Using weighted Markov SCGM(1,1)_c model to forecast gold/oil, DJIA/gold and USD/XAU ratios

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Abstract
Grey model can be counted as a potent approximation for extracting system dynamic information with only small amount of data. A weighted Markov model is appropriate for predicting the stochastic fluctuating dynamic by a transition probability matrix and normalizing autocorrelation coefficient as weighted and a single gene system cloud grey SCGM(1,1)_c model. It is applied to regulate the development trend of time series. In this paper we employed a weighted Markov SCGM(1,1)_c model for predicting the gold/oil, DJIA/gold and USD/XAU ratios. By examining the forecasted results, it was concluded that the weighted Markov SCGM(1,1)_c model is a reliable and effective modeling method.

Keywords: Weighted Markov chain , SCGM(1,1)_c Model , gold, oil, DJIA, XAU

INTRODUCTION

Economic systems are convoluted and can be specified by deterministic or random models. Gold, oil, dollar and Dow Jones index are playing an important role in these systems. Over the long term gold keeps its value in real terms, but in short run factors such as financial stress, inflation, real interest rates, political turmoil, etc., can move gold away from its long run balance for extended times. Predicting and analyzing the movements of these draw much attention from policy makers now days. Gold and oil are critical not only in the assessing of derivatives and hedging plans, but also in larger financial market and the world economy; Moreover their degree of correlation is greatly positive (J. Simakova, 2011). The gold-to-oil ratio indicates the interrelationship between the commodity that makes the foundation of global economy and the commodity that has been the ultimate form of money. Dow Jones index is an indicator of aggregate stock market activity. Dow to gold ratio shows that how many ounces of gold it would take to buy the Dow on any given month. USD/XAU rate is another important indicator which some currency rankings demonstrate that it is the most popular gold exchange rate. The monthly fluctuations of gold/oil, DJIA/gold and USD/XAU ratios in recent years are shown in Figure 1 and Figure 2. The variations of these ratios are vital issues of macroeconomic.

By using various methods the relations between these variables have been analyzed in literature. (K. S. Sujit , B. Rajesh Kumar, 2011) established the dynamic relationship among gold price, Oil price with exchange rate and stock index using vector autoregressive technique.

Figure 1. Monthly trend of Gold/Oil and DJIA/Gold ratios from January 2000 to March 2013

Figure 2. Monthly trend of USD/XAU ratio from January 2000 to March 2013
(H.F. Chang, L.C. Huang, M.C. Chin, 2013) examined the correlations of oil prices, gold prices and the NT Dollar versus US Dollar exchange rate by the vector auto-regression and variance decomposition method. (C. Toraman, C. Basarris, M. F. Bayramoglu, 2011) examined the effects of oil prices, USA exchange, inflation and interest rates on the gold prices with MGARCH model. (M.M. Baig, M. Imran, M. Jabbar, Q.U. Ain, 2013) studied the relationship between gold prices, oil prices and KSE100 return with augmented Dickey-Fuller, Phillip-Perron, and Johannes and Jelselius Co-integration and variance decomposition test. (J.C. Reboredo, 2013) used a method based on copulas to analyses the dependence structure between gold and oil price markets. (J. Barunik, E. Kocenda, L. Vacha, 2013) studied the dynamics of the price of gold, oil and S&P500 with methods of nonparametric realized volatility, a parametric DCCGARCH model and wavelet analysis. (J. Beckmann, R. Cruzdaj, 2013) analyzed the oil and gold price dynamics and their relation to US prices and the dollar exchange rate applying a cointegrated VAR model. (N. Apergis, D. Papapoukos, 2013) examined the association between the exchange rate between Australian Dollar against US Dollar and gold prices with the error correction model and the generalized autoregressive heteroskadastic method.

(A. Jain, S. Ghosh, 2013) investigated cointegration and causality and examined the generalized error variance decomposition of these variables among global oil prices, precious metal prices and Indian Rupee-US Dollar rate. (G.C. Nath, 2013) studied the long term relationship between crude oil and gold prices using granger causality test and regression with lags. (T. Ewing, F. Malik, 2013) applied univariate and bivariate ARCH and GARCH models to analyze the volatility of gold and oil futures. (T.H. Le, Y. Chang, 2011) found that the oil price causes the gold price nonlinearly and can be applied to forecast the gold price. The grey system theory is the study of grey system modeling, analysis, decision making, prediction and control theory. The fuzzy mathematics copes with issues of phenomenon with cognitive uncertainty by experience and affiliation functions. Probability and statistics need specific distributions and large sample. When any necessary distribution cannot establish or we do not have any prior experience or large sample, the grey models can be used (Liu S., Lin Y., 2006). The grey model examines and detects the realistic laws of evolution of events through the works of sequence operators and information coverage (Liu S., Lin Y., Forrest J.Y.L., 2010). These characteristics make the grey models superior compared to probability, statistics and fuzzy mathematics models. The grey models have been used in many fields such as economics (C. Wang, Y. Chen, L. Li, 2007), (G. Kim, R.S. Yun, 2012), (C.C. Hus, C.Y. Chen, 2003), energy issues (Z. Yunlong, L. Mao, 2011), (H. Mostafa, Sh. Kordnoori, 2011), environment (Z. Yunlong, L. Mao, 2011), engineering (J. Gu, N.H. Viehare, B. Ayubb, M. Pecht, 2010), sociology (L. Juan, W.J. Liu, 2011), seismicity (J. Min, W. Shang-Xu, C. Shuang-quan, 2005).

The SCGM(1,1), model is considered as the best extension of GM(1,1) model. Moreover the SCGM(1,1) model has more theoretical basis and can more profoundly search practical information from its data series. Compared with other grey prediction models, this model has some advantages such as low calculation complexity, less information required and better prediction accuracy. The compound model of Markov chain and grey theory has been used in many domains. (W. Zeng-min, W. Kai-Jue, 2012) applied the grey weighted Markov chain model to predict mobile communications markets. (Y.M. Tian, H.L. Shen, L. Zhang, X.R. Lv, 2010) forecasted the utility water supply with the GM(1,1) weighted Markov chain. (F. Zhang, Z.P. Jia, H. Xia, et al., 2012) suggested the improved SCGM(1,1) model based on Markov theory and fuzzy identification to predict the node trust in mobile and hoc networks. (C. Zhang, C.B. Ma, J.D. Xau, 2006) predicted air disaster death toll with the grey Markov SCGM(1,1), model. (G.Q. Xiang, Q.J. Gao, 2007) proposed an algorithm of similarity prospecting in time series data according to the grey Markov SCGM(1,1), model. (X.C. Jiang, S.F. Chen, 2009) applied a combination of the weighted SCGM(1,1), model and Markov chain to drought crop area. (Z. Ling, X. Hong Ke, 2014) used grey weighted Markov SCGM(1,1), to predict the traffic accident times of Beijing. (Z. Gong, C. Chen, X. Ge, 2013) applied weighted Markov and grey weighted Markov method to predict the risk of low temperature in china.

The goal of this paper is to introduce the new model by combining the benefits of SCGM(1,1), model and Markov chain. We predict the ratios of gold/oil prices, DJIA/gold and USD/XAU by applying the weighted Markov SCGM(1,1), model.

**THE MATHEMATICAL MODEL**

Suppose \(X^{(0)}\) as the initial time series as follows:

\[
X^{(0)} = \{X^{(0)}(1), X^{(0)}(2), ..., X^{(0)}(n)\}
\]

(1)

A new sequence \(\hat{X}^{(1)}\) is obtained by the transformation of \(X^{(0)}\) as

\[
\hat{X}^{(1)}(k) = \sum_{m=2}^{n} \hat{X}^{(0)}(m), (k = 2, 3, ..., n)
\]

(2)

where

\[
\hat{X}^{(1)}(k+1) = \frac{\hat{X}^{(0)}(k+1)+\hat{X}^{(0)}(k)}{2}
\]

(3)

which can be expressed as

\[
\hat{X}^{(1)} = \{\hat{X}^{(1)}(2), \hat{X}^{(1)}(3), ..., \hat{X}^{(1)}(n)\}
\]

(4)

Provide that \(f(k) = be^{a(k-1)} - c\) is a discrete exponential function of non-homogenous and time series \(\{\hat{X}^{(1)}(k)\}\) is a trend relationship, the system cloud grey SCGM(1,1), model is

\[
\frac{dx^{(1)}(k)}{dk} = ax^{(1)}(k) + u, (k \geq 2)
\]

(5)

The response function is presented as

\[
x^{(1)}(k) = \left( x^{(1)}(k) + \frac{u}{a} \right) e^{ak} - \frac{u}{a}
\]

(6)

where

\[
a = \frac{\sum_{k=3}^{n} \hat{X}^{(0)}(k-1)\hat{X}^{(0)}(k)}{\sum_{k=2}^{n} (\hat{X}^{(0)}(k-1))^2}
\]

(7)

\[
b = (n - 1) \sum_{k=2}^{n} e^{2a(k-1)} - \sum_{k=2}^{n} e^{a(k-1)^2} - 1, [n - 1] \sum_{k=2}^{n} e^{a(k-1)^2}X^{(1)}(k) - \sum_{k=2}^{n} e^{a(k-1)} (n+1) \sum_{k=2}^{n} \hat{X}^{(1)}(k)]
\]

(8)

\[
c = \frac{1}{n-1} \sum_{k=2}^{n} e^{a(k-1)^2}b - \frac{n}{\sum_{k=2}^{n} \hat{X}^{(1)}(k)}
\]

(9)

\[
U = ac
\]

(10)

\[
\hat{X}^{(1)}(1) = b - c
\]

(11)

The system cloud grey SCGM(1,1), is achieved by replacing \(\hat{X}^{(1)}(k)\) as

\[
\hat{X}^{(0)}(0) = \frac{2b(1-e^{-a})}{(1+e^{-a})}, e^{a(k-1)}
\]

(12)

The grey precision index which shows the departure degree between the raw data and the fitted value is calculated as follows:

\[
Y(k) = \frac{x^{(0)}(k)}{\hat{x}^{(0)}(k)}
\]

(13)

The \(Y(k)\) series created a nonstationary random process.

Hence for evaluating the fluctuation rule of grey precision the Markov processes are applied in order to increase the prediction precision of SCGM(1,1), model. Moreover more precise forecasting result can be obtained by the weighted Markov model when the data are a stochastic fluctuating dynamic process. A Markov chain is a stochastic process \(\{X_n, n = 0,1, \ldots\}\) in discrete time with infinite or
finite state space S which satisfies: (Markov property). If \( E \) is an event relying only on any subset of \( \{X_{n-1}, X_{n-2}, \ldots, 0\} \) for each \( n \geq 1 \) then
\[
P(X_{n+1} = j | X_n = i, E) = P(X_{n+1} = i | X_n = i) \quad \forall \, i, j \in S
\]
Markov theory predicts the future state of the system based on state transition probability. The transition probability reflects the influence degree of the stochastic factors.

The advantages of weighted Markov chain and the grey theory are identifying the state transition regularity and showing the variation trend of time series data, respectively which gathered in the weighted grey Markov SCGM(1,1), model simultaneously, therefore the precision of high volatile time series data is increased. Any state of \( Y(k) \) is expressed as
\[
S_i \in \{\Theta_{1i}, \Theta_{2i}\}, \quad i = 1, 2, \ldots, m
\]
where \( S_i \) is the \( i \)th state, the lower and upper bounds of the \( i \)th state are \( \Theta_{1i} = Y(k) + A_i \), \( \Theta_{2i} = Y(k) + B_i \), respectively in which \( A_i \) and \( B_i \) are regarded as constant.

An element \( p_{ij} \) of the transition probability is calculated as
\[
p^{(w)}_{ij} = \frac{M^{(w)}_{ij}}{M^w}, \quad i, j = 1, 2, \ldots, m
\]
where \( M^{(w)}_{ij} \) is the number of occurrence that altering from states \( S_i \) to \( S_j \) with \( \omega \) steps and \( M^w \) is the number of state \( S_i \) in the Markov chain of \( Y(k) \) index. As a result the \( m \times m \) step of transition probability matrix is achieved as
\[
p^{(w)} = \begin{pmatrix}
p^{(w)}_{11} & p^{(w)}_{12} & \cdots & p^{(w)}_{1m} \\
p^{(w)}_{21} & p^{(w)}_{22} & \cdots & p^{(w)}_{2m} \\
\vdots & \vdots & \ddots & \vdots \\
p^{(w)}_{m1} & p^{(w)}_{m2} & \cdots & p^{(w)}_{mm}
\end{pmatrix}
\]
The related importance of each transition probability is quantified with the \( \omega \) order autocorrelation coefficient of data as
\[
r^w_\omega = \frac{\sum_{t=0}^{\omega}(Y(t+i)-\bar{Y})(Y(t+i+w)-\bar{Y})}{\sum_{t=0}^{\infty}(Y(t)-\bar{Y})^2}
\]
Then \( r^w_\omega \) is normalized to get
\[
\theta_w = \frac{|r^w_\omega|}{\sum_{w=1}^{\omega}|r^w_\omega|}, \quad \omega \leq m
\]
where \( m \) is the highest order by forecasting inquiry, frequently taken \( |r^w_\omega| \geq 0.3 \).

Associating the initial state as the relating state of grey preccession index in the preceding one year with the row vector of its corresponding transition probability matrix leads to state transition probability vector in the year as
\[
p^{(w)}_i = (p^{(w)}_{i1}, p^{(w)}_{i2}, \ldots, p^{(w)}_{im}), \quad i \in S
\]
The \( m \)-order weighted state transition probability matrix is calculated as
\[
p^{(w)} = \begin{pmatrix}
p^{(w)}_{11} & p^{(w)}_{12} & \cdots & p^{(w)}_{1m} \\
p^{(w)}_{21} & p^{(w)}_{22} & \cdots & p^{(w)}_{2m} \\
\vdots & \vdots & \ddots & \vdots \\
p^{(w)}_{m1} & p^{(w)}_{m2} & \cdots & p^{(w)}_{mm}
\end{pmatrix}
\]
Consequently state transition probability of grey precision index to forecasted year is
\[
P_i = \sum_{\omega=1}^{m} \theta_w \cdot p^{(w)}_i, \quad i \in S
\]
We consider \( \max \{P_i, i \in S\} \) as a forecasted state of grey precision index by the weighted Markov chain. By linear interpolation the predicted value \( \hat{Y}(n + 1) \) is calculated as
\[
\hat{Y}(n + 1) = \Theta_{1i} \times \frac{P_{i-1} + P_{i+1}}{P_{i-1} + P_{i+1}} + \Theta_{2i} \times \frac{P_{i+1} - P_{i-1}}{P_{i+1} - P_{i-1}}
\]
At last the predicted value in the \( (N + 1) \) th year is obtained as follows:
\[
\hat{X}^{(0)}(n + 1) = \hat{Y}(n + 1), \hat{X}^{(0)}(n + 1)
\]
The mean absolute percentage error (MAPE) is used for evaluating the prediction precision of the model as
\[
M A P E = \frac{1}{n} \sum_{k=1}^{n} \left| \frac{X^{(0)}(k) - X^{(0)}(k)}{X^{(0)}(k)} \right| \times 100%
\]

**CASE STUDIES AND DISCUSSION**

Gold has a thorough impact on the value of world currencies. This paper employed the weighted Markov SCGM(1,1), model to monthly fluctuations of Gold/Oil, DJAI/Gold and average USD/XAU ratios. The data of these ratios from January 2011 to February 2013 are used for modeling and listed in Table 1.

### Table 1. The data of Gold/Oil, DJAI/Gold and USD/XAU ratios.

<table>
<thead>
<tr>
<th>Date</th>
<th>Gold/Oil Ratio</th>
<th>DJAI/Gold Ratio</th>
<th>USD/XAU Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan. 2011</td>
<td>15.29</td>
<td>8.29</td>
<td>0.022851</td>
</tr>
<tr>
<td>Feb. 2011</td>
<td>14.30</td>
<td>8.89</td>
<td>0.022656</td>
</tr>
<tr>
<td>March 2011</td>
<td>13.09</td>
<td>8.48</td>
<td>0.021873</td>
</tr>
<tr>
<td>April 2011</td>
<td>12.72</td>
<td>8.44</td>
<td>0.021054</td>
</tr>
<tr>
<td>May 2011</td>
<td>13.99</td>
<td>8.33</td>
<td>0.020544</td>
</tr>
<tr>
<td>June 2011</td>
<td>14.55</td>
<td>7.91</td>
<td>0.020347</td>
</tr>
<tr>
<td>July 2011</td>
<td>14.71</td>
<td>7.94</td>
<td>0.019816</td>
</tr>
<tr>
<td>Aug. 2011</td>
<td>17.96</td>
<td>6.45</td>
<td>0.017716</td>
</tr>
<tr>
<td>Sep. 2011</td>
<td>17.87</td>
<td>6.31</td>
<td>0.017573</td>
</tr>
<tr>
<td>Oct. 2011</td>
<td>17.81</td>
<td>6.60</td>
<td>0.018662</td>
</tr>
<tr>
<td>Nov. 2011</td>
<td>19.73</td>
<td>6.79</td>
<td>0.017887</td>
</tr>
<tr>
<td>Dec. 2011</td>
<td>16.04</td>
<td>7.31</td>
<td>0.018925</td>
</tr>
<tr>
<td>Jan. 2012</td>
<td>15.70</td>
<td>7.58</td>
<td>0.018844</td>
</tr>
<tr>
<td>Feb. 2012</td>
<td>15.79</td>
<td>7.38</td>
<td>0.017848</td>
</tr>
<tr>
<td>March 2012</td>
<td>14.45</td>
<td>8.17</td>
<td>0.018583</td>
</tr>
<tr>
<td>April 2012</td>
<td>14.78</td>
<td>7.88</td>
<td>0.018852</td>
</tr>
<tr>
<td>May 2012</td>
<td>15.47</td>
<td>7.99</td>
<td>0.019625</td>
</tr>
<tr>
<td>June 2012</td>
<td>18.00</td>
<td>7.86</td>
<td>0.019423</td>
</tr>
<tr>
<td>July 2012</td>
<td>16.73</td>
<td>8.04</td>
<td>0.019515</td>
</tr>
<tr>
<td>Aug. 2012</td>
<td>15.67</td>
<td>8.08</td>
<td>0.019109</td>
</tr>
<tr>
<td>Sep. 2012</td>
<td>16.82</td>
<td>6.96</td>
<td>0.017864</td>
</tr>
<tr>
<td>Oct. 2012</td>
<td>17.37</td>
<td>7.66</td>
<td>0.017809</td>
</tr>
<tr>
<td>Nov. 2012</td>
<td>17.60</td>
<td>7.49</td>
<td>0.018056</td>
</tr>
<tr>
<td>Dec. 2012</td>
<td>17.11</td>
<td>7.78</td>
<td>0.018452</td>
</tr>
<tr>
<td>Jan. 2013</td>
<td>16.09</td>
<td>8.15</td>
<td>0.018606</td>
</tr>
<tr>
<td>Feb. 2013</td>
<td>15.46</td>
<td>8.58</td>
<td>0.019092</td>
</tr>
</tbody>
</table>

We obtain:
- **Gold/oil ratio**: \( \hat{X}^{(0)}(k) = 15.924 \ \ e^{a(k-1)} \)
  \[ a = 0.001046, \quad b = 15224.33123 \]
- **DJAI/Gold ratio**: \( \hat{X}^{(0)}(k) = 7.7676 \ \ e^{a(k-1)} \)
  \[ a = -0.00224, \quad b = -3467.681652 \]
- **USD/XAU ratio**: \( \hat{X}^{(0)}(k) = 0.0213 \ \ e^{a(k-1)} \)
  \[ a = -0.00956, \quad b = -2.228465 \]
The grey precision indices are calculated according to Equation (13) which demonstrates the trend of these ratios in Table 2.

Table 2. Grey precision indices for Gold/Oil, DJAI/Gold and USD/XAU ratios.

<table>
<thead>
<tr>
<th>Date</th>
<th>Gold/Oil ratio</th>
<th>DJAI/Gold ratio</th>
<th>USD/XAU ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb. 2012</td>
<td>0.89704</td>
<td>0.102766</td>
<td>1.067261</td>
</tr>
<tr>
<td>March 2011</td>
<td>0.8820278</td>
<td>0.098945</td>
<td>0.983838</td>
</tr>
<tr>
<td>April 2011</td>
<td>0.796259</td>
<td>0.09389</td>
<td>0.978153</td>
</tr>
<tr>
<td>May 2011</td>
<td>0.874844</td>
<td>0.09389</td>
<td>0.985069</td>
</tr>
<tr>
<td>June 2011</td>
<td>0.909812</td>
<td>0.09389</td>
<td>0.995327</td>
</tr>
<tr>
<td>July 2011</td>
<td>0.917946</td>
<td>0.09389</td>
<td>1.001193</td>
</tr>
<tr>
<td>Aug. 2011</td>
<td>1.119584</td>
<td>0.09389</td>
<td>0.90431</td>
</tr>
<tr>
<td>Sep. 2011</td>
<td>1.112809</td>
<td>0.09389</td>
<td>0.954695</td>
</tr>
<tr>
<td>Oct. 2011</td>
<td>1.107913</td>
<td>0.09389</td>
<td>0.997198</td>
</tr>
<tr>
<td>Nov. 2011</td>
<td>1.039641</td>
<td>0.09389</td>
<td>0.978153</td>
</tr>
<tr>
<td>Dec. 2011</td>
<td>0.995327</td>
<td>0.09389</td>
<td>0.995327</td>
</tr>
<tr>
<td>Jan. 2012</td>
<td>0.973595</td>
<td>0.09389</td>
<td>1.002434</td>
</tr>
<tr>
<td>Feb. 2012</td>
<td>0.978153</td>
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<td>0.948644</td>
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<tr>
<td>March 2012</td>
<td>0.894207</td>
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<td>April 2012</td>
<td>0.913672</td>
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<td>May 2012</td>
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<td>0.978153</td>
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<td>June 2012</td>
<td>1.110401</td>
<td>0.09389</td>
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<td>July 2012</td>
<td>1.030927</td>
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<td>0.995327</td>
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<td>Aug. 2012</td>
<td>0.964646</td>
<td>0.09389</td>
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<td>Sep. 2012</td>
<td>1.034358</td>
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<td>Oct. 2012</td>
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<td>0.995327</td>
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<tr>
<td>Jan. 2013</td>
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<td>0.09389</td>
<td>0.995327</td>
</tr>
<tr>
<td>Feb. 2013</td>
<td>0.945764</td>
<td>0.09389</td>
<td>1.002434</td>
</tr>
</tbody>
</table>

The maximum order weighted state transition probability of Markov chain, normalized autocorrelation coefficients and weighted values of Markov chain and weighted Markov chain prediction probability for all ratios are presented in Table 4.

Table 3. The state partitions of grey precision indices of SCGM(1,1) model

<table>
<thead>
<tr>
<th>Gold/Oil ratio</th>
<th>E1:0.796259-0.8501465</th>
<th>E2:0.8501465-0.904034</th>
<th>E3:0.904034-0.9579215</th>
<th>E4:0.9579215-1.011809</th>
<th>E5:1.011809-1.0656965</th>
<th>E6:1.0656965-1.119584</th>
</tr>
</thead>
<tbody>
<tr>
<td>DJAI/Gold ratio</td>
<td>E1:0.827037-0.883899</td>
<td>E2:0.883899-0.940761</td>
<td>E3:0.940761-0.997623</td>
<td>E4:0.997623-1.054485</td>
<td>E5:1.054485-1.111347</td>
<td>E6:1.111347-1.168209</td>
</tr>
<tr>
<td>USD/XAU ratio</td>
<td>E1:0.89136-0.883899</td>
<td>E2:0.930633-0.97213</td>
<td>E3:0.97213-1.013627</td>
<td>E4:1.013627-1.055124</td>
<td>E5:1.055124-1.096621</td>
<td>E6:1.096624-1.138118</td>
</tr>
</tbody>
</table>

Table 4. Summary results of probability prediction by the weighted Markov chain.

<table>
<thead>
<tr>
<th>Ratio</th>
<th>state</th>
<th>E1</th>
<th>E2</th>
<th>E3</th>
<th>E4</th>
<th>E5</th>
<th>E6</th>
<th>r_o</th>
<th>\theta_o</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold/Oil</td>
<td>1</td>
<td>0.33333333</td>
<td>0.33333333</td>
<td>0</td>
<td>0.33333333</td>
<td>0.693254</td>
<td>0.6724445</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.28985714</td>
<td>0.255714</td>
<td>0.2885714</td>
<td>0.28</td>
<td>0.452726</td>
<td>0.406331</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.31555074</td>
<td>0.301658089</td>
<td>0.30667599</td>
<td>0.288321144</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GJIA/Gold</td>
<td>1</td>
<td>0.042857143</td>
<td>0.09285714</td>
<td>0.255714</td>
<td>0.2885714</td>
<td>0.28</td>
<td>0.452726</td>
<td>0.406331</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.01741419006</td>
<td>0.016253244</td>
<td>0.03773606895</td>
<td>0.10905509</td>
<td>0.1172553714</td>
<td>0.707441608</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USD/XAU</td>
<td>1</td>
<td>0.007936508</td>
<td>0.007936508</td>
<td>0.074829932</td>
<td>0.281503077</td>
<td>0.343051506</td>
<td>0.284742468</td>
<td>0.349727</td>
<td>0.21765001</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.001723731</td>
<td>0.001723731</td>
<td>0.016286735</td>
<td>0.061269147</td>
<td>0.74665164</td>
<td>0.844324191</td>
<td>0.349727</td>
<td>0.21765001</td>
</tr>
</tbody>
</table>
According to max p; for each of above ratios, it is inferred that the
state of grey precision index of SCGM(1,1), model in March 2013 for
Gold/Oil is state $E_3$ for DJAI/Gold is state $E_4$ and for average
USD/XAU is state $E_5$. Determining the nearness states of the plausible
state and with formula (23), we obtain:

$$\begin{align*}
\text{Gold/Oil ratio: } & \hat{y}(\text{March 2013}) = 0.95354 \\
\text{DJAI/Gold ratio: } & \hat{y}(\text{March 2013}) = 1.113147 \\
\text{USD/XAU ratio: } & \hat{y}(\text{March 2013}) = 1.096621
\end{align*}$$

At last a predicted value of weighted value of weighted Markov
SCGM(1,1), model for every ratios and the precision of forecasting are
calculated by formula (24) and (25) (table 5). The high precision of
forecasting values exhibit that the weighted Markov SCGM(1,1): model
gives the reliable and certified forecasting results.

**Table 5.** Forecasting results and their precisions for case study ratios.

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Predicted Value</th>
<th>Actual Value</th>
<th>Precision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold/Oil (March 2013)</td>
<td>15.60348</td>
<td>16.60</td>
<td>94%</td>
</tr>
<tr>
<td>DJAI/Gold (March 2013)</td>
<td>8.14411</td>
<td>8.62</td>
<td>94.48%</td>
</tr>
<tr>
<td>USD/XAU (March 2013)</td>
<td>0.01822</td>
<td>0.019526</td>
<td>93.32%</td>
</tr>
</tbody>
</table>

**CONCLUSION**

Grey theory utilizes comprehensive mathematics method to
forecast the insufficient system of information. Grey SCGM(1,1): model looks for obtained information from time series data themselves,
seeks for general altering trend and it is valid for arbitrary length series
data. Weighted Markov chain shows the influence degree of the
stochastic factor by a transition probability and it is applicable to
dynamic process with stochastic volatility. As gold holds an important
place in financial world, this paper combined these models and has
assessed the application of weighted Markov SCGM(1,1), model in
predicting the monthly ratios of gold/oil, DJAI/gold and USD/XAU.
The relative prediction errors 6%, 5.52% and 6.68% for gold/oil, DJAI/gold and USD/XAU ratios, respectively indicate that the model
was credible and achieved acceptable performance.

**REFERENCES**

from http://www.denverGold.org

Currency converter using official exchange rates. (2013). Retrieved from
http://www.fxtom.com

A. Jain, S. Ghosh. (2013). Dynamics of global oil prices, exchange rate and
precious metal prices in India. Resources Policy, 38(1), 88–93. DOI:10.1016/j.resourpol.2012.10.001

model improve by nonlinear regression. *Procedia Engineering*, 15, 5020–
5024.


affecting the price of Gold : A study of MGARCH model. *Business and

C. Wang, Y. Chen, L. Li. (2007). The forecast of gold price based on the
GM(1,1) and Markov chain. *Proceedings of 2007 IEEE International
China, 739-743.

to predict air disaster death toll. *Systems Engineering Theory and Practice*,
5, 135-144.

Ad Hoc Networks based on Multi-dimensional fuzzy and Markov
SCGM(1,1)c model. *Computer Communications*, 35(5), 589-596.

G. Kim, R.S. Yun. (2012). A hybrid forecast of exchange rate based on discrete
grey Markov and Grey Neural network model. *arXiv preprint
arXiv:1207.2254*.

Finance Lab*, 3(7), 10-12.

data on the basis of grey Markov SCGM(1,1) model. *IEEE International

and treatment. *IEEE International Conference on grey systems and

H.F. Chang, L.C. Huang, M.C. Chin. (2013). Interactive relationships between crude

developments of GDP, Population and Energy Consumption in Iran.

arXiv:1308.0210*.

J. Beckmann, R. Czudaj. (2013). Oil and gold price dynamics in a multivariate

J.C. Reboreda. (2013). Is gold a hedge or safe haven against oil price movements?
*Resources Policy*, 38(2), 130-137.

model for failure prognostics of electronics. *International Journal of
Perfomability Engineering*, 6(5), 435-442.


*Journal of Finance*, 651-662.

price, Oil price, exchange rate and stock market returns. *International

L. Juan, W.J. Liu. (2011). Population forecasting in China based on the Grey-
Markov model. *International Conference on Information Management,


German: Springer-Verlag Berlin Heidelberg.

between gold prices, oil prices and Karachi stock market. *Acta

Open Economics Journal*, 6, 1-10.

B.T. Ewing, F. Malik. (2013). Volatility breaks transmission between gold and

T.H. Le, Y. Chang. (2011). Oil and gold: correlation or causation? *Economics


X.C. Jiang, S.F. Chen. (2009). Application of weighted Markov SCGM(1,1),
model to predict drough crop area. *Systems Engineering- Theory &
Practice*, 29(9), 179-185.

via a GM(1,1) weighted Markov chain. *Journal of Zhejiang University -

city based on grey weighted Markov model. *Natural Hazards*, 71(2),
1159–1180.

Markov SCGM(1,1), *Computer Engineering and Applications*, 48(31),
11-15.

Z. Yunlong, L. Mao. (2011). Application of grey model GM(1,1) to
environmental pollution and destruction accidents. *2nd IEEE International
Conference on Emergency Management and Management Sciences*, 8-10