The Oil-Dollar Exchange Puzzle

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ABSTRACT

Many efforts have been put into analyzing the relationship between oil price fluctuation and US dollar exchange rate changes. Krugman, in his 1980's paper, shows that the direction of the effect depends on a comparison between the magnitudes of change in balance of payments from higher oil price fluctuation and change in balance of payment from adjustment of OPEC consumption. Empirical evidences have proven that oil price fluctuation has significant effect on the value of US dollar; while the reverse impact is still unclear, most available studies indicates statistically meaningful results yet not so significant impacts. This paper investigates the potential effects of Euro-US dollar exchange rate fluctuations on the oil price. We propose theoretical explanation from the perspective of purchasing power channel-transmission, and test it with causal empiricism.

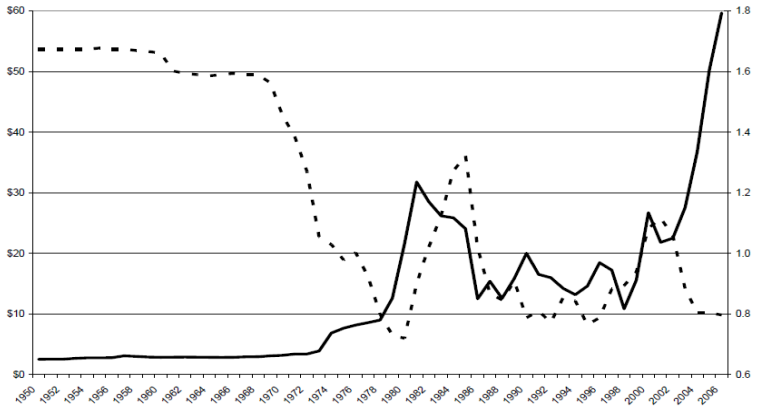
1. Briefs of Oil and Dollar Exchange Rate

Crude Oil price and US dollar exchange rates are two key subjects under frequent scrutiny for their significant implications on international trade of general commodities, global level of inflationary pressure, energy outlook and especially economic growth. The relationship between these two factors, particularly the interaction and direction of causal effects, influencing and under the influences of the macro-economic conditions mentioned above, has been studied extensively. Many studies on this topic estimate the value of US dollar with US trade-weighted exchange rate. In this paper, Euro-Dollar exchange rate is adopted to approximate the nominal exchange rate. Our justification for this adjustment is the high weight of Euro in the Geneva I+U.S. dollar currency basket, which amounts to 46.6% (Mazraati, 2005). It is also worth to point out here, that the weight of euro will probably shrink due to the uprising of emerging developing markets and their large demand of oil. This section briefly examines the history of oil pricing and Euro-Dollar exchange rate, and provides justification for the emphasis on OPEC's influences in oil price.

1.1 General Timeline of Oil Price and Euro-Dollar Exchange rate

A brief history of oil price and Euro-Dollar exchange rates from 1950 to 2005can be roughly divided into three phases. The graph below depicts the annual time series of nominal dollar/euro exchange rate and crude oil prices (EIA), black line represents crude oil price, and dashed line is the USD/EUR exchange rate.

Figure 1: Annual Time Series between USD/EUR and Oil Prices



During the first phase from 1950-1980, the large negative correlation of oil price and Euro-USD is visible. This period of time experienced the rise and fall of the Bretton Woods system, and exerted great stability in the exchange rate. The establishment of OPEC in 1960 also helped regulate and maintain oil price below $3. The breakout of first oil crisis in 1973 drove up oil price from $2.9 in September to $11.65 per barrel in December, the upward trend didn't end until the subsequent oil crisis and panics sent price further up to $34 per barrel. In parallel, in 1971, the discontinuation of gold full convertibility of US dollar causes the value of US dollar to drop as low as $0.8 per Euro. Since oil is traded in US dollar, oil-export countries suffered from decreasing purchasing power of their oil revenue and increasing cost of the imports from Japan and Germany.

The second phase from 1980 to 2000 saw reduced degree of correlation and less volatility. The period during 1980 to 1990 actually produced positive correlation. The negative correlation resumed after 1990. Facing with the low value of dollar and stagflation, the new Fed Chairman Paul Volcker restrained monetary policy by imposing higher interest rate. Dollar temporarily regained its strength but collapsed again in 1986, following the Plaza Accord. Crude oil price experienced similar trend of rise and fall, followed by frequent fluctuations due the collapse of OPEC. In 1985, Saudi Arabia stopped acting as the swing producer with abundant spare capacity, and actually linked their oil prices to crude spot market and doubled their extraction quantity, which led to further drop of oil price. In 1990, the oil price picked up slightly when Iraq invaded Kuwait. But later declined again when demand falls during the Asia crisis in 1997-1998.

The third phase from 2000 till now witnessed the soaring of the oil price, which is arguably caused by increasing demand in emerging markets. OPEC underestimated the economic recovery of the Asian countries and underinvested in new field exploration, and failed to react to demand surge. From 2007 to 2008, oil price saw further rise and broke the $120 ceiling. At the beginning of 2000s, US dollar appreciated with the support from short-lived booming of US economy, which ended quickly after 911 attack. In mid-2000s, the positive interest rate differential and negative growth differential between US and EU were enlarged, which added negative pressure on the exchange rate.

This brief overview suggests the importance of geopolitical and economic events in influencing oil price, US dollar and the interconnections between these two factors. In an effort to formulate and interpret a possible causal relationship, a variety of factors should be taken into consideration simultaneously.

1.2 Why OPEC Matters

OPEC, the Organization of the Petroleum Exporting Countries, was founded in Baghdand, Iraq in 1960, and based its headquarter in Vienna since 1965. Its 12 members are major oil-exporting countries. Besides serving and ensuring the best interest of the member countries, the organization has also been making effort to stabilize the price in the international oil market by providing a constant and efficient supply of petroleum to oil-consuming nations. OPEC owns 81% of the world's total proven oil reserve, as shown in Figure 3 below, and accounts for on average of 35% of the total world oil supply over the years. This 35% empowers OPEC to have a strong position in setting the oil price.

Figure 2

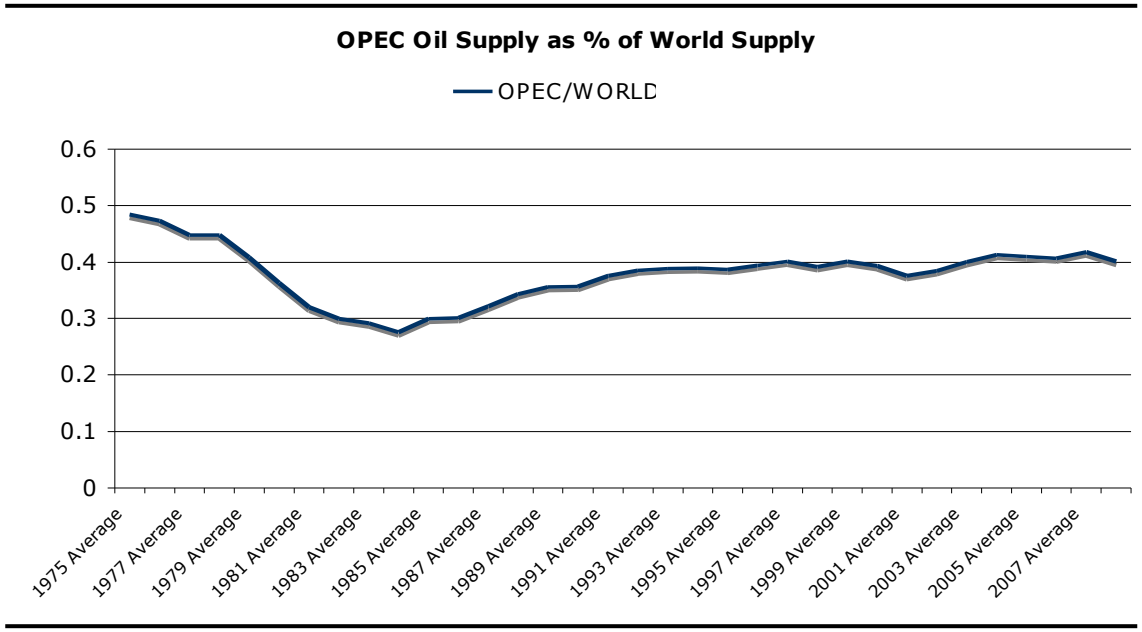
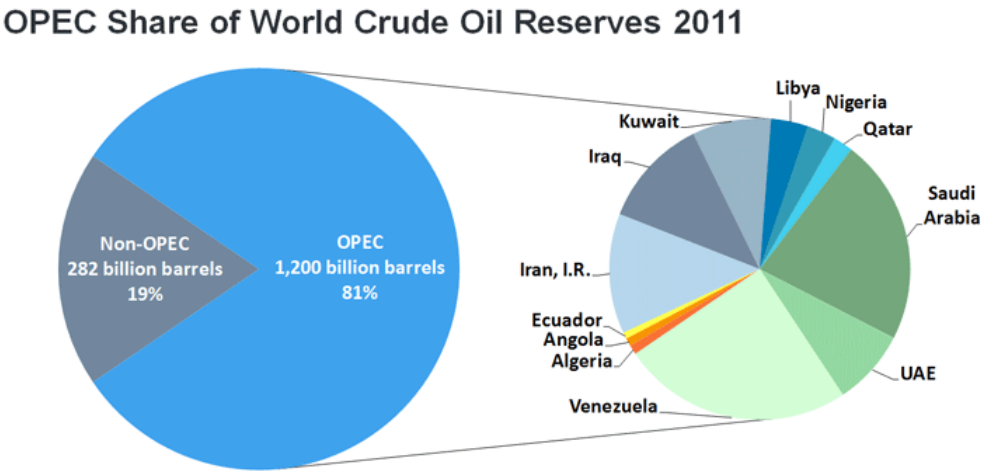


Figure 3



OPEC proven crude oil reserves, end 2011
(billion barrels, OPEC Share)

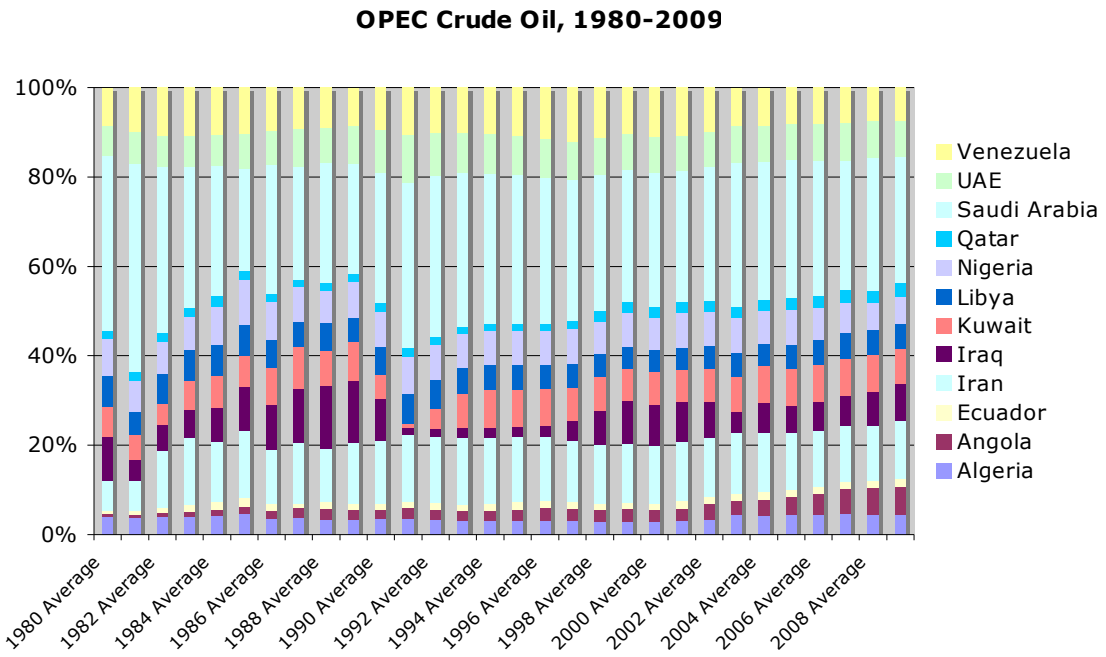
Venezuela	297.6	24.8%	Iraq	141.4	11.8%	Libya	48.0	4.0%	Algeria	12.2	1.0%
Saudi Arabia	265.4	22.1%	Kuwait	101.5	8.5%	Nigeria	37.2	3.1%	Angola	10.5	0.9%
Iran, I.R.	154.6	12.9%	United Arab Emirates	97.8	8.2%	Qatar	25.4	2.1%	Ecuador	8.2	0.7%

Source: OPEC Annual Statistical Bulletin 2012

However, setting a balanced price that is high enough to be lucrative and not so high to disrupt the market is a tricky and delicate matter. On one hand, OPEC member countries depends on Oil exports as their major source of revenue, so they want to keep the oil price at relatively high and stable level. At the same time, OPEC fears that high oil price would making their oil less competitive, and diluting the market with cheap oils from Russia. In the long-run, it would trigger new oil explorations and make oil-consuming countries more inclined to alternative energies.

Among the OPEC member countries, Saudi Arabia has the second most reserve and plays a special role. Its close relationship with US and relatively pro-US attitude is partially reinforced by the fact that large proportion of its oil revenue is recycled back to United States in forms of capital and assets investment. Under these constraints, Saudi Arabia is more eager to stabilize oil price and more conservative toward oil production, by putting aside sufficient amount of spare capacity, approximately two million barrels per day. This spare capacity enables Saudi Arabia to fill the gap to stop price swings in case an external shock reduces the oil production in some oil-exporting nation, making it the price leader.

Figure 4



The ability of OPEC to quickly react to shortage and excess demand, added in its large shares in the oil market, allows it to stabilize the market under all kinds of negative external shocks. The one we are interested in is the shock generated in exchange rate fluctuations. The trading pattern of OPEC, the fact that oil export invoiced in US dollar and commodity import is paid in Euro, make it vulnerable to Euro-USD exchange rate variation. When USD depreciates against Euro, imports from EU becomes more expensive, at the same time, investment in USD denominated assets losses money. Theoretically, in reaction, OPEC would reduce the oil production to drive up oil price, thus to prevent or even compensate the loss. The crucial role of OPEC in oil price adjustments and the exchange rate variation in motivating the price adjusting mechanism are also justifications of using Euro-USD exchange rate as estimates of US effective exchange rate. This purchasing power channel will be further discussed in section 2.

1.3 Oil Futures Market

The oil futures market serves as another mechanism to predict oil price and provides both buyers and sellers some flexibilities against external shocks, for instance, natural disaster, worker strike or social instability. A futures contract promises a trade of a given quantity

of a standardized commodity at a previously agreed-upon price and place in the near future. The price in the oil futures market represents a realistic prediction of the supply and demand relationship. Firms are able to negotiate oil contracts based on the current trend of the futures market; they can also utilize the futures contracts to hedge against price fluctuations.

There are three major oil futures exchange market, NYMEX in New York, International Petroleum Exchange in London, and the Singapore Exchange. The trading prices in the three markets differ because each exchange posts its unique base price based on different types of crude oil; every other type of oils are traded on prices after price adjustments to the base crude, which are determined by both the quality and easiness of being transformed into high-value product as compared to the base crude. Take the NYMEX as an example, its base price is the prices of West Texas Intermediate since it is the highest quality crude oil to flow into US through Texas Gulf Coast ports.

Among the hundreds and thousands of contracts conducted everyday in the oil futures market, only a very small fraction of them are actually delivered, and most of them will be retraded according to the conditions in the market. This constant flow of trades and fluctuation of prices provides abundant information for predicting future spot price of oil contracts. Any slight alteration of oil-related market conditions, such a general strike or civil war can affect trader's confidence and expectation, and is instantaneously reflected in the revisions of oil price. It's no wonder that all the traders are news junkies and are sensitive to every bit of market swings.

2. Theoretical and Empirical Literature Review

Oil price is usually composed of three major components, the "basic" production cost, the fluctuation caused by short-term supply and demand alteration, and finally the price fluctuation associated with market expectation. The "basic" production cost covers cost with regard to oil exploration, drilling, and transportation of oil from oil to downstream refinery. This component is relatively stable in the short-term. And the adjustments of cost are systematic across all parties related to oil business. Supply and demand affects short-term oil price formation, and is prone to changes in macro-economic conditions. Expectation alteration is the most sensitive and volatile component among the three

components, and all factors influencing oil price probably goes through shaping expectations first.

A variety of factors cause oil price fluctuations by affecting any of the three components. Oil price reacts to assorted geopolitical and economic events, observable from both supply side and demand side. Iranian revolution and Arab Oil Embargo during the late 1970s reduced oil supply and caused a soar in oil price, and it peaked to $80 when Iran-Iraq war broke out. Contrarily, oil price dropped below $20 during the Asian financial crisis, when demand fell sharply. The period from 2002 to 2008 is a relatively high-growth and low volatility period for the world, especially for the emerging economies, with ever-increasing appetite for oil. Factoring in the fact that United States was entangled in two wars and Mideast was in chaos, the oil prices skyrocketed and broke the $120 ceiling; then only followed by the dramatic reversal of course when global financial crisis exploded, causing universal cuts in consumption, making the case for the strong impact embedded in the health of the macro-economy of oil-importing countries on influencing oil consumption and price.

2.2 Theoretical Model

The link between oil price and USD exchange rate is only natural for the fact that the most commodities are invoiced in USD. For countries with floating exchange rates, it is efficient and optimal to evolve with fluctuation of the value of dollar, yet also suffers from extreme swings of dollar values translating into commodity prices, for instance, crude oil. We propose here to explain the possible negative link between oil price and USD through purchasing power channel. Both the supply side and demand side will be considered.

Consider the scenario in which USD depreciates against Euro, to protect the purchasing power of their USD denominated export in terms of their Euro denominated imports, the oil-exporting country will react to increase the export price. The magnitude of such mechanism depends on the proportion of goods priced in dollar relative to goods priced in other currencies in their trade structure (Schulmeister, 2000). Most oil-exporting

countries collect oil revenue in US dollar and spends Euro when consuming goods from Europe; thus, they are especially prone to double-effects from change in Euro-USD exchange rate, and have incentives to increase export prices.

The price-setting capacity of OPEC is already discussed in section 1.2, However, this channeling effect is only effective and feasible when two other conditions are met. These are: first, US dollar as the trade and vehicle currency; second, goods from Europe constitutes great portion of their total imports.

As to the first condition, US dollar is the world's reserve currency and is universally adopted as invoicing currency in commodity goods trade, including crude oil. In 1973, shortly after the collapse of the Bretton Woods System, Saudi Arabia started to accept only US dollar as the payment for oil. By 1975, all OPEC members adopted the same system, selling oil in US dollar. The decision to invoice US dollar for oil, and later extended for commodity exchange, is probably due to U.S.'s reputation of a dominant and stable economy and the maturity of its financial markets. This petrodollar system is brilliant and beneficial for the US economy, creating an ever-growing international appetite for US dollar. And since many oil-exporting countries reinvest their oil revenues back in US treasuries, the rest of the world essentially supports both US government and private spending. The dollarization is advantageous for the oil-exporting countries for their dependence on the export of a single commodity, crude oil, and it lowers the transaction cost incurred in goods exchange, and also attracts foreign investment for their connection to the dollar. The downside is also self-evident, monetary expansion in US can easily transmit the subsequent inflationary power to oil-exporting countries, on top of the already high inflation level caused by rising oil price. Recent developments seem to suggest a deviation of the OPEC countries from petrodollar system to euro or a broader basket of currencies. Nevertheless, in the short-term, US dollar still dominates the commodity trades.

As to the second condition, the structure of trade for oil-export countries is rather asymmetric. On the export side, since oil is traded in US dollar, it is reasonable to

consider that all oil exports are going to areas where US dollar is in use. On the import side, 2005 data from ECB indicates 41.9% of the total imports for the ten major oil exporter are from EU, 29.2% from Euro area, 25.4% from Asia, and only 6.8% from U.S(ECB, 2007), making EU the most important source for consumption and investment, and Euro-USD exchange rate the critical and widely influencing.

Above discussed the story of the supply side, the demand side is comparably simple. Fluctuations of Euro-USD exchange rate break the equilibrium condition in the oil market. Oil is less expensive for importing-countries when dollar depreciates, which stimulates their demand for petroleum and related products. In the short-run, supply would react fast enough to reach a new equilibrium; excess demand pushes up the oil price. Breitenfellner and Cuaresma (2008) discoveries a highly negative correlation of -

Paper	Causality	Theory	Period	Exchange rate Data	Oil Price Data	Regression Model	Result
Yousefi and Wirjanto,2005	USD → oil	Purchasing Power channel	1989-1999	REED USD	Monthly spot price	OLS Standard error corrected	Negative export price elasticity
Chen, 2008	USD → oil	Purchasing power, local price, investment and monetary channel	1980-2007	NEER and REER USD	Average Petroleum spot price	Dynamic OLS	Short- and long-term negative
Breitenfellner and Cuaresma, 2008	USD ↔ oil	Purchasing Power channel	1983-1996	NEER USD	Monthly spot Price	AR/VAR/VEC	Short-and long-term negative
Huang andTseng, 2010	USD ↔ oil	Purchasing Power channel	1983-2008	NEER USD	Monthly Spot Price	VEC	cointegration, long-term negative
Novotny, 2012	USD → oil	Purchasing Power and investment Channel	1994-2010	NEER USD	Monthly spot Price	GLS, standard error corrected	Negative after 2005
Zhang, *et al,* 2008	USD → oil	-	2000-2005	NEER USD	Monthly spot price	VARM/ARCH	Cointegration, long-term negative

0.81 between European demand for oil and its related products and Euro-US dollar exchange rates, based on annual BP data from 1965 to 2007.

2.3 Relevant Studies

Many other theoretical explanations are proposed and examined by empirical works. The table above summarizes a variety of relevant empirical works on the link between oil price and the value of USD. Over the years, amounting research works have amounted increasing support for the negative relationship between oil price and US dollar, carried through the effects of exchange rate fluctuation. Chen (2008) confirms both short- and long-term negative impact of US dollar on Euro from 1980 to 2007, except for certain time periods of 1980s. Yousefi and Wirjanto (2005) show, for data from 1989 to 1999, US dollar depreciation leads to upward adjustment of oil price, under error corrected OLS model. Breitenfellner and Cuaresma (2008) illustrate the subjects from the perspective of Euro-Dollar exchange rate and find both short- and long-term significant impacts on the oil pricing fluctuation.

However, there are disagreements. Schimmel (2008) tests data from 1985 to 2006, and concludes the lack of cointegration and the independence of two trends. Earlier works done by Amano and Norden (1997) confirms the correlation between the two factors but denies the one-way causal effect on oil price from US dollar valuation. Overall, the correlation is unanimously agreed to be statistically significant, but the direction of causality still remains rather obscure. Recently, the new development in the subject field is the investigation of causality between US dollar value and general commodity price, which might reveal more insights into the dollar-oil price puzzle. Clements and Fry (2006) investigate and estimates the joint determinants of the prices of both currencies and commodities using Kalman filter, and concludes that currencies are indeed driven by commodities and the reverse causation also exists during the period 1975 to 2005.

3. Data and Methodology

3.1 Data

In this study we analyze the relationship between USD/EUR exchange rate and oil price, using monthly time series data from January 1999 to June 2012.

The data are from Federal Reserve Economic Data database. The main variables for our study are USD/EUR exchange rate and oil price which is in U.S. dollar per barrel (West Texas Intermediate).

3.2 Model

We want to exam whether USD/EUR exchange rate can predict oil price. However, since current oil price may be correlated to past oil price and past USD/EUR exchange rate, a time series model is more accurate than a simple line regression model.

In this study, we use vector-autoregressive(VAR) model to analyze the relationship. A vector-autoregressive (VAR) model is a multi-variate way of modeling time series. We have two series (USD/EUR exchange rate and oil price) and want to explain these two with their own past realizations and past realizations of the other series.

A simple bivariate VAR(2) process is:

$y_t = c_2 + \varphi_{21}y_{t-1} + \varphi_{22}y_{t-2} + \varphi_{23}x_{t-1} + \varphi_{24}x_{t-2} + \varepsilon_{2t}$

$x_t = c_1 + \varphi_{11}x_{t-1} + \varphi_{12}x_{t-2} + \varphi_{13}y_{t-1} + \varphi_{14}y_{t-2} + \varepsilon_{1t}$

where xt = log of USD/EUR exchange rate and yt = log of oil price

In general, our VAR(p)-process model would be:

$Y_t = c + \varphi_1 Y_{t-1} + \varphi 2 Y_{t-2} \ldots \varphi_p Y_{t-p} + \varepsilon_t$ where ε_t ： iid $N(0,\Sigma)$

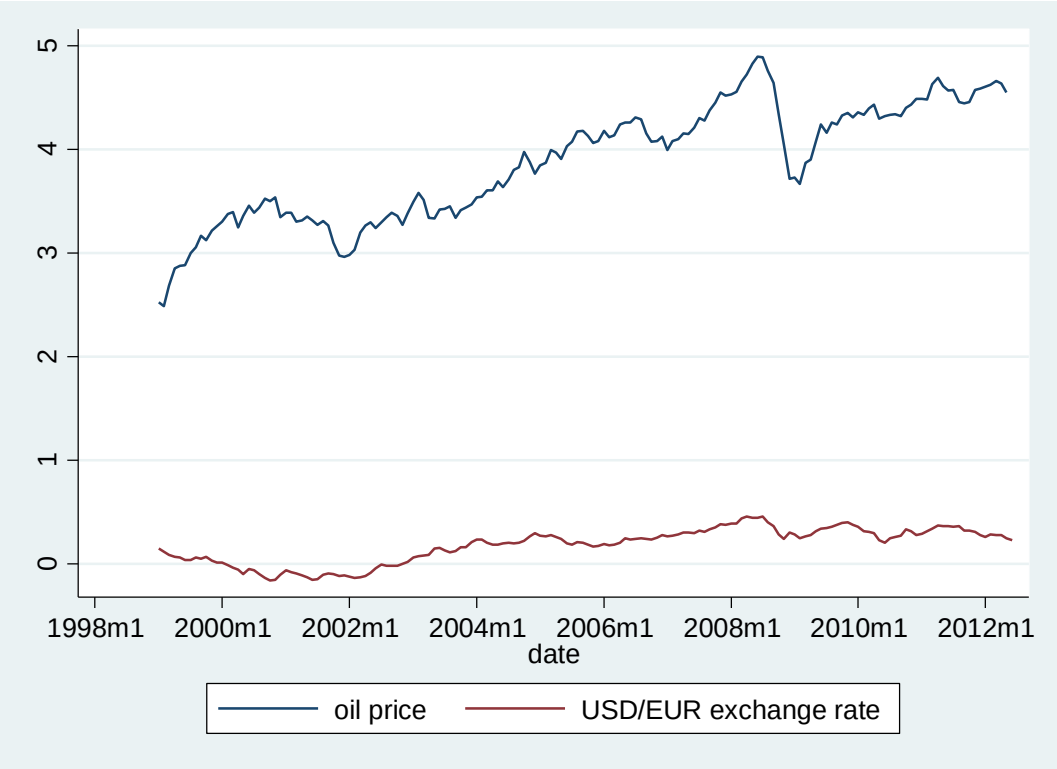
where p is the lag length, c a vector of constants, Σ the variance-covariance matrix of the error term and Yt a vector containing the different time series.

3.3 Stationarity

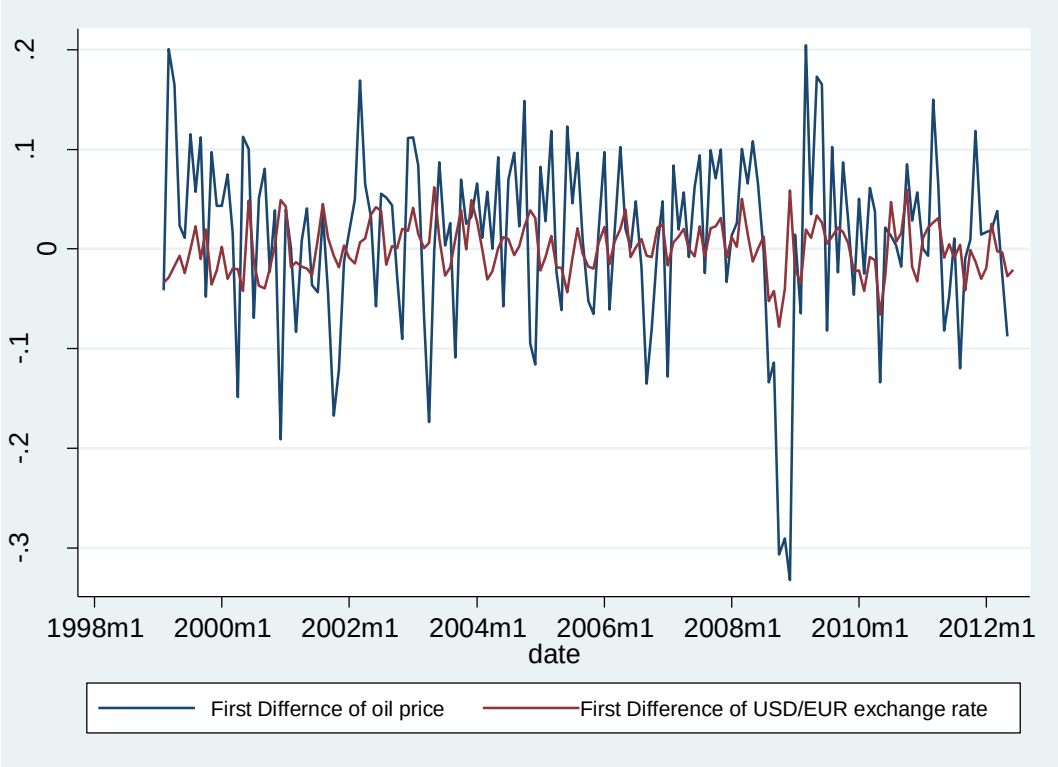
To estimate a VAR-model properly, we need stationary data.

First, we plot the series to find out if the series is stationary.

Taking a look at the monthly oil price and USD/EUR exchange rate from January 1999 to June 2012 shows us a non-stationary time series having a trend already.



Since the series is not stationary, we generate a first differenced version:



The first differences show no obvious trend.

3.4 Estimate a VAR

We first use the standard command without any options, and then determine the lag-length after the estimation.

Standard estimation:

```
Vector autoregression

Sample:  1999m4 - 2012m5                        No. of obs      =       158
Log likelihood =  535.2878                      AIC             = -6.649213
FPE            =  4.44e-06                      HQIC            = -6.570494
Det(Sigma_ml)  =  3.91e-06                      SBIC            = -6.455378

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
fy                     5     .085268   0.0857   14.81069   0.0051
fx                     5     .024435   0.1037   18.27043   0.0011
----------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
fy           |
          fy |
         L1. |   .2238791   .0791654     2.83   0.005     .0687178    .3790403
         L2. |   .0778231   .0790196     0.98   0.325    -.0770524    .2326986
             |
          fx |
         L1. |   .3231321   .2795849     1.16   0.248    -.2248443    .8711085
         L2. |   .0205594   .2787991     0.07   0.941    -.5258768    .5669956
             |
       _cons |   .0073477   .0067997     1.08   0.280    -.0059794    .0206747
-------------+----------------------------------------------------------------
fx           |
          fy |
         L1. |    .011681   .0226862     0.51   0.607    -.0327832    .0561451
         L2. |   -.002408   .0226444    -0.11   0.915    -.0467903    .0419742
             |
          fx |
         L1. |   .3260275   .0801199     4.07   0.000     .1689955    .4830596
         L2. |  -.1341014   .0798947    -1.68   0.093    -.2906921    .0224893
             |
       _cons |   .0006802   .0019486     0.35   0.727    -.0031389    .0044993
------------------------------------------------------------------------------
```

Now, we need to decide the number of lagged differences to include in the estimations.

```
Selection-order criteria
Sample:  1999m7 - 2012m5                     Number of obs      =       155
+---------------------------------------------------------------------------+
| lag |    LL      LR      df    p      FPE       AIC      HQIC      SBIC    |
|-----+---------------------------------------------------------------------|
|  0  |  510.472                     4.8e-06  -6.56092  -6.54497  -6.52165  |
|  1  |   521.82  22.696*   4  0.000  4.4e-06* -6.65574* -6.60789* -6.53793* |
|  2  |  524.481  5.3227    4  0.256  4.5e-06  -6.63846  -6.55871  -6.44211 |
|  3  |  525.678  2.3933    4  0.664  4.7e-06  -6.60229  -6.49064   -6.3274 |
|  4  |  527.581  3.8063    4  0.433  4.8e-06  -6.57524  -6.43168  -6.22181 |
|  5  |  529.284  3.4059    4  0.492  4.9e-06   -6.5456  -6.37014  -6.11363 |
+---------------------------------------------------------------------------+
Endogenous:  fy fx
 Exogenous:  _cons
```

It turns out that according to information criteria AIC, the optimal lag-length is one lag.

Using only one lag, we get the result:

```
Vector autoregression

Sample:  1999m3 - 2012m5                          No. of obs      =       159
Log likelihood =  533.5479                        AIC             = -6.635823
FPE            =  4.50e-06                        HQIC            = -6.588795
Det(Sigma_ml)  =  4.17e-06                        SBIC            = -6.520015

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
fy                     3     .086408   0.0698   11.93471   0.0026
fx                     3     .024474   0.0910   15.92048   0.0003
----------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
fy           |
          fy |
         L1. |   .2377826    .078352     3.03   0.002     .0842154    .3913498
             |
          fx |
         L1. |   .2713272   .2721169     1.00   0.319    -.2620122    .8046665
             |
       _cons |   .0096117   .0068636     1.40   0.161    -.0038406     .023064
-------------+----------------------------------------------------------------
fx           |
          fy |
         L1. |   .0089435   .0221921     0.40   0.687    -.0345523    .0524392
             |
          fx |
         L1. |   .2931897   .0770732     3.80   0.000      .142129    .4442505
             |
       _cons |   .0004883    .001944     0.25   0.802    -.0033219    .0042984
------------------------------------------------------------------------------
```

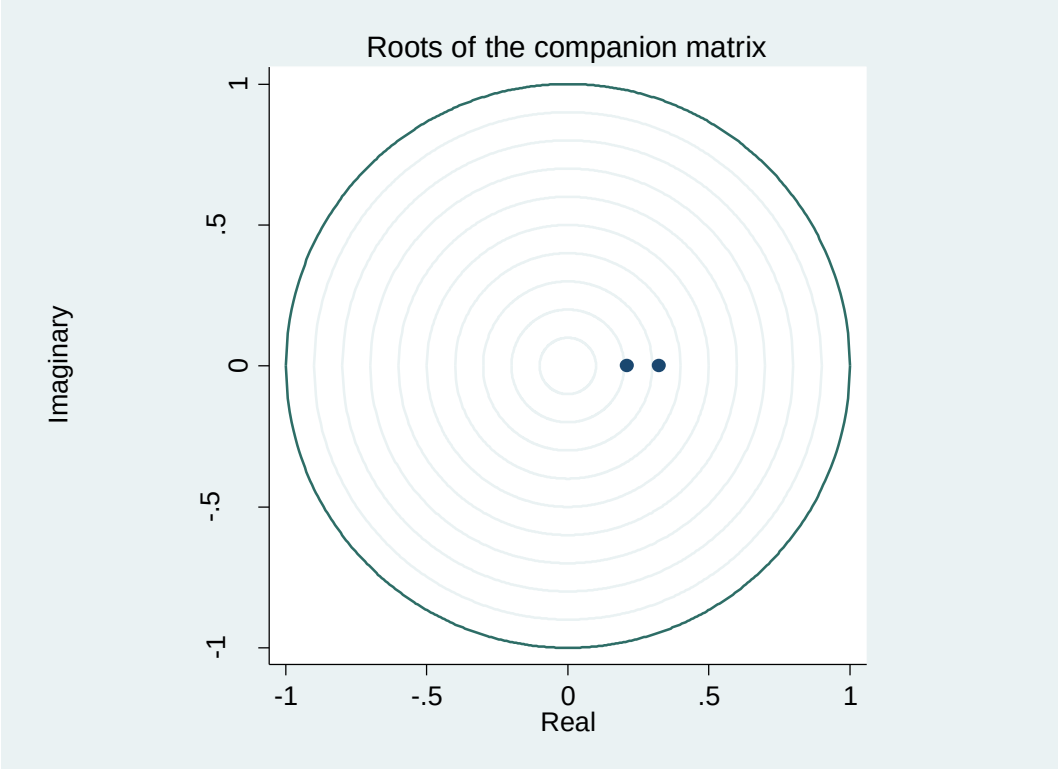
3.5 Test for VAR stability

For a stable VAR-model we want the eigenvalues to be less than one.

```
Eigenvalue stability condition

+----------------------------+-----------+
|        Eigenvalue          |  Modulus  |
|----------------------------+-----------|
|   .3220025                 |  .322002  |
|   .2089699                 |   .20897  |
+----------------------------+-----------+

All the eigenvalues lie inside the unit circle.
VAR satisfies stability condition.
```



The result says that all the eigenvalues lie inside the unit circle and VAR satisfies stability condition.

4. Empirical Evidence

Our results in 3.4 show that oil price and USD/EUR exchange rate are actually correlated with their own first lag values instead of with the other's lag value.

Oil price is not determined or well correlated with past USD/EUR exchange rate so that change of USD/EUR exchange rate cannot be used to forecast the change of oil price.

Also, we find that USD/EUR exchange rate is not well correlated with past oil price, either. Based on our results, we conclude that past USD/EUR exchange rate and oil price cannot be used to forecast each other.

Further research should include more variables in the vector, such as the determinants of USD/EUR exchange rate. The USD/EUR exchange rate is sometimes assumed to be

determined by changes in the relative money supply, output and interest rate changes in the USA and the euro area. We can add in these variables and perform more detailed analysis. We can also use a vector error correction (VEC) model for these variables in further study.

5. Conclusions

The fact that commodities are generally invoiced in US dollar naturally prompt the concern over the relationship between commodity price and value of dollar.

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