کارگاه‌های آموزشی مرکز اطلاعات علمی

مقاله نویسی علوم انسانی
اصول تنظیم قراردادها
آموزش مهارت های کاربردی در تدوین و چاپ مقاله
Estimating the demand function for gold in Iran from 1995 to 2016 (A State-Space model)

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Abstract
The main purpose of this study is to estimate the demand function and price elasticity of demand for gold in Iran from 1995 to 2016. In this paper, the demand for gold has been estimated by the state-space model and the Kalman filter technique in a time-varying pattern. Based on the results, it can be concluded that one-percent increase in the real price of gold demand results in 1.17 percent decrease in gold demand. The elasticity of gold demand and GDP is not statistically significant morever the elasticity of gold demand and population variable indicates that one percent increase in the population of Iran, leads to 0.03 percent increase as well. The price elasticity of demand for gold in Iran from 1990 to 2016 has almost risen, indicating an increase in the sensitivity of gold consumers in the face of gold price changes.

Keywords: Gold Demand, Price Elasticity of Demand, Population, State-Space model, Kalman filter Technique.

JEL: L72, Q31, C22
Introduction

Because of its golden and beautiful color, its strength, its softness and ductility, and most importantly its scarcity, gold was always special. Because of its golden and beautiful color, its strength, its softness and ductility, and most importantly its scarcity. The demand for gold by individuals, governments and central banks was high at all times. It is important to note that much of the demand for gold was jewelry demand which caused stagnation. As a result, the identification of factors influencing demand for gold seems to be important.

Gold serves several functions in the world economy, and its links with financial and macroeconomic variables are quite well-established (Pierdzioch, Risse, & Rohloff, 2014a, 2014b). It has a monetary value and is sought after by central banks to be part of their international reserves (Gupta, Hammoudeh, Kim, & Simo-Kengne, 2014). Serving as a hedge against major currencies is another role the literature has bestowed upon gold prices. Ghazali, Lean, & Bahari, 2013 argue in modern finance, it is used as a hedge against inflation and a safe haven during crises. Another argument also says that gold is really best treated as a monetary asset, at least when it comes to its relationships with exchange rates and oil prices. It has industrial uses and can be transformed into jewelry (Ciner, Gurdgiev, & Lucey, 2013).

The main objective of this study is to investigate the effect of gold price, GDP, population and previous gold demand, on gold demand in Iran between 1990 and 2016. For this purpose, the Kalman filter technique and the State-Space-model are used to estimate the price elasticity of demand for gold and the demand function for gold.

The Rest of the study is structured as follows: Section 2 discusses the methodological issues in literature concerning gold demand and price elasticity of demand. Section 3 outlines the methodology and construction econometric model for estimating the demand function for gold in Iran. Section 4 reports the estimation results and their discussion. Finally, Section 5 concludes the study with discussion on policy implications and direction for future research.

Literature review

Batchelor & Gulley, (1995) investigate the relationship between jewelry demand and the price of gold in USA, Japan, Germany, France, Italy, and the UK. The price elasticity of demand of gold jewelry was found to be between −0.5 and −1, with an average of −0.64. In these western countries, the negative price elasticity of demand points to gold as a discretionary asset. There has been limited academic research on economic issues relating to any of the practical uses for gold (O'Connor, Lucey, Batten, & Baur, 2015).

Tully & Lucey, (2007) investigate macroeconomic influences on gold using the asymmetric power GARCH model (APGARCH). They utilize the methodology of (Ding, Granger, & Engle, 1993) and (Brooks, Faff, McKenzie, & Mitchell, 2000). They have examined the fit of the APGARCH model for six gold models. As specified in (Ding et al., 1993) a number of autoregressive conditional heteroscedasticity (ARCH) and GARCH models are nested within the APGARCH model. To estimate the goodness of fit of each model, likelihood ratio tests are used to assess the significance of each model and provide the best fit for the data. They found US dollar is the main, indeed in many cases the sole, macroeconomic variable which influences gold by using gold cash and futures data over a long period.

Starr & Tran, (2008) estimated factors affecting physical demand for gold, using panel data which cover 21 countries for the period from 1992 to 2003. As it might be expected, their paper finds considerable heterogeneity among the drivers of demand in different countries. In developing countries, gold consumption rises with falling income pointing a precautionary motive. The fact that the development of credit markets decreases the demand for gold in these countries reinforces this view. In developed economies, gold demand rises with per capita GDP, possibly as gold is viewed as a discretionary expenditure. While this paper does not discuss unit root or co-integration issues despite some of the variables used being commonly seen as non-stationary, interpreting this paper's findings should be used cautiously.
Toraman, Basarir, & Bayramoglu, (2011) studied the factors affecting the gold prices with monthly data between June, 1992 and March, 2010. Their model included Oil prices, USA exchange rate, USA inflation rate, USA real interest rate data as variables. They found highest correlation between gold prices and USA exchange rate negatively and a positive correlation between gold prices and oil prices.

Mozes & Cooks, (2013) findings are that the drivers of consumer and investment demand for physical gold differ from the drivers of gold returns and that global consumer and investment demand do not explain movements in gold prices. A basic conclusion is that increasing physical gold demand is not necessarily related to higher gold prices. Thus, even though increasing wealth in emerging markets such as China, India, and Brazil will likely lead to increased consumer and investment demand for physical gold, there is little reason to expect that increased demand to lead to increased gold prices. This conclusion differs from that of (Levin, Montagnoli, & Wright, 2006), who predict that rising gold demand from global consumers and investors will support high gold prices.

Kanjilal & Ghosh, (2014) investigate cointegration relationship among gold import demand, gold price and GDP for India during the period Q1’ 1998–1999 to Q3’ 2012–2013. They also estimate short-run and long-run elasticities of import demand for gold with respect to gold price and GDP. They find gold demand has high elasticity with respect to its price. They also find income and price have impacts on the demand for gold import in the long-run.

Babaei, Molaei, & Dehghani, (2015) estimated consumption function for copper in Iran using (Johansen, 1988) approach between 1991 and 2011. The estimation results show that there is a positive correlation between industrialization intensity variable and the price of sustainable product (Aluminum) and copper consumption ratio. A significant negative correlation between copper prices and complementary commodity price also found in this study.

Aye, Gupta, Hammoudeh, & Kim, (2015) develop several models to examine possible predictors of the return of gold by using a recursive principal component analysis (PCA) and two uncertainty and stress indices (the Kansas City Fed’s financial stress index and the U.S. Economic policy uncertainty index). They compare alternative predictive models and found that the dynamic model averaging (DMA) and dynamic model selection (DMS) models outperform linear models. They conclude that financial variables have stronger predictive power for gold returns than real economic variables. This is particularly so with the exchange rate, the financial stress index and the stock market.

Choudhry, Hassan, & Shabi, (2015) study the nonlinear dynamic co-movements between gold returns, stock market returns and stock market volatility during the recent global financial crisis for the UK (FTSE 100), the US (S&P 500) and Japan (NIKKEI 225) by using daily data from January 2000 to March 2014. The results point that gold may not perform well as a safe haven during the financial crisis period due to the bidirectional interdependence between gold returns and, stock returns as well as stock market volatility. However, gold may be used as a hedge against stock market returns and volatility in stable financial conditions.

Mukherjee, Mukherjee, & Das, (2017) examine the gold demand pattern in India between 1996 and 2014 by using the partial adjustment, (Houthakker & Taylor, 1970) state adjustment and ARDL¹ models. The gold imports used for different purposes were analyzed separately. They find different motives play roles in shaping demand for different forms of gold, although investment behavior dominates over habit persistence in aggregate.

**Methodology**

First, there is an overview of the state space model and the Kalman filter, then the model's estimation and estimation of the demand function for gold will be considered.

State-space model (SSM) refers to a class of probabilistic graphical model (Koller, Friedman, & Bach, 2009) that describes the probabilistic dependence between the latent state variable and the observed

¹. Autoregressive distributed lag model
measurement. The state or the measurement can be either continuous or discrete. The term “state-space” originated in 1960s in the area of control engineering (Kalman, 1960).

Economic systems are complex, especially in financial sector and the coefficients are also uncertain. The state-space models, which have a Markov property (Markov, 1954), are vast models that include many linear models such as ARMA. The risk of asset management decision-making and optimization is also minimized in these models.

The most important feature is when state space models using particular algorithms are written, they do not require stagnation and inversion. One of the most important one of these particular algorithms is the Kalman filter is most important particular algorithms which is predictable and smooth. It is an efficient recursive filter that estimates the internal state of a linear dynamic system from a series of noisy measurements (Andreasen, 2008; Strid & Walentin, 2009). This method, as compared to the GARCH2, ARMA3 and AR4 models, which are classical methods in econometrics, makes consistent estimation in a time series analysis. The Kalman filter is a basic tool used in state-space models, and is a recursive method for calculating an error term or a state vector at time t, according to the information available at time t. The Kalman filter can be used to calculate the likelihood function by analyzing the error term.

The Kalman filter can be divided into three categories: state variables estimation, system variables estimation, and simultaneous estimation of state variables and system variables.

**State variable estimation**

For a discrete nonlinear system, the main framework of the dynamic state-space model is as follows:

\[
X_{k+1} = f(X_k, u_k, v_k) \tag{1}
\]

\[
Y_k = h(X_k, u_k, v_k) \tag{2}
\]

Where \(X_k\) represents the non-visible state of the system, \(u_k\) represents the externally detected input and \(Y_k\) represents the measurable signal. The process noise \(v_k\) is due to the system dynamics and the observer noise is determined by \(n_k\). In the dynamic model of the system, \(f\) and \(h\) are assumed to be given that are determined by a set of specified parameters. The purpose is to determine the state of the system's variables based on the specified values.

**System variable estimation**

Variable estimation or system identification is another Kalman filter application. For example, if the non-linear function \(g(0)\) is expressed the relationship between the output of a system, \(y_k\), and its input variable, \(X_k\), as the following equation:

\[
y_k = g(X_k; w) \tag{3}
\]

Where \(w\), is the unknown coefficient of the model, and \(k\), is the number of samples in the system. The Kalman filter can be used to determine the unknown coefficients of \(w\), and a dual, \((X_k, d_k)\), which the first component is input and the second component is desirable output. The error is defined as follows:

\[
e_k = d_k - g(X_k; w) \tag{4}
\]
By using the Kalman filter, the \( w \) parameters are calculated in a way that the error function defined above is minimized.

**Simultaneous estimation of state variables and system variables**

The simultaneous estimation of state variables and system variable is another application of the Kalman filter. This method is used when the input is not measurable, and the simultaneous estimation of state variable and system variable is required. To simultaneously estimate the system, we refer to the nonlinear discrete-time dynamical systems.

\[
X_{k+1} = f(X_k, u_k, v_k; w) \tag{5}
\]

\[
y_k = h(X_k, n_k; w) \tag{6}
\]

In these equations, both the state variable, \( X_k \), and the parameters of the dynamic model, \( w \), should be estimated only by using the visible signal with the noise \( y_k \). Simultaneous estimation can be divided into two methods: JF\(^5\) and DF\(^6\).

In DF method, a separate state-space is used for the state variable and parameters. At each stage of time, the state filter is used as a definite input for estimating the parameter \( \hat{w}_k \). On the other hand, to estimate the state variable \( \hat{X}_k \), the parameter filter is used.

In JF method, the parameters and the unknown state variable of the system are defined as a state vector \( \tilde{X}_k \):

\[
\tilde{X}_k = [X_k^T \ w_k^T] \tag{7}
\]

The state-space model of the system is defined as follows:

\[
\tilde{X}_{k+1} = \tilde{f} (\tilde{X}_k, u_k, \tilde{v}_k) \tag{8}
\]

\[
y_k = h(\tilde{X}_k, n_k) \tag{9}
\]

Which can be expanded as follows:

\[
[\begin{bmatrix} X_{k+1} \\ w_{k+1} \end{bmatrix} = [f(X_k, u_k, v_k; w_k) + [0 \\ w_k] 
\]

\[
y_k = h(X_k, n_k; w_k) \tag{10}
\]

Where \( r_k \) is noise parameter of the system and \( \tilde{v}_k = [V_k^T \ r_k^T] \).

**TVP\(^7\) models and the Kalman filter**

We describe the State-Space model and Kalman filter with focus on Time-Varying-Parameters (TVP) models here.

The model in this study is similar to the following regression model in which regression coefficients are changing with a certain process over time.

\[
y_t = x_t \beta_t + e_t \quad t = 1,2,3,\ldots,T \tag{12}
\]

\[
\beta_t = \tilde{\mu} + F \beta_{t-1} + \nu_t \tag{13}
\]

\(^5\) Joint Filtering  
\(^6\) Dual Filtering  
\(^7\) Time-Varying-Parameter
Where \( y_t \) is a vector of \( 1 \times K \) of the endogenous variables. \( e_t \) and \( v_t \) are independent. It is also assumed that \( \beta_t \) from the dimension \( k \times 1 \), \( F \) and \( Q \) is from \( k \times K \) dimension. For example, with \( \mu = 0 \) and \( F = I_k \), each regression coefficient \( \beta_t \) follows a random walk. If \( F \) is a diagonal matrix and the absolute value of its main diagonal elements is less than one, each regression coefficient will follow an AR (1) stationary process.

The Time-Varying-Parameters (TVP) model, discussed in relationships (12-14), is a specific mode of State-Space model in general. The general mode in the measurement equation is \( y_t = H_t \beta_t + A Z_t + e_t \), where \( H_t \) is a matrix of predetermined variables. For example:

\[
y_t = \beta_{1t} x_{1t} + \beta_{2t} x_{2t} + \beta_{kt} x_{kt} + e_t \\
\]

(15)

\[
(\beta_{it} - \delta_i) = \phi_i (\beta_{it-1} - \delta_i) + v_{it} \\
v_{it} \sim \text{i.i.d. } N(0, \sigma^2) \quad i = 1.2.\ldots k
\]

(16)

\[
E(e_t v_{ik}) = 0 \quad \text{&} \quad t.s.l = 1.2.\ldots k
\]

(17)

In the above equation, \( i = 1.2.\ldots k \) and \( x_{it} \) are endogenous variables. The measurement equation and the transfer equation will be:

**Measurement equation:**

\[
y_t = [x_{1t} \ x_{2t} \ \ldots \ x_{kt}] \begin{bmatrix} \beta_{1t} \\ \beta_{2t} \\ \vdots \\ \beta_{kt} \end{bmatrix} + e_t
\]

(18)

( \( y_t = x_t \beta_t + e_t \) )

**Transfer equation:**

\[
\begin{bmatrix} \beta_{1t} \\ \beta_{2t} \\ \vdots \\ \beta_{kt} \end{bmatrix} = \begin{bmatrix} \delta_1^t \\ \delta_2^t \\ \vdots \\ \delta_k^t \end{bmatrix} + \begin{bmatrix} \phi_1 & 0 & 0 & 0 \\ 0 & \phi_2 & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & \phi_k \end{bmatrix} \begin{bmatrix} \beta_{1t-1} \\ \beta_{2t-1} \\ \vdots \\ \beta_{kt-1} \end{bmatrix} + \begin{bmatrix} v_{1t} \\ v_{2t} \\ \vdots \\ v_{kt} \end{bmatrix}
\]

(20)

In equation (20):

\[
\beta_t = \mu + F \beta_{t-1} + v_t
\]

(21)

\[
\delta_i^* = \delta_i (1 - \phi_i) \quad i = 1.2.\ldots k
\]

(22)

By comparing Equations (8) with (1), we find that the Time-Varying-Parameter model, is a specific mode of State-Space model, where \( H_t = x_t = [x_{1t} \ x_{2t} \ \ldots \ x_{kt}] \) and \( x_t \), must be uncorrelated with \( e_t \).

We consider the following regression model. In one of the regression, coefficients are varying over time (random walk), while another one has constant coefficients:

\[
y_t = \beta_{1t} + \beta_{2t} x_{2t} + \beta_{3t} x_{3t} + e_t
\]

(23)

\[
\beta_{it} = \beta_{it-1} + v_{it} \quad i = 1.2
\]

(24)
Measurement equation:

\[ y_t = [1 \ x_{2t}] \begin{bmatrix} \beta_{1t} \\ \beta_{2t} \end{bmatrix} + \beta_3 x_{3t} + e_t \]  
(25)

\[ (y_t = H_t \beta_t + \beta_3 x_{3t} + e_t) \]  
(26)

Transform equation:

\[ \begin{bmatrix} \beta_{1t} \\ \beta_{2t} \end{bmatrix} = \begin{bmatrix} \beta_{1,t-1} \\ \beta_{2,t-1} \end{bmatrix} + \begin{bmatrix} \nu_{1t} \\ \nu_{2t} \end{bmatrix} \]  
(27)

\[ (\beta_t = \beta_{t-1} + \nu_t) \]  
(28)

MLE\(^8\) estimation

Foreign studies

One way to get the model estimation is when the assumption of a certain distribution is based on the sample of the observations vector is Maximum Likelihood Estimation. Contrary to the least squares method used in two times, the maximum likelihood estimation combines with the method of work with the full distribution of observations. For a thorough analysis of the maximum likelihood estimation method, refer to (Davidson & MacKinnon, 1993) and (Harvey, 1990).

Results

Studying the trend of real gold prices, gold price elasticity and gold demand show that real gold prices have always been bullish.

The demand function for gold estimated in this study is as follows:

\[ \log QG_t = c_1 + c_2 \log PG_t + c_3 \log GDP + c_4 \log POP + c_5 \log QG_{t-1} + \epsilon_t \]

Where \( QG_t \) represents the demand for gold at time \( t \), \( PG_t \) represents the real price of gold at time \( t \), and GDP and POP represent the growth of GDP and population respectively. \( \log QG_{t-1} \) also represents the demand for gold on the previous year.

The coefficient of real price of gold, is the price elasticity of demand of gold which is not constant and changes randomly over time. This is a feature of the State-Space models.

Estimation of demand function for gold

The estimation results of demand function for gold, using Eviews software and the State-Space model in the time varying coefficient and the Kalman Filter technique between 1990 and 2016 is specified in Table 2.

<table>
<thead>
<tr>
<th>Variable coefficient</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>( C_1(\text{Intercept}) )</td>
<td>203.01</td>
<td>3.017</td>
<td>1.19</td>
<td>0.310</td>
</tr>
<tr>
<td>( C_2(\text{gold price}) )</td>
<td>-1.17</td>
<td>0.011</td>
<td>-2.53</td>
<td>0.001</td>
</tr>
<tr>
<td>( C_3(\text{GDP}) )</td>
<td>0.36</td>
<td>0.103</td>
<td>1.56</td>
<td>0.204</td>
</tr>
<tr>
<td>( C_4(\text{Population}) )</td>
<td>0.708</td>
<td>0.031</td>
<td>7.05</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

\(^8\) Maximum likelihood estimation
Based on the estimation results, the gold price coefficient is -1.17. On this basis, it can be concluded that with a one-percent increase in the real price of gold between 1990 and 2016 in Iran, gold demand fell by 1.17 percent. The elasticity between demand for gold and GDP is 0.36, which is not statistically significant. The elasticity between demand for gold and population variable is 0.031, indicating that with a one percent increase in the population of Iran during the period under review, demand for gold has increased by about 0.03%.

We estimate gold demand price elasticity in Iran during 1990 to 2016 by the state-space model with time varying coefficient (table 2).

Table2- Estimation of the price elasticity of demand for gold between 1990 and 2016 in Iran.

<table>
<thead>
<tr>
<th>Year</th>
<th>Price elasticity of gold demand</th>
<th>Year</th>
<th>Price elasticity of gold demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>-0.002</td>
<td>2003</td>
<td>-0.021</td>
</tr>
<tr>
<td>1991</td>
<td>-0.005</td>
<td>2004</td>
<td>-0.021</td>
</tr>
<tr>
<td>1992</td>
<td>-0.009</td>
<td>2005</td>
<td>-0.019</td>
</tr>
<tr>
<td>1993</td>
<td>-0.011</td>
<td>2006</td>
<td>-0.021</td>
</tr>
<tr>
<td>1994</td>
<td>-0.014</td>
<td>2007</td>
<td>-0.023</td>
</tr>
<tr>
<td>1995</td>
<td>-0.012</td>
<td>2008</td>
<td>-0.023</td>
</tr>
<tr>
<td>1996</td>
<td>-0.013</td>
<td>2009</td>
<td>-0.024</td>
</tr>
<tr>
<td>1997</td>
<td>-0.013</td>
<td>2010</td>
<td>-0.025</td>
</tr>
<tr>
<td>1998</td>
<td>-0.013</td>
<td>2011</td>
<td>-0.026</td>
</tr>
<tr>
<td>1999</td>
<td>-0.016</td>
<td>2012</td>
<td>-0.026</td>
</tr>
<tr>
<td>2000</td>
<td>-0.017</td>
<td>2013</td>
<td>-0.028</td>
</tr>
<tr>
<td>2001</td>
<td>-0.017</td>
<td>2014</td>
<td>-0.028</td>
</tr>
<tr>
<td>2002</td>
<td>-0.018</td>
<td>2015</td>
<td>-0.027</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2016</td>
<td>-0.028</td>
</tr>
</tbody>
</table>

**Conclusion**

The main objective of this study is to investigate the effect of gold price, GDP, population and previous gold demand, on gold demand in Iran from 1990 to 2016. For this purpose, the Kalman filter technique and the State-Space-model are used to estimate the price elasticity of demand for gold and the gold demand function. According to the results, it can be concluded that from 1990 to 2016 in Iran, an increase of one-percent in the real price of gold, would decrease the demand for gold by 1.17 percent. The price elasticity of demand for gold with respect to the population is 0.031, indicating that an increase of one-percent of the population of Iran during this period, would increase the demand for gold 0.03 percent. It is noticeable that the price elasticity of demand for gold in the period of 1990-2016 in Iran has almost risen, indicating an increase in the sensitivity of gold consumers in the face of gold price changes.
References


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