Focus on some aspects of market price trends for tungsten

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The contribution deals with prices of tungsten concentrate and ammonium paratungstate (APT) where the latter represents the most common form of tungsten for trading purposes. Taking examples of US and China tungsten markets, this paper demonstrates that the tungsten market price is influenced by many other factors than only those of supply and demand. As based on the past pricing trends for tungsten ore concentrates and also ammonium paratungstate (APT), a two year's tungsten price forecast has been developed. The data published by the Metal Bulletin between January 2002 and June 2015 served the purpose of our future trend forecasting. The forecast took advantage of the programme, @RISK by Palisade Corporation, Ithaca, New York (Industrial Edition, Excel Version 6.3.1). The forecast outcomes acquired by GARCH (Generalized Auto-Regressive Conditional Heteroskedastic Model) implied a modification of the original time series of the APT prices, i.e. exclusion of relatively stable prices of the initial period, and the immediate phase of their temporary growth. In the next step, the forecast for APT prices was obtained by means of applying the model MA (Moving Average Model). The outcome corroborates the theory of the growth and drop pricing cycles, which mechanism also applies to tungsten ore concentrate markets.

Keywords: *tungsten, price forecasting, price influencing, Generalized Auto-Regressive Conditional Heteroskedastic Model, Moving Average Model*

Introduction

Forecasting is an integral part of the corporate management and new project assessment practices as they both concern future economic trends (Jurkasová and Domaracká, 2011). The forecasts should also be respected by mining industries. The forecasts should not only be method oriented (Mukattash and Samhouri, 2011; Krzemień et al., 2016) but also concern practical aspects of the industry, namely those of mining for metals (Lasheras et al., 2015; Dooley and Lenihan, 2005; Yerramilli and Sekhar, 2006; Chen, 2010; Sánches et al., 2015).

Both the specification and forecasting activities go hand in hand with looking for reasons of metal pricing trends. (Labys et al., 1999; Evans and Lewis, 2002). The economic cycles are considered to be a major reason for metal price fluctuations.

Some minerals are of such importance for particular state governments that they intervene in and interfere with the free market mechanism of supply and demand.

An example of the latter can be provided by the trading of tungsten ores and products with tungsten. The extracted tungsten minerals of wolframite or scheelite are processed to provide for tungsten concentrate. The latter is further processed to make ammonium paratungstate (APT) or ferrotungsten (FeW) which compounds serve the purpose of the original stock material for various tungsten products, especially so-called hard metals for production of metal working tools and drilling equipment. The powder tungsten is used for the making of bulb filaments, electrodes, electrical contacts, etc., as well as producing of tungsten alloys. Application of tungsten by military industries is of major importance.

The ammonium paratungstate (APT) represents the most common form of the tungsten for trading purposes. The APT cost directly reflects the price of the tungsten concentrate (Vital Metals, 2014), as the only added value cost is that of transforming the concentrate to APT. The quote price usual currency is USD per mtu (metric ton unit), which unit in an alternative usage of metal (tungsten, manganese) trading in the US can mean not 1.000 but only 10 kilograms, referring to a tradition of taking a metric ton of ore as containing 1 % (i.e. 10 kilograms) of metal.

Assuming realization of a tungsten new mining project or utilization of the standing supplies, the final extraction product is tungsten concentrate as the outcome of the mine processing plant. The price of the concentrate can be directly estimated on the grounds of the concentrate's past prices, or APT's prices decreased by the related processing costs.

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Our short-term forecast has concerned the APT price in the perspective of two years. Our observations were mainly oriented by considering tungsten a major item of commodity trading, whose price is not subject and outcome of free market mechanisms. The issues of the Minerals Yearbooks published by the US Geological Survey or other sources evidence many state government interventions in the supply and demand free market of tungsten and tungsten related products (Dvořáček and Sousedíková, 2015a). Such interventions have distorted the theoretical free market price of this mineral commodity.

Theoretical free market price generation vis-a-vis state government interventions and influences

As based on the theory of the free market mechanism, the price is the outcome of the play of two forces, namely demand and supply as illustrated in Fig. 1.

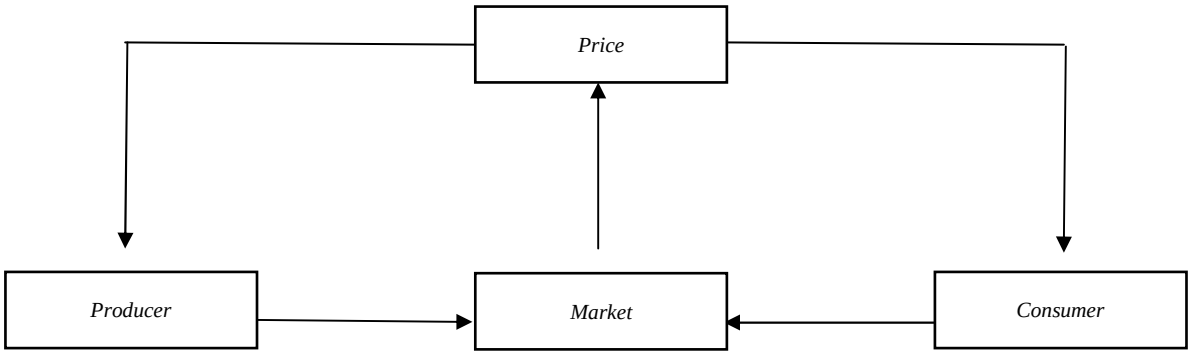

Fig. 1. Free market system (Šnapka and Dvořáček, 1995).

Individual producers are relatively free in deciding levels of their production, and consumers decide freely how much they can consume. Producers' and consumers' decision making is oriented by the price of the commodity traded. This mechanism can be basically represented by a feedback control circuit operating with information on supply and demand developments (Šnapka and Dvořáček, 1995).

Nevertheless, such model of the market price origin is influenced by supply and demand fluctuations that are subject to the current economic conditions, occurrences of war, or political interventions. These influences are directly mirrored by changing prices or are subject to the indirect effect of changing quotas of production, import, or consumption. The case for tungsten can be demonstrated by examples of influences on the US and Chinese market.

The United States of America

Price increases caused by:

- Loss of Korean and Chinese supplies due to Korean War in 1950,
- High demand resulting from increased armament production since 1935, and especially the outbreak of WW II,
- High demand in the second half of the sixties of the past century due to Vietnam War,
- The announcement of the Domestic Tungsten Purchase Program in 1951, aiming at purchasing of tungsten ores extracted in the US.

Increased production and import caused by:

- Establishment of the Council of National Defence in 1916 targeting, among others, increased production of materials vital for building of US Army, inclusive tungsten,
- Drop of tungsten import from China since 1938 caused by the hostile Japanese invasion of the country, which occurrence implied support of domestic production,
- Enactment of the Strategic Materials Act in 1939 with the budget of 100 million US Dollars assigned for stocking of US government strategic materials during four years,
- Chinese repayments of US loans in the form of strategic material supplies inclusive tungsten, 1940-1941,
- Founding of the Metals Reserve Corporation in 1940 hedging against risks of strategic material deficiency on national and specific industry levels,
- Assigning of troops to provide services for mining of tungsten ores in 1942, as a countermeasure to the workforce drop in the field,
- US Dollar one million loan to Portuguese tungsten mining industry in 1950 repaid by supplies of tungsten ore concentrates.

Production and import decrease caused by:

- The collapse of US steel industries due to the World economic crisis, 1929-1933.

People's Republic of China

Production increases caused by:

- Governmental purchase of a sixty-day production of their own tungsten mines to provide for strategic stocks in 1996,
- Introduction of production quotas; measures supporting export of higher value added products; support of key organisations involved in ore processing, metallurgy activities, and related commerce in 2000.

Production decreases caused by:

- China government decision in 1991, restricting production of tungsten ore concentrates and forbidding their export for six months, at which point only larger and competitive companies are allowed to operate in mining of tungsten ores,
- Issuing export licences for tungsten ore concentrates in 1993 aiming at restriction of current production excess implying low market prices,
- Temporary closure of mines in 1995 due to low market prices,
- Closure of illegal, environment unfriendly or deposit damaging mines in 1999,
- Reducing number of mines from 170 to 123 in 2002, based on the analyses of production volumes, environment protection, organisational standards, and market shares of mining companies,
- Closure of non-standard mines, increasing royalties on mineral extraction, ban on foreign investment in prospecting and extraction of tungsten ores, and restriction on issue of new mining licences in 2007,
- Restricting export of raw materials of low added value in 2013.

The state interventions are either administratively or economically oriented. They are direct, or they are of motivation character. The intervention is very often influenced by current economic trends (economic cycles) in the world that imply cyclical pricing trends for raw materials, especially metals (Deaton and Laroque, 1992; Cashin et al., 2002; Humphreys, 2010; Labys et al., 1998; Roberts, 2009).

The cyclicality as such derives from the concept of economic cycles developed by the US National Bureau of Economic Research. They define cyclicality as repeated but aperiodic fluctuations.

The cyclical development is characterized by peaks and valleys. A growth phase ends by reaching a peak value, which represents the highest pricing level valid for six months before and six months after the peak (Roberts, 2009) resp. 2 years (Davutyan and Roberts, 1994). A decline phase is finalized by a through price, which is the lowest price effective in the period (months or years) before and after the through. The growth phase lasts for the time that elapses between reaching the peak from the adjacent through. The decline phase time is measured between the peak and its related through. The whole (total) cycle comprises both growth and decline phases. It is the time measured between adjacent peaks or adjacent throughs.

The economic change, political upheavals, or war atrocities are to be assumed to happen also in future, and their exact occurrence is rather difficult to predict. The price forecasting can only rely on determination, and outlook of general trends. This view can be exemplified by citing what Makridakis and Wheelwright said in 1989, namely '… most raw materials prices cannot be predicted more accurately than by extrapolating the current price'.

APT price development forecast

The data published by the Metal Bulletin between January 2002 and June 2015 served the purposes of our future trend forecasting. The Tungsten APT European Mid prices (USD/mtu) of our reference correspond to the last trading day of each month specified. The forecasting took advantage of the programme, *@RISK* by Palisade Corporation, Ithaca, New York (Industrial Edition, Excel Version 6.3.1). Fig. 2 illustrates the data time series of our analysis:

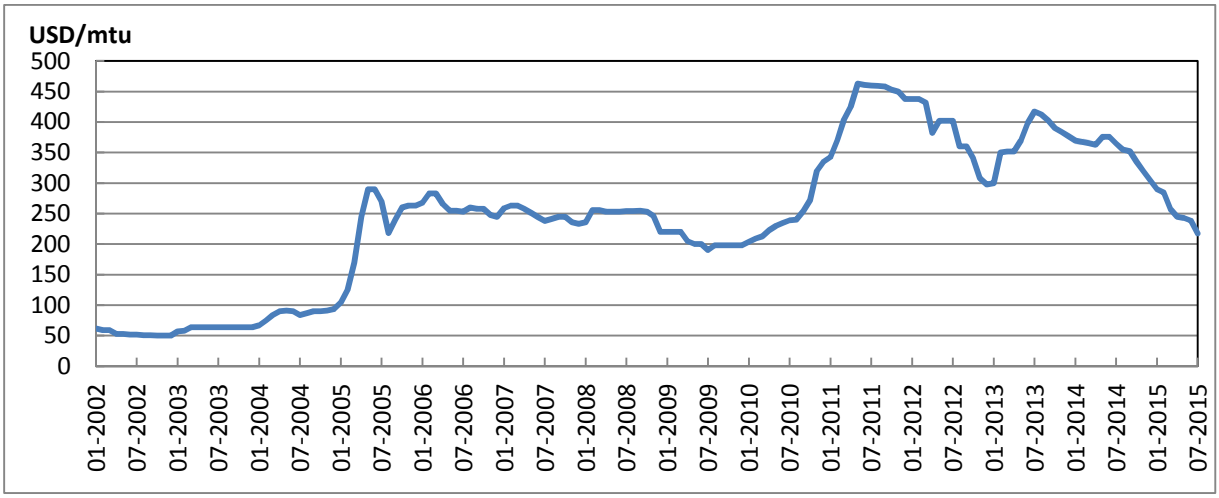

Fig. 2. European Mid Price (USD/mtu) for APT since January 2002 till June 2015.

The time series specification assumes stationarity of APT prices, which means that the distribution mean and variation values are constant in time. To verify the time series stationarity, the Autocorrelation function (ACF), and Partial autocorrelation function (PACF) have been plotted in order to find repeating patterns.

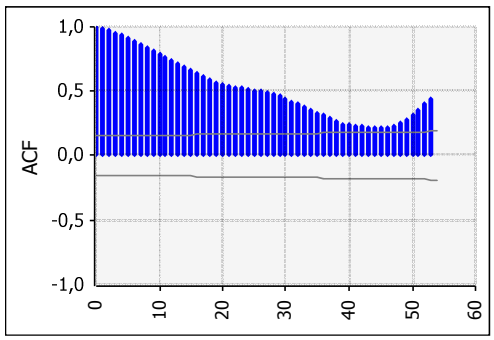

Fig. 3. Autocorrelation function.

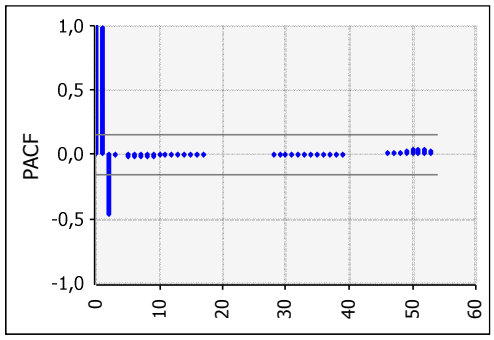

Fig. 4. Partial autocorrelation function.

It is obvious from the Figs. 3 and 4 that the time series of our analysis is not stationary. To provide its stationarity, the time series has been transformed by the first order differencing (viz. Fig. 5).

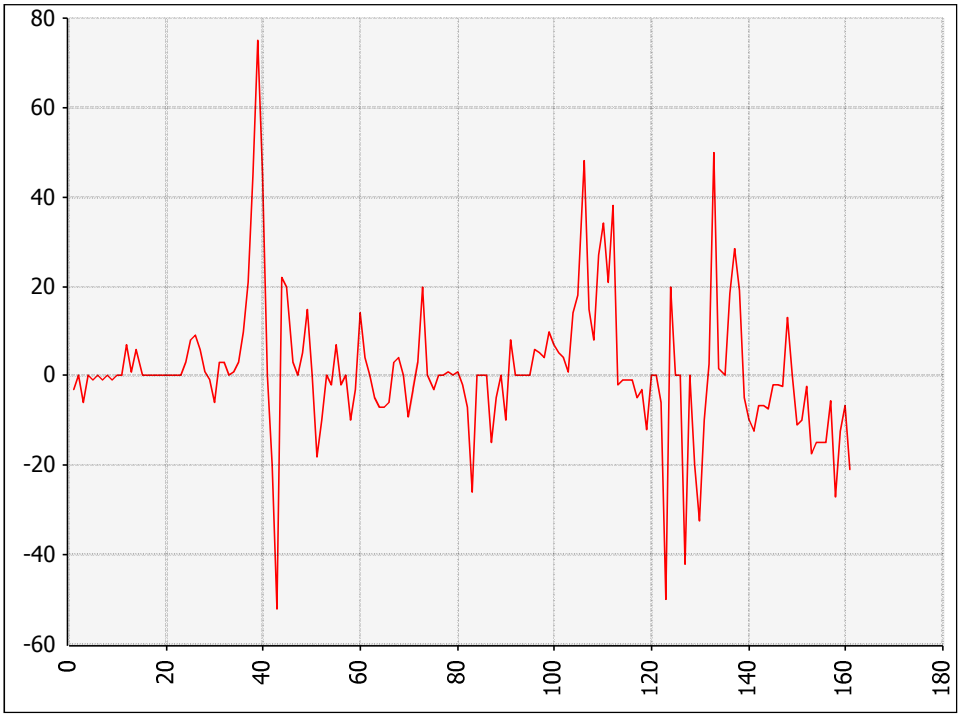

Fig. 5. Time series after the first order differencing.

The functions, ACF and PACF, after first order differencing of original data, are illustrated by Figs. 6 and 7:

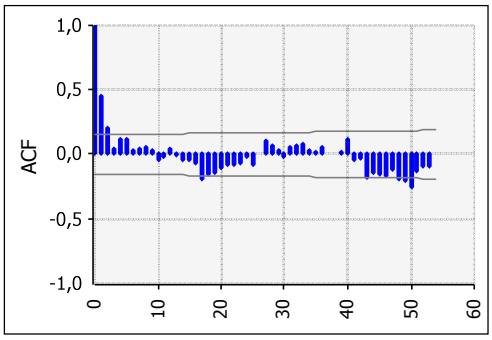

Fig. 6. Autocorrelation function after data transformation.

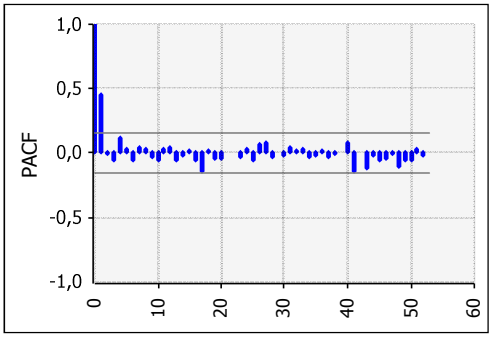

Fig. 7. Partial autocorrelation function after data transformation.

The Akaike information criterion (AIC), as the measure of our model quality, has concluded the model, GARCH (1,1), (Generalized Auto-Regressive Conditional Heteroskedastic time series of the parameters, p and q as equal to 1) to be the best one. The Fig. 8, apart from the historical data, provides for confidence bands and APT price forecasts ahead of 24 months.

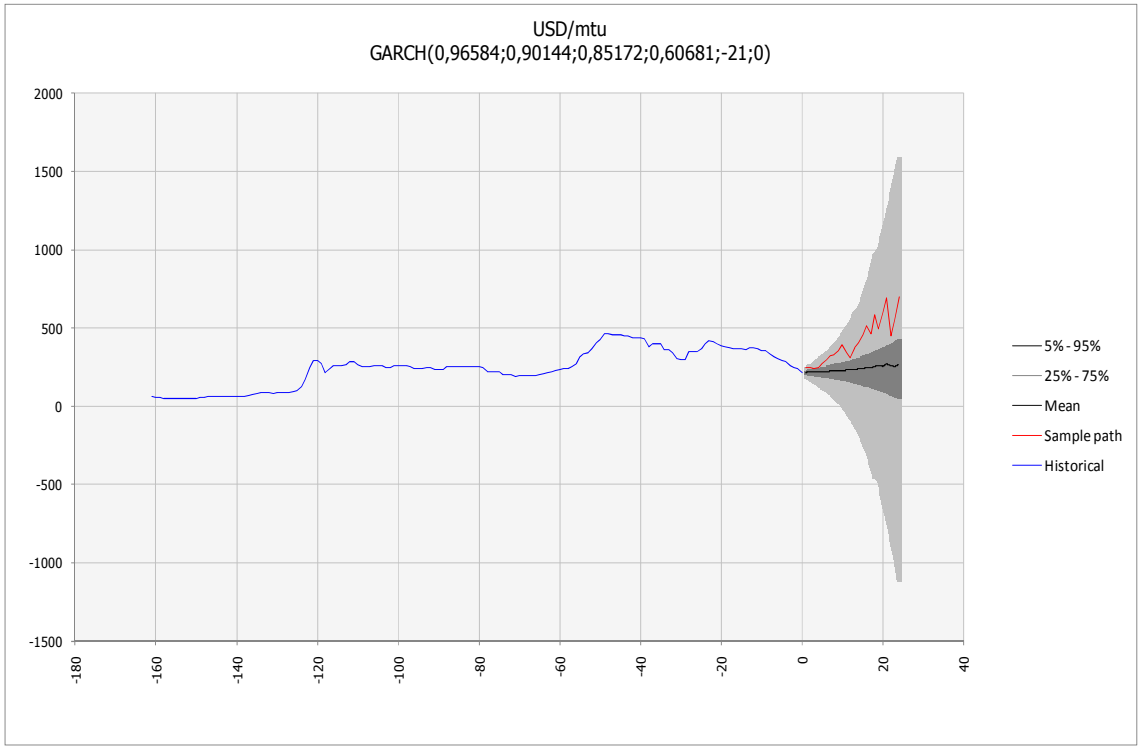

Fig. 8. Historical data, APT price forecast and confidence bands in perspective of 24 months.

The APT price forecast development for the next 24 months, from July 2015 to June 2017, is as follows:

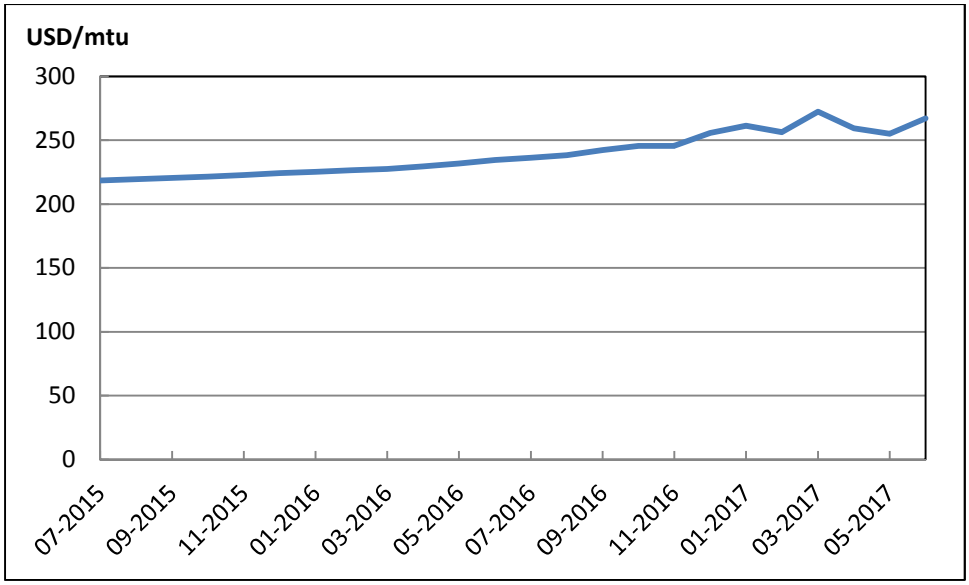

Fig. 9. APT price development forecast for the future period from July 2015 to June 2017.

This forecast is difficult in that it implies such wide band of confidence that the forecast values can hardly be specified with any degree of confidence. That was the reason why instead of the data from 2002, we rather employed the data from the period since 2006. Ignoring relatively stable prices of the initial period, and the following phase of their temporary growth, we could provide a better forecast of the APT price future development. The data of our analysis are illustrated in Fig. 10:

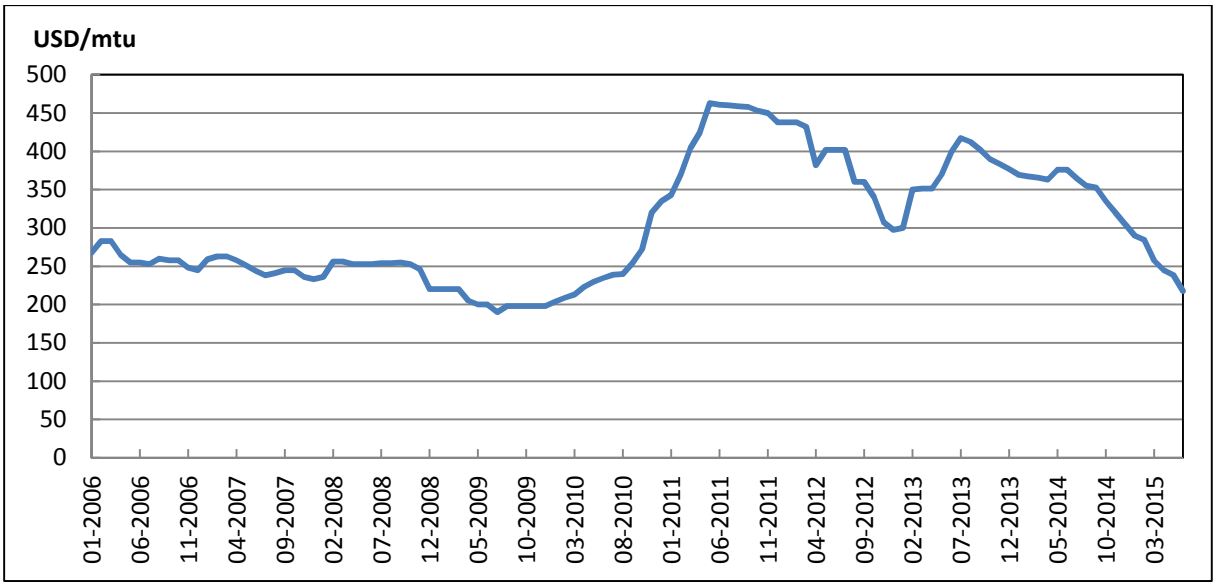

Fig. 10. APT European Mid Price (USD/mtu) development from January 2006 till June 2015.

By application of the same process, we concluded that the data had not been stationary, and we could provide for stationarity by their logarithmic transformation and the first order differencing.

Again, so that an optimum model variant could be specified, the AIC was used, which resulted in the highlighting of the moving average model, MA(1). The ACF of this model drops sharply to zero after a lag of 1, and its PACF decreases geometrically. The data of the model along with 24-month forecast and their confidence intervals are subject of the Fig. 11.

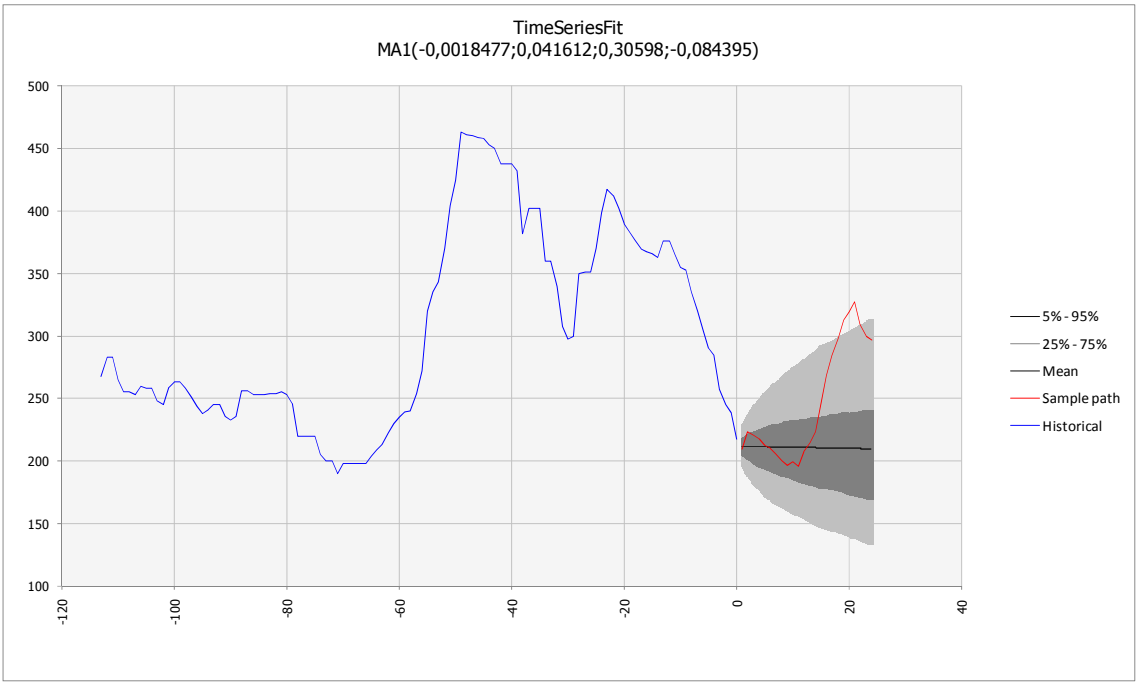

Fig. 1. Model data, APT price (USD/mtu) forecast and confidence bands in perspective of 24 months.

The Fig. 12. illustrates the comparison of empirical data with those acquired by our model.

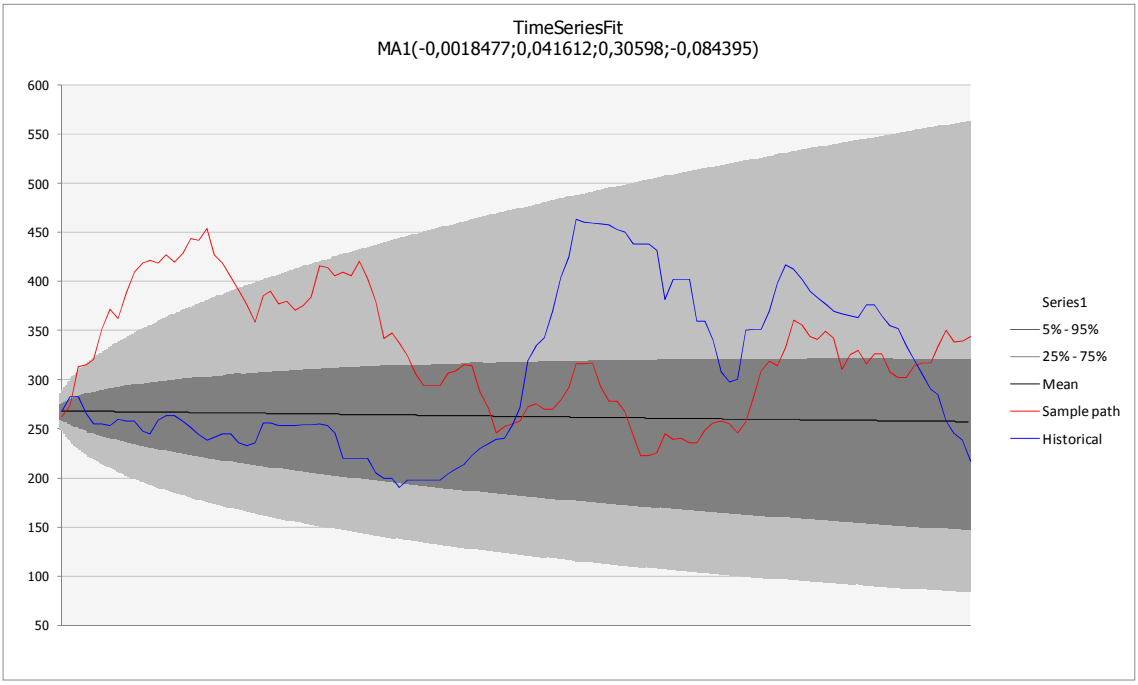

Fig. 12. Comparison of the model generated and empirical data (USD/mtu).

The APT 24-month price forecast is given by Fig. 13 and Tab. 1:

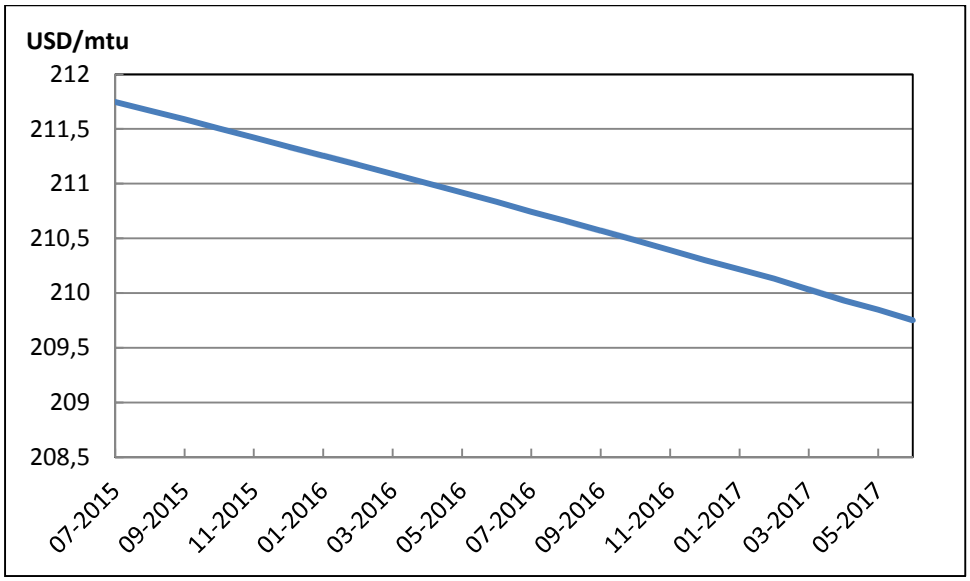

Fig.13. The APT 24-month price forecast.

Tab. 1. The APT 24-month price forecast.

Date	Price	Date	Price
July 2015	211,74718	July 2016	210,74440
August 2015	211,66763	August 2016	210,65945
September 2015	211,58844	September 2016	210,57038
October 2015	211,50491	October 2016	210,48420
November 2015	211,42101	November 2016	210,39299
December 2015	211,33876	December 2016	210,30250
January 2016	211,25680	January 2017	210,21554
February 2016	211,17238	February 2017	210,13212
March 2016	211,08924	March 2017	210,03092
April 2016	211,00351	April 2017	209,93249
Mai 2016	210,91747	Mai 2017	209,84630
June 2016	210,83381	June 2017	209,75042

Discussion

Tungsten is not traded on the London Metal Exchange. A lot of tungsten trade is spot market realised, which implies a greater volatility of prices. Given the trade volume, the benchmark APT prices are those that relate to tungsten concentrates. The actual APT prices result from the current APTs by deducting concentrate processing cost of about 25 % (Edison Investment Research 2014) in accordance with price fluctuations. If the APT forecast price for the second half of 2017 is USD 210/mtu, the tungsten concentrate price for this period can be calculated to be about 158 USD/mtu. If the tungsten concentrate price forecast is based on extrapolating of EU market quarterly values, it can be about 150 USD/mtu for 2017 (Dvořáček and Sousedíková, 2015a). The measure of the value agreement is high. Nonetheless, we are aware of possible inaccuracies referring to the evaluation of processing costs, which can make a difference.

Our calculations have been based on the cyclicality assumption valid for the price development of tungsten or raw materials in general as the case might be. The literature references given above make it evident that fluctuating prices of metal ore concentrates or the metals per se represent a major economic problem. The fluctuations have two aspects:

- The measure of price variations is considerable, and it is often in excess of price fluctuations of other industries,
- The growth and decline phases of metal price fluctuations are long, and their duration is irregular.

It is of major practical importance, whether the pricing cycle is cyclical or none of it. In fact, an absence of cyclicality implies inability of short term forecasting for pricing developments.

It is obvious that the time series for pricing developments comprise irregularities concerning both the decline and growth phases of the cycle. It means that the time series of the given phase do not develop in one or the other direction only. If a definite number of months or years can be established for a constant pricing trend, it can be prevented that any change of the development direction is misinterpreted as a growth or decline phase.

Conclusion

The calculation results corroborate the theory of the mineral price cycles, which in this particular case concerns tungsten ore concentrates.

Our forecast for tungsten prices has faced the demand for growth or decline phase duration to be in excess of two years. The European pricing trends for tungsten concentrate are those of the US Geological Survey (Minerals Yearbook 2014). The conversion of pricing series to real prices by the GDP deflator (US Bureau of Economic Analysis, 2015) provided for establishing of 3 pricing cycles commencing in 1972, namely:

1. Cycle: Growth Phase, 1972 – 1977 (6 years), Decline Phase, 1978 – 1986 (9 years), Cycle Duration, 15 years;
2. Cycle: Growth Phase, 1987 – 1989 (3 years), Decline Phase, 1990 – 2002 (13 years), Cycle Duration, 16 years;
3. Cycle: Growth Phase, 2003 – 2006 (4 years), Decline Phase, 2007 – 2014 (8 years), Cycle Duration, 12 years (obviously an unfinished cycle).

The real pricing trend made a deduction possible, namely that the last cycle was incomplete (Dvořáček et al., 2015) but of short duration after which the prices of tungsten would start rising again.

As based on APT price assumptions, our forecast for tungsten concentrate prices correlates positively with the prices extrapolated from the price of the tungsten concentrate, nevertheless unexpected, hard to predict supply and demand circumstances happening at future tungsten market can interfere with the forecast.

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