

# MIXED-FREQUENCY DRIVERS OF PRECIOUS METAL PRICES

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## Abstract

LIBERDA MATĚJ. 2017. Mixed-frequency Drivers of Precious Metal Prices. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 65(6): 2007–2015.

Lack of intrinsic value, hybrid nature of commodities and recent financialization of commodity markets make of understanding precious metals price moves complicated. Predicting future development of precious metals market can be more feasible if we discover what drives these markets and describe nature of the drivers. The aim of the paper is to explain metal price movements by assessing an impact of multiple economic and financial factors. Based on the literature review we study 8 possible macroeconomic and financial drivers. The data are collected from Bloomberg. We use mixed-data-sampling methodology that enables me to study drivers of various frequencies (daily and monthly) simultaneously in a single model. Results show that the interest rate, the exchange rate, stock levels, stock index returns and crude oil returns are generally significant to drive precious metal markets. The stock index has the most significant impact on the metals returns that is negative. Furthermore, the results divide precious metals into two groups with gold and silver on the one hand and platinum and palladium on the other. The first group is worse explained by considered drivers. Moreover, the interest rate does not have any impact on the price development of gold and silver and crude oil returns influence the pair negatively, contrary to the second pair of platinum and palladium.

Keywords: financial markets, MIDAS, precious metals, commodities, drivers

## INTRODUCTION

Large number of financial investors and speculators have entered commodity markets in recent 20 years seeking new opportunities to realize profits. Consequently, commodity market has grown in immense pace. To illustrate this growth, Clayton (2016) states that the interest in the commodity markets by institutional investors jumped from \$15 bn. to \$200 bn. between 2003 and 2008. Furthermore, commodity markets became volatile more than ever before after the financial crisis of 2008 (see Fig. 1), precious metals markets not being an exception. Since precious metals are widely industrially used on one the hand and have always played an important role as a store of value, we must identify and analyse what stands behind such uncertainty. To better understand the large spikes in precious metals prices will help us anticipate them and prepare for them.

Commodity markets in general, or precious metals markets in particular, are specific in several aspects

in comparison with markets with other asset classes, such as equities or bonds. First, commodities lack an intrinsic value. It is not possible to conduct a financial analysis to compute a fair value of a commodity, to which its price should converge, as it is in the case of equities. Second, commodity markets are driven by diverse range of factors, due to a dual nature of commodities being both real as well as financial assets. Frankel (2014) describes this hybrid feature of commodities, specifically of fossil fuels, minerals, and agricultural commodities as follows. On the one hand, they are like assets having their price determined by supply of and demand for *stocks*, and on the other hand they bear features of goods, for which the *flows* of supply and demand drive the price. Both facts make the markets with commodities considerably volatile.

For investors, it is therefore substantially challenging to make their investment decisions in the commodity markets. As stated, they cannot base their decision on any calculation of an intrinsic

value and they must be prepared for large price swings. Thus, on what can they base their decision? The idea of this paper is to find major drivers of precious metals markets and to measure and to compare their impact on precious metals prices. Subsequently, investors should be able to predict the future development of precious metals prices by predicting the values of each driver.

Commodity market consists of several commodity classes, such as energy, metal, agricultural commodities etc. These classes have naturally different characteristics and usage. Hence, it is beneficial to focus on just one of the classes if we want our results to be transparent and their interpretation to be concrete. Due to changes that precious metals markets underwent in recent 20 years, mainly intensive financialization, it is interesting target for this research. Furthermore, gold market is understood as a main representative of commodity markets thanks to its substantial role in the world economy in past and so it is subject to elevated interest in the literature.

The paper is aimed to explain metal markets price movements by assessing an impact of multiple economic and financial factors of different frequencies using innovative econometric approaches. Drivers of various nature are considered, ranging from macroeconomic variables to financial market characteristics, implying that collected data are observed in different frequencies. Thus, an econometric model of mixed data sampling (MIDAS), which enables one to include data of different frequencies into a model without a need of their aggregation, is used. In other words, full explanatory potential of the data is exploited.

We contribute to the existing literature on topic with an approach which studies as many possible drivers as possible in a single linear model. The drivers of precious metals markets were predominantly studied separately so far. Moreover,

we use the MIDAS techniques in a completely new way since it has mostly been used to study volatility in financial markets.

The paper sheds light into understanding of metal markets dynamics. Through the analysis of main market drivers, it aspires to make price predictions on metals market more accurate. The remainder of the paper is organized as follows. Section 2 reviews literature on the topic. Section 3 presents methodology and data that are used in the paper. Section 4 relates to achieved results. Section 5 discusses the results with previous findings and the last section concludes.

### Literature review

The problem of what drives metals prices, or commodity prices in general, was addressed in a range of papers, especially after global economic crisis that burst out in 2008. On the other hand, studies usually vary in methodological framework that they use, which results in the fact that they do not reach any major concurrence regarding the drivers and a nature of their impact. Sometimes they are limited by the methodology and thus they focus on a separated effect of a single driver or on slightly different aspects of the markets. Major limitation of methodologies used so far is the fact that they do not permit one to include drivers of different frequencies in the paper. Finally, since commodities can be divided into diverse classes having different characteristics, studies that aim to study commodity market as a whole do not reach any strong conclusions.

Main purpose of the literature review is to identify drivers that could be further considered in the research based on the previous research. Summary of relevant papers concerned with either precious metal markets or commodity markets in general is presented in Tab. I.

I: Summary of papers on commodity markets and precious metal markets.

Paper	Methodology used	Drivers identified
Frankel and Rose (2010)	"Overshooting model"	GDP, inflation, volatility, inventories, spot-forward spread
Gorton <i>et al.</i> (2013)	Two-period mean-variance model	Inventories
Śmiech <i>et al.</i> (2015)	SVAR	Industrial production, interest rate
Büyüksahin and Robe (2014)	ARDL model	Stock market index
Hammoudeh <i>et al.</i> (2010)	VARMA models	EURUSD exchange rate
Kagraoka (2016)	Generalized dynamic factor model	Inflation, industrial production, stock index, crude oil price
Zhang and Wei (2010)	Cointegration and Granger causality tests	Crude oil price
Sari <i>et al.</i> (2010)	Generalized impulse response approach	EURUSD exchange rate, crude oil price

Source: Own elaboration.

Frankel and Rose (2010) argue that there have been long time periods in which majority of commodities has been moving in the same direction indicating a presence of fundamental drivers behind these moves. They consider four prevailing theories explaining this phenomenon: strong global growth, easy monetary policy, speculation, and risk (or geopolitical uncertainties) and they build an “overshooting model” in which commodity prices should converge to an equilibrium level in the long-run. They find global output and inflation to have positive effect on real commodity prices as well as strong effect of microeconomic variables, specifically volatility, inventories and spot-forward spread.

Gorton *et al.* (2013) show that commodity futures and spot prices carry relevant information about the state of inventories. We can thus imply that a change in inventories should drive a change in commodity prices.

More recently, Śmiech *et al.* (2015) used the structural VAR framework to examine an effect of real and financial processes on energy and non-energy commodity prices in the euro area macroeconomy. They also work on the assumption that certain common fundamentals cause co-movements of the commodities. Real processes are represented by industrial production, interest rates are used as a proxy variable for financial processes. Whereas before the financial crisis energy prices were rather linked to financial processes, after the crisis the commodity prices were driven by the real processes. More importantly for this study, they find non-energy commodity price index (including metals prices) insensitive to industrial activity. On contrary, the interest rate is found a significant driver for both energy and non-energy commodities. The latter is explained by Frankel (2014) who argues that the interest rate drives the price of storable commodities through its impact on the demand for inventories.

The role of financial market characteristics in a determination of metals price increases with the recent financialization of commodity markets. Büyüksahin and Robe (2014) use unique, non-public dataset of trader positions in U.S. commodity futures markets to find evidence on greater participation of speculators in commodity market. They also show that correlation between the rates of return on investible commodity and equity indices rises.

Kagraoka (2016) uses a generalized dynamic factor model to examine vast panel data of monthly returns of numerous commodities. Number of common factors driving commodity prices in general is determined to 4 corresponding to the U.S. inflation rate, the world industrial production, the world stock index, and the price of crude oil.

Precious metals are subject to a research of Hammoudeh *et al.* (2010), particularly they focus on a relation between precious metals and EURUSD exchange rate. They show that volatility sensitivity

to the exchange rate volatility is the highest for silver. On contrary, gold is the safest hideaway from the exchange rate fluctuations. Another conclusion of the study is close relationship between gold and silver and platinum and palladium. Implication of this fact for our study is that these two groups could show similar results concerning their drivers.

Zhang and Wei (2010) examine a relation between gold and crude oil market. Their empirical analysis shows significant positive correlation coefficient 0.9295 between these two markets. Furthermore, crude oil price change linearly Granger causes the volatility of gold prices according to them.

Crude oil is also considered as possible driver for precious metal prices in the paper of Sari *et al.* (2010), which focuses on the co-movements and information transmission between spot prices of gold, silver, platinum, and palladium and oil price and the US dollar/euro exchange rate. Although they do not find evidence of a strong long-run equilibrium relationship, strong feedbacks in the short run between the prices and both variables are discovered.

Based on the aforementioned papers, following variables are chosen to be candidates for possible metal markets drivers: industrial production, inventories, inflation rate, interest rate, stock index, US dollar/euro exchange rate, price of crude oil and GDP growth.

Higher industrial production is expected to drive the prices up through raised demand, since the metals are amply used in numerous industries. Inventories may signalise both excess supply and excess demand. In the first case, there is an overproduction of metals that are not sold that quickly and have to be stored. In the latter case, raised stocks of metals may imply that suppliers hold more of the metals in their stocks to be prepared to satisfy the excess demand. Thus, the anticipated effect of inventories is ambivalent. Third, the inflation rate reflects rising prices in economy, including metal prices. The interest rate drives the storable commodity prices through its impact on the demand for inventories according to Frankel (2014). Stock market (represented by stock index) and crude oil market could be understood by investors as alternatives when they consider their investments. In this case funds would spill over the markets and the coefficients would be negative. All metals are mainly traded in US dollars. Therefore, weaker dollar should result in increase of metal prices.

## MATERIALS AND METHODS

### Mixed data sampling

The analysis is based on mixed data sampling regression models (so called MIDAS regression) introduced in Ghysels *et al.* (2004) and advanced in Ghysels, Santa Clara, and Valkanov (2006) and Andreou, Ghysels, and Kourtellis (2010).

The MIDAS regression enables the researcher to include time series of several different frequencies in the modelling. Such facility is achieved through frequency alignment procedure.

Frequency alignment transforms the time series of a high-frequency variable to a matrix formed by vectors of a length corresponding to a length of a low-frequency variable time series. Consequently, the number of vectors forming the high-frequency matrix is equal to the number of high-frequency observations falling into one low-frequency period (or its multiple, if we consider lags through numerous periods). Coefficients for each vector of the matrix are then estimated by a regression. A general example may be more instructive.

Let  $y$  be a dependent variable observed in  $m$  periods and  $x$  be an explanatory variable observed in  $n$  periods,  $k$  times more frequently than  $y$ . Thereafter, to be able to perform a regression, we need to transform variable  $x$  to a matrix of  $k$  vectors of a length  $m$  (provided that we consider data from only one low-frequency period to influence the contemporary observation). In such case,  $n$  is equal to a product of  $m$  and  $k$ . The above mentioned general example is best illustrated by the equation (1):

$$\begin{bmatrix} y_1 \\ \vdots \\ y_m \end{bmatrix} = \alpha + \begin{bmatrix} x_1 & \cdots & x_k \\ \vdots & \ddots & \vdots \\ x_{n-k+1} & \cdots & x_n \end{bmatrix} \begin{bmatrix} \beta_1 \\ \vdots \\ \beta_k \end{bmatrix} + \varepsilon, \quad (1)$$

where the vector of the dependent variable  $y$  is of length  $m$ , the matrix of the variable  $x$  is a  $m \times k$  matrix,  $\alpha$  is a constant term and the vector of  $\beta$  represents respective coefficients for each column of the  $x$  matrix. In the paper, dependent variable is observed monthly, whereas explanatory variables are observed on monthly as well as on daily basis. Thus, daily explanatory variables are transformed into matrices of 21 vectors, each representing particular number of a day in month.

Faroni *et al.* (2015) introduced a modified version of MIDAS, so called reverse unrestricted MIDAS that enables one to incorporate a high-frequency variable as the dependent one. In this case, it would mean that a use of daily metals returns would be possible. On the other hand, it would result in a system of 21 equations instead of 1 in each step of the analysis, which would make the results of the study considerably more complex. For the sake of the results transparency it was thus decided to use monthly returns as a dependent variable.

There are several ways to employ functional constraints in order to reduce the number of coefficients that need to be estimated. Such feature can be particularly useful when a model is not feasible to be estimated unrestricted for too many coefficients. However, it is not a case of this study and so employing functional constraints was not found necessary. Moreover, restricting the model by the constraints means adding an information in

it, which often can be plainly arbitrary and lead to in some way biased results. Additionally, unrestricted MIDAS regression can be estimated using standard OLS method.

Although there is no specific way how MIDAS would deal with the spurious regression problem, there are several arguments that let us assume that such risk is not at hand in this paper. First, examined financial and economic variables are chosen carefully only after they were discussed in other studies. Moreover, we comment the economic intuition underlying the choice of each variable. And last, dependent variables are studied in their stationary forms of returns which should further decrease the risk of the spurious regression.

### Factors impacts analysis

Impacts of factors on metal prices are compared as follows. First, regressions of each factor on each metal monthly returns are run separately. These regressions always contain monthly GDP growth as a control variable, although its own significance is not considerable. Adjusted coefficients of determination are estimated for each regression. Afterwards, they are compared to determine which of the factors contribute to explanation of the returns variability significantly. The equation (2) generally illustrates the form of the partial regressions, that are run in the research:

$$r_{a,t} = \alpha + GDP_t + x_{b,t} + \varepsilon_t; \quad a \in \{1; 2; 3; 4\}, b \in \{1; 2; \dots; 7\}, \quad (2)$$

where  $r_a$  represent monthly returns of gold, silver, platinum and palladium respectively and  $x_b$  denotes each of the 7 possible drivers chosen. Consequently, we have a system of 7 equations for each of the 4 metals, totalling 28.

Subsequently, we estimate an overall regression for each metal, including all factors that were found relevant for the respective metal in the previous step, accounting for 4 equations of the following form:

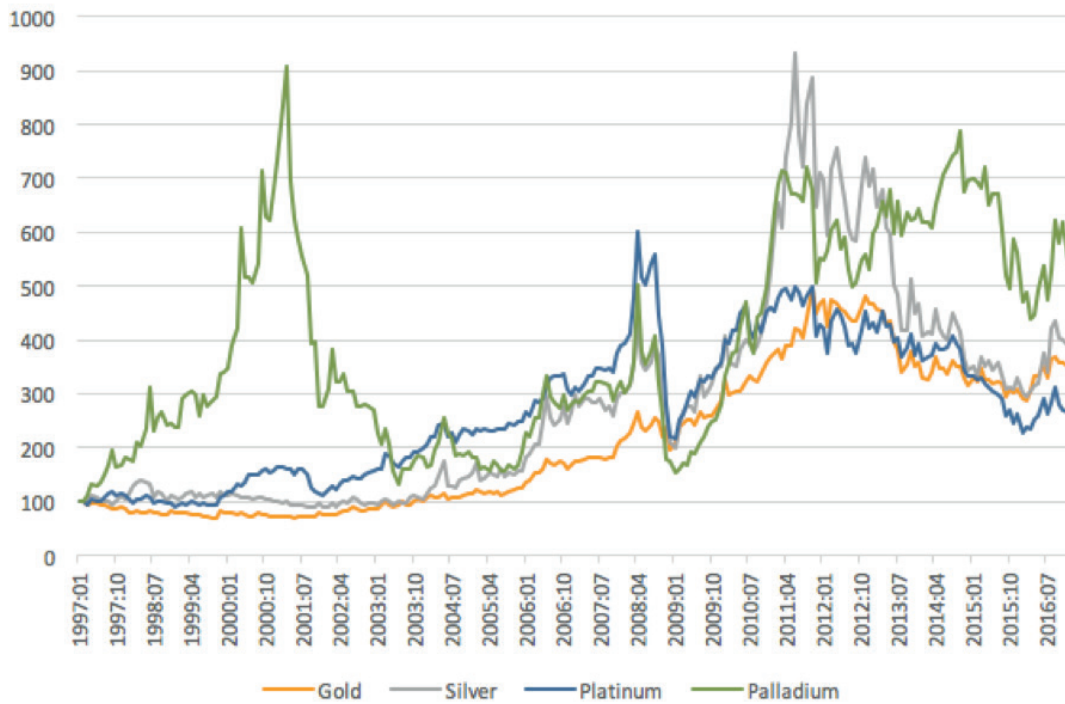
$$r_{a,t} = \alpha + GDP_t + \sum_{b=1}^7 \beta_b x_{b,t} + \varepsilon_t; \quad a \in \{1; 2; 3; 4\}, b \in \{1; 2; \dots; 7\}, \quad (3)$$

Out of all coefficients estimated (there is a large number of them due to the MIDAS technique) the most significant ones for each factor are chosen and compared.

### Data

Data are collected across the period of 1997:01–2016:12, which accounts for 240 monthly and 5,040 daily observations. Monthly spot prices are collected for gold, silver, platinum and palladium in dollars per troy ounce. Their development from across the examined period can be seen in Fig. 1.





1: Monthly spot prices of gold, silver, platinum and palladium. 1997:01 price = 100.  
Source: Own elaboration based on data collected from Bloomberg.

We compute monthly returns from the prices using their log difference.

We can identify several common patterns of precious metals price development looking at Fig. 1. Prices of all precious metals were rising before the outbreak of the economic crisis in 2008 (although the rise of gold was substantially lower compared to the rest of metals). During the crisis, the prices fell sharply, to recover fast in period from 2009 to 2011. We can also see common stagnation of prices in recent years. Palladium stands out from the group in the period from 1997 to 2003 because one of its major producers was experiencing serious crisis. Palladium prices are also more volatile from 2010 onwards in comparison with other precious metals. Augmented volatility affected silver from 2011 to 2013 as well. These distinctions may have an impact on results of the study decreasing significance of the drivers.

We consider 8 variables as possible price drivers. Macroeconomic variables comprise *GDP growth, inflation, industrial production and interest rate*. Financial market characteristics include *exchange rate, stock index*

*and crude oil prices*. We calculate returns from the stock index and crude oil prices in the same manner as it was for the metals returns. We include *Stock of each metal* to reflect the supply side of the metal market. Data for all variables are collected from Bloomberg.

Descriptive statistics of the metals monthly returns are presented in the Tab. II. As it was mentioned in the price development description, palladium is the most volatile precious metal followed by silver (measured by standard deviation). Correspondingly, average and median returns of these two metals exceed the ones of gold and platinum. For detailed information about the drivers' data see Tab. III and Tab. IV. Data about metal inventories are worth interest. Platinum and palladium stocks are considerably lower and more volatile with respect to the gold and silver ones. Relatively low bottom of palladium stock corresponds to the mentioned crisis in 2001–2003.

While inflation and industrial production are observed monthly, the rest of the factors are observed daily. The daily time series consist of 252 working days per year, resulting in 21 days

II: Descriptive statistics of the metals monthly returns.

	Mean	Median	Standard deviation	Minimum	Maximum
<b>Au</b>	0.0048	0.0016	0.0502	−0.1853	0.1966
<b>Ag</b>	0.0052	0.0038	0.0894	−0.3125	0.2199
<b>Pt</b>	0.0038	0.0059	0.0690	−0.3327	0.2316
<b>Pd</b>	0.0078	0.0128	0.1112	−0.3768	0.3638

Source: Own elaboration.

## III: Descriptive statistics of the price drivers.

	Mean	Median	Standard deviation	Minimum	Maximum
<b>GDP</b>	2.35	2.40	1.87	-4.10	5.30
<b>Inflation</b>	2.16	2.10	1.25	-2.10	5.60
<b>IP</b>	1.55	2.31	4.34	-15.40	8.65
<b>IR</b>	2.38	1.50	2.22	0.25	6.50
<b>ER</b>	1.20	1.22	0.17	0.83	1.60
<b>S&amp;P 500</b>	0	0	0.01	-0.09	0.11
<b>Crude oil</b>	0	0	0.02	-0.17	0.16

Source: Own elaboration based on data analysis in R interface.

## IV: Descriptive statistics of the price drivers – stock levels, in troy ounces.

	Mean	Median	Standard deviation	Minimum	Maximum
<b>Au stock</b>	5,903,159	7,077,126	3,711,497	427,584	11,728,462
<b>Ag stock</b>	124,677	116,414	30,624	71,919	203,982
<b>Pt stock</b>	87,893	53,400	74,926	5,300	288,053
<b>Pd stock</b>	356,594	404,297	305,341	3,900	1,193,100

Source: Own elaboration based on data analysis in R interface.

per month on average. GDP growth is typically observed quarterly. However, for purposes of this study the data were collected on a monthly basis. Time series of quarterly frequency would make the MIDAS regression model considerably less feasible. It is thus assumed that if a certain year-over-year growth rate was registered for the quarter, the equal year-over-year growth rate holds for each month of this quarter.

All the macroeconomic variables correspond to the US economy since it is considered world centre of the precious metals trade. From the US stock indices S&P 500 is chosen being the most traded one. Source of metal stocks data is the New York Mercantile Exchange (NYMEX) for platinum and palladium and Commodity Exchange (COMEX) for gold and silver.

## RESULTS

As it was mentioned in the previous section, the analysis is initiated with separate regressions of each factor on each metal. Adjusted coefficients of determination are presented in the Tab. V. Coefficients of determination of industrial production and inflation were negligible for all four

metals. GDP growth was included in all regressions as control variable.

Different nature of behaviour can be seen for the two pairs of metals. Platinum and palladium are relatively better explained by the considered factors than gold and silver, silver being the most problematic with only stock index explaining at least some variability. A fact that gold and silver are traded in larger volumes and that silver has a vast application in various industries may result in more factors being involved in market price moves. Leaving silver apart, gold is explained in a similar nature as platinum and palladium by the stock and exchange rate changes. On the other hand, platinum and palladium are significantly better explained by interest rates and the stock index.

The returns of the stock index and crude oil contribute considerably to the return variability explanation of all four metals examined. The stock market activity and sentiment are thus linked with the returns on commodity markets. Aforementioned financialization of the commodity markets empirically demonstrated in Büyüksahin and Robe (2014) stand for possible explanation of this phenomenon. In other words, metals are

V: Adjusted  $R^2$  of partial regressions. Based on analysis performed in R on data collected from the Bloomberg Terminal.

	IR	Stock	S&P 500	ER	Crude oil
<b>Au</b>	–	0.0696	0.0452	0.0394	0.0633
<b>Ag</b>	–	–	0.0665	–	0.0422
<b>Pt</b>	0.0799	0.0539	0.1374	0.0412	0.1450
<b>Pd</b>	0.1158	0.0119	0.0980	0.0167	0.0931

Source: Own elaboration based on data analysis in R interface.

Note: In partial regressions, GDP growth and respective factor were included as explanatory variables.

“–” represents adjusted  $R^2$  being inconsiderable.

VI: Estimated coefficients for overall regressions. Based on analysis performed in R on data collected from Bloomberg.

	IR	Stock	S&P 500	ER	Crude oil	Adjusted R <sup>2</sup>
<b>Au</b>	–	2.0e–07' (4)	–8.4e–01* (5)	1.09' (16)	–5.1e–01** (19)	0.138
<b>Ag</b>	–	–	–2.08*** (2)	–	–6.8e–01* (19)	0.089
<b>Pt</b>	–7.5e–01* (16)	5.6e–06' (7)	–1.89*** (2)	–1.89* (18)	5.2e–01** (9)	0.293
<b>Pd</b>	–3.5e–01' (20)	–3.0e–06' (11)	–1.84* (2)	2.73' (16)	1.07** (15)	0.196

Source: Own elaboration based on data analysis in R interface.

Note: “–” marks that the factor was not included in the regression. Figures in brackets represent number of lag, in which the most significant coefficient was found. \*\*\*, \*\*, \*, ‘ represent the level of significance of 0.001, 0.01, 0.05, and 0.10 respectively.

considered an asset class to invest in, an alternative to equities and bonds for the investors. Moreover, this holds true not only for gold and silver, which are traditionally seen as an instrument to invest in real assets, but also for platinum and palladium, expected to be rather industrial resources. Crude oil seems to be important driver as it is an important resource for the metals production. Another explanation of its significant role may relate to its industrial use. When a demand for crude oil is high due to high industrial production, it can be concluded that the metals are demanded for the production as well. On the other hand, the analysis determined neither inflation nor industrial production as relevant factors to explain any metal return variability.

The next step was to estimate regressions incorporating factors that showed explanatory potential for respective metal in the regressions of the previous step. Coefficients of relevant factors for each metal are presented in Tab. VI.

The interest rate coefficient is negative for platinum and palladium for which it was found relevant in the previous step. Coefficients for stock are not considerably significant whereas those for the S&P 500 are significant at least at the level of 0.05 for gold and palladium and even at the level of 0.001 for platinum and silver. The coefficients are negative. Coefficients of the exchange rate are again not so significant and rather heterogeneous. In contrast, estimates for crude oil are for 3 metals significant at the level of 0.01. Division between the two pairs of metals is clear here. On the one hand, the coefficients are negative for gold and silver. On the other hand, they are significantly positive for platinum and palladium. Finally, there are many coefficients that refer to lag orders between 15 and 20. We identify such high lag orders for daily variables. Since the month is 21 trading days long, these lag orders refer to an economic situation at the beginning of the month.

The best score achieved by the model for platinum can be due to low volatility of its returns in the examined period. This could mean that we are able to forecast some of the variability according to factors considered in this study in periods of continuous market development. In

contrast, in turbulent periods these factors lose their explanatory or forecasting power. Such hypothesis could explain low number of considerable factors for silver and low levels of significance of the palladium equation estimates, whose elevated volatility was shown in Fig. 1. Both metals are relatively more volatile with respect to gold and platinum.

## DISCUSSION

In the literature, evidence of negative impact of interest rates on commodity prices is one of the most present (see Frankel (2014) or Šmiech *et al.* (2015)). Significant and negative coefficients for the interest rate were found for platinum and palladium in line with the present research. Easy monetary policy supplies financial markets (including metal markets) with relatively cheap funds, which drives the prices up. On contrary, this was not the case for gold and silver, which may indicate that these metals are not subject to financial conditions and are rather driven by different factors in the studied period.

Furthermore, the stock index and the crude oil returns are factors for which general conclusions may be drawn too. The stock index was confirmed as one of the main common factors for all commodities in Kagraoka (2016). Büyüksahin and Robe (2014) also find evidence on existing link between the stock market and commodity markets. The relevance of stock market returns is confirmed in this paper and we find that an impact of the stock market is negative. This means that metals are understood by investors as an alternative to equities, a safe haven where they fly to when the conditions on the stock market are unfavourable. Such hypothesis corresponds to the financialization of the commodity markets proved by Büyüksahin and Robe (2014).

With reference to the finding of Zhang and Wei (2010) that between crude oil and gold exists close relationship, the results of this paper show that crude oil strongly influences precious metal prices in general. However, the impact of crude oil returns divides the metals into two groups with gold and silver on the one side and palladium on the other, a division that Hammoudeh *et al.* (2010) suggested

too. While gold and silver may be considered as an alternative asset investment to crude oil (similarly to the equities), for platinum and palladium the co-movement with oil arising from their industrial use of all prevails.

Stock levels are found relevant for three metals (silver being the exception) as proposed Frankel and Rose (2014) and Gorton *et al.* (2013), although their significance is low. The significance of the exchange rate should be relatively stronger as well, according to Sari *et al.* (2010). On the other hand, low significance of these variables can stem

from properties of the unrestricted MIDAS model, namely from a large number of coefficients.

The inflation rate is not found contributory to the explanation of the metals returns variation in opposition to Kagraoka (2016) and Frankel and Rose (2014). Moreover, the analysis proved industrial production not relevant for the price changes of precious metals, which is in line with Šmiech *et al.* (2015). A link between metals prices and how much industries produce is not so direct as producers are usually hedged against instant price changes.

## CONCLUSION

A mixed-data-sampling model was employed to assess an impact of multiple macroeconomic and financial factors on prices of four precious metals. The aim was to explain price changes in the precious metals markets by eight drivers of various frequencies, that were considered in previous research.

The stock market index and crude oil returns were found the most significant drivers. The impact of the stock market index on precious metals returns is negative. Crude oil returns influence differently the pair of gold and silver and the pair of platinum and palladium. The impact on the first group is negative whereas it is positive on the second one. The two pairs differ concerning the impact of the interest rate (for the first pair none, for the second negative) and the overall explanation power of the drivers (volatility of platinum is explained best – from 27% in opposition to 9% of volatility explained for silver).

To conclude, the interest rate, the stock index and the crude oil market should be the most relevant clues for investors willing to invest in precious metals. They should also pay attention to a nature of the effect that these drivers have on precious metal prices since it varies with respect to each metal.

The research may be extended with additional drivers (such as more detailed data on the drilling costs of the major producers or on the consumption in relevant industries). Other specifications of MIDAS model may be employed as well, such as its reverse form (to incorporate daily returns of metals instead of the monthly ones). It might be also tested if employing any functional constraints improves the model with acceptable bias. Finally, such approach may be applied to other commodity classes and the results can be compared.

## Acknowledgements

I wish to thank to Oleg Deev for his helpful comments and remarks. This research is supported by grant financing from Masaryk University in Brno thanks to the Programme of Rector and to the project no. MUNI/A/1039/2016.

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