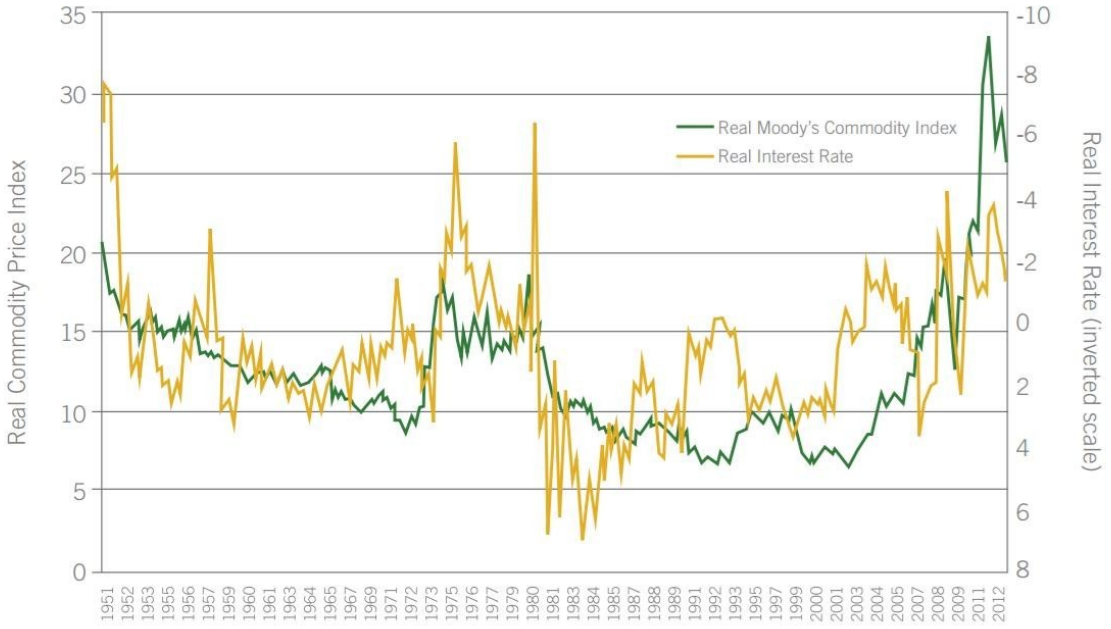
When analyzing the movement in prices of commodities on the market, the typical approach is to look at certain micro factors which differ from mineral to mineral or crop to crop. Among the obvious factors, we should count in the weather conditions in crop industry or technology which is used for gathering of oil. Surely, the majority of variability in commodity market is caused by facts or processes of this nature but there are also some other factors that have to be taken into account such as macroeconomic variables or monetary actions. Big macroeconomic factors can be considered as significant – like interest rates that are usually overlooked due to a more essential economic growth in the case of commodities.

However, before we continue, it is important to clarify one aspect of the interest rate and thus defining the distinction between "nominal" interest rate and "real" interest rate. The interest rate which is publicly discussed and stated on basic loan papers is so-called "nominal" interest rate. After taking the inflation into account, we refer to the "real" interest rate. The simplified equation looks like this: $nominal\ interest\ rate = real\ interest\ rate + inflation$ (also known as Fisher's equation). Therefore,

[11] Taking into account that a shock of this magnitude on the individual closed economy would have much worse consequences.

according to J.A. Frankel, in connection with commodity prices, we refer to the "real" interest rate.

According to T.Palaskas and P. Varangis (1989), Q.F.Akram (2008) and J. Frankel (2012), there is a correlation between the "real" interest rate and commodity prices. Looking at the historical data, nearly all commodities were on the rise during the mid to late 1970s and went up again between 2000 and 2008 - right during the times when the real interest rate was at zero or even negative. All this development is supported by the opposite co-movement found in the Figure 8. The graph below depicts the development of the Real Commodity Price index on a normal scale together with time series for real interest rate on an inverted scale. The author selected aggregate Moody's Commodity price index over prices of individual commodities due to the potential that *"... the host of idiosyncratic factors that influences each individual sector may wash out."*



Source: Jeffrey Frankel

Figure 7 - Opposite co-movement of the Real Commodity Price index and the Real Interest Rate

Source: www.hks.harvard.edu

The core of this correlation is based on the cost of holding the inventories known as "cost of carry". In general, a low interest rate environment secures cheaper financing of inventories (costs associated with holding goods/materials under your roof). It is also necessary to take several other factors into account when thinking about how/why low interest rates should drive prices of commodities up

- by demotivating owners to extract the commodity now due to low interest earnings, thus decreasing supply and pushing prices up – so-called “Now versus later”,
- by encouraging speculators to make commodity contracts when looking for things to buy due to low yields , e.g. from treasury bills,
- by appreciating the domestic currency to challenge the price of domestic commodities to go down on the international market (even if there is no real change in price for other countries).

All these mechanisms contribute to progressivity of prices as can be deducted from behavior of commodities in 2007-2008 and 2011, according to J.Frankel (2012).

Conversely, it is in contradiction with the results of a study conducted by the aforementioned author in 2009 where he claims that there is no direct evidence that easy monetary policy and low real interest rates contribute to upward pressure on real prices of disparate set of commodities[12]. In addition, Pindyck and Rotemberg (1988) argue that there is a significant co-movement among prices of objects on commodity market not caused as a consequence of anything that can be explained by macroeconomic variables such as interest rates, inflation etc. They also performed research on a wide spectrum of commodities[13] examining an excessive common development from 1960 to 1985. One caveat can be raised (and also was raised by researchers themselves) that macroeconomic factors have a higher impact over longer holding periods than monthly frequency therefore exclusion of these variables could possibly increase unexplained similar movement. Nevertheless, the spill-over effect among commodity prices can be related,to some extent, to the substitution effect (Q.F.Akram, 2008). If there is increase in price of one commodity, the investors can transfer their funds to its substitute with expectation of price increase.

[12] In his research he studied impact on these commodities: corn, copper, cotton, cattle, hogs, oats, oil, platinum, silver, soybeans and wheat. Data were annual from 1960 to 2008

[13] Among analyzed commodities were wheat, cotton, copper, gold, crude oil, lumber, and cocoa.

5 Data description

Following paragraphs will be devoted to a general description of what the dataset looks like and an approach in the selection of variables. The significant modifications were made to the original data mainly due to missing values and aggregation.

5.1 Sources

The dataset used for the analysis consists primarily of four main datasets.

The first one contains monthly data on Inflation. This database is administrated by Organization for Economic Cooperation and Development (OECD).

The next two datasets from data-collection maintained by the International Monetary Fund (IMF) include records of interest rates and GDPs. The Central Bank Policy Rates were acquired from the International Financial Statistics (the IFS) that stores data monthly and GDP from The World Economic Outlook (WEO). The WEO database is created and published aside the WEO exercise semi annually (results are available in April and September). Both the IFS and WEO belong to Fund's principal statistical datasets.

The last dataset contains prices of energy, metal, and industrial commodities obtained from The World Bank database. These are presented in the Commodity Price Data (also known as the Pink Sheet) and have been updated monthly since 1960. Each commodity is recorded in its most suitable/common unit for the market, e.g. gold is measured in $/toz (abbreviation for troy ounce, approximately 31.1 grams), crude oil in $/bbl (abbreviation for barrel, approximately 159 liters), aluminum in $/mt (abbreviation for metric ton which equals 1000 kg) etc.

These selections were perceived, among other sources, to be the most suitable for analytical purposes of this research as they code necessary information in a concise way. However, beside these four main datasets, other sources were be used in order to obtain missing data for certain countries.

5.2 Manipulation

A few issues arose from the construction of datasets. At the start, as pool of countries in each dataset differs, we selected the countries from the intersection. This sample was after that considered as not large enough and therefore not suitable for

aggregation. Hence, in order to incorporate as many countries as possible, the data from other sources were added. This extra information was needed only in the case of the CBPR data and it followed in two phases. The first phase – Euro Area. As most of European countries are members of the Eurozone, their monetary policy is under surveillance of the European Central Bank (ECB) and thus the dataset of the CBPR lists only the interest rate of the Eurozone and non-euro countries. However, all Eurozone members have their individual inflation rates and, of course, GDP. Therefore, all these countries were added to the CBPR dataset with the values of the Eurozone (while naturally taking into account their admission date). The second phase dealt with incomplete series of some countries. Missing values where restored from the datasets of central banks or other relevant sources. Due to month-to-month granularity of inflation, the CBPR and mainly commodity prices dataset, the most of the modification was done with the GDP data. As mentioned in the previous subchapter, the GDP dataset has annual records and this brought up a question regarding the further approach. Due to the consecutive aggregation of all collections and, in particular, the construction of GDP-related variable, the constant trend was selected over the linear one[14] when formatting monthly records of the GDP. The further modification was done by the aforementioned aggregation through countries of all datasets apart from commodities. In addition, after a detailed look into the databases, it was decided that year 2000 is the relevant starting point and other data was edited this way.

5.3 Variables

All following variables are of monthly frequency, covering the time period from 2000 to 2016.

In this research, we take the price of each commodity as a dependent variable. As it was explained in the previous subchapters, raw data of commodities were appropriately structured so there was no need to do any modification to it. Each commodity used in this study is listed in Table 1 together with its unit and basic statistics. Values of prices are nominal and refer to dollar per given unit. In Box 3 (see Appendix 4), we can observe a decline in prices of all listed commodities before 2016 with a following recovery continuing till now for all but precious metals that have been experiencing a downward pressure since the last quarter of 2016. The correlation matrix

[14] Linear method was considered as uncommon approach so all the months in the same year had the same annual value.

(see Appendix 7) is showing, in average, relatively strong positive correlation among all selected commodities. However, we can observe weaker dependency of Nickel, Zinc and US Natural gas prices on movements in the market.

Commodity	*Unit*	*Min*	*Median*	*Mean*	*Max*
Aluminum	*$ / mt*	1282	1816	1907	3071
Coal	*$ / mt*	22,25	59,83	65,83	180,00
Copper	*$ / mt*	1377	5559	5184	9868
Crude oil, Brendt	*$ / bbl*	18,60	58,96	64,92	133,87
Crude oil, Dubai	*$ / bbl*	17,53	56,72	62,05	131,22
Crude oil, WTI	*$ / bbl*	19,31	59,27	62,50	133,93
Gold	*$ / toz*	260,5	873,7	869,0	1772,1
Iron ore	*$ / dmtu*	28,79	67,65	84,72	197,12
Natural gas LNG	*$ / mmbtu*	3,96	7,68	9,28	18,11
Natural gas, US	*$ / mmbtu*	1,17	4,25	4,82	13,52
Nickel	*$ / mt*	4825	14565	16026	52179
Platinum	*$ / toz*	429,9	1121,4	1121,3	2052,4
Rubber	*$ / kg*	0,49	1,76	2,03	6,92
Silver	*$ / toz*	4,02	13,82	14,65	42,70
Tin	*$ / mt*	3694	14742	13879	32363
Zinc	*$ / mt*	747,6	1853,9	1793,8	4405,4

Table 1 - Selected commodities with basic statistical description[15]

In the case of regressors, we control for the Inflation, Central bank policy rate and GDP ratio. *Inflation rate* is measured by the annual growth rate in the consumer price index (CPI). Due to substantial changes in interest rate in the past few years, it was decided to select the Central bank policy rate among interest rates. This interest rate is used by the central banks to signal its monetary policy view. The specific financial instrument covered by the *CBPR* can vary from country to country. For instance, some countries use the repurchase agreement rate as the CBPR while in the other ones, it stands for the discount rate. The overall Central bank policy rate of 33 countries (listed in Appendix 5) was aggregated together and thus created the CBPR variable which denotes mean value of the CBPR in the world (keeping in mind that this average just approximates the real world's average CBPR). Moreover, this interest rate is of the nominal level, in contrast with almost all studies. The main reason for this unusual

[15] *mt* – metric tonne, *bbl* - , *toz* – Troy ounce, *dmtu* – dry metric tonne (same mass value as a metric tonne, but the material has been dried to decrease the moisture level), *mmbtu* – indicate 1000000 BTU (British thermal unit)

approach is to include information of the level of nominal interest rate and inflation since the real interest rate does not differ between the nominal interest rate and inflation both of 8 % and both of 1 %.

The last dependent variable, *prop_of_GDP* , measures the percentage proportion in GDP of countries with the introduced negative CBPR against the total world's GDP. Gross domestic product obtained from the IMF database is based on the purchasing-power-parity (PPP) valuation of country's GDP[16] in order to enable a comparison and it is measured in current international dollars. This variable is a "special one" created to study the respective power of negative interest rates through economic output. In theory, a strong big economy, like the US, that agreed to negative rates is likely to somehow influence the commodity market. However, what about the combined power of smaller economies if they are the ones undergoing negative interest rates?

[16]The PPP method was preferred over the nominal approach as it controls for differences in living standards and mainly due to stability of PPP exchange rate.

6 Methodology

An inspection of the dataset uncovered that we are dealing with time-series. The original nature of data would lead us to think that the combination of time-series and cross-sections should be used, thus a panel data or pooled cross-sectional data. However, regarding the fact that we are dealing with commodity prices, it is more appropriate to aggregate the datasets and use clear time-series. An overall depiction of methodology - the methods used during the model creation and introduction of our research model - will follow in the next paragraphs.

Wooldridge (2012) offers method of linear regression of time-series that will be applied in this research - the method of the ordinary least squares (OLS). When estimating the OLS using time-series data examining contemporaneous relationship between variables made by time-series data, we refer to a model like this

$$y_t \sim \beta_0 + \beta_1 x_{it} + u_t \quad , where\ t = 1, \dots, n\ \ and\ i = 1, \dots, k$$

In this model, t represents the time index, n is a number of observations, i stands for i^{th} variable if there is k of them.

Given this approach, we expect our model to be constructed in this form:

$$commodity_t \sim CBPR_t + Inflation_t + prop\_of\_GDP_t$$

In a brief explanation, we regress the price of a single commodity on average inflation in the world, the average interest rate in the world, and proportion of countries with the NIR expressed in % of the world's GDP.

While we are dealing with time-series, we are obliged to inspect a couple of characteristics before we can approach the model itself. The stochastic processes in time-series require that OLS models have to be stationary in order to maintain the ability of making statistical inference trustworthy. If not, the models with non-stationary variables will result in a spurious regression due to bias in estimated coefficients. Therefore, we performed a test for unit-root on all our variables. The augmented Dickey-Fuller test was selected from the pool of tests for examining stationarity and

revealed a presence of unit-root in each variable[17]. Results can be found in Table 3 (see Appendix 6).

Therefore, we can conclude that all series are integrated of at least order one and the information provided by the lagged level of series has no relevance in predicting the change in the original series with no lag. At this point, we can decide between two options.

The first alternative is differencing the series making them stationary as the first differences of the majority of time-series processes are stationary. Afterwards, the vector autoregression model (VAR) is used. Nevertheless, the main drawback of this approach lies in the loss of an important "long run" relationship between the levels. The second option is to test for so-called "cointegration". If some linear combination of two or more integrated series has a lower order of integration then this series are said to be cointegrated. This vector of coefficients usually forms a stationary linear combination of these series. Thus if such a condition exists then the best choice is the vector error correction model (VECM). If it not such a situation then we get back to the first alternative consisting of the VAR model.

To briefly describe the VECM estimation, this econometric model is utilized to discover the linear interdependencies among several time-series. Allowing more variables to evolve, the VECM model extends the classic autoregressive models. This approach is sometimes called the "restricted" VAR model as the error correction term is incorporated into the standard VAR model due to the cointegration of variables used in the model. Including the error correction term permits us to use basic statistics and rely on the resulting inference.

The most frequent test for cointegration is the Johansen test where asymptotic properties play an important role. If the sample is too small, the results' reliability is shattered. In addition, it is important to set the appropriate number of lags of given variables. In our case, it was estimated to two. We had enough observations and fortunately, the tests confirmed that the cointegration exists in all models (for each commodity, see Table 3 in Appendix 6). Moreover, the Johansen test also determined the rank of cointegration to 1. Hence one linear combination of selected series that is stationary certainly exists. This verification allows us to continue towards the VECM estimation. The examples of VECM application in this area of expertise are papers by

[17] Although for some variables test could prove stationarity, the level of confidence for rejecting the null hyphotesis was not high enough.

T.Palaskas and P. Varangis (1989) or Gil et al. (2009). The results of our estimation are presented in the next chapter.

7 Results

In the previous chapter, we discussed the approach and introduced the final method used in/for this research. Now we can proceed towards an analysis of the regression and inference.

At the beginning, we inspected any connection between commodities. From the correlation matrix it can be easily observed that there is a high correlation among selected materials. In the case of energy, it is understandable (also because there are prices from a different market of one commodity). However, there is also a really strong co-movement of prices through the whole sample, with no regard to the type. This trend is studied in the paper by Pindyck and Rotemberg (1988). If we look at our explanatory variables, it is not surprising that there is a significant correlation between inflation and nominal interest rate as higher inflation drives up the nominal interest rates. The NIR proportion on GDP seems to be slightly negatively connected with the previous two variables. An overall look reveals that inflation and interest rates tend to move in opposite direction than commodity prices.

In this analysis our aim was to investigate relationships between selected variables. Therefore we did not continue to estimate the IRF in order to look at the short-run dynamics nor did we proceed to prediction section. Tables in the Box 2 with results show the coefficients of individual variables, t-statistics and significance of the given estimate. As this analysis does not compute any predictions or nor does comparison of models with different specifications, it was decided that goodness-of-fit measures of the model like R-squared will not be interpreted.

The VECM model, like all the other models, needs to satisfy certain assumptions in order to maintain the ability of relevant interpretation. Verification of these assumptions revealed, in some cases, potential for heteroskedastic residuals (see Appendix 7). Thus the interpretation of the analysis is just an approximation due to potentially inconsistent variance in the residuals. We will now proceed to a comment on the relationship between nominal macroeconomic factors and individual prices of commodities. The results of regression can be seen in Box 2.

Aluminum.l2	Estimate	t value	Pr(>|t|)	Sign. Level
CBPR.l2	-1611,2549	5,5297	0,0000	***
Inflation.l2	2744,6008	-5,8647	0,0000	***
prop_of_GDP.l2	-71,6513	0,2035	0,8389	
const	-669,3132	0,6732	0,5016	

Coal.l2	Estimate	t value	Pr(>|t|)	Sign. Level
CBPR.l2	-50,0847	7,9690	0,0000	***
Inflation.l2	71,8261	-7,1950	0,0000	***
prop_of_GDP.l2	-1,2522	0,1640	0,8699	
const	32,5169	-1,5380	0,1126	

Copper.l2	Estimate	t value	Pr(>|t|)	Sign. Level
CBPR.l2	-3782,3860	6,7953	0,0000	***
Inflation.l2	5032,0114	-5,6452	0,0000	***
prop_of_GDP.l2	-522,3069	0,7760	0,4386	
const	4250,5494	-2,2423	0.02602	*

Crude_oil_B.l2	Estimate	t value	Pr(>|t|)	Sign. Level
CBPR.l2	-44,8429	7,5048	0,0000	***
Inflation.l2	58,3723	-6,1370	0,0000	***
prop_of_GDP.l2	-8,9408	1,2334	0,2189	
const	60,3369	-2,9808	0,0032	**

Crude_oil_D.l2	Estimate	t value	Pr(>|t|)	Sign. Level
CBPR.l2	-44,7047	7,4945	0,0000	***
Inflation.l2	58,3140	-6,1440	0,0000	***
prop_of_GDP.l2	-8,5161	1,1770	0,2406	
const	56,7250	-2,8095	0.005449	**

Crude_oil_W.l2	Estimate	t value	Pr(>|t|)	Sign. Level
CBPR.l2	-38,5885	7,1670	0,0000	***
Inflation.l2	50,7719	-5,9180	0,0000	***
prop_of_GDP.l2	-8,0677	1,2371	0,2175	
const	57,0810	-3,1310	0,0020	**

Gold.l2	Estimate	t value	Pr(>|t|)	Sign. Level
CBPR.l2	-645,1770	8,1055	0,0000	***
Inflation.l2	793,5290	-6,2702	0,0000	***
prop_of_GDP.l2	-2,8110	0,0290	0,9769	
const	887,4759	-3,2899	0,0012	**

Iron_ore.l2	Estimate	t value	Pr(>|t|)	Sign. Level
CBPR.l2	-76,2339	7,7790	0,0000	***
Inflation.l2	109,4060	-6,9689	0,0000	***
prop_of_GDP.l2	-11,2198	0,9627	0,3368	
const	37,3778	-1,1387	0,2562	

Natural_gas_LNG.l	Estimate	t value	Pr(>|t|)	Sign. Level
CBPR.l2	-8,3366	7,2340	0,0000	***
Inflation.l2	11,8860	-6,4570	0,0000	***
prop_of_GDP.l2	-1,3883	0,9929	0,3219	
const	4,5265	-1,1592	0,2477	

Natural_gas_US.l2	Estimate	t value	Pr(>|t|)	Sign. Level
CBPR.l2	5,9996	-5,4712	0,0000	***
Inflation.l2	-9,7245	5,5752	0,0000	***
prop_of_GDP.l2	-0,5397	0,4049	0,6860	
const	13,4107	-3,6093	0,0004	***

Nickel.l2	Estimate	t value	Pr(>|t|)	Sign. Level
CBPR.l2	-134595,2100	5,2486	0,0000	***
Inflation.l2	231733,9300	-5,6637	0,0000	***
prop_of_GDP.l2	-939,4100	0,0302	0,9759	
const	-210426,0700	2,4169	0,0165	*

Platinum.l2	Estimate	t value	Pr(>|t|)	Sign. Level
CBPR.l2	-570,6200	7,4729	0,0000	***
Inflation.l2	743,4900	-6,0917	0,0000	***
prop_of_GDP.l2	-94,1230	1,0247	0,3067	
const	1040,3000	-4,0379	0,0001	***

Rubber.l2	Estimate	t value	Pr(>|t|)	Sign. Level
CBPR.l2	-1,5302	8,1245	0,0000	***
Inflation.l2	2,0112	-6,7049	0,0000	***
prop_of_GDP.l2	-0,3028	1,3206	0,1881	
const	1,7546	-2,7490	0,0065	**

Silver.l2	Estimate	t value	Pr(>|t|)	Sign. Level
CBPR.l2	-13,0408	8,1364	0,0000	***
Inflation.l2	16,9304	-6,6407	0,0000	***
prop_of_GDP.l2	-0,5927	0,3043	0,7612	
const	12,0823	-2,2241	0,0272	*

Tin.l2	Estimate	t value	Pr(>|t|)	Sign. Level
CBPR.l2	-10408,4100	7,8730	0,0000	***
Inflation.l2	13458,0500	-6,3777	0,0000	***
prop_of_GDP.l2	-34,4670	0,0216	0,9828	
const	11801,4769	-2,6341	0,0091	**

Zinc.l2	Estimate	t value	Pr(>|t|)	Sign. Level
CBPR.l2	-13038,9660	5,1805	0,0000	***
Inflation.l2	22367,2041	-5,5553	0,0000	***
prop_of_GDP.l2	-153,5073	0,0502	0,9600	
const	-19945,8300	2,3236	0,0211	*

***** p < 0,001 , ** p < 0,01 , * p < 0,05 , blank means insignificant variable**

Box 2 - VECM estimation

In line with the expectations, the analysis showed that prices of commodities are strongly influenced by movement of nominal interest rate and inflation. This qualitative effect can be illustrated like this:

$$commodity \sim "-" \ CBPR \ "+" \ Inflation$$

Given Fisher equation

$$r = i - \pi$$

and the results of Frankel's research

$$price\ of\ commodity \uparrow \Rightarrow \downarrow \ real\ interest\ rate$$

it should hold that if ceteris paribus nominal interest rates go up than commodities should be less valuable.

Unsurprisingly, our research revealed expected qualitative effects. If there is, in average, increase in inflation or decline in nominal interest rates there is upward

pressure on prices of commodities. This holds up for all but one commodity – Crude_oil_US. The one reasonable explanation for this anomaly could be invalidity of data due to no cointegration present (the test was inconclusive, see Appendix 6). Although the important outcome of this regression is qualitative information of the variables it seems like that the inflation can be more informative and influential than nominal interest rates. But this is not the case of such a quantitative study. Unfortunately, our constructed variable is found to provide no relevant information to the development on commodity market. Therefore, we can conclude, that negative interest rates have not revealed any hidden influence for now.

Nevertheless, there are some directions in which can be this paper improved. Including the omitted variables is one possibility. Another improvement of this study is to widen the pool of the countries that are selected to be averaged. We selected mostly developed countries with a similar decreasing movement of inflation and nominal interest rate. When assessing effects on commodity prices we should take such territories into consideration where these minerals and raw materials are mined or gathered, like Africa, Australia and West Asia. The selection of the countries before averaging did not include big exporters like Australia (Coal, Iron Ore), Venezuela (Oil), Sudan (Oil, Natural gas), Uzbekistan (Gold, Copper) etc. that suffer from high inflation and interest rates (except Australia). On the other hand, data from these regions are hard to obtain on a monthly basis for such a long period of time.

One of the biggest limitations of this paper is potentially heteroscedastic residuals. We allowed for more strict p-value for rejection and consequently approached with caution to the inference. We suggest for future analysis to improve the model and resolve this issue.

Conclusion

The world's economic situation has been balancing on the edge in the last decade. The strike of financial recession in 2008 liquidated companies and brought droughts to the financial system. The statement of (L.B.Smaghi, 2009): *"In abnormal times conventional monetary policy tools may prove insufficient to achieve the central bank's objective."* proved to be true. The central banks were forced to lower interest rates to the minimum of zero lower bound and eventually to implement unconventional measures like quantitative easing. This monetary tool should persuade banks to loan more and to reboot the economy (C.O.Roche, 2014). It has proved to mitigate some economic issues since the crisis according to the International Monetary Fund (Klyuev et al. 2009) and the U.S. Federal Reserve System (Stein, 2012). Nevertheless, it was not enough in final calculation and we were therefore introduced to the policy of negative interest rates.

The main aim of this paper was to inspect the theory, development and consequent impacts of negative interest rates in detail. We were interested in questions related to the impact of macroeconomic factors on interest-sensitive markets and particularly on the commodity market. As expected, we found sufficient evidence that nominal interest rates and inflation can be important determinants of commodity prices. The sample consisted of 16 commodities (energy, metals and industrial materials) which demonstrated a high intermarket correlation of prices. The regression required the use of Vector Error Correction model (VECM) and confirmed a negative effect of the nominal Central bank policy rate (CBPR) as well as a positive inflation effect on commodity prices. This indicates that if the nominal interest rates (CBPR) decline then commodities become more valuable. It was intended to extend the range of Frankel's (2012) study of opposite co-movement between the real interest rates and real commodity prices but with regard to information hidden in nominal interest rates and inflation. This goal was successfully achieved. Nevertheless, the main purpose of finding relationship between newly adopted negative interest rates and commodity market fluctuations failed due to no significant evidence supplied.

Bibliography

(2016). Account of the monetary policy meeting of the governing council of the european central bank.

Akram, Q. F. (2009). Commodity prices, interest rates and the dollar. Energy Economics, 31(6):838–851.

Baffes, J. and Haniotis, T. (2010). Placing the 2006/08 Commodity Price Boom into Perspective. World Bank Policy Research Working Paper No. 5371. Available at SSRN: https://ssrn.com/abstract=1646794.

Bech, M. L. and Malkhozov, A. (2016). How have central banks implemented negative policy rates? resreport.

Blanchflower, D. (2009). The future of monetary policy. Cardiff University.

Bosley, C., O'Brien, F., and Schwalbe, J. (2016). Switzerland Weathers the Superstrong Franc. Bloomberg.

Brunnermeier, M. K. and Koby, Y. (In Preparation). The Reversal Interest Rate: The Effective Lower Bound of Monetary Policy.

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

Cahlík, T., Hlaváček, M., and Seidler, J. (2013). Makroekonomie. Karolinum.

Campbell, M. and Levring, P. (2016). The Land Below Zero: Where Negative Interest Rates Are Normal. Bloomberg Markets.

Denizer, C. (1989). Primary commodity prices and macroeconomic variables: A long run relationship. resreport, Center for Economics and Econometrics; World Bank

Frankel, J. A. (2012). Commodity prices and interest rates. CoBank outlook, 9:1–6.

Frankel, J. A. (2013). Effects of speculation and interest rates in a model of commodity prices. Working Paper 19463, National Bureau of Economic Research.

Frankel, J. A. and Rose, A. K. (2010). Determinants of agricultural and mineral commodity prices. resreport, John F. Kennedy School of Government, Harvard University.

Friedman, G. (2016). The export crisis: The 10 worst hit countries and the 5 most at risk. Geopolitical Futures.

Fujikia, H. and Tomurab, H. (2017). Fiscal cost to exit quantitative easing: the case of Japan. Japan and the World Economy, 42:1–11.

Gil, J. M., BenKaabia, M., and Chebbi, H. E. (2009). Macroeconomics and agriculture in Tunisia. Applied Economics, 41(1):105–124.

Group, W. B. (2017). Commodity Markets Outlook, January 2017: Investment Weakness in Commodity Exporting Countries. Technical report, World Bank, Washington, DC

Gruber, J. W. and Vigfusson, R. J. (2016). INTEREST RATES AND THE VOLATILITY AND CORRELATION OF COMMODITY PRICES. Macroeconomic Dynamics, pages 1–20.

Keynes, J. (2007). The General Theory of Employment, Interest and Money (Collected Works of Keynes). Palgrave Macmillan.

Klyuev, V., De Imus, P., and Srinivasan, K. (2009). Unconventional choices for unconventional times credit and quantitative easing in advanced economies. IMF Staff Position Notes 2009/27, International Monetary Fund.

Kurtzman, J. (2012). The new energy abundance. Outlook Newsletter, 9(10).

Mankiw, N. G. (2009). It may be time for the fed to go negative. The New York Times.

Meggyesi, P. (2010). Reflections on negative interest rates in Switzerland. J.P.Morgan.

Mercein, T., Faery, R., Garcia, S., Ciejka, A., and Uong, M. (2016). The upside of negative rates: Opportunities for financing and growth. Credit Suisse Corporate Insights.

Pindyck, R. S. and Rotemberg, J. J. (1988). The excess co-movement of commodity prices. resreport 2671, National Bureau of Economic Research.

Roche, C. O. (2014). Understanding quantitative easing. Technical report.

Rogoff, K. (2014). Costs and benefits to phasing out paper currency. resreport, Harvard University.

Smaghi, L. B. (2009). Conventional and unconventional monetary policy. International Center for Monetary and Banking Studies (ICMB).

Snowdon, B. and Vane, H. R. (2005). Modern Macroeconomics: Its Origins, Development and Current State. Edward Elgar Pub.

Stein, J. C. (2012). Evaluating large-scale asset purchases. Brookings Institution, Washington, D.C.

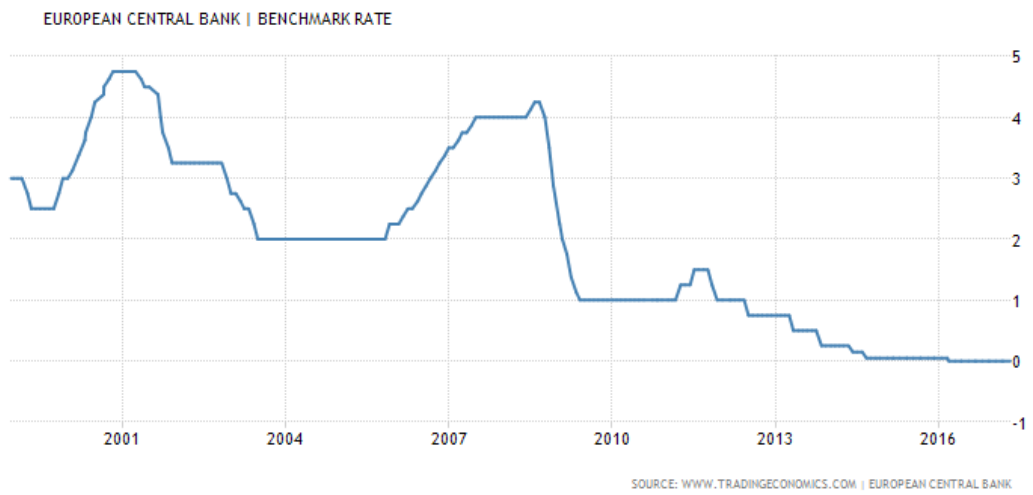
Yoshino, N., Taghizadeh-Hesary, F., and Miyamoto, H. (2017). The effectiveness of japan's negative interest rate policy. ADBI Working Paper Series.

Wooldridge, J. M. (2006). Introductory econometrics: A modern approach. Mason, OH: Thomson/South-Western.

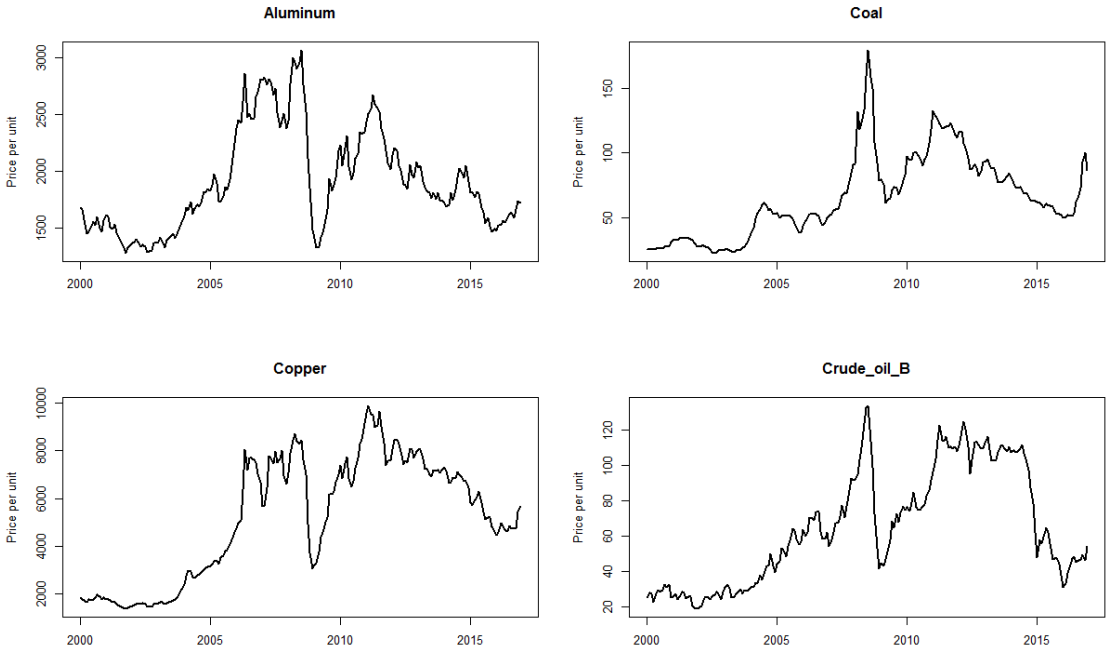
Appendices

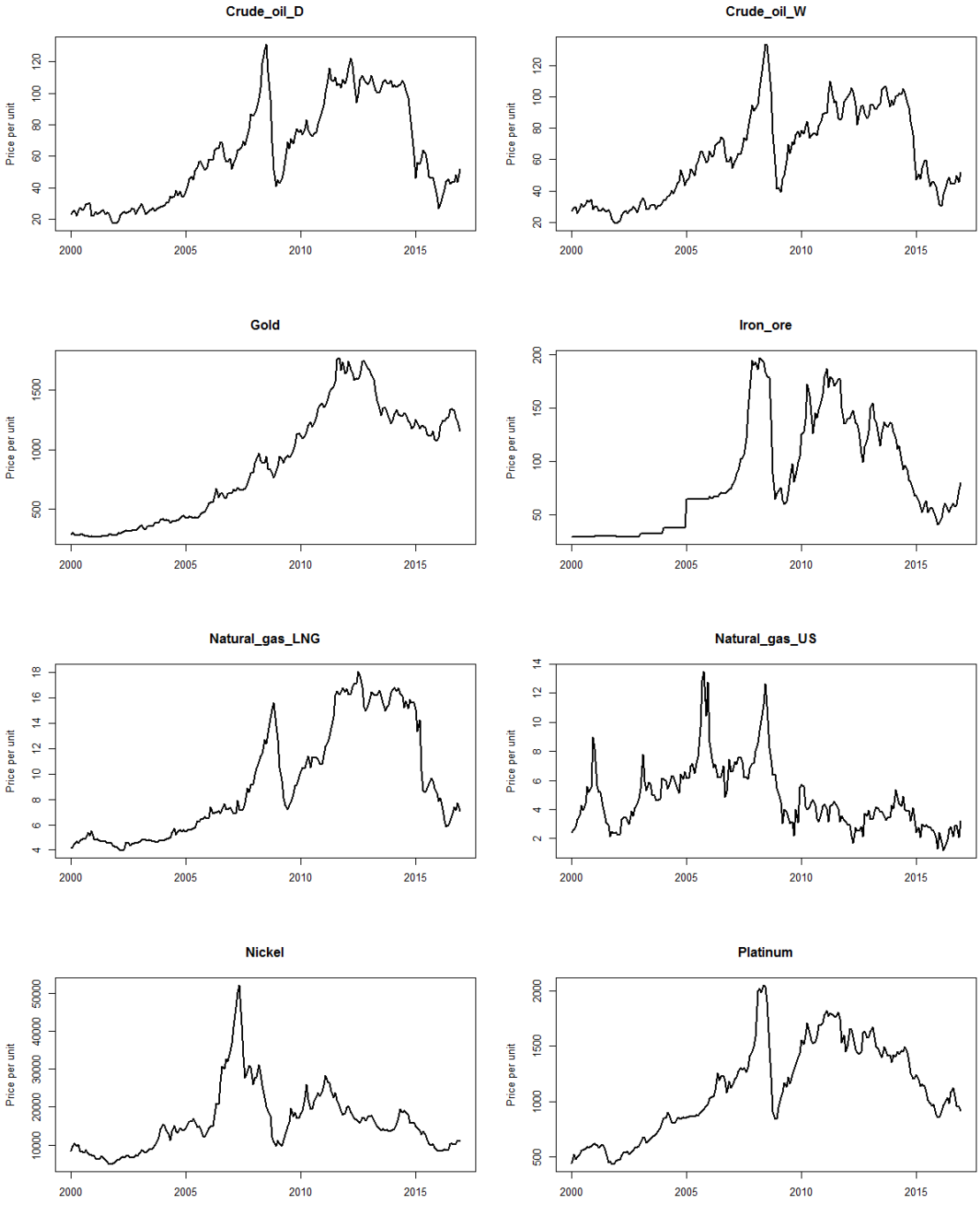
Each Appendix consists of attachments related to the Chapter of the same number:

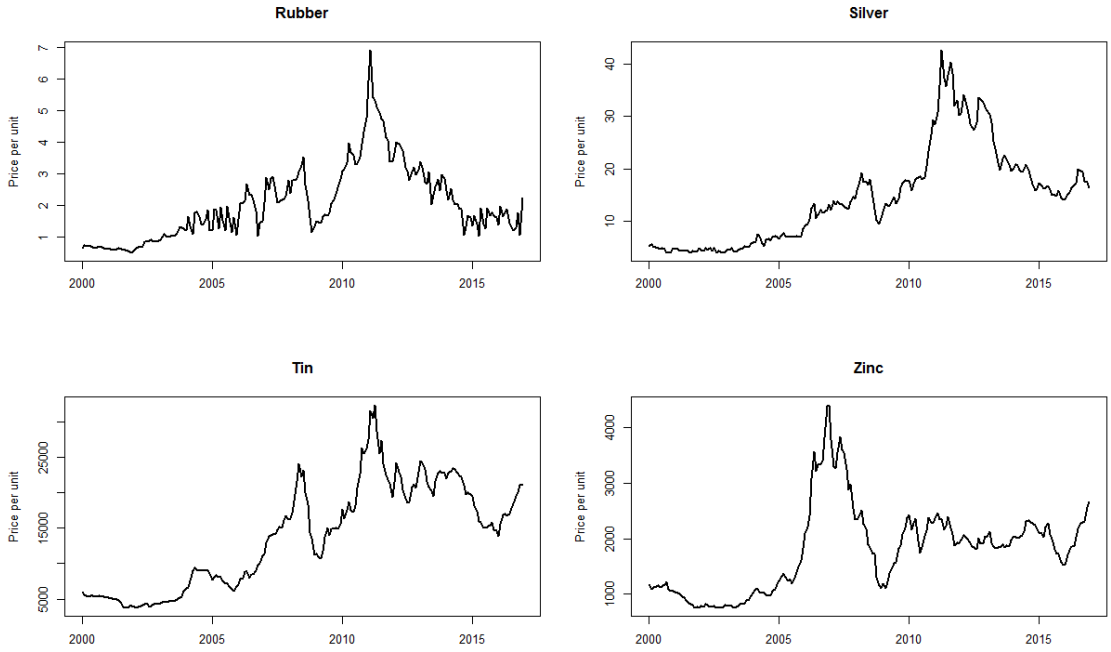
Appendix 3: Long-term development of Eurozone's macroeconomic indicators



Appendix 4: Development of commodity prices




Crude_oil_D
Crude_oil_W
Gold
Iron_ore
Natural_gas_LNG
Natural_gas_US
Nickel
Platinum
Price per unit
2000
2005
2010
2015



Box 3- Long-run development of commodity prices

Appendix 6: Pool of countries before aggregation

Countries included in the research: Austria, Belgium, Brazil, Canada, Columbia, the Czech Republic, Denmark, Finland, France, Germany, Great Britain, Greece, Hungary, Chile, China, Iceland, India, Ireland, Italy, Japan, Korea, Luxemburg, Mexico, Norway, Portugal, Russia, the Slovak Republic, South Africa, Spain, Sweden, Switzerland, Turkey, the United States.

Appendix 6: Tests for unit root presence and cointegration

Augmented Dickey-Fuller test for unit-root	*k=1*		*k=2*		*k=3*	
	Dickey-Fuller	*p-value*	*Dickey-Fuller*	*p-value*	*Dickey-Fuller*	*p-value*
CBPR	-3.2586	0.0796	-2.5482	0.3464	-2.8947	0.2012
Inflation	-3.3325	0.0673	-3.1659	0.09506	-3.4435	0.04932
prop_of_GDP	-0.30345	0.9899	-0.21161	0.99	-0.13113	0.99
Aluminum	-2.1358	0.5192	-2.303	0.4491	-2.6677	0.2963
Coal	-2.3814	0.4163	-2.7423	0.2651	-2.5095	0.3626
Copper	-2.0501	0.5551	-2.0254	0.5654	-1.9817	0.5837
Crude_oil_B	-2.1826	0.4996	-2.2554	0.469	-2.113	0.5287
Crude_oil_D	-2.3487	0.43	-2.4638	0.3817	-1.9299	0.6054
Crude_oil_W	-2.4625	0.3823	-2.7213	0.2739	-2.4542	0.3858
Gold	-0.88641	0.9524	-0.79113	0.9609	-0.84081	0.9565
Iron_ore	-2.1381	0.5182	-1.9596	0.593	-2.1265	0.5231
Natural_gas_LNG	-0.82863	0.9576	-1.5809	0.7517	-1.4483	0.8072
Natural_gas_US	-3.2539	0.0804	-3.2795	0.07612	-3.4026	0.05561
Nickel	-2.3249	0.4399	-2.2111	0.4876	-1.8722	0.6296
Platinum	-1.9015	0.6173	-2.1949	0.4944	-2.2059	0.4898
Rubber	-2.1592	0.5094	-1.9622	0.5919	-2.4479	0.3884
Silver	-1.684	0.7085	-1.4093	0.8236	-1.3769	0.8372
Tin	-2.3355	0.4355	-2.8236	0.231	-2.7824	0.2483
Zinc	-2.2306	0.4794	-1.9827	0.5833	-1.9772	0.5856

Table 2- Augmented Dickey-Fuller test for unit root

Commodity	No. of cointegration vectors	Johansen test	P - value		
			0,1	0,05	0,01
Aluminum	r <= 3	1.1	7.52	9.24	12.97
	r <= 2	1.4	13.75	15.67	20.20
	r <= 1	17.65	19.77	22.00	26.81
	r = 0	33.37	25.56	28.14	33.24
Coal	r <= 3	1.1	7.52	9.24	12.97
	r <= 2	1.4	13.75	15.67	20.20
	r <= 1	12.70	19.77	22.00	26.81
	r = 0	40.43	25.56	28.14	33.24
Copper	r <= 3	1.1	7.52	9.24	12.97
	r <= 2	1.4	13.75	15.67	20.20
	r <= 1	14.79	19.77	22.00	26.81
	r = 0	37.02	25.56	28.14	33.24
Crude_oil_B	r <= 3	1.1	7.52	9.24	12.97
	r <= 2	4.2	13.75	15.67	20.20
	r <= 1	12.17	19.77	22.00	26.81
	r = 0	38.24	25.56	28.14	33.24
Crude_oil_D	r <= 3	1.1	7.52	9.24	12.97
	r <= 2	1.3	13.75	15.67	20.20
	r <= 1	12.78	19.77	22.00	26.81
	r = 0	37.98	25.56	28.14	33.24
Crude_oil_W	r <= 3	1.1	7.52	9.24	12.97
	r <= 2	4.10	13.75	15.67	20.20
	r <= 1	15.43	19.77	22.00	26.81
	r = 0	37.13	25.56	28.14	33.24
Gold	r <= 3	2.7	7.52	9.24	12.97
	r <= 2	5.3	13.75	15.67	20.20
	r <= 1	6.73	19.77	22.00	26.81
	r = 0	40.08	25.56	28.14	33.24
Iron_ore	r <= 3	1.1	7.52	9.24	12.97
	r <= 2	1.4	13.75	15.67	20.20
	r <= 1	13.48	19.77	22.00	26.81
	r = 0	43.49	25.56	28.14	33.24
Natural_gas_LNG	r <= 3	1.2	7.52	9.24	12.97
	r <= 2	1.3	13.75	15.67	20.20
	r <= 1	7.78	19.77	22.00	26.81
	r = 0	39.06	25.56	28.14	33.24
Natural_gas_US	r <= 3	1.1	7.52	9.24	12.97
	r <= 2	1.4	13.75	15.67	20.20
	r <= 1	17.70	19.77	22.00	26.81
	r = 0	31.56	25.56	28.14	33.24
Nickel	r <= 3	1.1	7.52	9.24	12.97
	r <= 2	1.4	13.75	15.67	20.20
	r <= 1	12.34	19.77	22.00	26.81
	r = 0	31.54	25.56	28.14	33.24
Platinum	r <= 3	1.1	7.52	9.24	12.97
	r <= 2	1.4	13.75	15.67	20.20
	r <= 1	14.23	19.77	22.00	26.81
	r = 0	40.82	25.56	28.14	33.24
Rubber	r <= 3	1.1	7.52	9.24	12.97
	r <= 2	1.4	13.75	15.67	20.20
	r <= 1	13.43	19.77	22.00	26.81
	r = 0	43.33	25.56	28.14	33.24
Silver	r <= 3	1.1	7.52	9.24	12.97
	r <= 2	1.3	13.75	15.67	20.20
	r <= 1	7.74	19.77	22.00	26.81
	r = 0	41.81	25.56	28.14	33.24
Tin	r <= 3	1.1	7.52	9.24	12.97
	r <= 2	1.3	13.75	15.67	20.20
	r <= 1	11.77	19.77	22.00	26.81
	r = 0	40.68	25.56	28.14	33.24
Zinc	r <= 3	1.1	7.52	9.24	12.97
	r <= 2	1.5	13.75	15.67	20.20
	r <= 1	10.65	19.77	22.00	26.81
	r = 0	30.70	25.56	28.14	33.24

Table 3 - Johansen test for Cointegration

Appendix 7: Assumptions verification

The "Asymptotic" Gauss-Markov Assumptions for time series regression

Due to large enough sample (over 200 observations) it is sufficient to satisfy just asymptotic assumptions to enable valid inference:

1 *Linearity and Weak Dependence* – We assume linear relationship between regressands and regressors. The revealed cointegration (see Table XX) provides the linear combination of variables that is stationary.

2 *No Perfect Collinearity* – Correlation matrix below provides correlation coefficients and confirms no perfect correlation between prices of commodities and independent variables.

Correlation matrix	CBPR	Inflation	prop_of_GDP	Aluminum	Coal	Copper	Crude_oil_B	Crude_oil_D	Crude_oil_W	Gold	Iron_ore	Natural_gas_LNG	Natural_gas_US	Nickel	Platinum	Rubber	Silver	Tin	Zinc
CBPR	1																		
Inflation	0,82	1																	
prop_of_GDP	-0,31	-0,36	1																
Aluminum	-0,13	-0,05	-0,19	1															
Coal	-0,46	-0,21	0,01	0,63	1														
Copper	-0,59	-0,46	0,01	0,77	0,82	1													
Crude_oil_B	-0,53	-0,33	-0,13	0,65	0,85	0,91	1												
Crude_oil_D	-0,54	-0,34	-0,13	0,63	0,85	0,91	1,00	1											
Crude_oil_W	-0,49	-0,31	-0,15	0,70	0,85	0,90	0,98	0,98	1										
Gold	-0,76	-0,61	0,27	0,32	0,74	0,81	0,80	0,81	0,73	1									
Iron_ore	-0,41	-0,20	-0,13	0,71	0,90	0,88	0,90	0,89	0,90	0,70	1								
Natural_gas_LNG	-0,59	-0,40	-0,07	0,36	0,74	0,77	0,87	0,88	0,82	0,87	0,73	1							
Natural_gas_US	0,34	0,29	-0,34	0,47	0,07	0,02	0,08	0,05	0,18	-0,38	0,14	-0,18	1						
Nickel	-0,17	-0,20	-0,21	0,87	0,47	0,70	0,54	0,52	0,57	0,28	0,62	0,29	0,34	1					
Platinum	-0,57	-0,41	-0,06	0,73	0,88	0,95	0,93	0,93	0,93	0,80	0,93	0,78	0,10	0,65	1				
Rubber	-0,52	-0,31	-0,09	0,64	0,82	0,85	0,81	0,80	0,77	0,73	0,86	0,65	-0,02	0,58	0,87	1			
Silver	-0,64	-0,45	0,11	0,47	0,79	0,85	0,85	0,85	0,77	0,94	0,78	0,83	-0,28	0,40	0,85	0,85	1		
Tin	-0,68	-0,52	0,19	0,50	0,85	0,88	0,87	0,87	0,84	0,92	0,83	0,84	-0,20	0,44	0,89	0,82	0,91	1	
Zinc	-0,33	-0,40	0,12	0,80	0,42	0,78	0,54	0,53	0,56	0,45	0,53	0,37	0,14	0,83	0,63	0,50	0,48	0,52	1

Table 4 - Correlation matrix

3 *Zero Conditional Mean* – After graphical verification we assume that this assumption holds.

4 *Homoskedasticity* – If this assumption is violated, the residuals do not have constant variance and the statistical inference is invalid. The most common test for heteroskedasticity is Breuch-Pagan test. Unfortunately, the test showed potential for inconsistent variance in errors – mainly in the case of Silver. Although the regression was made on all selected commodities, the results of

Silver were not included into inference due to this issue (null hypothesis was rejected). For all the other commodities we chose level of significance to be lower than 0.01 for the rejection of homoskedasticity hypothesis. To our level of knowledge of VECM model we considered it to be appropriate. Also it is considered as one of the biggest limitations of this analysis.

Tests for heteroskedasticity and serial correlation	*B-P test*	*B-G test*
Aluminum	0,355	0,441
Coal	0,187	0,446
Copper	0,278	0,923
Crude_oil_B	0,012	0,324
Crude_oil_D	0,015	0,273
Crude_oil_W	0,011	0,109
Gold	0,426	0,538
Iron_ore	0,496	0,192
Natural_gas_LNG	0,609	0,013
Natural_gas_US	0,319	0,793
Nickel	0,469	0,402
Platinum	0,214	0,249
Rubber	0,098	0,383
Silver	0,000	0,075
Tin	0,042	0,023
Zinc	0,041	0,079

Table 5 - Results of Breuch-Pegan test (Heteroskedasticity) and Breusch-Godfrey test (Serial Correlation)

5 *No Serial Correlation* – This issue is always a threat when dealing with time-series data. Fortunately, we ruled out any type of autocorrelation.