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# ASSESSMENT OF EQULIBRIUM EXCHANGE RATE IN COMMODITY BASED ECONOMIES

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# Assessment of the equilibrium exchange rate in commodity based economies

Nurbulat Mukanov[1], Kamila Mekenbayeva[2]

## Abstract

The purpose of the research is to determine those factors, which form the exchange rates in commodity based economies. As a part of the research there have been analyzed the countries, where raw material resources account for a significant share in the structure of exports. Thus, a sampling included the oil exporting countries: Russia, Kazakhstan, Venezuela, Norway, Canada and Nigeria; copper exporting countries: Chile and Peru; gold exporting countries: Kyrgyzstan and the Republic of South Africa and soybean exporting countries: Brazil and Argentina. Nonstandard and unique econometric methods of nonlinear estimation applied to a strictly defined and theoretically justified specification of the model have been used for empirical estimations.

***Keywords:*** exchange rate, purchasing power parity, nonlinear estimation, piecewise linear regression, commodity based economies, Russia, Kazakhstan, Venezuela, Norway, Canada, Nigeria, Chile, Peru, Kyrgyzstan, the Republic of South Africa, Brazil, Argentina.

***JEL classification:*** C24, F31.

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## 1. Introduction

The exchange rate is one of the most important macroeconomic indicators, whose dynamics significantly impacts the functioning of the economy. The value of the exchange rate serves as an indicator of the state of internal and external balance of the economy.

Given the importance of the exchange rate from a viewpoint of the macroeconomic processes, determination of its equilibrium value is an important task. The most popular approach among the existing theories and approaches is the one, which is based on the purchasing power parity (PPP). However, the results of empirical estimations of the PPP theory as applicable to different countries and time periods appear to be contradictory.

In addition to the fundamental factors influencing formation of the exchange rate, there is also a number of market factors that may include the global commodity prices. A specific feature of the commodities is that they are traded on centralized international currency markets, as distinct from other goods, which are traded on a bilateral basis between the countries, and this determines formation of the global prices on these goods. High volatility in commodity prices is a source of external shocks for the trading conditions of the commodity exporting countries, which, in its turn, influences formation of the exchange rate in these countries.

Interest to the matter of interrelation between commodity prices, dynamics in the exchange rate and inflation rate has enhanced after a slump in oil prices in the second half of 2014 and subsequent decline of prices in the global commodity markets. The shock in the commodity markets has caused depreciation of currencies of the commodity exporting countries and resulted in a jump in the inflation rates in those countries.

In view of a high relevance of these events and their impact on the economy as a whole, the research has been conducted on the basis of a comparative analysis of a number of commodity based economies. As a result, the purpose of the research is to study the processes of formation of an equilibrium nominal exchange rate in commodity based economies[3], in particular, in oil exporting countries (Venezuela, Canada, Kazakhstan, Nigeria, Norway, Russia), copper exporting countries (Peru and Chile), gold exporting countries (Kyrgyzstan and the Republic of South Africa (RSA), and soybean exporting countries (Argentina and Brazil).

Thus, as a part of the research, the hypotheses of negativity of coefficient of elasticity of the nominal exchange rate to the commodity prices, nonlinearity

[3] Commodity based economy is an economy, where the extractive industries determine the structure of the Gross Domestic Product or commodities prevail in the structure of exports.

thereof and fundamental dependence of the nominal exchange rate on inflation rate have been put forward and verified.

The original methodology of the piecewise linear evaluation with a strictly defined and theoretically justified specification of the model has been used as an analytical tool, which confirmed the input prerequisites and, accordingly, its applicability. In addition, this methodology enables comparing the countries exporting different commodities.

The research findings indicate that the PPP theory is applicable to explain formation of an equilibrium exchange rate in commodity based economies, taking into account the factor of prices of the relevant commodities.

The research is structured as follows. The first section includes a literature review, which presents the theoretical and empirical approaches to assessing the equilibrium exchange rate. Further, the methodological bases of the research and data used are detailed followed by the discussions of findings. Conclusions and recommendations for further researches are provided in the concluding part.

## 2. Literature Review

Formation of dynamics of the exchange rate is influenced by various macroeconomic variables, which are conditionally subdivided into fundamental factors and market factors. Models developed on the basis of these factors make possible to understand better the volatility of the exchange rate and forecast its future dynamics.

Since the late 1970s, a good many theoretical and empirical approaches have been formulated in the economic literature, which enabled determining the level of impact of different factors on the dynamics of the exchange rate.[4]

Collapse of the Bretton Woods monetary system and transition of the majority of the world economies to a floating exchange rate regime have resulted in the intensification of the impact of the fundamental factors and market factors on the formation of the exchange rate. However, a level of impact of the factors on dynamics of the exchange rate varies significantly, depending on the time period. Thus, the current exchange rate has resulted from the mutual effect of a few factors: relative prices (purchasing power parity) in two countries in the longer term; business cycles and trade balances in the mid-term, and difference in the interest rates between two countries in the short run (Volkov and Yuhn, 2016).

For the purpose of determining the exchange rate, a long-run period is a period, during which the exchange rate trend coincides, more or less, with the

[4] More detailed review of models is provided in Isard (1978), Taylor (1995), Kavtaradze and Mokhtari (2017).

dynamics of the exchange rate forecasted by the purchasing power parity. In the mid-term, the exchange rate demonstrates a trend aimed at reducing the imbalances of the current account. Therefore, the current account indicators allow explaining certain mid-term deviations of the exchange rate from its long-term trend. In the short run the exchange rates represent the asset prices that depend on expectations of the economic agents, and the value of which is determined by reference to equilibrium in the financial markets alongside with other asset prices, such as interest rates (Stockman, 1980).

The models based on the monetary approach, which describe the short-term exchange rate fluctuations, are widely represented in the works of Frankel (1976), Kouri (1976), Dornbusch (1980), Mussa (1984), Branson (1984), Uz and Ketenci (2008), Loria and other (2010). Lane and Milesi-Ferretti (2002), Lee and Chinn (2006), and Müller-Plantenberg (2010) have applied a balance-of-payments approach in their studies.

However, the theory of purchasing power parity (PPP) is one of the first and most widespread and well-studied approaches to determining the exchange rate dynamics. The theory of absolute PPP that was first formulated by G. Kassel (1922) states that the exchange rates between any two countries are to reflect the changes in the price levels of two countries. Absolute PPP expresses the law of one price, under which the prices of the same goods in different countries should be equal, if they are expressed in one currency. In case when the prices of the same basket of goods differ in different countries, the arbitration will continue until the exchange rate reaches the level at which the prices will be the same.

According to the theory of relative PPP, any change in the exchange rate over the time should be proportional to the relative change in price levels in two countries during the same period of time. The relative version of PPP emphasizes the arbitration over time, and not in space (Hakkio, 1992). Thus, in the long run, the real exchange rate should remain unchanged, while the nominal exchange rate always changes just so far as required to compensate for the difference in the dynamics of the price levels in different countries.

The applicability of the PPP theory to determination of the exchange rate dynamics has been assessed by many economists who used the data of the developed and developing countries at different time intervals (Froot and Rogoff, 1994; Taylor, 1995). The results of empirical studies confirm that the PPP theory is valid to describe the long-term fluctuations in the real exchange rate; however, in the short run this theory turned out to be inapplicable.

Deviation of the exchange rate from its equilibrium value in the short term may be due to the price rigidity (Dornbusch, 1980); incomplete effect of transferring the exchange rate changes to prices (Feenstra and Kendall, 1994); existence of tariffs, various taxation schemes, transaction costs and barriers (Pakko and Pollard, 1996); the difference in productivity and production costs (Kravis and Lipsey, 1983); availability of tradable and non-tradable goods in the structure of price indices (Samuelson, 1964); changes in the terms of trade (Stockman, 1980), and various exchange rate regimes and interest rates.

Many empirical studies of the late 1990s challenged the significance of long-term PPP in determining the equilibrium exchange rate. Economists rejected the hypothesis that the PPP followed a stationary process or assumed that the real exchange rate returned back too slowly to the long-term equilibrium value corresponding to the theory (Rogoff, 1996; Froot and Rogoff, 1994).

The findings gave rise to development of the models, which considered the importance of market factors and fundamental factors as sources of deviation of the exchange rate from the parity. In addition, as the financial markets were liberalized and more countries were involved in the international trade, the influence of market factors on the dynamics of the exchange rate increased. On the other hand, development of the econometric techniques and quantitative methods, and accumulation of longer historical series of the functioning of a freely floating exchange rate made it possible to deepen the analysis of interconnection between the exchange rate, inflation rate and market factors and obtain new results.

Thus, a whole research trend has emerged in the literature, which is devoted to the interrelation between the global commodity prices, exchange rate and inflation rate.

Chen and Chen (2007), having tested data of actual oil prices and real exchange rates of the G7 countries for the period from 1972 to 2005, discovered a statistically significant long-term relation between the variables. In addition, according to empirical estimations, the oil prices in real terms can be used to forecast dynamics of the exchange rate with high level of accuracy for longer time periods. The impact of oil prices and other commodities prices on the formation of exchange rates is also studied in the papers by Amano and Van Norden (1998), Cashin (2003), Fratzcher et al. (2014), Pershin et al. (2016), and others.

Volkov and Yuhn (2016) have assessed the impact of oil price shock on dynamics of the exchange rate in five major oil exporting countries: Russia, Brazil, Mexico, Canada and Norway. The results of the study showed that the impact of oil price shock on volatility of the exchange rate is stronger in Russia, Brazil and

Mexico. In addition, the return of the exchange rate to equilibrium levels in these countries takes longer than in Canada and Norway. The authors believe that the asymmetry of the exchange rate behavior in the sample countries depends more on the differences in the efficiency of financial markets than on significance of oil money for the country.

Another area of research relates to check of the theoretical basis of formation of the equilibrium exchange rate. Chen (2004) reviewed the interrelation between the exchange rate and fundamental factors in three commodity exporting countries - Australia, New Zealand and Canada - and found out that the nominal exchange rates of these countries responded to changes in prices of the respective commodities. Moreover, inclusion of commodity prices in the structural models of the exchange rate improved significantly the characteristics of the model and its predictive abilities. Thus, taking into account the impact of global commodity prices on short-term fluctuations of the exchange rate in the commodity based economies, the author confirms the importance of the PPP theory for explaining formation of the equilibrium level of the exchange rate.

Bjørnland and Hungnes (2005) performed a similar research and obtained similar results for the real exchange rate of the krone of Norway, which is also considered to be a commodity based economy. The authors revealed that deviations of the exchange rate from the parity were caused by the interest rate differential and changes in the global oil prices, which confirms the PPP theory as a basis to determine the long-term value of the exchange rate.

The work of Lothian (2016) is worth mentioning among the recent works devoted to the theory of purchasing power parity. The author tested the applicability of the theory of purchasing power parity to explain the long-term dynamics of exchange rates using the panel data for three historical periods ranging from the gold standard era of the 19$^{th}$ century and until 1998. The research findings demonstrated that depending on the similarities and differences in monetary policy regimes in the countries, the price behavior of the countries may differ from the equilibrium value that the parity stipulates. The inflation rates adjusted for changes in the exchange rate as a whole are highly correlated and have a one-to-one relation throughout the entire time period and in circumstances of various monetary policy regimes.

This research continues a series of works devoted to determination of the equilibrium exchange rate on the basis of the fundamental factors and market factors as a whole, in the commodity based countries. At the same time, as distinct from previous researches, this paper analyses the processes of formation of the exchange rate simultaneously in the countries exporting different commodities.

The article covers the period of a sharp decline in commodity prices in the late 2014 – 2015, using an approach based on assessment of the exchange rate elasticity to the world prices of the country's main export commodity.

## 3. Methodology

As a part of the research there has been developed the methodology, where the following factors determining the basic dynamics are singled out in order to assess the equilibrium value of the exchange rate:

1) a fundamental factor - the purchasing power parity;

2) a market factor - the prices of key export commodities.

Preserving of the purchasing power parity (price parity) implies that if the domestic inflation rates are higher than the foreign inflation rates (month-to-month), the exchange rate should be depreciated by the value of their difference, otherwise the exchange rate should strengthen. Theoretically, with the price parity, the cost of an identical basket of goods inside the country and abroad will be the same. However, as the countries use not the identical but individual baskets of goods to calculate the inflations rates, the deviations from the equilibrium exchange rate may arise.

For the sake of simplicity and comparability, the national currency exchange rates against the US dollar were used in the research, i.e. disregarding the US share in the structure of commodity turnover of a particular country in question. In addition, to calculate the price parity a general basis was used – December 2000, the beginning of a period of price rises in the commodity markets, as well as a general assumption that during this period the rates were at their equilibrium levels and reflected adequately the current economic situation. To provide a demonstrative example and ensure proper understanding Table 1 shows the summary of calculations of the purchasing power parity for Kazakhstani tenge on the basis of inflation rate statistics in Kazakhstan and United States.

***Table 1. Price parity calculation***

| Date | Kazakhstan basket | US basket | Price parity |
|---|---|---|---|
| December 2000 | 144.31₸ | 1.00$ | 144.31 |
| December 2001 | 153.61₸ | 1.02$ | 151.18 |
| December 2002 | 163.78₸ | 1.04$ | 157.29 |
| … | … | … | … |
| December 2014 | 415.12₸ | 1.35$ | 306.74 |
| December 2015 | 471.38₸ | 1.36$ | 346.04 |
| December 2016 | 510.78₸ | 1.39$ | 367.27 |

*Sources: the authors' calculations*

It means that if the economic conditions determining the economy had not changed, i.e. the prices of the key export commodities had not changed for the entire period under consideration since December 2000, the difference in the inflation rates would have been the main factor forming the nominal exchange rate of tenge, which would have been equal to the price parity. However, the actual exchange rate may not correspond to the price parity and may deviate significantly when the economic conditions change, for example, when prices on the key export commodities rise.

For the reason given, a respective econometric model has been developed to estimate the equilibrium nominal exchange rate in commodity based economies, which has a nonstandard but clear theoretical structure (equation 1):

$$ER_{USD/XXX} = ER_{USD/XXX}^{PPP_{2000M12}} \left(1 + \alpha * \left(\frac{P^{COMMODITY}}{P_{2000M12}^{COMMODITY}} - 1\right)\right) \quad (1)$$

where,

| | |
|---|---|
| $ER_{USD/XXX}$ | nominal exchange rate against US Dollar in the country in question |
| $ER_{USD/XXX}^{PPP_{2000M12}}$ | price parity against US Dollar in the country in question on the basis of difference in the inflation rates (December 2000 = 100) |
| $P^{COMMODITY}$ | current price on the respective commodity in the country in question |
| $P_{2000M12}^{COMMODITY}$ | price on the respective commodity in the country in question in December 2000 |
| $\alpha$ | a coefficient of elasticity of the nominal exchange rate according to parity to the percent change in the commodity price against the reference period |

Thus, in simple phrase the basic idea of this model can be explained as follows: **"if the price of the key export commodity in the commodity based country is equal to the price in the reference period, the nominal exchange rate should be equal to the parity, if the price is higher, the exchange rate will be formed below the parity and vice versa."**

It follows from the above that, theoretically, the coefficient α should be negative, that is, with increase of the price on the key export commodity as compared with the price in the reference period, the strengthening of the nominal exchange rate and, accordingly, standing below the parity should be expected. It is also as likely as not that the consistency of internal and external inflation rates will result in stabilization of the price parity and a lower amplitude of deviation therefrom in case of changes in economic conditions; therefore, a lower coefficient of elasticity can be expected.

In the course of the research it was assumed that the relation may be non-linear and vary depending on the range in which the commodity prices are located, and this assumption was checked by modifying the model into a kind of piecewise

linear regression using the dummy variables for different price ranges (equation 2)[5]:

$$ER_{USD/XXX} = ER_{USD/XXX}^{PPP_{2000M12}} \left(1 + \alpha_i * \left(\frac{P_i^{COMMODITY}}{P_{2000M12}^{COMMODITY}} - 1\right)\right) \quad (2)$$

where,

$P_i^{COMMODITY}$ — a commodity price in different price ranges *i*

$\alpha_i$ — a coefficient of elasticity of the nominal exchange rate according to parity to the percent change in the commodity price against the reference period in different price ranges *i*

It is also as likely as not that lower inflation rate results in more stable price parity and a smaller amplitude of deviation therefrom in case of change in economic conditions, so a lower coefficient of elasticity can be expected.

As a result of the research, the following hypotheses are put forward, which need to be checked and confirmed:

1) The coefficients of elasticity should be negative;
2) The coefficients of elasticity are not linear for different price ranges;
3) The coefficients of elasticity depend on the inflation rate.

## 4. Data Description

For the purpose of the research there has been collected the monthly data on the inflation rates and exchange rates of the national currencies against the US Dollar for the selected commodity based countries that export oil (Russia, Kazakhstan, Venezuela, Norway, Canada and Nigeria), copper (Chile and Peru), gold (Kyrgyzstan and the Republic of South Africa) and soybeans (Brazil and Argentina); global prices on oil, copper, gold and soybeans for the period from January 2000 to March 2017 (graphic representation and statistical indicators are presented in **Appendices** 2-5).

Selection of countries has been determined by a few factors. Firstly, due to the growing number of empirical studies that show a significant correlation between exchange rates and global commodity prices, those countries have been selected, where the commodities account for a considerable share in the export structure (Table 2). Thus, there have been selected the countries that are exporting oil, copper, gold and soybeans, and are representative of the oil market, market of metals, precious metals and food market. Lack of statistical data or inconsistency thereof for some countries limited the selection of countries.

[5] Methodological example of calculations for Russian and Canada is presented in the form of Eviews codes in Appendix 1.

***Table 2. Selection of countries***

| *Key export commodity* | *Country* | *Key export commodity's share in the country's structure of export (2015)* | *Note* |
|---|---|---|---|
| ***Oil*** | | | |
| | *Venezuela* | *89,0%* | *crude oil, refined oil* |
| | *Canada* | *18,3%* | *crude oil, refined oil, oil gas* |
| | *Kazakhstan* | *57,5%* | *crude oil, refined oil, oil gas* |
| | *Nigeria* | *93,3%* | *crude oil, refined oil, oil gas* |
| | *Norway* | *57,4%* | *crude oil, refined oil, oil gas* |
| | *Russia* | *54,0%* | *crude oil, refined oil, oil gas* |
| ***Copper*** | | | |
| | *Peru* | *23,5%* | *copper ore, refined copper* |
| | *Chile* | *47,6%* | *copper ore, copper rock, refined copper* |
| ***Gold*** | | | |
| | *Kyrgyzstan* | *42,0%* | *gold* |
| | *Republic of South Africa* | *21,0%* | *gold, platinum* |
| ***Soybeans and soybean products*** | | | |
| | *Argentina* | *31,2%* | *soybeans, soybean milk, soybean oil* |
| | *Brazil* | *14,6%* | *soybeans, soybean milk, soybean oil* |

*Source: http://atlas.media.mit.edu/en/*

It should be noted that there are certain limitations in the data. Thus, data on the inflation rates in Venezuela is available only until December 2015. However, given the sharp devaluation of the nominal exchange rate of the Venezuelan bolivar in 2016, the lack of data on the inflation rates makes it impossible to draw the unambiguous conclusions concerning the interrelation between the variables during the period after 2015. The reliability of official data on the inflation rates in Argentina from INDEC statistics agency is doubtful, and the inflation rate historical dynamics is available only until December 2013. In this regard, there are external estimates of the inflation rate in Argentina from MIT Sloan School of Management project "The Billion Prices Project", which were used to build an alternative model for Argentina[6].

Inflation data were converted into indices against the reference period - December 2000. On the basis of the obtained food price indices and exchange rates in the reference period, the respective price parities were calculated for the models, and the dummy variables were generated for the piecewise linear estimation, which divide the time series based on the price range, in which the current price is located. For example, the price of Brent crude oil is divided into 12 ranges with a $10 increment from the minimum prices to $140 per barrel; the price of copper is

[6] Filling the Gap in Argentina's Inflation Data: http://www.mit.edu/~afc/papers/FillingTheGap.pdf

divided into 9 ranges with increments of $1000 from the minimum prices to $10,000 per metric ton; the price of gold is divided into 16 ranges with an increment of $100 from the minimum prices to $1800 per troy ounce; and the price of soybeans is divided into 10 ranges with an increment of $50 from the minimum prices to $650 per metric ton. The specified number of ranges will give us a respective number of estimations of the coefficients of elasticity for the dynamics in changes of the prices on particular commodities.

When analyzing the exchange rate regimes in the countries of question, it was found out that the freely floating exchange rate of the national currency is the basic regime used in the most countries (Table 3). At the same time, monetary regulators reserve the right to make interventions to prevent the dramatic changes in the exchange rates, which could adversely affect the financial stability in the country. An exception is Venezuela, where two exchange rates are operating. The official exchange rate is determined by the central bank of the country and is a de jure exchange rate, while the exchange rate formed on the black currency market is used as a de facto exchange rate. The controlled exchange rate operates in Argentina, which is determined against the basket of currencies of the major trading partners.

***Table 3. Foreign exchange regime in the countries of question***

| ***Key export commodity*** | ***Country*** | ***Current regime of the monetary policy*** | ***Current regime of the exchange rate*** |
|---|---|---|---|
| ***Oil*** | | | |
| | *Venezuela* | | *Fixed exchange rate** |
| | *Canada* | Inflation targeting (February 1991) | *Freely floating exchange rate since 1970* |
| | *Kazakhstan* | Inflation targeting (August 2015) | *Exchange rate corridor during 2009-2015; freely floating exchange rate since August 2015* |
| | *Nigeria* | Monetary aggregate targeting | *Freely floating exchange rate since May 2016* |
| | *Norway* | Inflation targeting (March 2001) | *Freely floating exchange rate since 1999* |
| | *Russia* | Inflation targeting (2014) | *Freely floating exchange rate since November 2014* |
| ***Copper*** | | | |
| | *Peru* | Inflation targeting (January 2002) | *Freely floating exchange rate since 2002* |
| | *Chile* | Inflation targeting (September 1999) | *Freely floating exchange rate since 1999* |
| ***Gold*** | | | |
| | *Kyrgyzstan* | Interest rate targeting regime (2014) | *Freely floating exchange rate since 1993* |
| | *Republic of* | Inflation targeting (February 2000) | *Freely floating exchange rate since* |

| | | | |
|---|---|---|---|
| | *South Africa* | | *1999* |
| ***Soybeans and soybean products*** | | | |
| | *Argentina* | Inflation targeting (September 2015) | *Controlled exchange rate (against a basket of currencies of major trade partners, since December 2015)* |
| | *Brazil* | Inflation targeting (June 1999) | *Freely floating exchange rate since 1999* |

Source: prepared on the basis of data published on the official sites of central banks
*There are two exchange rates in Venezuela at a time: the official exchange rate is established by the Central Bank of Venezuela, while the second exchange rate is a black market exchange rate

## 5. Discussion of Results

Using the above-described methodology the following specifications of the model with a reference period of December 2000 have been obtained, where *i* is a number of price ranges of the respective commodity:

1) For oil exporting countries:

$$ER_{USD/XXX} = ER_{USD/XXX}^{PPP_{2000M12}} \left(1 + \alpha_i * \left(\frac{P_i^{BRENT}}{26.66} - 1\right)\right)$$

2) For copper exporting countries:

$$ER_{USD/XXX} = ER_{USD/XXX}^{PPP_{2000M12}} \left(1 + \alpha_i * \left(\frac{P_i^{COPPER}}{1852.4} - 1\right)\right)$$

3) For gold exporting countries:

$$ER_{USD/XXX} = ER_{USD/XXX}^{PPP_{2000M12}} \left(1 + \alpha_i * \left(\frac{P_i^{GOLD}}{271.89} - 1\right)\right)$$

4) For soybeans exporting countries:

$$ER_{USD/XXX} = ER_{USD/XXX}^{PPP_{2000M12}} \left(1 + \alpha_i * \left(\frac{P_i^{SOYBEAN}}{185.96} - 1\right)\right)$$

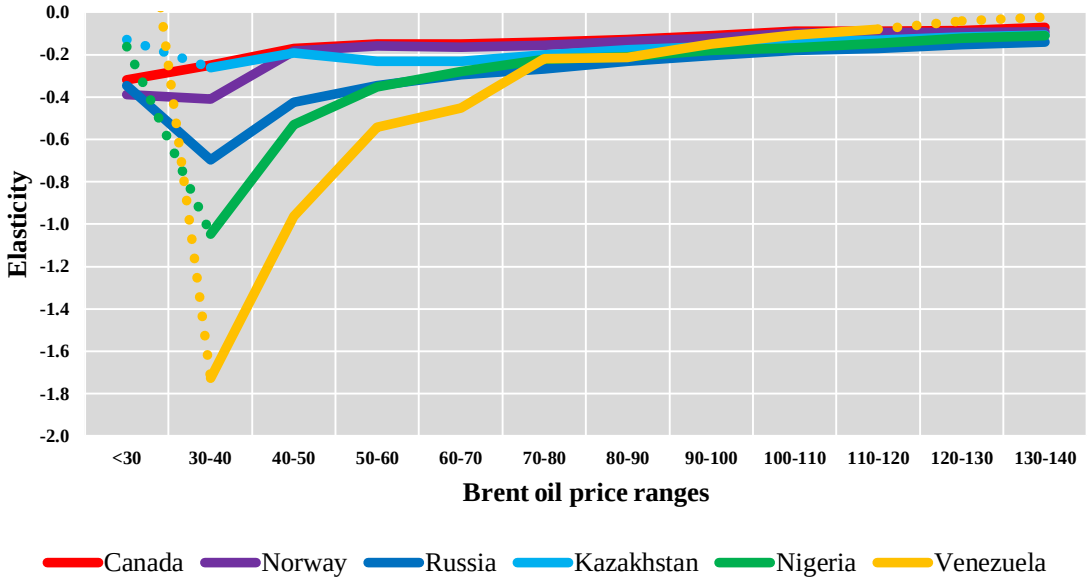
where,

| | |
|---|---|
| $P_i^{BRENT}$ | price of Brent oil in different price ranges *i* |
| $P_i^{COPPER}$ | copper price in different price ranges *i* |
| $P_i^{GOLD}$ | gold price in different price ranges *i* |
| $P_i^{SOYBEAN}$ | soybean price in different price ranges *i* |

Based on these models the estimates of the coefficients of elasticity were obtained, which are presented in **Appendix** 6.

Accordingly, the following diagram 1 has been constructed for the oil exporting countries,

**Diagram 1. Elasticity of the nominal exchange rate of oil exporting countries to different prices of Brent oil**




*Note: the dotted line indicates statistically insignificant coefficients of elasticity*
*Source: Authors' calculations*

Based on the results obtained, it should be noted that all statistically significant estimations of the coefficients for the oil exporting countries, as it was suggested by the hypotheses put forward, are within a negative zone and differ for each country and individual ranges of prices of Brent oil.

Venezuela demonstrates the largest number of statistically insignificant coefficients, which may be a result of frequent interferences in the exchange rate formation. Meanwhile, Venezuela has the highest coefficients of elasticity when the oil prices are below $70 per barrel, and the lowest coefficients of elasticity when the oil prices are above $110 per barrel. This fact is indicative of the high sensitivity of the Venezuelan bolivar to low oil prices and low sensitivity to high oil prices, which is typical for the countries with a controlled exchange rate and protective currency policy.

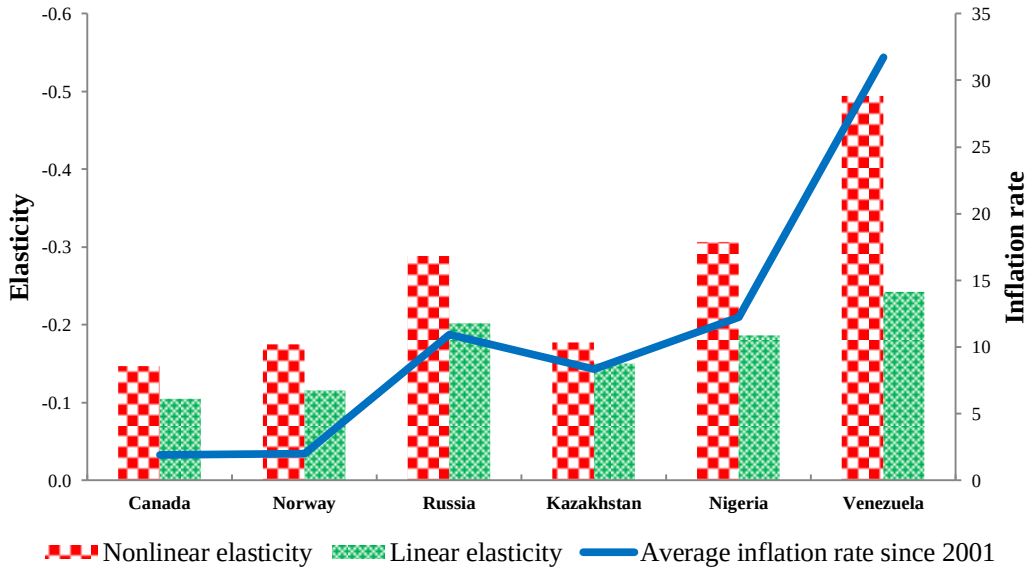
The next country in terms of sensitivity to oil prices is Nigeria that has 1 statistically insignificant coefficient, as well as Kazakhstan, for a price range below $30 per barrel of oil. The main cause of this can be the fact that oil prices below $30 are the most characteristic for the period until 2004, when the exchange rates were not strongly influenced by the dynamics of oil prices.

The developed countries, such as Canada and Norway, are the least sensitive to oil prices.

In general, one can note an observation, which is common for all oil exporting countries: the lower is the oil price, the higher are the coefficients of elasticity[7]; therefore, we can arrive at the following conclusion: "**The nominal exchange rate is more sensitive to changes in economic conditions when the oil prices are lower**."

Thus, the first two hypotheses were confirmed for the oil exporting countries, and to confirm the third hypothesis it is necessary to compare the average estimations of significant coefficients with the average inflation rates for the observed period since 2001 (Diagram 2).

**Diagram 2. Comparison of the average values of elasticity and inflation rates for oil exporting countries**




*Source: the authors' calculations*

This diagram just confirms vividly the dependence of elasticity on the level of inflation, which is explained by the fact that the high inflation rate forms a high parity, deviation from which, in the event of commodity price shocks, results in the respective high amplitude of the exchange rate elasticity to changes in economic conditions and vice versa, the lower inflation rate results in the low elasticity.

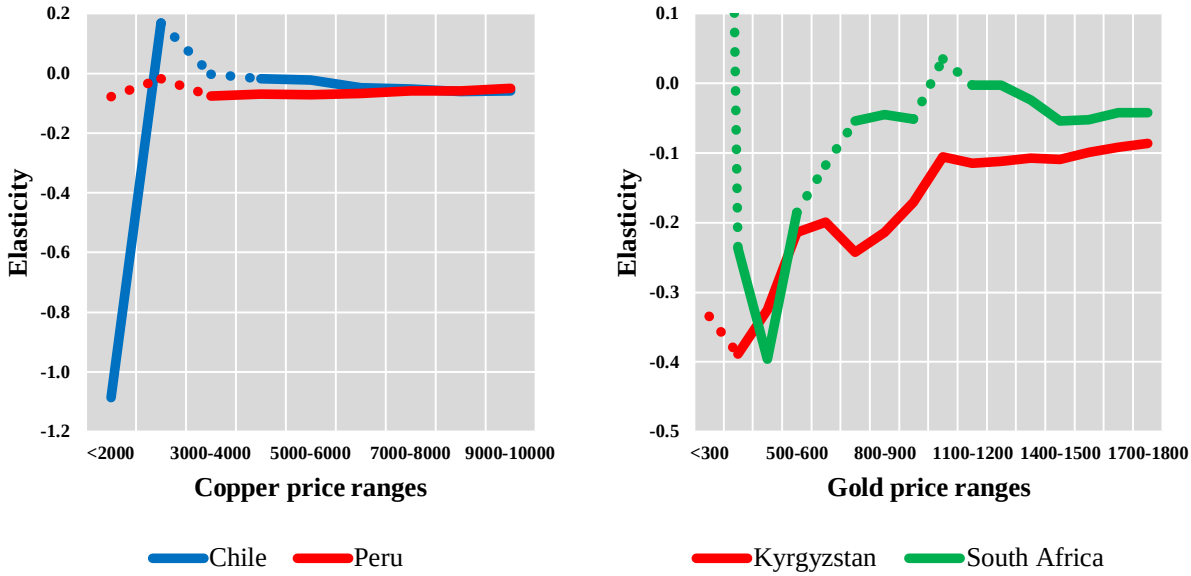
Using the obtained coefficients of elasticity it is possible to make a retrospective "in-sample" estimate, which is provided in **Appendix** 7. In general, the obtained specifications of the models describe good enough the dynamics of the nominal exchange rates of oil exporting countries and explain why they are at

[7] Except for the oil price range below $30 per barrel existed in early in 2000, when the majority of the countries of question did not apply the freely floating exchange rate

certain equilibrium levels, except for Venezuela, where it is difficult to assess the equilibrium level based on historical data, against the background of high inflation rate and exchange rate regulation. The difference between the estimated and actual values can be explained by influence of other factors, including non-economic ones, which requires more in-depth study and identification of the factors of dynamics of an individual exchange rate.

Further, we will analyze similar results for the copper and gold exporting countries (Diagram 3).

**Diagram 3. Elasticity of the nominal exchange rates of the copper and gold exporting countries to different prices on copper and gold**




*Note: the dotted line indicates statistically insignificant coefficients of elasticity*
*Source: the authors' calculations*

When considering the results for the copper exporting countries it is possible to note a significant difference between the estimates of the coefficients of elasticity for Chile and Peru, especially in the low price ranges. Thus, Chile has the highest sensitivity level when the copper prices are low, with 1 statistically insignificant coefficient and 1 positive coefficient of elasticity, which has no economic interpretation.

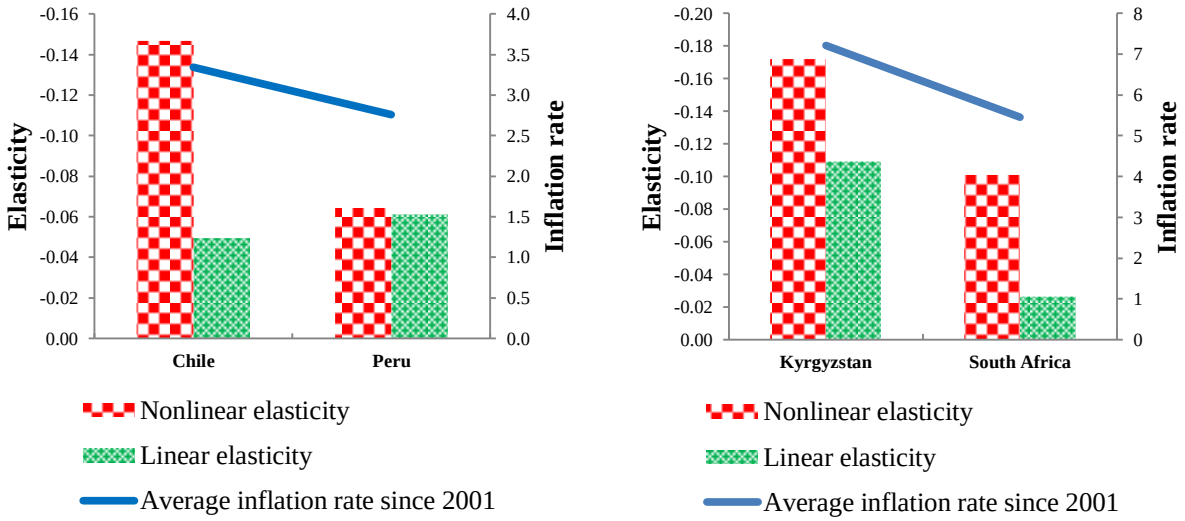
The difference between the significant coefficients of elasticity of the gold exporting countries is insignificant; in this regard the Republic of South Africa has many statistically insignificant coefficients and 1 coefficient, which has no economic interpretation, which can be explained by substantial influence of other factors in addition to the dynamics of the gold price. For Kyrgyzstan, the dynamics

of the gold price is probably the key factor that forms the nominal exchange rate, which fact is confirmed by fairly reliable estimates of the coefficients of elasticity.

In general, most of the coefficients are negative and the coefficients differ for each country and individual price ranges for copper and gold, which meets the assumptions made. As a result, it is possible to draw a conclusion similar to one for the oil exporting countries: the nominal exchange rates of the copper and gold exporting countries are more sensitive to changes in economic conditions when the copper and gold process are low.

Confirmation of the third hypothesis using the data for the copper and gold exporting countries is presented in diagram 4.

**Diagram 4. Comparison of average values of elasticity and inflation rate for the copper and gold exporting countries**



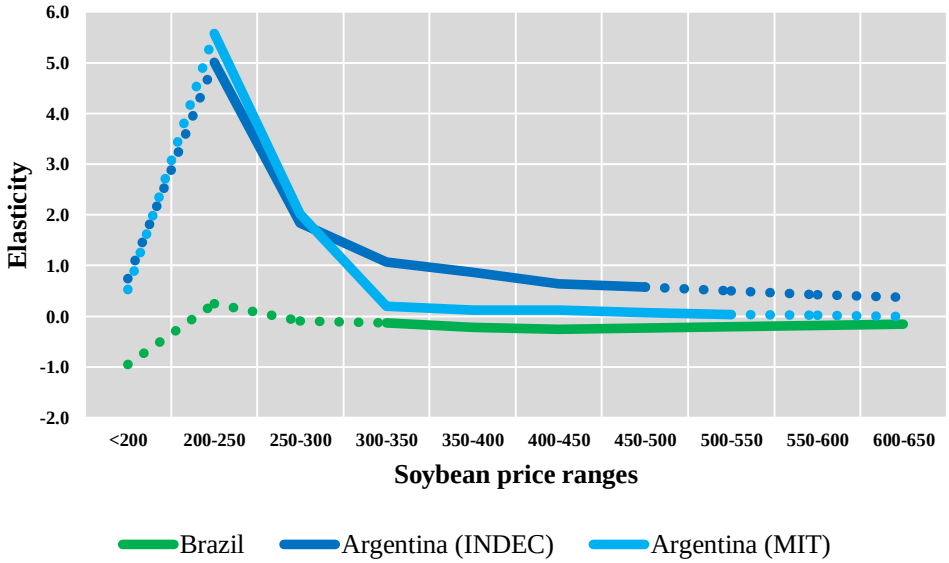

*Source: the authors' calculations*

A similar retrospective "in-sample" estimate for the copper and gold exporting countries is provided in **Appendix** 8.

The obtained specifications of the models for Chile and Kyrgyzstan describe well enough the dynamics of the nominal exchange rates. However, the obtained models for Peru and Republic of South Africa, notwithstanding the generally correct estimates of the coefficients of elasticity, do not explain in full, why the exchange rate is formed at certain levels, which may be due to the significant influence of other factors that have not been considered in the models.

The obtained estimates of the coefficients for soybean exporting countries require a separate analysis (Diagram 5).

**Diagram 5. Elasticity of the nominal exchange rate of soybean exporting countries to different soybeans prices**




*Note: the dotted line indicates statistically insignificant coefficients of elasticity*
*Source: the authors' calculations*

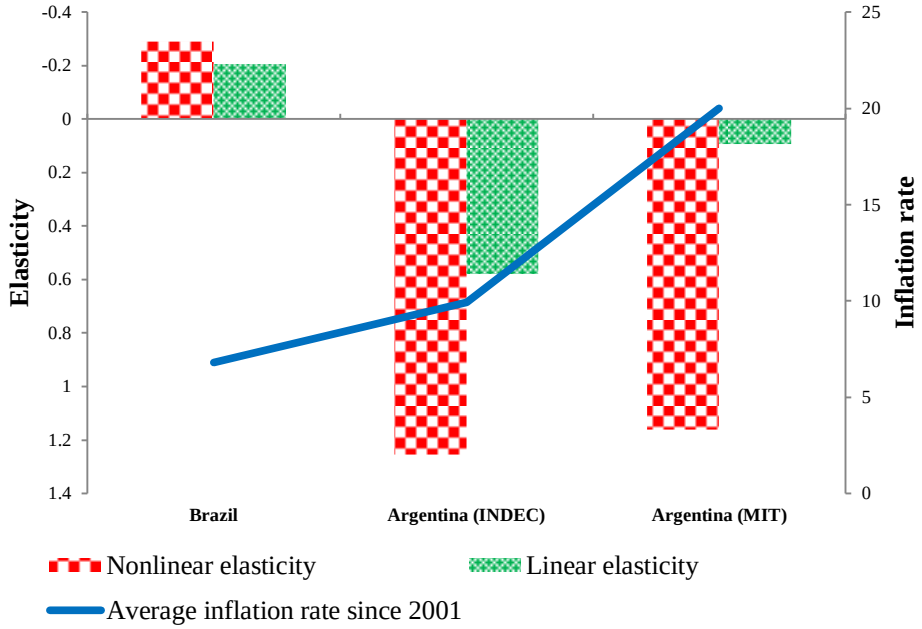
The analysis shows the ambiguity of the elasticity estimates for the soybean exporting countries. For example, the elasticity estimates for Brazil are negative, in general, which complies with the assumptions made, despite the availability of a few statistically insignificant coefficients and 1 positive coefficient.

The estimates of elasticity for Argentina are within a positive zone and do not comply with the theoretical expectations; therefore, they do not have an economic interpretation. At the same time, the coefficients of elasticity are almost completely positive, even taking into account the alternative methodology for estimating inflation as compared with MIT Sloan School of Management "The Billion Prices Project". This is due to the fact that the period of revaluation of inflation as a part of the project starts from 2007, i.e. the reliability of the previous values is still doubtful, which probably understates the parity of prices and prevents from analyzing the reasons for formation of the exchange rate at a certain level. In addition to the problem of reliability of inflation rate statistics, the exchange rate of the Argentinian peso could be formed under the influence of many other factors, including political and economic events.

Eventually, as far as the soybean exporting countries are concerned, the hypotheses of nonlinearity and location of the coefficients of elasticity within a negative zone are confirmed only for Brazil, while it is not possible to check the reliability of these hypotheses for Argentina because of the doubtful data on the inflation rates. The third hypothesis about the interrelation between inflation rate and sensitivity to dynamics of the commodity prices for soybean exporting

countries is difficult to confirm without a comparative analysis against the background of unreliable results for Argentina (Diagram 6).

**Diagram 6. Comparison of average values of elasticity and inflation rates for the soybean exporting countries**




*Source: the authors' calculations*

A retrospective "in-sample" estimate for the soybean exporting countries is provided in **Appendix** 9. The specification of the model obtained for Brazil describes well enough the general dynamics of the nominal exchange rate of the Brazilian real per 1 US Dollar, except for the certain periods where the political and economic factors had significant influence. For Argentina, with both specifications of the models, the actual exchange rate is formed above the parity, against the background of higher prices for soybeans as compared to the prices in the base year, which does not comply with the theoretical assumptions and cannot be interpreted. This fact reflects once again unreliability of the parity estimate based on doubtful data on the inflation rates in Argentina.

It should be noted that the methodology used has a feature of comparability between several groups of exporters of different commodities. Thus, for the countries that export different commodities, the obtained estimates of the coefficients of elasticity are comparable and commensurable, which allows to confirm the third hypothesis - dependence of the coefficients of elasticity on the inflation rates - using a wider and heterogeneous sampling of countries (**Appendix** 10).

## 6. Conclusions and Recommendations for Further Research

As a part of the research there has been used the unique methodology of the piecewise linear estimation with a strictly defined and theoretically justified specification of the model, which confirmed its efficiency and prerequisites inherent therein. The methodology has also proved to be universal and allows comparing countries exporting different types of commodities.

The main conclusion of the research is as follows: inflation appears to be a fundamental factor that influences formation of the exchange rates in the commodity based economies. Thus, as a part of the research and based on data for different groups of commodity exporters, three hypotheses have been put forward and confirmed: on negativity of the coefficients of elasticity for commodity prices, their nonlinearity and fundamental dependence on the inflation rate.

In general, the nonlinear sensitivity of the exchange rate to the dynamics of commodity prices has a protectionist orientation practically for all countries and to a different extent, while it is less pronounced for the developed countries, which may be indicative of the high quality-based competitiveness. Therefore, a significant difference between the coefficients of elasticity for different ranges of commodity prices may testify to possible interference in the formation of the exchange rate by means of use of the monetary policy instruments.

At the same time rather ambiguous results have been obtained for certain countries, such as Venezuela and Argentina. Unreliable results for Venezuela are due to the regime of a regulated exchange rate; therefore the estimated equilibrium values of the nominal exchange rate may be somewhat biased. In the case of Argentina, the analytical complexity is associated with the doubtful statistics on the inflation rate, in this case the alternative estimates of inflation from MIT were of no help, which indicates that the quality of data before 2007 is dubious. As a result, the estimated price parities are likely to be significantly underestimated and, accordingly, estimates of the coefficients of elasticity of deviation from the price parities for Argentina are also unreliable.

It should be noted that, in addition to the impact of fundamental and market factors, the nominal exchange rate in the short run can be also formed under the significant influence of political and economic factors, which affect the expectations of economic entities; these are not taken into consideration in the methodology used. The methodology used can be improved by focusing on the individual details. For example, to use data with a higher frequency (daily, weekly) to assess the elasticity more accurately; to take into account the asymmetry of the exchange rate elasticity to the prices on export goods; to include simultaneously

the dynamics of a few major export goods weighted by their shares in exports as market factors, and consider the change in structure of the economy during the period under review; to use the ratio to the basket of currencies of major trading partners; to consider the Balassa - Samuelson effect by categorizing the goods as tradable and non-tradable; to use the individual bases for calculation given the effect of uncovered interest rate parity, which will be more relevant for developed countries.

Based on results of the research, it is possible to conclude that the key recommendation for the commodity based countries may be as follows: to reduce the inflation rate to the optimal levels commensurate with the inflation rates of their main trading partners. From the viewpoint of the methodology used, this will reduce the parity of prices and sensitivity of the nominal exchange rate to the dynamics of commodities, while from the viewpoint of the real economy this will promote a qualitative growth of the competitiveness against the background of moderate rates in the economy that contribute to achievement of target inflation rate.

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# Appendices

## Appendix 1. Methodology example of calculations of Russian and Canada in the form of Eviews codes

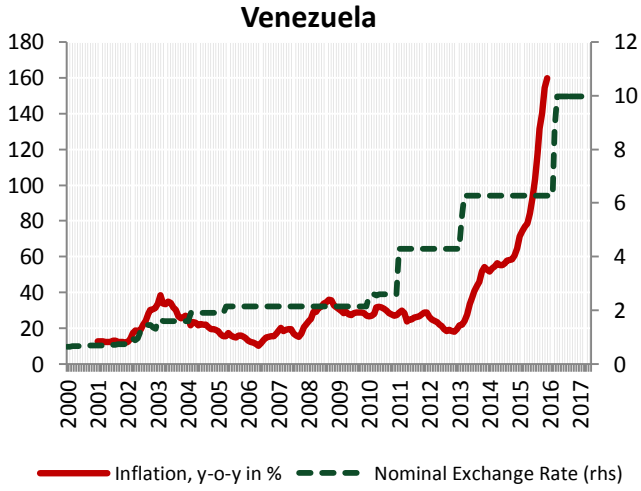
```
'create workfile=============================================================================================================================
wfcreate m 2000 2017
'import data from FRED========================================================================================================================
dbopen(type=fredv1, server=api.stlouisfed.org/fred)
fetch("link", m) CPIAUCSL mcoilbrenteu RUSCPIALLMINMEI CCUSMA02RUM618N CANCPIALLMINMEI EXCAUS
'rename series===============================================================================================================================
series brent=mcoilbrenteu
series cpi_us=CPIAUCSL
series cpi_ru=RUSCPIALLMINMEI
series usd_rub=CCUSMA02RUM618N
series cpi_ca=CANCPIALLMINMEI
series usd_cad=EXCAUS
'set base====================================================================================================================================
%base="2000M12"
'make an cpi index to the base===============================================================================================================
genr cpi_us_index=(cpi_us/@elem(cpi_us, %base))*100
genr cpi_ru_index=(cpi_ru/@elem(cpi_ru, %base))*100
genr cpi_ca_index=(cpi_ca/@elem(cpi_ca, %base))*100
'estimate purchase parity to the base========================================================================================================
genr parity_ru=(cpi_ru_index/cpi_us_index)*@elem(usd_rub, %base)
genr parity_ca=(cpi_ca_index/cpi_us_index)*@elem(usd_cad, %base)
'create dummy for BRENT price================================================================================================================
series d30=@recode(brent<30, 1, 0)
series d40=@recode(brent>=30 and brent<40, 1, 0)
series d50=@recode(brent>=40 and brent<50, 1, 0)
series d60=@recode(brent>=50 and brent<60, 1, 0)
series d70=@recode(brent>=60 and brent<70, 1, 0)
series d80=@recode(brent>=70 and brent<80, 1, 0)
series d90=@recode(brent>=80 and brent<90, 1, 0)
series d100=@recode(brent>=90 and brent<100, 1, 0)
series d110=@recode(brent>=100 and brent<110, 1, 0)
series d120=@recode(brent>=110 and brent<120, 1, 0)
series d130=@recode(brent>=120 and brent<130, 1, 0)
series d140=@recode(brent>=130 and brent<140, 1, 0)
'set BRENT price in base=====================================================================================================================
scalar brent_b=@elem(brent, %base)
''Set sample=================================================================================================================================
smpl 2000M01 2017M3
'models with linear elasticity==============================================================================================================
equation eq_linear_ru
eq_linear_ru.ls usd_rub=parity_ru*(1+c(1)*(brent/brent_b-1))
equation eq_linear_ca
eq_linear_ca.ls usd_cad=parity_ca*(1+c(1)*(brent/brent_b-1))
'models with non-linear elasticity==========================================================================================================
equation eq_non_linear_ru
eq_non_linear_ru.ls                usd_rub=parity_ru*(1+c(30)*d30*(brent/brent_b-1)+c(40)*d40*(brent/brent_b-1)+c(50)*d50*(brent/brent_b-1)+c(60)*d60*(brent/brent_b-1)+c(70)*d70*(brent/brent_b-
1)+c(80)*d80*(brent/brent_b-1)+c(90)*d90*(brent/brent_b-1)+c(100)*d100*(brent/brent_b-1)+c(110)*d110*(brent/brent_b-1)+c(120)*d120*(brent/brent_b-1)+c(130)*d130*(brent/brent_b-
1)+c(140)*d140*(brent/brent_b-1))
equation eq_non_linear_ca
eq_non_linear_ca.ls                usd_cad=parity_ca*(1+c(30)*d30*(brent/brent_b-1)+c(40)*d40*(brent/brent_b-1)+c(50)*d50*(brent/brent_b-1)+c(60)*d60*(brent/brent_b-1)+c(70)*d70*(brent/brent_b-
1)+c(80)*d80*(brent/brent_b-1)+c(90)*d90*(brent/brent_b-1)+c(100)*d100*(brent/brent_b-1)+c(110)*d110*(brent/brent_b-1)+c(120)*d120*(brent/brent_b-1)+c(130)*d130*(brent/brent_b-
1)+c(140)*d140*(brent/brent_b-1))
```

## Appendix 2. Data applied

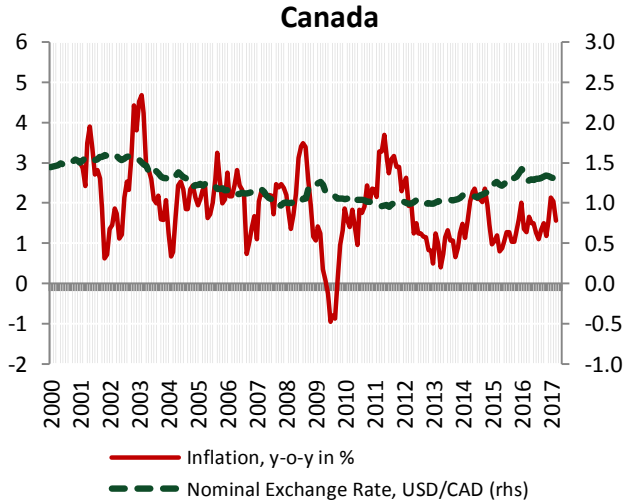
| Variable | Notation convention | Measuring unit | Period | Source/database | Identifier in the database |
|---|---|---|---|---|---|
| Brent oil price | brent | ISD per barrel | 2000M01-2017M05 | Federal Reserve Economic Data (FRED) | MCOILBRENTEU |
| Gold price | gold | USD per troy ounce | | | GOLDAMGBD228NLBM |
| Copper price | copper | USD per metric ton | | | PCOPPUSDM |
| Soybean price | soybean | | | | PSOYBUSDM |
| US CPI | cpi_us | index (1982-1984=100) | | | CPIAUCSL |
| Russia CPI | cpi_ru | index (2010=100) | 2000M01-2017M03 | | RUSCPIALLMINMEI |
| Norway CPI | cpi_no | | | | NORCPIALLMINMEI |
| Canada CPI | cpi_ca | | | | CANCPIALLMINMEI |
| Chile CPI | cpi_cl | | | | CHLCPIALLMINMEI |
| South Africa CPI | cpi_za | | | | ZAFCPIALLMINMEI |
| Brazil CPI | cpi_br | | | | BRACPIALLMINMEI |
| USD/RUB exchange rate | usd_rub | currency unit per 1 USD | | | CCUSMA02RUM618N |
| USD/CLP exchange rate | usd_clp | | | | CCUSSP02CLM650N |
| USD/NOK exchange rate | usd_nok | | 2000M01-2017M05 | | EXNOUS |
| USD/CAD exchange rate | usd_cad | | | | EXCAUS |
| USD/ZAR exchange rate | usd_zar | | | | EXSFUS |
| USD/BRL exchange rate | usd_brl | | | | EXBZUS |
| USD/KZT exchange rate | usd_kzt | | | nationalbank.kz | |
| Kazakhstan CPI | cpi_kz | as % to previous month | | | |
| Argentina CPI (MIT) | cpi_ar_mit | index | | thebillionpricesproject.com | |
| Argentina CPI (INDEC) | cpi_ar_indec | index (2008M04=100) | 2000M01-2013M12 | Quandl | CPI_ARG |
| Venezuela CPI | cpi_ve | index (2010=100) | 2000M01-2015M12 | Thomson Reuters | aVECCPIF/C |
| Kyrgyzstan CPI | cpi_kg | | 2000M01-2017M04 | data.imf.org | |
| Nigeria CPI | cpi_ng | | | | |
| Peru CPI | cpi_pe | | | | |
| USD/ARS exchange rate | usd_ars | currency unit per 1 USD | | | |
| USD/VEF exchange rate | usd_vef | | | | |
| USD/KGS exchange rate | usd_kgs | | | | |
| USD/NGN exchange rate | usd_ngn | | | | |
| USD/PEN exchange rate | usd_pen | | | | |

*Source: prepared by the authors*

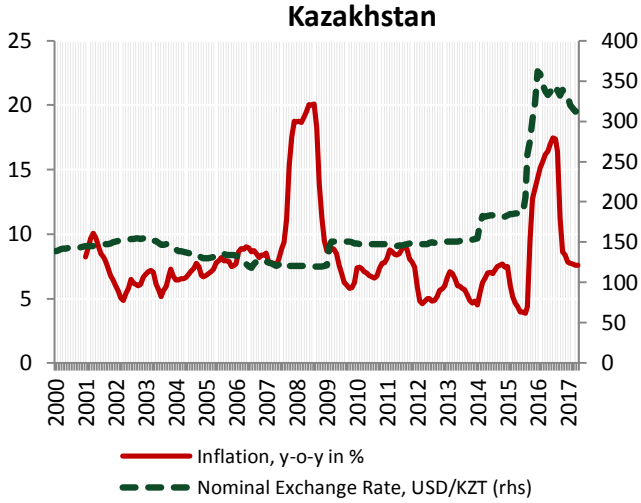
## Appendix 3. Dynamics of inflation rate and nominal exchange rate



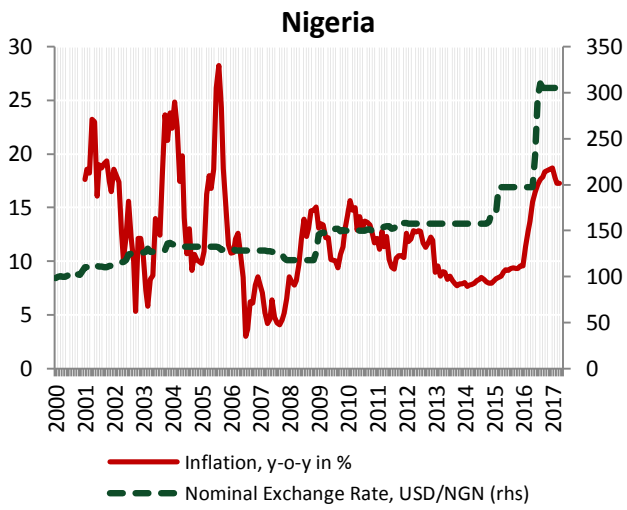

*Source: Thomson Reuters, IMF*



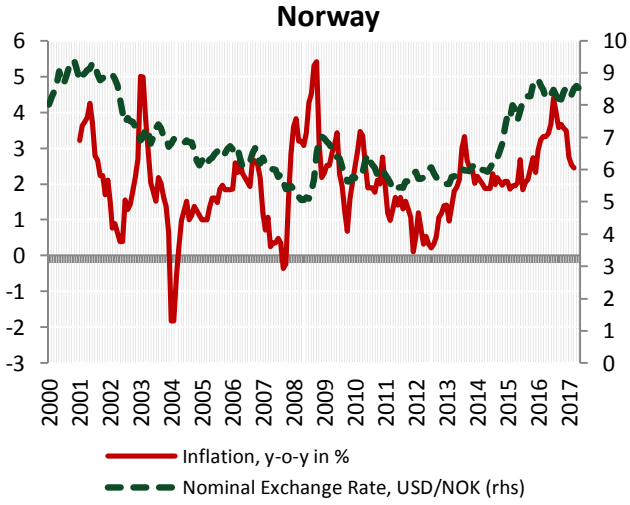

*Source: FRED Economic Data*



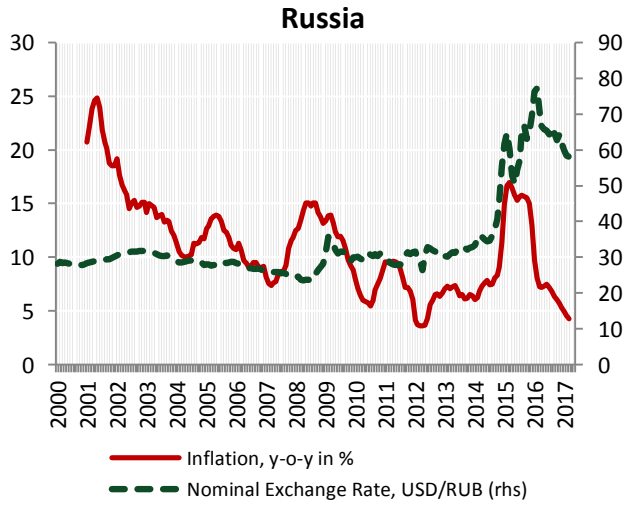

*Source: National Bank of Kazakhstan*



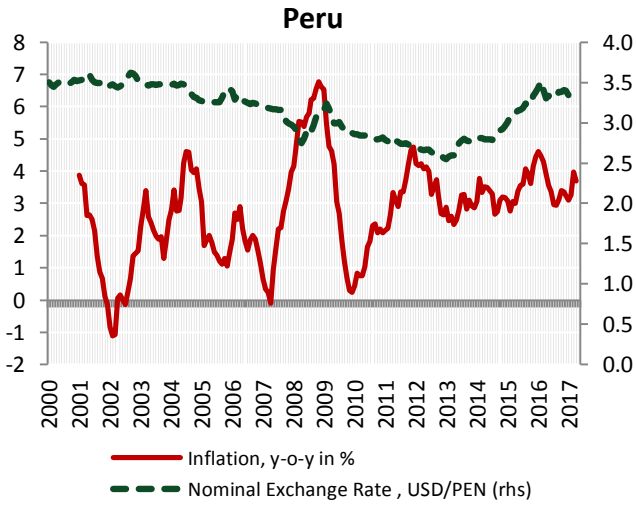

*Source: IMF*



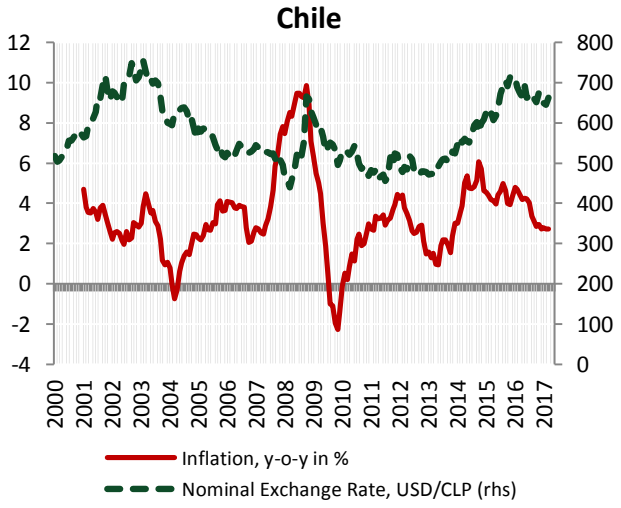

*Source: FRED Economic Data*



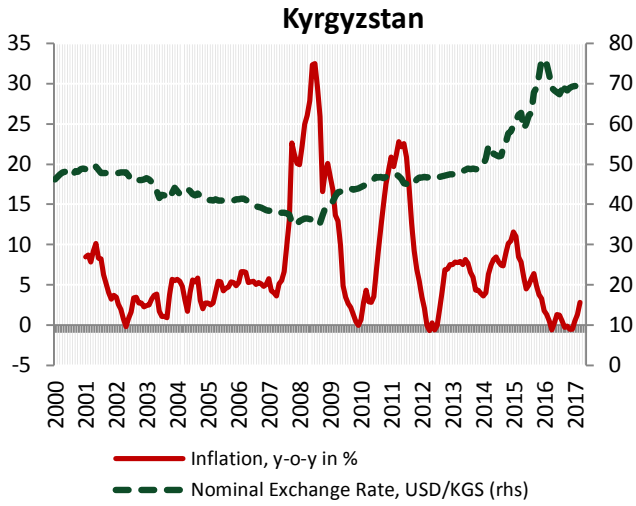

*Source: FRED Economic Data*



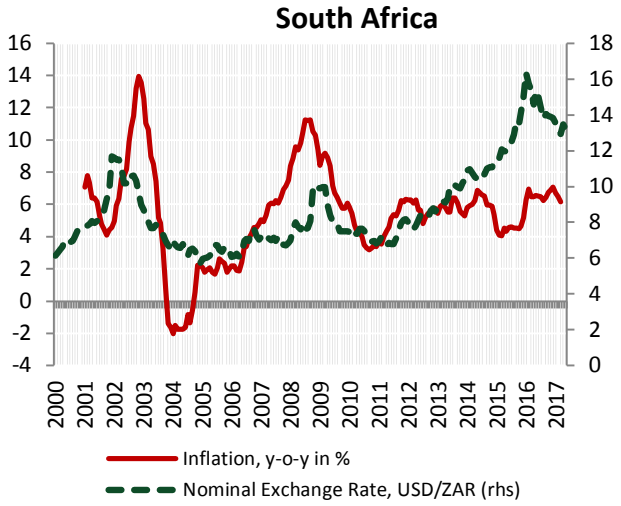

*Source: IMF*



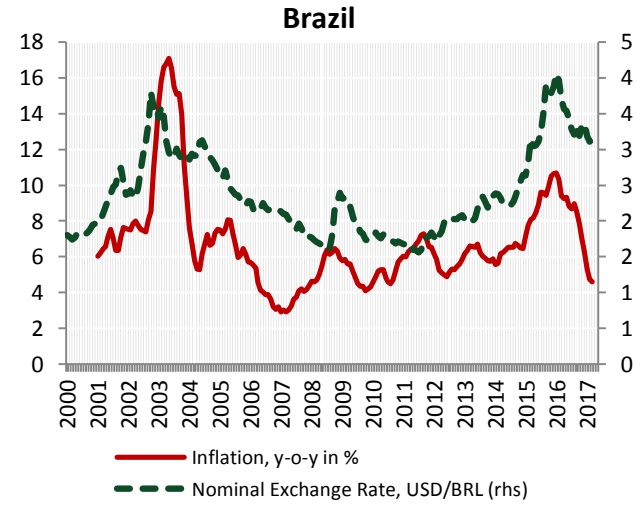

*Source: FRED Economic Data*



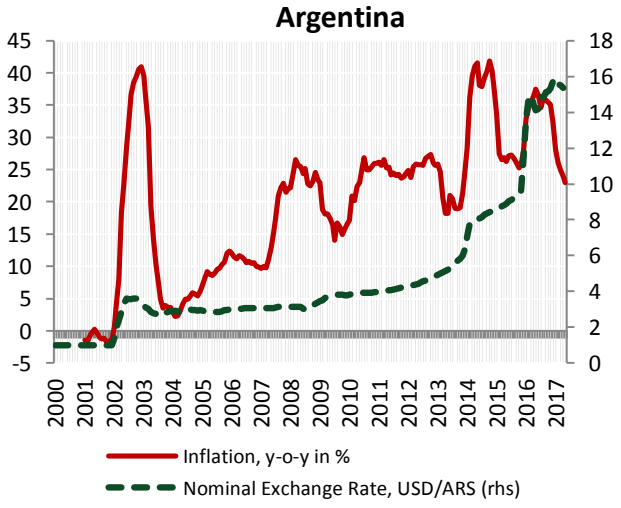

*Source: IMF*



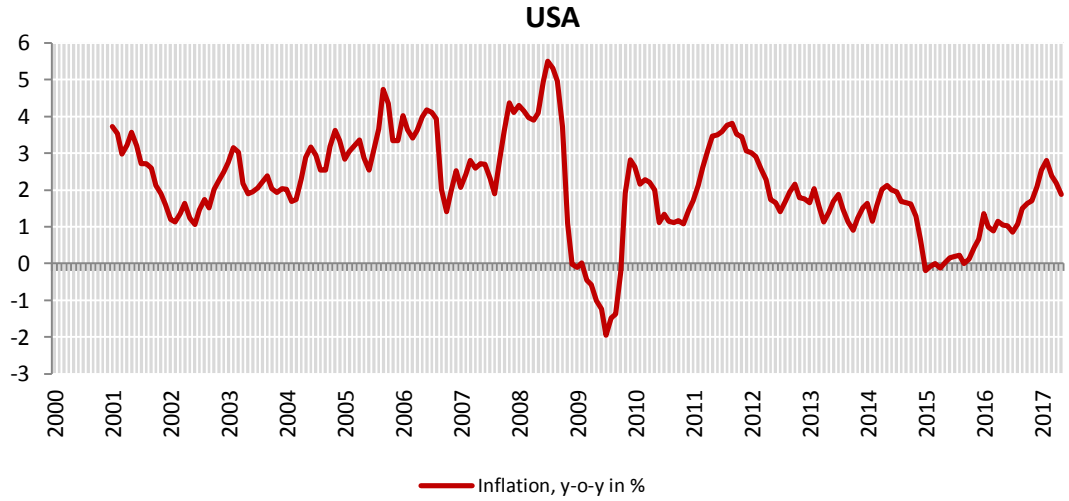

*Source: FRED Economic Data*




*Source: FRED Economic Data*

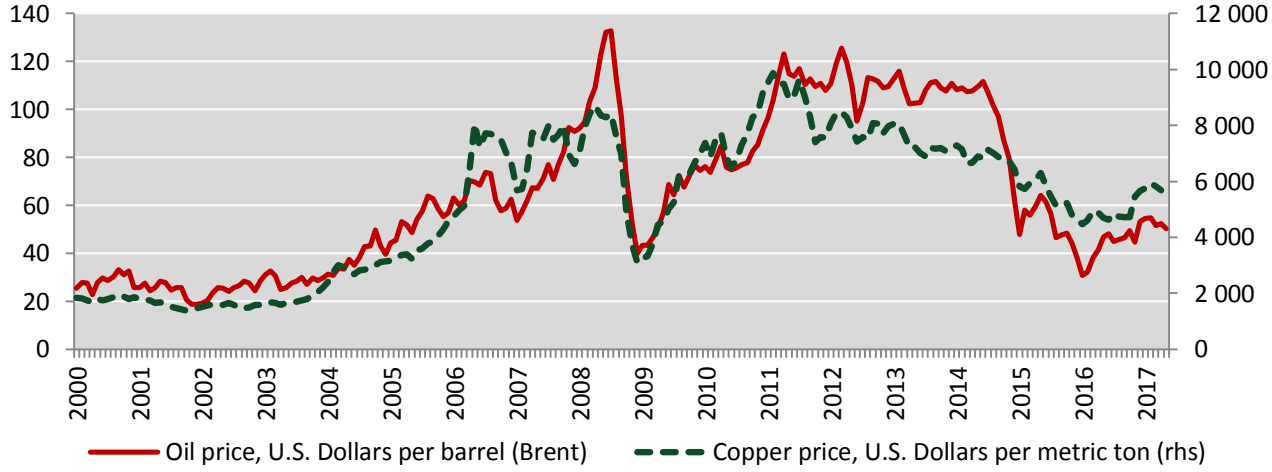



*Source: INDEC, MIT, IMF*

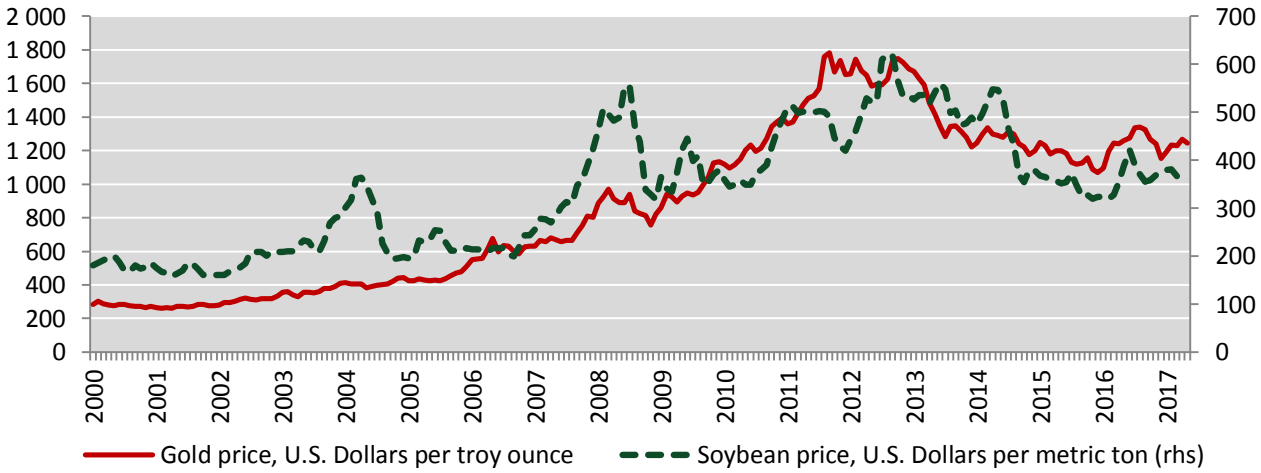



*Source: FRED Economic Data*

## Appendix 4. Prices of major export goods




*Source: FRED Economic Data*




*Source: FRED Economic Data*

## Appendix 5. Statistical values of the data used

| | Oil (Brent) | Copper | Gold | Soybean |
|---|---|---|---|---|
| Mean | 64.500 | 5199.638 | 877.844 | 337.862 |
| Median | 58.100 | 5683.903 | 889.536 | 347.861 |
| Maximum | 132.700 | 9880.938 | 1780.648 | 622.914 |
| Minimum | 18.710 | 1377.376 | 260.750 | 158.611 |
| Std. Dev. | 31.973 | 2513.855 | 471.069 | 125.356 |
| Obs. | 197 | 197 | 197 | 197 |

| Oil exporting countries | | | | | | |
|---|---|---|---|---|---|---|
| Nominal exchange rate | Venezuela | Canada | Kazakhstan | Nigeria | Norway | Russia |
| Currency | *Venezuelan bolivar* | *Canadian dollar* | *Kazakhstan tenge* | *Nigerian naira* | *Norwegian krone* | *Russian ruble* |
| Mean | 2.384 | 1.220 | 163.518 | 148.509 | 6.884 | 34.163 |
| Median | 2.236 | 1.182 | 147.520 | 133.868 | 6.500 | 30.161 |
| Maximum | 4.056 | 1.560 | 362.379 | 309.730 | 9.379 | 77.217 |
| Minimum | 1.563 | 0.955 | 118.130 | 98.490 | 5.055 | 23.350 |
| Std. Dev. | 0.611 | 0.192 | 57.416 | 42.676 | 1.186 | 12.039 |
| Obs. | 197 | 197 | 197 | 196 | 197 | 195 |

| | Copper exporting countries | | Gold exporting countries | | Soybean exporting countries | |
|---|---|---|---|---|---|---|
| Nominal exchange rate | Peru | Chile | Kyrgyzstan | South Africa | Brazil | Argentina |
| Currency | *Peruvian new sol* | *Chilean peso* | *Kyrgyz som* | *South African rand* | *Brazilian real* | *Argentinian peso* |
| Mean | 3.141 | 574.853 | 47.645 | 8.796 | 2.385 | 4.734 |
| Median | 3.220 | 556.380 | 46.516 | 7.858 | 2.236 | 3.490 |
| Maximum | 3.619 | 753.540 | 75.880 | 16.325 | 4.056 | 15.909 |
| Minimum | 2.552 | 439.090 | 34.881 | 5.724 | 1.563 | 0.999 |
| Std. Dev. | 0.307 | 77.660 | 9.069 | 2.439 | 0.611 | 3.607 |
| Obs. | 195 | 195 | 196 | 197 | 197 | 196 |

| Oil exporting countries | | | | | | |
|---|---|---|---|---|---|---|
| Inflation rate, % | Venezuela | Canada | Kazakhstan | Nigeria | Norway | Russia |
| Mean | 31.721 | 1.879 | 8.335 | 12.244 | 2.014 | 10.944 |
| Median | 26.426 | 1.919 | 7.446 | 11.705 | 1.975 | 10.141 |
| Maximum | 159.692 | 4.684 | 20.105 | 28.232 | 5.406 | 24.832 |
| Minimum | 10.381 | -0.955 | 3.850 | 3.009 | -1.833 | 3.607 |
| Std. Dev. | 24.584 | 0.920 | 3.629 | 4.759 | 1.168 | 4.437 |
| Obs. | 180 | 195 | 197 | 196 | 195 | 195 |

| | Copper exporting countries | | Gold exporting countries | | Soybean exporting countries | |
|---|---|---|---|---|---|---|
| Inflation rate, % | Peru | Chile | Kyrgyzstan | South Africa | Brazil | Argentina (MIT) |
| Mean | 2.767 | 3.340 | 8.335 | 5.453 | 20.042 | 6.802 |
| Median | 2.834 | 3.077 | 7.446 | 5.690 | 22.812 | 6.315 |
| Maximum | 6.778 | 9.859 | 20.105 | 13.928 | 41.868 | 17.085 |
| Minimum | 1.114 | -2.274 | 3.851 | -2.041 | -1.743 | 2.906 |
| Std. Dev. | 1.511 | 2.069 | 3.629 | 2.954 | 11.432 | 2.700 |
| Obs. | 196 | 195 | 197 | 195 | 197 | 195 |

## Appendix 6. Coefficients of elasticity for commodity based countries

| **Oil price** (U.S. Dollars per barrel) | **Canada** | **Norway** | **Russia** | **Kazakhstan** | **Nigeria** | **Venezuela** |
|---|---|---|---|---|---|---|
| <30 | -0.32 | -0.39 | -0.35 | -0.13 | -0.16 | 1.21 |
| 30-40 | -0.25 | -0.41 | -0.70 | -0.26 | -1.05 | -1.73 |
| 40-50 | -0.17 | -0.18 | -0.43 | -0.19 | -0.53 | -0.96 |
| 50-60 | -0.15 | -0.16 | -0.35 | -0.23 | -0.35 | -0.54 |
| 60-70 | -0.15 | -0.16 | -0.30 | -0.23 | -0.28 | -0.45 |
| 70-80 | -0.14 | -0.16 | -0.27 | -0.20 | -0.22 | -0.22 |
| 80-90 | -0.13 | -0.14 | -0.23 | -0.18 | -0.21 | -0.21 |
| 90-100 | -0.11 | -0.12 | -0.20 | -0.16 | -0.18 | -0.15 |
| 100-110 | -0.09 | -0.10 | -0.18 | -0.14 | -0.17 | -0.11 |
| 110-120 | -0.09 | -0.10 | -0.17 | -0.13 | -0.15 | -0.08 |
| 120-130 | -0.09 | -0.10 | -0.15 | -0.12 | -0.12 | -0.04 |
| 130-140 | -0.07 | -0.09 | -0.14 | -0.11 | -0.11 | -0.02 |
| **Mean of significant coefficients** | **-0.15** | **-0.18** | **-0.29** | **-0.18** | **-0.31** | **-0.49** |
| **Linear coefficients of elasticity** | **-0.10** | **-0.12** | **-0.20** | **-0.15** | **-0.19** | **-0.24** |

| **Gold price** (U.S. Dollars per Troy Ounce) | **Kyrgyzstan** | **South Africa** |
|---|---|---|
| <300 | -0.33 | 2.48 |
| 300-400 | -0.39 | -0.24 |
| 400-500 | -0.32 | -0.40 |
| 500-600 | -0.21 | -0.19 |
| 600-700 | -0.20 | -0.12 |
| 700-800 | -0.24 | -0.05 |
| 800-900 | -0.21 | -0.04 |
| 900-1000 | -0.17 | -0.05 |
| 1000-1100 | -0.11 | 0.04 |
| 1100-1200 | -0.11 | 0.00 |
| 1200-1300 | -0.11 | 0.00 |
| 1300-1400 | -0.11 | -0.02 |
| 1400-1500 | -0.11 | -0.05 |
| 1500-1600 | -0.10 | -0.05 |
| 1600-1700 | -0.09 | -0.04 |
| 1700-1800 | -0.09 | -0.04 |
| **Mean of significant coefficients** | **-0.17** | **-0.10** |
| **Linear coefficients of elasticity** | **-0.11** | **-0.03** |

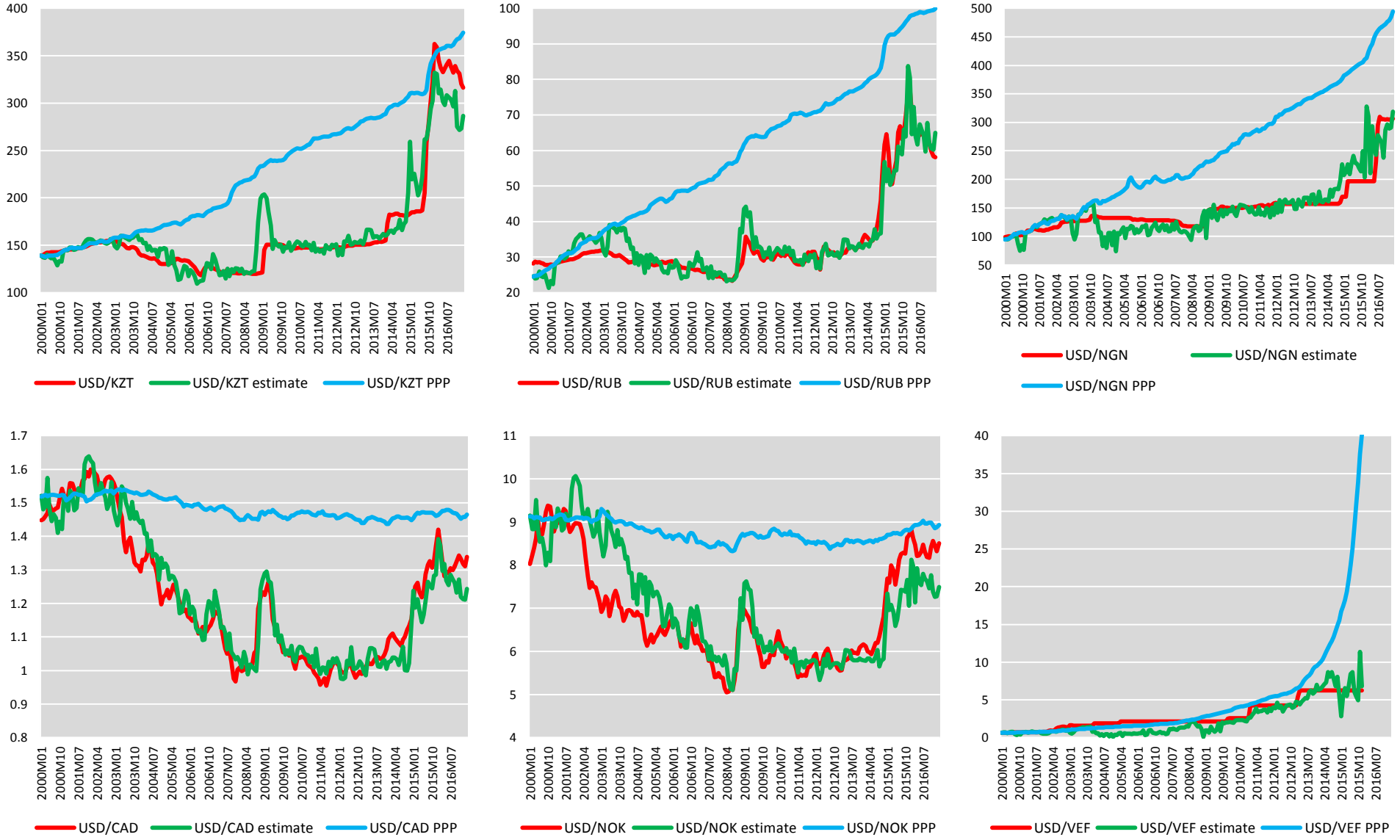
| **Soybean price** (U.S. Dollars per Metric Ton) | **Brazil** | **Argentina (INDEC)** | **Argentina (MIT)** |
|---|---|---|---|
| <200 | -0.95 | 0.74 | 0.53 |
| 200-250 | 0.25 | 5.01 | 5.57 |
| 250-300 | -0.09 | 1.83 | 2.01 |
| 300-350 | -0.13 | 1.06 | 0.19 |
| 350-400 | -0.22 | 0.86 | 0.12 |
| 400-450 | -0.25 | 0.64 | 0.12 |
| 450-500 | -0.23 | 0.58 | 0.07 |
| 500-550 | -0.20 | 0.51 | 0.04 |
| 550-600 | -0.18 | 0.43 | 0.03 |
| 600-650 | -0.15 | 0.38 | -0.01 |
| **Mean of significant coefficients** | **-0.29** | **1.26** | **1.16** |
| **Linear coefficients of elasticity** | **-0.2** | **0.6** | **0.1** |

| **Copper price** (U.S. Dollars per Metric Ton) | **Chile** | **Peru** |
|---|---|---|
| <2000 | -1.09 | -0.08 |
| 2000-3000 | 0.17 | -0.02 |
| 3000-4000 | 0.00 | -0.08 |
| 4000-5000 | -0.02 | -0.07 |
| 5000-6000 | -0.02 | -0.07 |
| 6000-7000 | -0.05 | -0.07 |
| 7000-8000 | -0.05 | -0.06 |
| 8000-9000 | -0.06 | -0.06 |
| 9000-10000 | -0.06 | -0.05 |
| **Mean of significant coefficients** | **-0.15** | **-0.06** |
| **Linear coefficients of elasticity** | **-0.05** | **-0.06** |

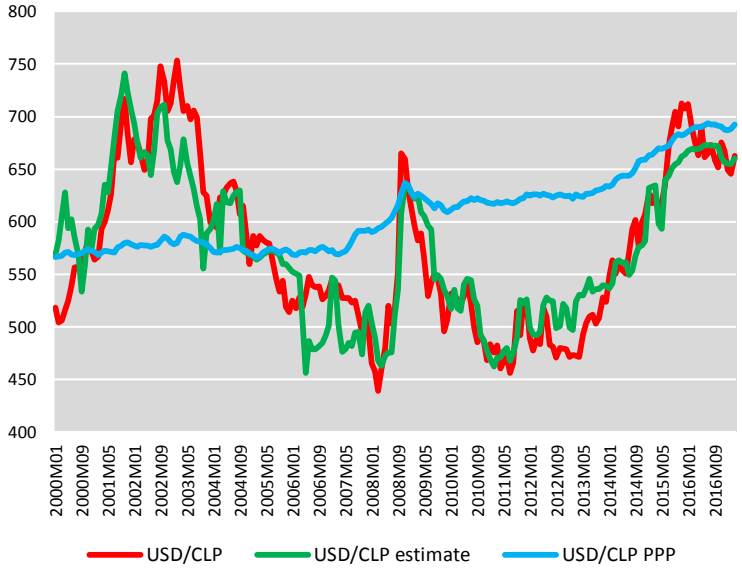
*Notes: grey shaded boxes and not shaded boxes reflect, respectively, non- interpretable data and statistically insignificant coefficients of elasticity; other coefficients of elasticity are statistically significant at the level of 5%*

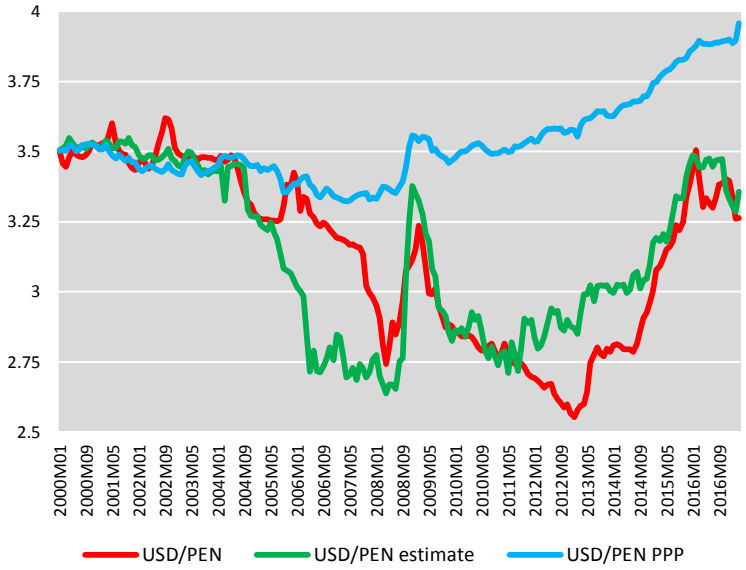
*Source: the authors' calculations*

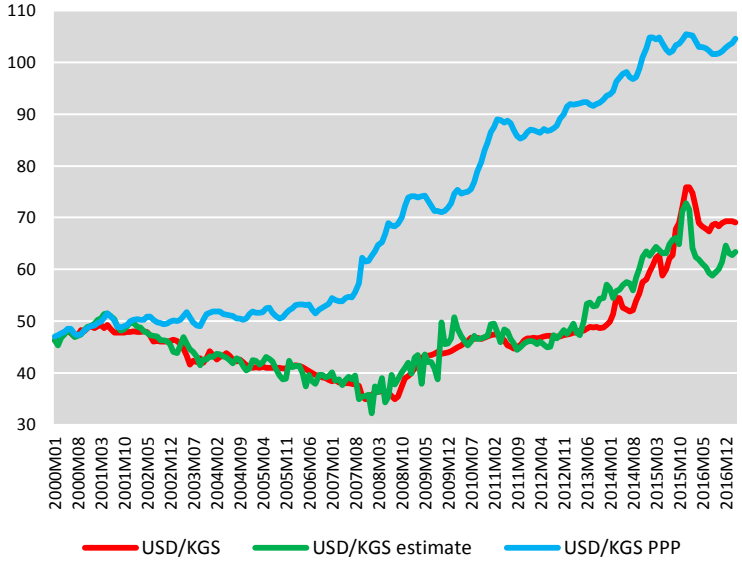
# Appendix 7. Model estimations of exchanges rates and parities for oil exporters

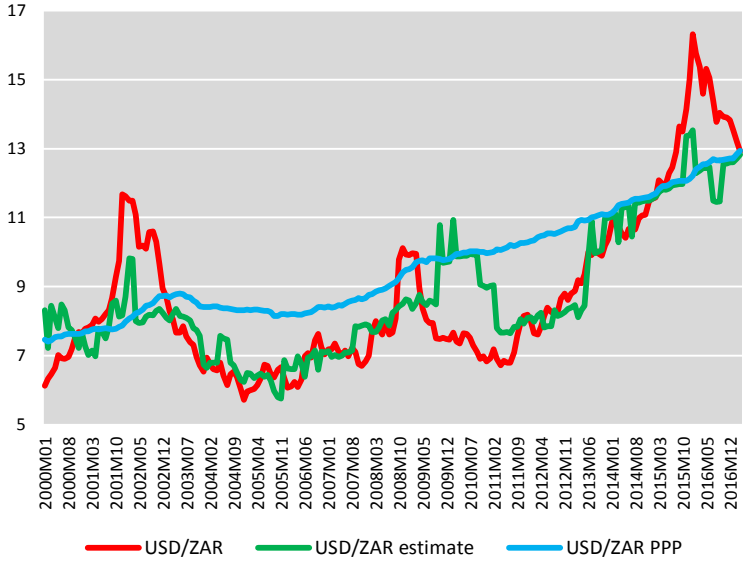


## Appendix 8. Model estimations of exchanges rates and parities for copper and gold exporters

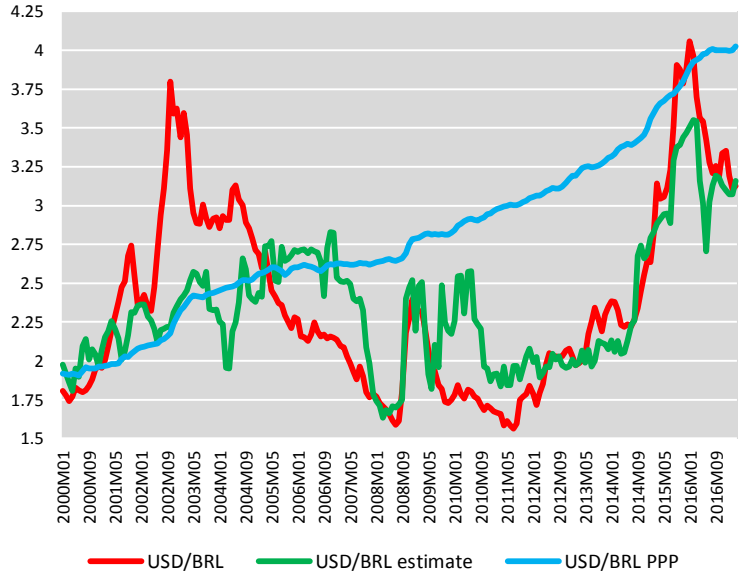


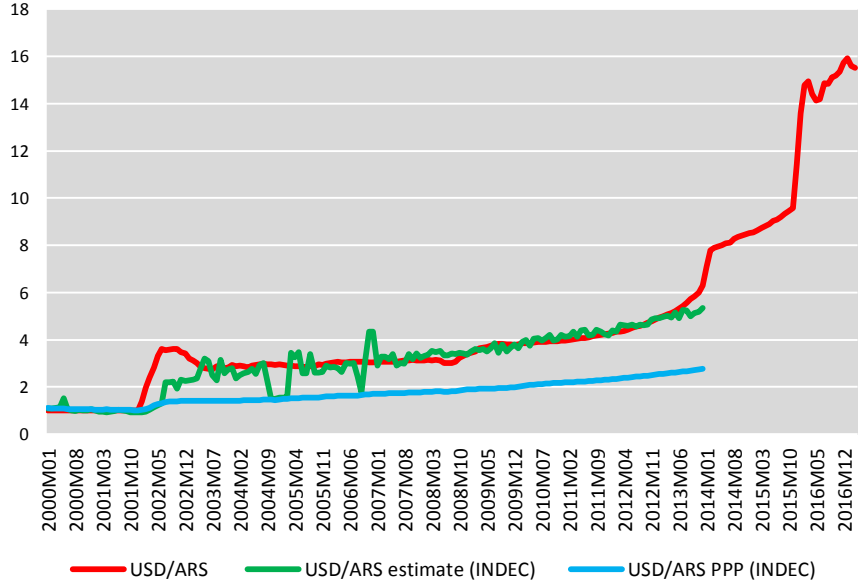



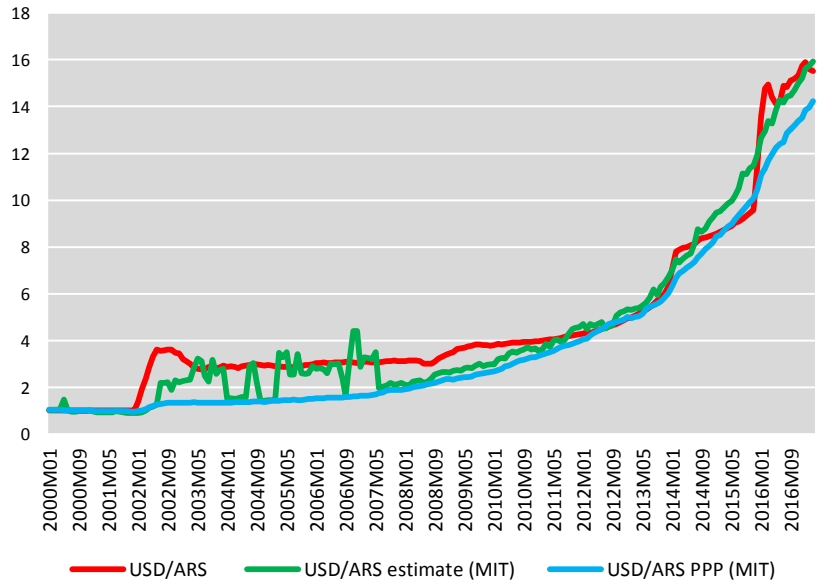



# Appendix 9. Model estimations of exchanges rates and parities for soybean exporters



**Appendix 10. Comparison of mean values of elasticity and inflation rates for commodity exporting countries**