EKONOMETRIA ECONOMETRICS 32 • 2011

ISSN 1507-3866

Monika Papież, Sławomir Śmiech
Cracow University of Economics

THE ANALYSIS AND FORECASTING OF COKE PRICES

Summary: The authors of the paper, on the basis of data from the period 2003-2010, attempted to establish whether there is a link between coke prices and the prices of other resources. Since coke is one of the basic ingredients used in the process of steel production, its price should be correlated with coking coal price and the situation on the iron and steel markets. This situation is closely linked with the pace of world economy growth. It should be noted that the specificity of coke lies in the fact that its price is not quoted on world stock exchanges (like e.g. gold or petroleum). The article also presents the forecast of coke prices and the evaluation of the usefulness of the models used in forecasting.

Key words: coke prices; steel market; coking coal market; PMI; ARIMAX, VAR, and VECM models.

1. Introduction

Up till August 2008, China was the largest exporter of coke in the world with its share in the world export amounting to 45% in the years 2003-2008. Poland was the runner-up, with a share which increased from 14.5% to 20% in the same period. In 2009, Chinese exports drastically decreased to 3.7% due to the fact that in August 2008 the Chinese government raised export tax from 25% to 40%, which directly led to two important changes on the coke market: the change in the structure of the international market and the change in the referential coke prices. In 2009 Poland became the main coke exporter with share of 32%, and Russia followed with a share of 27.5%. Another change was connected with a benchmark for coke prices. Before August 2008, Chinese coke prices were considered to be the main benchmark for coke prices worldwide: 10.5% or 12/12.5% Ash at USD/tonne FOB China. As a direct result of raising export tax, the export price of Chinese coke ceased to serve as a referential price and the need for a new benchmark arose. Two new benchmarks for coke prices were proposed to come into force in January 2009: the first being the price index for the western hemisphere, namely: the European blast-furnace coke price at USD/tonne C&F northern Europe; the second being the price index for the eastern hemisphere, namely: the Indian blast-furnace coke price at USD/tonne C&F India. It is worth noting that the feature which makes coke unique is the fact

that its prices are not quoted on the world stock exchange, like e.g. the prices of gold or petroleum.

On the basis of the data from a Polish coking plant from the period 2003-2010 the authors of the article attempted to establish the link between the coke prices from this plant, the prices of Chinese coke, the benchmark, and the prices of other resources. Since coke is one of the basic ingredients used in steel production, its price should depend on the prices of coking coal and the situation on the iron and steel markets, which, in turn, is closely connected with the growth rate of the world economy.

The analysis of links between the prices on the coke market was carried out with the use of VAR models. The authors of the article also tried to develop a forecast of coke prices and to point at the best models to be used in the process of forecasting those prices taking into consideration the specificity of the market. To achieve this aim, models for monthly and quarterly data were developed which were then evaluated twice with the use of the mean absolute percentage error (MAPE).

2. The characteristics of the prices on the coke, steel and coking coal markets

Coke prices, as in the case of prices of other resources, depend on the economic situation. The boom is connected with the growth in the construction industry, machine-building industry, and the automotive industry, which entail an increased demand for steel products. A direct effect of the growth in the production of steel and blast-furnace pig iron is an increased demand for iron ores, coke and coking coal. That is why the prices of steel products, such as: flat products – HRC, flat products – plate, long products – rebar, and pig iron, are used in the analysis of the correlation of the prices on the coke and steel markets. The prices of iron ores and scrap are also taken into consideration in the analysis, as they are used in the process of steel production. Iron ore prices on the world markets are mainly agreed on in long-term contracts. Up till 31th March 2010 the prices and the tonnage were agreed on for the period of one year, called a fiscal year beginning on 1st April and finishing on 31st March of the next year. Since 1st April 2010 the contracts have been agreed on for a period of a quarter. The contract prices are dictated by three main world providers of iron ores: Rio Tinto, BHP Billiton and Vale.

Another factor influencing coke prices is the price of coking coal, which is one of the main ingredients used in metallurgic coke production. The prices of coking coal and iron ores are agreed on in long-term contracts. Up till 31th March 2010 the prices were agreed on for a period of one year, and since 1st April 2010 the contracts have been agreed on for a period of a quarter. Because coal prices on the world markets depend on supply and demand, the contracted quantities of coking coal are supplemented on the *spot* market, which constitutes about 10% of the turnover of coking coal on the world markets. However, the changes in prices on the *spot* market affect the change tendencies in future contracts. Benchmark prices are agreed on

during negotiations between the biggest coal exporter in the world – the Australian concern BHP BM and the Japanese metallurgic concern JMS − which are the main recipients of coking coal (2008 was an exception: the prices were agreed on between BHP BM and ArcelorMittal).

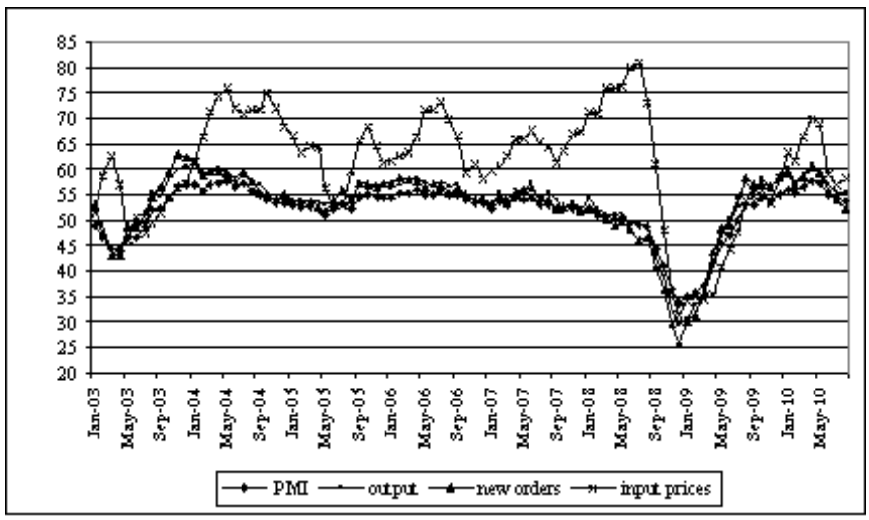


Figure 1. The values of PMI index and its output, new orders, input prices between January 2003 and August 2010

Source: www.markit.com.

As has already been mentioned, the prices of coke, steel and coking coal depend mainly on the economic situation. For an analysis of the development of the world economy the authors of the article chose JPMorgan Global Manufacturing PMI – an economic activity index and its components: output, new orders, input prices, employment. This index is compiled on the basis of the surveys covering 7500 purchasing executives in 29 countries, which account for about 90% of the global manufacturing output. Figure 1 presents the values of PMI index and its components: output, new orders, and input prices in the period January 2003 – August 2010. The values above 50 indicate a predicted (by managers) increase in the variable since the previous month, and the values below 50 indicate a decrease.

3. Variables used in the analysis of the dependencies and forecasting of coke prices

The analysis of the dependencies between the prices on the coke, steel and coking coal markets is based on the data from the period 2003-2010: monthly data from the period: January 2003 – August 2010 and quarterly data from the period: the first

quarter 2003 – the third quarter 2010. Table 1 presents the variables used for the analysis of the dependencies and for the development of the models used for forecasting coke prices.

Table 1. Variables used in the analysis of the dependencies of prices on coke, steel and coking coal markets in the period 2003-2010

Variable symbol	Variable
Coke_Pk	Blast-furnace coke price at US$/tonne FCA coking plant
Coke_Ch	Chinese metallurgic coke price 12.5% at US$/tonne FOB China
Coke_Bench	Indian coke price with ash 10.5%/12.5% at US$/tonne c&f India (benchmark price)
Coal	Benchmark Australian hard coking coal price at USD/tonne FOB Australia
HRC	Average price of flat steel products – HRC at USD/tonne *ex works* Northern Europe
Plate	Average price of flat steel products − plates at USD/tonne *ex works* Northern Europe
Rebar	Average price of long steel products – rebar at USD/tonne *ex works* Northern Europe
Scarp	Average price of scrap at US$/tonne *ex works* Northern Europe
Pig	Average pig iron price (*Brazil export FOB Ponta da Madeira $/t*)
Fe	Average iron ore price – (*Vale blast furnace pellet 65.7% Fe - Europe / Brazil export FOB Tubarão $ cent/dmtu*);
PMI	Index value *JPMorgan Global Manufacturing PMI*
PMI_Out	*PMI* − Output index
PMI_N_ord	*PMI* − New Orders index
PMI_Price	*PMI* − Input Prices index
Steel prod	Monthly steel production in European countries in thousand tons
Steel world prod	Monthly world steel production in thousand tons

Source: own elaboration.

4. Forecasting coke prices

The following groups of models have been chosen to forecast coke prices:
– ARIMA models,
– ARIMAX models, in which additional descriptive variables introduced into standard ARIMA models were differential series of the variable values from Table 1,
– nonlinear autoregressive models SETAR, LSTAR[1], AAR,

[1] With logistic smooth transition function. More information regarding SETAR and LSTAR models can be found in [Osińska 2006]. The description of additive models AAR was presented in [Breiman, Friedman 1985].

– VAR models,
– VECM models.

The choice of the order of the autoregressive delays in particular models was based on the analysis of the informative AIC criterion. Threshold models were developed for two regimes. The threshold was chosen in such a way as to minimise root mean squared error.

The aim of the development of autoregressive models (including ARIMA models) was to answer the question whether information obtained only from the past order values of coke prices was enough for accurate forecasting. ARIMAX models were developed in such a way as, firstly, to embrace a lot of various kinds of information (numerous variables potentially influencing coke prices were chosen), and, secondly, to obtain economical parameterisation (only the orders of variable delays which were statistically significant were chosen). The final version of these models was developed in the same way as in case of stepwise regression. Initially the model was developed with a maximum number of variables, out of which those insignificant ones were gradually eliminated to achieve the final version of the model. The main criterion for evaluating these models was the analysis of mean absolute percentage error (MAPE).

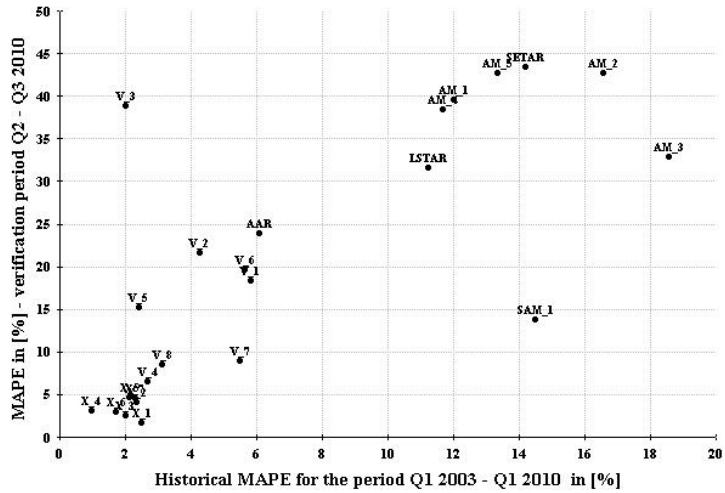
VAR models were used to reconstruct the hypothetical systems of dependencies between: coke prices on different markets, coke prices and steel prices and steel production. This approach was expected to make the analysis of the causality in possible systems and to foster an accurate forecast.

VECM[2] models obtained for monthly data reflected respective VAR models, but took into account the long-term equilibrium of the variables in a system.

Due to the specificity of coke, steel and coking coal markets, on which the prices used to be agreed on in annual contracts and now in quarterly contracts, the models were also developed using monthly and the quarterly data. The period January 2003 – August 2010 was chosen for the monthly analysis. The models were developed till May 2010, and the period of the next three months: June, July, and August, was used to verify the forecast. As far as the quarterly data are concerned, two versions of the models were developed: the first used data coming from the period: the first quarter of 2003 − the first quarter of 2010, and the second and third quarters of 2010 were used for verification; and the second used data from the period: the first quarter of 2003 − the second quarter of 2010, and the third quarter of 2010 was used for verification. The models were evaluated both by a calculated value of MAPE for the data from the sample and by the value of MAPE which allowed to compare forecast values from the verification period with their actual realizations.

Figures 1-3 present the dependencies between the MAPE value for historical data and the MAPE value from the verification period for the analyzed groups of models.

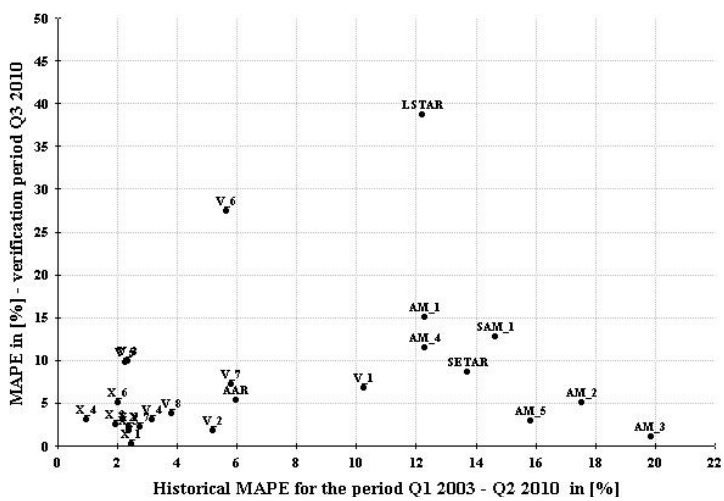
[2] Cointegration for quarterly variables has not been confirmed.



Abbreviations: AM stands for ARIMA models; X stands for ARIMAX models; V stands for VAR models.

Figure 1. Dependencies between the MAPE value for historical data from the period first quarter 2003 – first quarter 2010 and the MAPE value from the verification period second quarter − third quarter 2010 for selected groups of models

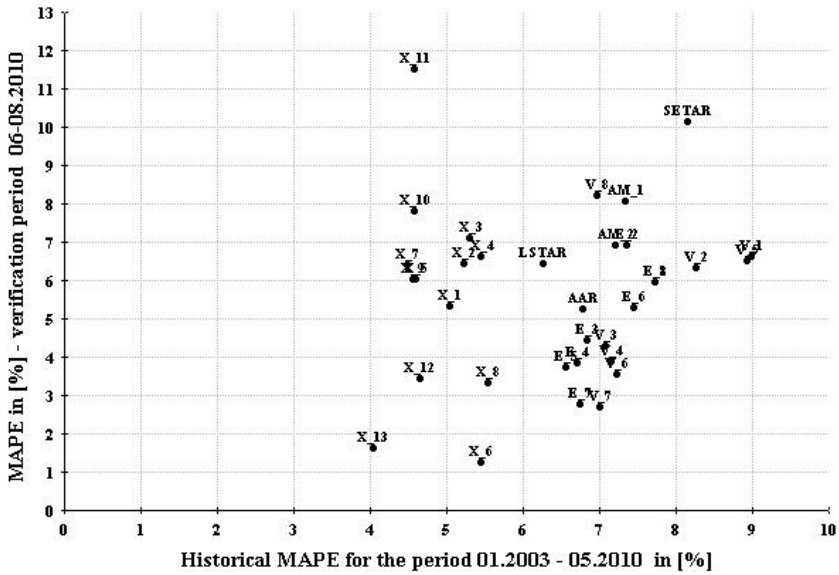
Source: own elaboration.



Abbreviations: AM stands for ARIMA models; X stands for ARIMAX models; V stands for VAR models

Figure 2. Dependencies between the MAPE value for historical data from the period first quarter 2003 – second quarter 2010 and the MAPE value from the verification period third quarter 2010 for selected groups of models

Source: own elaboration.



Abbreviations: AM stands for ARIMA models; X stand for ARIMAX models; V stands for VAR models

Figure 3. Dependencies between the MAPE value for historical data from the period January 2003 – May 2010 and the MAPE value from the verification period July – August 2010 for selected groups of models

Source: own elaboration.

While discussing Figures 1-3 it is necessary to mention distinct differences between the MAPE values for quarterly forecasts (Figures 1 and 2) and for monthly forecasts. Much bigger errors (both in the historical and the verification periods) were obtained for the quarterly data. In this case, the order of coke prices was characterized by a significant variation, and the periods of monotonic changes were shorter (weaker results of MAPE in historical periods). That is why turning points occurred more often than in the case of monthly data. Autoregressive models − both linear and nonlinear − turned out to be the weakest in each approach, the only exception being additive autoregressive model (AAR), which yielded results comparable to the results obtained by using the best models.

The best results were obtained from the models taking into account different versions of purchasing managers' indices (PMI) among exogenous variables. Thanks to them it was possible to predict turning points of the order of prices. ARIMAX models yielded the lowest values of forecast errors.

5. The analysis of causality in VAR models

The analysis of causality was conducted for models using both monthly and quarterly data. The most significant results for the second set of models are presented in Table 2.

Table 2. The values of *p* for the Granger causality test in selected VAR specifications

Variables in the system	The number of model delays	Cause	p-value
Coke_Pk, HRC, Steel prod	4	Coke_Pk	0,1721
		HRC, Steel_prod	0,04266
Coke_Pk, HRC, Coke_bench	2	Coke_Pk	0,1211
		HRC, Coke_bench	1,890e-11
Coke_PK, Coke_Bench, Coke_Ch	2	Coke_Pk	0,06287
		Coke_Bench, Coke_Ch	6,987e-10

Source: own elaboration.

The influence of system variables on coke prices was observed in all systems, however, it was not possible to confirm the causality of Polish raw materials on other variables in the system. Most probably the coking plant in question is too small a producer and exporter to influence the prices of final products. The causality of other variables on coke indicates that the Polish producer reacts to price changes (caused by demand fluctuations) and adjusts them to a current situation on the market.

6. Conclusion

The choice of the groups of models for forecasting coke prices turned out to be problematic. ARIMAX models, which were the best in respect of accuracy of forecasts measured by MAPE, have a number of restrictions. They cannot be used for long-term forecasts because of the lack of access to information concerning exogenous variables; that is why forecasts for longer periods will depend on arbitrary assumptions adopted for those variables. It can be expected that ARIMAX models will work well in forecasts for the first quarter (to develop models using quarterly data). In the case of monthly data, only the variables with a delay no shorter than 3 were included into models, to develop forecasts without additional assumptions regarding the values of exogenous variables. With such restrictions, ARIMAX models can be used for forecasts for one quarter. The second group of models which yielded reasonably good results were VAR models. However, it is necessary to point out that low MAPE values for historical data did not guarantee obtaining equally good results in the future – they refer to quarterly data. For monthly data it turned out

that using VAR models (e.g.V_8) the accuracy of forecasts for the verification period was much lower than for the historical period. Similar tendencies were characteristic of VECM models. Autoregressive models, which get data only from past order values, did not produce such good MAPE results either for monthly or for quarterly data. Taking everything into consideration, it can be concluded that long-term forecasting of coke prices is a difficult task.

Literature

Breiman L., Friedman J.H., *Estimating optimal transformations for multiple regression and correlations (with discussion)*, "Journal of the American Statistical Association" 1985, no. 80 (391).

Dittmann P., *Prognozowanie w przedsiębiorstwie*, Oficyna Ekonomiczna, Kraków 2003.

Kośko M., Osińska M., Stempińska J., *Ekonometria współczesna*, Towarzystwo Naukowe Organizacji i Kierownictwa Dom Organizatora, Toruń 2007.

Kufel T., *Ekonometria. Rozwiązywanie problemów z wykorzystaniem programu GRETL*, Wydawnictwo Naukowe PWN, Warszawa 2007.

Maddala G.S., *Ekonometria,* Wydawnictwo Naukowe PWN, Warszawa 2006.

Makridakis S., Wheelwright S.C., Hyndman R.J., *Forecasting: Methods and Application*, John Wiley & Sons, New York 1998.

Osińska M., Ekonometria finansowa, PWE, Warszawa 2006.

Ozga-Blaschke U.**,** *Uwarunkowania importu węgla koksowego do Polski*, „Przegląd Górniczy" 2010, nr 3-4.

Ozga-Blaschke U**.**, *Wpływ kryzysu gospodarczego na rynki stali, węgla koksowego i koksu*, „Przegląd Górniczy" 2009.

Welfe A., *Ekonometria. Metody i ich zastosowanie*, PWE, Warszawa 2009.

Zeliaś A., Pawełek B., Wanat S. *Prognozowanie ekonomiczne. Teoria, przykłady, zadania*, PWN, Warszawa 2003.

Zeliaś A., *Teoria prognozy*, PWE, Warszawa 1997.

ANALIZA I PROGNOZOWANIE CEN KOKSU

Streszczenie: W referacie autorzy na podstawie zgromadzonych danych na lata 2003-2010 próbowali ustalić, czy istnieje związek między cenami koksu oraz cenami innych surowców. Ponieważ koks jest jednym z podstawowych surowców potrzebnych do produkcji stali, stąd jego cena powinna zależeć od cen węgla koksowego oraz od koniunktury na rynku żelaza i stali. Koniunktura ta jest z kolei ściśle związana z tempem wzrostu gospodarki światowej. Należy dodać, że specyfika koksu polega na tym, że jest to surowiec, którego ceny nie są notowane na giełdach światowych (jak np. złota czy ropy naftowej). Drugim celem artykułu jest zbudowanie prognozy cen koksu oraz ocena, jaka klasa modeli jest przydatna do jej budowania.