Simultaneous Equation Analysis of the Supply and Demand of the World Gold Market

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Abstract

This thesis examines the world gold market for the period of the last thirty years. The particular objects of interest are the factors that determine the supply and demand of gold. I apply simultaneous equations method to estimate the impact of these factors using the Two Stage Least Squares approach. This allowed me to derive the supply and demand functions which can be plotted in rectangular coordinate system. Findings show high influence of the gold jewelry market and net investors position on the demand side but somewhat less dependence on the inflation adjusted price. Contrary, price of gold plays a crucial role for the supply side along with the average profitability level in the gold mining industry and the Trade Dollar Index.

Keywords: gold market, simultaneous equations method, two stage least squares, demand-supply analysis.

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Table of Contents

Abstract	ii
Acknowledgement	iii
List of Figures:	V
List of Tables:	V
Introduction	1
1 Literature review	3
2 Data	7
2.1 Variables description	8
2.2 Summary statistics	15
3 Model	17
3.1 Basic Model Specification	17
3.2 Least Squares Estimates	19
3.3 Simultaneous Equation Estimates	20
4 Results	24
Conclusions	28
References	29
Appendix	31

List of Figures:

Figure 1 Total World Gold Reserves	32
Figure 2 Yearly average Prices Denominated in Major Currencies	32
Figure 3 The five year daily gold price (per oz) in selected currencies	33
Figure 4 Demand and supply curves, 1982	34
Figure 5 Demand and supply curves, 2008	34

List of Tables:

Table 1 Net investors position regression (OLS)	11
Table 2 Descriptive statistics	15
Table 3 Observed vs Predicted values	26
Table 4 Correlations (3 years ending 25 September 2009, weekly returns)	31
Table 5 Correlation of the exogenous variables with the error term	32

Introduction

Gold is a unique and unusual commodity that has played a role of a currency for the last 2 500 years. Due to its special characteristics gold is indestructible unlike other commodities - oil or coffee and thus virtually all of the underground bullion stocks that have been mined still exist in one form or the other. Since gold is no perishable and can be relatively easily melted down and converted into bars or coins the supply of this commodity does not depends solely on the production (mining).

For the substantial period of time gold served as an official currency in most of the countries. This role was even more important during the XVIII - early XX century, when monetization of the economy enhanced and money became a key element in the exchange, eliminating barter. That is why the supply of gold into the economy was closely tied with the monetary supply. The abolishment of the gold standard *dejure* turned gold into simple commodity but it is still is part of the central bank reserves and a popular way to invest money or a storage of wealth.

The main objective of this works is to make a supply-demand analysis of the world market of physical gold that covers modern days. I consider the period of 1977-2009 in this thesis. This is already the time after the abolishment of the gold standard in all the countries.

In order to estimate what factor influence the supply and demand of gold in poststandard era I apply simultaneous equation method that consists of 2 equations system. First I calculated this system using the simple ordinary least squares (OLS) regression and then I apply the Two Stage Least Squares (2SLS) method. The obtained coefficients allow constructing supply and demand functions and plotting them on the graph. These functions are the key outcome of this analysis. Chapter 1 of this work is dedicated to the review of the economic literature which is related to this topic. Second chapter speaks about the data source and the period of the observations. I justify the usage of the particular variables and their role for the supply or the demand side of the market. Chapter three presents and analyzes the model and the estimated results of the equations. Subsequently I have rearranged the obtained results in the chapter four and estimated demand and supply functions for gold with latter plotting them on the rectangular system of coordinate. Chapter five is the closing one and contains the conclusions.

1 Literature review

The identification and estimation of structural relationships in simultaneous equation systems was first developed by Trygve Haavelmo over 60 years ago (Haavelmo 1943). The most commonly used model in econometric science is a two-equation system of supply and demand relationship that jointly estimates the quantity and price sold for of a non-durable goods (Epple and McCallum 2004). The paper by Epple and McCallum developed the econometric method for this particular type of research and provided a first example using the real data for the US poultry market. Unfortunately, no paper exists that is trying to do the same for the gold market - neither for the particular country nor in the global scope. Thus, in this sense current thesis is an endeavor to explore new field using a well-know approach.

Significant part of the literature is dedicated to the research on price of gold as a key indicator of market efficiency. Solt and Swanson who were trying to test it have observed some positive dependence in weekly gold returns but no strong evidences of market inefficiency were found (Solt and Swanson 1981). Another paper written by Adrian Tschoegl tested the data against seasonality in the market. It looks at monthly mean daily returns of gold over the 1975 to 1984 and tests them against three definitions of seasonality. He found no stable cyclical pattern or so-called 'January effect' for the given data but there was an above average returns in March and below average returns in September. However it was explained to be consistent with seasonality in Eurodollar interest rates and hence cannot be an evidence of gold market inefficiency (Tschoegl 1987). Thus I find it reasonable to make an assumption that market price includes all the possible relevant information and is efficient.

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One can observe three main periods of increased interest in "gold" topic in the economic literature. The first one dates back to the First World War and the *de-facto* abolishment of the gold standard. During this period the total supply of the gold in the economy formed its monetary supply. Thus variations in the first were responsible for the country's price level and trade balance (Cooper, Dornbusch and Hall 1982).

Usage of gold as a world currency, i.e. international world standard, was supposed to eliminate the disparity in the exchange rates. If the ratio between two currencies backed by gold falls below the fixed mint rate by more than the cost of shipping a large inflow or outflow was supposed to occur. This brought up the idea of the interdependence of gold supply and the exchange rate fluctuations. Berridge was among those who questioned the topic of the necessary amount of bullion for the monetary purposes. He claimed that the gold which is in private possession constitutes a reservoir that can be used world's need of gold for as a currency increases (Berridge 1920).

Second period starts at the end of the Great depression with another gold crisis troubling the society. Researches were questioned by the problems of gold supply and the shortage of physical gold in the economy. Keynes pointed out the connection between the price increase and the following growing supply from new mines in South Africa and Soviet Russia and predicted the continuity of the process. He also tried to give a numerical estimation for the world gold demand, and particularly estimate private hoarding of bullion (Keynes 1936). Work of Rufus Tucker which also belongs to this period is among the first who tries to explain the changes in gold price by the changes in it supply or demand. He develops the idea that fluctuations of gold stocks in the economy are responsible for the general price level variation and concentrate on the Fishers equation in this study. One of the main

conclusions of the paper was a very high correlation between the rate of the monetary gold supply growth and the volume of production in the United States. (Tucker 1934).

The last period of the interest splash in the gold topic occurred in the mid 1970-s and early 1980-s after the abolishment of the fixed price of gold and subsequent enormous price spring in 1982. Some of the researches find gold price to be an indicator of financial instability and point out the correlation with the inflation (Abken 1980). Abken tries to distinguish between gold stocks and gold flows. Mine production, according to him, contributes to the total gold stock while industrial demand or usage for the purposes of arts shrink the stocks as it becomes economically inefficient or impossible to recycle such bullion. He also argues for relative insignificance of supply and demand factors for the market in the terms of gold flows. He suggested that psychological issues drives the public opinion on gold and appear to prevail during the period of social unrest and economic slowdowns. In other words he argued for market sentiments to play a very important role for the gold market.

Gold classed both as a commodity and a monetary asset and thus the correlation with other commodities plays a key role in the world of bullion. A positive correlation between returns on gold and those on the CRB index, aluminum, copper, lead and silver has been reported (Lawrence 2003).

The biggest part of the related literature consists of the studies of macroeconomic influences on the gold market. Tully and Lucey use the asymmetric power GARCH model (APGARCH) to estimate the influence of US Dollar, British Pound, FTSE 100 Index, US interest rates and the Consumer price index on the returns of gold. They found that the US currency has the largest influence but other variables seemed to

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be statistically insignificant. Despite the common perception of gold as an inflation hedging investment, they claim no statistical relationship between interest rates or inflation and gold (Tully and Lucey 2007). Another study performed by Lawrence looks for the correlation between gold and equities and bonds but also finds its absence. At the same time other commodities like zinc or lead show exposure to the movements of the stock market and macroeconomic conditions have much stronger impact on them than they have on gold (Lawrence 2003).

Hillier et al try to capture the correlation between gold returns and major financial indexes. They find the absence of any significant evidence of co movement suggesting gold and other precious metals to be a useful mean of portfolio diversification. They also exhibit some hedging capability, particularly during periods of abnormal stock market volatility (Hillier, Draper and Faff 2006).

2 Data

All the gold related data used in this paper is provided by the CPM Group Gold Yearbook 2009 - the research materials from one of the leading consulting services related to precious metals and commodities (CPM Group 2009). Dataset covers the period from 1977 to 2009 with the figures being reported on the annual basis.

This period belongs to the post-gold-standard era when currency of nay country was no longer backed by the precious metal. During this period gold no longer play role in the monetary process but stays among the primary spheres of investment. Consumer demand together with industry and investment demand are almost the solely components of the gold demand now.

The observed years are characterized by two splashes of the activity - at the beginning of 1980-s when the price of gold skyrocketed and reached the all-times high value and 2006-2009 during which it has passed the psychological mark of \$ 1000 per ounce (see Figure 2). The period between these years is basically characterized as bear market (CPM Group 2009) when the price did not make any major springs and remain relatively stable.

As the main object of this study is the world gold market, all the figures I used were reported as 'total' numbers in the Yearbook. Such statistics of course might be a subject to the estimation bias due to the misreporting or the lack of reliable statistic from particular countries like the Soviet Union. Despite the political or other obstacles it is reasonably to believe that the data provided by the CPM Group represents the closest possible estimation of the world gold market and can be used for the research purposes.

2.1 Variables description

Quantity $(Q)^1$ - accounts for the physical volume of the market. Here it is the total amount of gold supply or demand measured in millions of troy ounces. Note that the supply equals to the demand: $Q_s = Q_d$. The assumption made here is that all the gold produced from the mines and from the melted down scrap is bought and the difference between the supply and demand is compensated by the investors' net position and official transactions. Since it is true for every year from the data sample one have reasons to believe that in a given market the effects of consumers and producers is such to establish a quantity and price under which the market clears.

Sources of gold supply include both mine production and the recycling or of existing above-ground stocks. The first is the main source of gold supplied into the market. Gold mines are dispersed throughout the globe and operate independently - any disruption to production in any one locality is unlikely to affect the overall supply. Gold scrap is gold that has been recovered from already existing products, primarily jewelry, melted down, refined and cast into bars for further sale into the gold market. There was almost 50% rise in the total scrap supply during the period I am looking at. The Asian crisis and collapse of many of the East Asian currencies has left many household in desperate situation of trading family jewelries for some cash.

Official sector sales constitute small but significant part of the supply. Historically, central banks have kept gold as a strategic reserve asset. However, since 1989 the official sector has been a net seller of gold supplying an average of 407 tons per year from 1989 to 2007².

¹ Here and below the letter in the parentheses denotes the corresponding variable in the model.

² According SPDR Gold Trust.

Data excludes paper transactions from measures of physical supply - it does not count the turnover of gold in the market due to various financial transactions as sources of physical supply and thus trading fluctuations does not deteriorate the total figures.

Price of gold (P) - calculated as yearly average price of one troy ounce (31.1034768 grams) of gold calculated by London Bullion Market Association (LBMA). Variable is inflation-adjusted and denominated in 2009 US dollars according to consumer price index.

Gold market is assumed to be efficient, following the study of Solt and Swanson who found that the market price of gold reflects the relevant information set at every point in time (Solt and Swanson 1981).

Over the long period the real price of gold has shown no clear trend when measured in real terms (Neuberger 2001).

A substantial gap has been observed between the prices quoted by the LBMA and the retail prices of gold (CPM Group 2009). This discrepancy is explained by the differences between the wholesale price³ and the price of single gold coins or bars sold at to the individual investors. While a substantial share of the market belongs to the retail sales that are extremely decentralized there is no plausible way to get a single variable that capture this prices. Thus I will use those figures that represent the wholesale market assuming a very high correlation with the retail market.

The movements in gold prices reflect the fluctuations of investment demand for physical gold, as well as gold in other derivative forms, such as options, futures, forwards, and gold-indexed securities issued by major bullion trading banks or

³ Gold is sold in 100-ounces bars at the London Bullion Market Association (CPM Group 2009).

financial institutions. Data in the paper accounts only for the physical gold that is actually traded. Hence there is a need for a variable that will reflects the market sentiments and control for the speculative demand.

This variable is the **Net investors position** (I). Gold's use as an investment was one of the primary function that has rooted since the ancient times. Since gold is only mined but not issued by any country it is not someone's liability. So unlike currencies, bonds or equities it does not carry the risk of becoming worthless through the default of the issuer. Today gold serves as an excellent portfolio diversification as a result of the gold price lack of correlation with the mainstream investment solutions (see

Table 4), (Hillier, Draper and Faff 2006).

Investment position is calculated as the total amount of golden bars medals or medallions sold to private investors during the year plus the official transactions conducted by the central banks or the IMF. Note that while the sales of gold in bars or coins are always a positive number, the amount of gold in the reserves has shrunk over the last quarter of century and represents a negative amount (see Figure 1). Thus, the latter term is smaller than the first, variable gets a negative sign.

Central banks began to sell gold increasingly since the 1980-s following the price decline. The former Soviet Union used its gold reserve sto finance the pre-collapse period. The new independent countries that were created instead of USSR continued to spend the leftovers of reserves trying to overcome the economic difficulties of the 1990-s. Middle Eastern governments made large unreported sales in order to finance the Persian Gulf War. Some of the OECD countries like Canada or the Netherlands used their gold to finance the current budget deficit (Bernstein Research 1997).

Private investment demand is thought to consist of two main parts: a speculative demand (which is an expectation of realized capital gains from the price increase) and hedging demand (using gold as an alternative store of value against the currency which is expected to devaluate due to the inflation or other matters).

I would claim is that it reasonable to use this measure as the instrumental variable for the market sentiments. Since gold is seen as a very stable "currency" private and corporate investors would be willing to buy more bullion during the periods of instability. Chicago Board Options Exchange Volatility Index (VIX) is a measure of the stock market volatility. The greater value of VIX means greater risk of the investments in the stocks and pushes the demand for gold.

	(a)	(b)	(c)
S&P 500 Index	-0,02		-0,02
	(0,01)		(0,01)
VIX		0,69	0,45
		(0,22)	(0,26)
С	1,86	1,72	2,49
	(1,19)	(1,29)	(1,13)
R2	0,14	0,26	0,46
Observations	32	20	20

Table 1 Net investors position regression (OLS)⁴

Table 1 shows the simple OLS regression of the net investors position on the S&P 500 index and VIX. Positive coefficient in regression (b) proves the assumption above. Unfortunately, the VIX Index was introduced only in 1993 with data set going

⁴ All the variables presented in the table are measured using the first difference approach; numbers reported in parentheses are White standard errors.

back as far as 1990 (Yahoo! Finance 2010). This fact would eliminate too many observations had it been included in the model. Thus I use the net investors position as a proxy variable for the market sentiments.

The volume of the *Jewelry* market (J) is jet another exogenous variable included in the model. Jewelry accounts for the largest share of around 70% of total gold demand. Demand for jewelry varies across the countries and is affected by different cultural and social factors. Thus recent researches had shown common patterns and attitudes in the jewelry consumption (World Gold Council 2007). For instance, the purchases are associated with special occasions such as Valentine's Day, birthdays, weddings, anniversaries and other holidays. Naturally sales are subject to seasonality with the usual peak in 4th quarter of the year. The main markets for jewelry are India, China, Turkey, Italy, UK, Saudi Arabia, UAE and Egypt.

Unlike gold bars or coins jewelry is sold for the price that is higher than the intrinsic value of the metal. Risk premium is relatively high (200%) for the jewelry produced in developed nations. Such purchases are originated by the reasons of adornment or gift giving. On the other hand jewelry in China is sold for as little as a 10% or 20% mark-up from its intrinsic bullion value. Such crude jewelry has smaller premiums that are usually set by the U.S. or other national mints (Bernstein Research 1997). Thus, to some extent this share of world gold deposits can be viewed as investments.

The variable used in the regressions is estimated as the total world demand for gold jewelry measured in millions of troy ounces. Since it has been an important driving factor for the gold market I expect the coefficient on JEWELRY variable to be both positive and statistically significant.

Trade Weighted US dollar Index (Broad index) (T) - measurement of the US dollar value relative to other world currencies. Federal Reserve System calculates this index as geometrical average of bilateral exchange rates with country's main trade partners⁵. Normally their share is not less than $\frac{1}{2}$ percent of overall US export or import. Nominal dollar exchange rate index at time *t*, *l*_t is:

$$I_{t} = I_{t-1} * \prod_{j=1}^{N(t)} {\binom{e_{j,t}}{e_{j,t-1}}}^{W_{j,t}}$$

where e_{j,t} is the prices of the U.S. dollar measured in foreign currency j at time t; w_{j,t} is the currency j weight in the index at time t; N(t) is the number of foreign currencies used for calculation. This index is believed to be successful in summarizing major fluctuations of US dollar exchange rate (Federal Reserve 2005). Federal Reserve System reports Broad index on daily and monthly basis. For the purpose of this study an annual figures were calculated using the simple arithmetical average of monthly data (Federal Reserve n.d.).

Increase of the index value represents stronger dollar; it is expected that the correlation between index and gold price is negative. Indeed, data suggests that this relationship holds: the 1974 and 1980 gold price peaks coincided with the periods of weak dollar while low gold prices in 1985 and 1991 reflected much stronger positions of the US currency. It was noticed that index alone sometimes can completely explain the price fluctuations as it did from March 1985 to December 1987 when the index value fell 40% and gold prices rose roughly 67% (Bernstein Research 1997).

⁵ Federal Reserve System uses the dollar exchange rate statistics against the currencies of 26 economies (EU, Canada, Japan, Mexico, China, United Kingdom, Taiwan, Korea, Singapore, Hong Kong, Malaysia, Brazil, Switzerland, Thailand, Philippines, Australia, Indonesia, India, Israel, Saudi Arabia, Russia, Sweden, Argentina, Venezuela, Chile, Colombia)for this index.

Profit or **Mines' Profit** (R) - is the differences between the price of bullion and the average cash operating costs of production in the industry. The variable used here is calculated using the formula:

$$R_t = \frac{NP_t - C_t}{NP_t} = \mathbf{1} - \frac{C_t}{NP_t}$$

where NP_t - price of one ounce of gold; C_t - cash operating costs of production of one ounce faced by the average gold mine. Unlike another price variable described above here I use the nominal price which is non-adjusted for the inflation term. This allows measuring more accurately the stimulus for the gold mines to adjust their business volume according to the profitability level they face and avoid the correlation with the price variable in the model.

Level of profit is one of the crucial characteristic for the gold mining industry and it is very much tied with the output of gold. Due to natural reasons some of the world's gold deposits are more expensive to develop and conduct mining in comparison to the others. Hence, a mine can slow down the production or decide to opt out the activities if the price level drops below the certain level. Contrary under the high prices it becomes economically profitable to extract bullion from previously untouched depositories.

However this measurement captures other factors of mining industry besides gold. These are the risk of political instability in the countries producers of gold; geological searches for the new depositories or particular economic conditions like interest rates or storage costs that affect the business.

Despite the fact that this measure does not incorporate many other expense such as royalties, reclamation, exploration, interest expense, administration or taxes I believe

it captures the fluctuations of profitability for the industry. It is reasonable to assume that cash operating expenses compared to the price of gold is the correct indicator of business profitability. Research conducted on the example of South-Africa has shown that gold-mining stocks mirror the returns on gold (Jaffe 1989).

2.2 Summary statistics

Table 2 displays summary statistics of the data. The only variable that can have a negative value is net investments meaning that net sales by the central banks or the IMF are bigger in volume that the private investment purchases. The real price of the gold appears to be the most volatile variable in the sample while mines' profit and

	Mean	Median	Max	Min	Stand Deviation
Real Price	657,89	634,87	1611,23	332,62	257,60
Quantity	81,86	83,50	118,60	48,00	24,10
Net investors position	13,02	10,40	47,30	-8,60	13,43
Jewelry	60,14	62,5	95,6	19,2	22,78
Trade Dollar	82,38	83,78	126,67	35,09	29,87
Mines' Profit	0,77	0,78	2,20	0,26	0,39

Table 2 Descriptive statistics

net investors position are the least volatile. The total number of observations for the period is 33.

The observed period of 1977 - 2009 contains no major shock for the gold market. Unlike the early periods there was no foremost policy changes regarding usage gold as a currency. Despite the fact that during the time frame considered in the work several financial crises occurred (Lawrence 2003). Accordingly, their influence for gold market was not proved and hence this work does not have any specifications for any kind of such event as they are assumed not have large enough impact on the gold market. The explanation for this was found in the low correlation of the gold term with the major macroeconomic variables.

3 Model

I use the simultaneous equation model (SEM) to analyze the supply and demand in the world gold market. The common approach in estimating SEM is the two stage least squares method. This is an equation-by-equation technique, where the endogenous variables on the right-hand side of each equation are being instrumented variables *X* from all other equations. This method is called "two-stage" because it implies estimation in two steps. In the first stage, each endogenous variable in the equation is regressed on all of the exogenous variables in the model. In the second stage, the regression is estimated using OLS, except that in this stage each endogenous variable is replaced with the predicted values from the first stage.

Using eViews make it possible to avoid these two steps but estimatesting the final coefficients all at once. However I will also compute the model using OLS to compare the results.

3.1 Basic Model Specification

For this supply-demand model the jointly determined variables are market price P and quantity Q. I construct two simultaneous equations for each side: demand and supply:

$$Q_d = \alpha_0 + \alpha_1 P_t + \alpha_2 I_t + \alpha_3 J_{t+} u_t \qquad (Demand) \qquad (1)$$

$$Q_s = \beta_0 + \beta_1 P_t + \beta_2 R_t + \beta_3 T_t + v_t \qquad (Supply) \qquad (2)$$

Both of the equations consist of two endogenous variables (P and Q) s and two additional exogenous variables for each of the equations. Having the equal number of exogenous variables makes the system exactly indentified (Epple and McCallum 2004) (Wooldrige 2004).

As it was already mentioned Qd = Qs and it represents the total amount of gold sold in the world market during the year. Equation 1 regresses this variable on the price one ounce of gold (P), net investors position (I) and world jewelry demand (J). Naturally one would expect negative correlation between the gold demand and the price while the rest coefficients should be positive as higher interest in gold as an investment instrument and higher sales of jewelry inevitably will raise the overall demand for gold.

Second equation is designed to explain fluctuations on the supply side of the market. It incorporates two exogenous variables: profitability level of the gold mines (R) and the broad index of the US dollar (T). The average industry profitability is ought to be positively correlated with the total supply as higher returns encourage mines to boost the outputs. Index of the foreign exchange value of the dollar captures the characteristics of gold returns to move in opposite direction with the US currency. Weak dollar increases gold's attraction as a stable place to invest money and hence in case of the first more money are invested in the gold stocks (Tully and Lucey 2007). Thus I expect this factor to be negatively related to the world supply of gold since a higher number of the index represents the stronger dollar. Price, the endogenous variable in equation (2) is likely to be positively correlated with Q according to the economic theory principles.

For the consistency of the estimations it is essential for the exogenous variables to be uncorrelated with the error terms:

$$corr(\Delta I, u_t) = 0$$
; $corr(\Delta J, u_t) = 0$; $corr(\Delta R, v_t) = 0$; $corr(\Delta T, v_t) = 0$.

As it can been seen from the Table 5**Error! Reference source not found.** neither of these variables violates this requirements at 10% significance level.

Note that in order for the model to be correct $\alpha_1 \neq \beta_1$; in other words, consumers should behave differently from producers with the respect to price changes (Anderson 1991).

I will use the equations (1) and (2) written in the terms first difference: $\Delta X = X_t - X_{t-1}$.

$$\Delta Q = \alpha_0 + \alpha_1 \Delta P_t + \alpha_2 \Delta I_t + \alpha_3 \Delta J_{t+} u_t$$
(3)

$$\Delta Q = \beta_0 + \beta_1 \Delta P_t + \beta_2 \Delta R_t + \beta_3 \Delta T_t + v_t$$
(4)

3.2 Least Squares Estimates

I begin with the structural supply and demand equations estimation, initially using least squares methods. Here, and in results reported below, the figures in parentheses are the standard errors. The reported R²s are unadjusted; SE stands for the standard errors of the deviation of the disturbance term. DW is the abbreviation for the value of the Durbin-Watson test and N represents the number of observations. For all the regressions I use the White heteroskedasticity consistent covariance estimates.

Estimation of the supply equation using the OLS method shows the encouraging results (see equation 5). First of all both of the exogenous variables appear to be statistically significant and have the "proper" sign. Price of the gold is the only problem for now as it has a very low t-statistics (0,71) and positive coefficient. This suggests that the demand for gold increases as its price rise which is commonly known to be not true⁶. Serial correlation of the equation is somewhat disturbing since the DW value is far from 2.

$$\Delta Q = 0.371 + 0.001 \Delta P_t + 0.91 \Delta I_t + 0.95 \Delta J_t$$
(5)

⁶ There is no evidence for gold to be a Giffen good (<u>http://en.wikipedia.org/wiki/Giffen_goods</u>).

$$(0,20)$$
 $(0,001)$ $(0,06)$ $(0,06)$
 $R^2 = 0.95$ SE = 0.91 DW = 1.17 N = 32

Equation (6) estimates the supply function using the OLS method. At the first glance one can say that this equation is no good as an explanation model: only the endogenous variable is statistically significant at 10% level. The positive matter is that all the variables have the correct sign which was predicted earlier.

$$\Delta Q = 1,72 + 0,014 \Delta P_t + 5,68 \Delta R_t + 0,19 \Delta T_t$$
(6)
(0,95) (0,07) (4,85) (0,24)
$$R^2 = 0,09 \quad SE = 3,99 \quad DW = 2,16 \quad N = 32$$

The value of Durbin-Watson statistics is 2,16 which is very close to the optimal level and suggests practically no serial correlation in the model. Thus I have the reasons to believe that this set of exogenous variables is correct for the estimations and will keep it for the further exploration using different method.

3.3 Simultaneous Equation Estimates

This other method is Two-Stage Least Squares estimation (2SLS). I use the same equations but add all the exogenous variables to it as the instrumental variables. The demand equation estimated by the 2SLS yields the following results:

$$\Delta Q = 0,33 - 0,006 \Delta P_t + 0,88 \Delta I_t + 1,028 \Delta J_t$$
(7)
(0,23) (0,004) (0,05) (0,08)
$$R^2 = 0,92 \quad SE = 1,18 \text{ DW} = 1,55 \text{ N} = 32$$

Here the coefficient on the price has got the negative sign - the one predicted by the economic theory. The variables appear to be much more statistically significant than it appeared in equation (5) but it does not have the acceptable t-statistics still.

Despite the very low value of the coefficient it will not be right to assume low dependence of the world gold market size on the price. Due to the fact that (Q) is measured in millions of ounces and price in US dollars nobody can except the coefficient to be around one. In fact -0,006 suggests that one dollar increase in the price of ounce will reduce the demand for gold by 6 000 ounces or 186 kilos of gold ceteris paribus conditions. It makes over 7,25 million dollars measured by current prices⁷.

The two other variables - net investors position and jewelry production remains to be statistically significant. However, there is one important difference between those two variables. While jewelry production enters the equation with the coefficient almost equal to 1, the coefficient on the other is somewhat close but statistically different from this value. It suggests that market is less responsive towards the changes in investors' expectations than it is to speculative demand. One possible explanation for this finding is the much bigger share of the gold market that belongs to the jewelry in comparison to the physical trade in the investment sector.

In general, the equation has a very good R^2 value and even lower serial correlation that before. This is the evidence that the model explains the demand side of the market very well despite the problems with the significance of the price variable.

Now I turn to the supply function which is estimated using the 2SLS method. Here one can observe even more unambiguous results (equation 8).

$$\Delta Q = 0.31 + 0.112 \Delta P_t + 56.14 \Delta R_t + 0.91 \Delta T_t$$
(8)
(1.96) (0.05) (29.3) (0.54)
$$R^2 = -3.64 \quad SE = 9.03 \quad DW = 2.25 \text{ N} = 32$$

⁷ One troy ounce of gold was priced at \$1208 on May,26th according to http://www.goldprice.org/

All the right hand side variables appear to be significant and enter the equation with the "correct" sign. Price appears to be much more important for the supply side of the market. It can be explained by the exposure of the producers to the cost of mining and reluctance to operate below the profit line. Now the same is not true for the majority of the gold buyers. Apart from those who use gold for industrial purposes⁸ they do not have clear analogue reference-point.

Trade weighted US dollar Index has a very interesting coefficient statistically close to 1 suggesting that one point yearly average index change shrinks or boost the world gold supply by one million ounces. This result to some extent resembles findings of other papers who tested the influence of the US currency on the gold market (Tully and Lucey 2007), (Lawrence 2003).

The average profit level of the gold mining industry is the significant determinant of the total gold supply on the market. A very high absolute value of the coefficient suggests high sensitivity of the market to the level of profitability.

Negative R² of the equation does not necessary implies worthlessness of the model. In fact it was admitted by many that this measure works well for the OLS method but not for 2SLS (Tomek 1973). The unexplained variation of the equation appears to be larger than the total variation implying a negative R2. Unlike the single equation system, 2SLS does not minimize the residuals but employs the maximum likelihood estimator (Power and Reid n.d.).

In order to estimate the goodness of fit for this model I will calculate the square of the correlation coefficient between the actual and fitted data values using the following formula (Everitt 2006):

⁸ Industrial demand constituted around 12% of the total demand for gold (CPM Group 2009).

$$\rho = \frac{E[(X - \mu_X)(\bar{X} - \mu_{\bar{X}})]}{\sigma_X \sigma_{\bar{X}}}$$

X represents the actual values of Q and \tilde{X} - the one obtained by the model. The estimated numbered is brought to the power of two and hence has to lie in the rage of [0;1]. Goodness of fit calculated for the equation (7) is 0,95 which is very close to its R² value. The correlation between fitted and actual values for the equation (8) is 0,28, which makes 0,08 when squared.

Despite the fact that this method of estimating goodness if fit it approximate it shows that the huge part of the gold supply is left unexplained by the model while the demand is very well explained.

Finally, I have to note that the previously stated assumption that $\alpha 1 \neq \beta 1$ holds - the coefficients on price variable in equations (7) and (8) are different.

4 Results

In order to illustrate the results I plot the demand and supply functions according to the estimated results. I begin deriving equation (3) neglecting the error terms:

$$\Delta Q = \alpha_0 + \alpha_1 \Delta P_t + \alpha_2 \Delta I_t + \alpha_3 \Delta J_t$$
(9)

For any variable, $z: \sum_{s=0}^{s=t} z_s = z_t - z_0$ (Epple and McCallum 2004). Adding up both sides of the previous equation over the interval [0,t] the demand function can be written as the following:

$$Q_{t} - Q_{0} = \alpha_{0} - \alpha_{0} + \alpha_{1}(P_{t} - P_{0}) + \alpha_{2}(I_{t} - I_{0}) + \alpha_{3}(J_{t} - J_{0})$$
(10)
Let $\lambda = Q_{0} - \alpha_{1} P_{0} - \alpha_{2}I_{0} - \alpha_{3}J_{0}$

Now plugging it back to the equation (9) we obtain:

 $Q_t = \lambda + \alpha_1 P_t + \alpha_2 I_t + \alpha_3 J_t$ and solve it for Pt what will make it possible to obtain an equation for the demand curve at date t.

$$P_{t} = (Q_{t} - \lambda - \alpha_{2} I_{t} - \alpha_{3} J_{t}) / \alpha_{1}$$
(11)

 λ can be easily calculated using the estimates from the equation (7): λ = 10,1. Substituting λ and coefficients on exogenous variables into equation (11) and plugging the values of I and J for the year t yields the demand equation for the year t. In order to get the numerical values example I chose two years: 1982 and 2008. These years are of the special interest for this study as one can observe huge nominal price increase during these years. The demand function for the 1982 is:

$$P_t = 8831,69 - 166,667 \, Qt$$
 (12)

and for 2008 it is:

$$P_t = 17510 - 166,667 Qt$$
 (13)

By analogy supply equations can be estimated using the equations (2) and (8):

$$P_t = 8,93 \text{ Qt} + 292,73$$
 (14)

and for 2008 it is:

$$P_t = 8,93 \text{ Qt} - 21,1$$
 (15)

Using equations (12) through (14) I have plotted the demand and supply functions for the respective years (see Figure 4 and Figure 5). These graphs are consistent with common understanding of such graphs except for the very steep slope of the demand function. To my mind this is an evidence of very inelastic demand for gold. It can be explained in a following way. Lower prices for the bullion encourage consumer demand; individuals are willing to buy jewelry for the reasons of for reasons of adornment or gift giving. Inflation hedging strategies and speculative demand are driving up prices and assure continues demand at the peak of the price growth. Combined this two factors cancel out each other keeping the demand for gold in a relatively narrow corridor.

Looking at the statistical data one can only observe equilibrium outcomes - while the graphs show what would be the supply or demand for gold in particular year had the price been different from the equilibrium values (Wooldrige 2004).

Table 3 shows the comparison of the actual values of the gold price and quantity versus the predicted by the model. Three out of four predicted values are smaller than the observed. The bias lay in the range of 4 to 15 percents. This might be the evidence that the error term still contains something unexplained.

Year	Equilibrium Price	Equilibrium Quantity	Observed Price	Observed Quantity
1982	726,91	48,63	845,36	50
2008	870,31	99,84	868,08	118,6

 Table 3 Observed vs Predicted values

In general one can see a clear shift of the equilibrium to the right suggesting higher turnover of the market. I believe that in the future this trend will continue to exist due to the fact that consumption of gold does not mean its physical annihilation and hence the volume of the market will expand.

The provided above estimations can be biased due to the following circumstances. First of all, a very important question that arises here is whether it is correct to use only the US dollar-measured price for the total world gold market. My reason for using dollar was the fact that prices are usually denominated in this currency and many researchers have pointed out its big influence (Lawrence 2003), (Tully and Lucey 2007). However, the US markets constitutes only around 12 % of the total gold demand (World Gold Council 2001), while most of the consumers earn and buy gold in a different currency. Figure 3 shows comparison of the gold prices denominated in four currencies that are used in the countries with major shares of the market (CPM

Group 2009). It is obvious from the table that price fluctuations in this case are far from being coherent. This leaves questions for the further researches of the topic.

The role of gold as we see it now - with no currency backed by it has been established relatively recently. This gives not many observations with annual pace which is the only possible for this market. Thus the lack of observations can cause the correlations to be biased.

Finally, for a significant period of time in the data sample the figures can be biased in one way or another as there was unreliable reports coming from the communist and some of the third-world countries (World Gold Council 1999).

However, despite the mentioned above problems, estimated results are consistent with the economic theory and with the previous findings on the topic. Since the work does not have the predecessors in form of papers that use the same approach I cannot compare the exact figures I got but the general idea, which in my mind describes the gold market very well.

Conclusions

This thesis looks at the world market of physical gold over the period of last thirty years. I examine the supply and demand side of it using the annual data in the global scope. Two different equations were constructed and estimated using the Two Stage Least Squares method.

Since only the equilibrium values can be observed for the each year, simultaneous equation method employed here allows answering the questions: how much gold the market will be willing to provide and how much consumers and investors will be willing to buy if the prices were different. In order to control for the other factors that influence the preferences of the market players I control for the number of exogenous variables.

The results suggest high influence of the exogenous variables on the volume of the world market. It was found that the price does not have as big influence on the demand side as it has for the supply. The reason for this is believed to lay in the investment demand and inflation hedging strategies that generate extra demand during the period of high prices. The factors that influence the demand are net investors position and the volume of the jewelry market. Supply side is determined by price, the average level of profit in gold mining industry and the strength of the US dollar measured by the Broad Trade Weighted Index.

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Appendix Table 4 Correlations (3 years ending 25 September 2009, weekly returns)

Data: Global Insight, Barclays Capital, WGC

	Gold	Silver	Oil	CRB Index	DJ AIG Commodity Index	MSCI World excl. US	DJ Industrial Average	S&P 500	Wilshire 5000	BarCap/Global Treasuries Index	BarCap/High Yield Bond Index	BarCap/US Credit Index	Dow Jones/Wilshire REITS Index	3- Month T- Bill Yields
Gold	1													
Silver	0,82	1												
Oil	0,34	0,41	1											
CRB Index	0,25	0,38	0,61	1										
DJ AIG Commodity Index	0,43	0,47	0,74	0,76	1									
MSCI World excl. US	0,11	0,26	0,5	0,62	0,62	1								
DJ Industrial Average	-0,12	0,02	0,29	0,41	0,4	0,82	1							
S&P 500	-0,07	0,08	0,33	0,44	0,44	0,85	0,98	1						
Wilshire 5000	-0,05	0,09	0,34	0,45	0,46	0,86	0,97	1	1					
BarCap/Global Treasuries Index	0,34	0,34	0,12	0,09	0,1	0,1	-0,21	-0,16	-0,16	1				
BarCap/High Yield Bond Index	0,07	0,15	0,19	0,28	0,11	0,04	-0,02	0	0	0,05	1			
BarCap/US Credit Index	-0,09	Collect EC	0,05	0,24	0,05	0,23	0,04	0,07	0,07	0,45	0,38	1		
Dow Jones/Wilshire REITS Index	-0,01	CEU G LD	0,09	0,04	0,01	0	0,02	-0,02	-0,02	0,16	0,1	0,22	1	
3-Month T- Bill Yields	-0,23	-0,06	0,12	0,23	0,16	0,28	0,2	0,24	0,25	-0,08	0,13	0,01	-0,11	1

Table 5 Correlation of the exogenous variables with the error term
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	Net investors position	Jewelry Demand	Mine's Profit	Trade Weighted US dollar Index
Coefficient	-4.19E-15	8.81E-15	-0.108	-0.191
S.E.	-3.59E-15	9.36E-15	-1.691	-0.251

Figure 1 Total World Gold Reserves



Source: WGC based on IMF data and national sources

Figure 2 Yearly average Prices Denominated in Major Currencies



Source World Gold Council:



Figure 3 The five year daily gold price (per oz) in selected currencies



Figure 4 Demand and supply curves, 1982

Figure 5 Demand and supply curves, 2008

