Does increase in oil prices caused overvaluation of national currency?
The equilibrium real effective exchange rate and misalignment in Azerbaijan

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Abstract

This research investigates equilibrium exchange rate in one of the main oil exporting country Azerbaijan in order to find out whether the increase of real oil price causes the appreciation real effective exchange rate and to determine whether national currency has become overvalued in the course of oil revenues boom of recent years. We derive the measure of real effective exchange rate and analyze the long-run relationship between real effective exchange rate and its determinants. The monthly data from 1997-2008 has been employed to estimate Error Correction Model. The results confirm strong relationship between real exchange rate and real oil prices and the coefficients of the error correction term indicate the gradual convergence of the exchange rate towards its long-run equilibrium. Though real oil price increases lead to considerable real appreciation of Azeri manat, the national currency is not overvalued, thus bringing support to the regulated exchange rate regime in Azerbaijan

Acknowledgement

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To the dearest memory of my lovely dog that will live in the memory of his family forever.

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1. Introduction

The exchange rate is arguably very important macroeconomic indicator to model empirically. REER, as a measure of competitiveness, determines and influences the performance of the export sector (Caballero, 1989). Considering its allocative and competitive roles, developing and emerging economies are encouraged by IMF to keep the actual REER close to the equilibrium real exchange rate (EREER). Misalignment of exchange rate has detrimental effects for economic growth and efficiency of capital. Real exchange rate overvaluation can also undermine export competitiveness and weaken the external position, while an undervalued exchange rate may create inflationary pressures. Also, the maintenance of real exchange rate close to the equilibrium level also prevents countries from currency and banking crises. Under fixed exchange rate regime if real shocks occur and exchange rate does not adjust accordingly.

Oil prices may be sufficient to explain the long-run fluctuations in exchange rate of oil exporting countries (Habib, 2007). The large increase in oil prices since the beginning of the new century has been associated with the emergence of large current account imbalances across the countries. Oil extracting countries have turned to the countries with the largest current account surplus. In April 2006, the statement of the Group of Seven (G7) explicitly mentioned oil exporting countries among countries playing critical role in adjustment of global imbalances. Indeed, the literature has identified the terms of trade as one of the potential determinants of the real exchange rate, which may explain long and persistent deviations from a simple Purchasing Power Parity (PPP) equilibrium. In oil exporting countries, the main driver of the terms of trade is the oil price.

According to the purchasing power parity (PPP) hypothesis, all movements in the real exchange rates are transitory. Rogoff (1996) gives both theoretical reasons why PPP may not hold and empirical evidence of large deviations from PPP. According to Balassa (1964) and Samuelson (1964), real exchange rates of countries with high productivity growth in the tradable sectors appreciate. A rise in productivity in the traded good sector will raise wages in the entire economy, and drive the prices up in non-traded sector. De Gregorio and Wolf (1994) extended this model to allow for changes in terms of trade, where improved terms of trade induce an appreciation in the equilibrium real exchange rate. Many authors consider net foreign assets as potential long-run determinant of REER. Bergvall (2004) argues that the approach using net foreign assets is restrictive and, therefore considers the long-run relationship between the trade balance and the real exchange rate, and not the long-run relationship between net foreign assets and the real exchange rate. The relationship between interest rates and exchange rates through uncovered interest parity (UIP) theory has been confirmed by several authors. Several authors find consistent relationship between the change of exchange rate and interest rate differentials in time span from three to ten years. MacDonald et al. (2000) confirm this evidence for real interest rate differentials. Taking into account these empirical findings the theoretical framework of our model observes the relationship between terms of trade, relative productivity and real interest rate differentials and real effective exchange rate.

After the recent global financial crisis while national currencies of emerging countries considerably depreciated, in the first quarter of 2009 Central Bank of Azerbaijan spent more than $500 million to prevent the depreciation. Therefore, this raises various questions related the equilibrium level and misalignment of the real exchange rate in Azerbaijan. The aim of this paper is to analyze whether there is reason for concerns about overvaluation of Azeri manat above its equilibrium level in the period of oil revenues boom and to determine the impact of the fluctuations of the long-run determinants on real effective exchange rate.

There has been several unpublished empirical works attempting to estimate equilibrium REER for Azerbaijan. However, these studies suffer from various serious weaknesses. These studies (i) fail to determine misalignment correctly; (ii) no study has correctly checked the stationarity properties; (iii) fail to use relevant econometric techniques to check the reliability of their results. This paper contributes to the existing empirical work done in Azerbaijan by overcoming above weak points, determining sound long-run equilibrium for exchange rate and considering oil price impact on exchange rate fluctuations. Also, some econometric analysis can contribute to the existing general literature and address common problems in specification and estimation overlooked by various authors investigating the exchange rate of different countries.

The rest of the paper is organized as follows. The next section presents the brief overview of Azerbaijan economy. Section 3 briefly summarizes the existing literature. Section 4 describes the empirical framework that includes the analytical model, discusses the description of data and stationarity analysis of the series. Section 5 contains empirical results and checking the reliability of these results. Section 6 discusses the empirical results and determines misalignment of real exchange rate. Finally, section 7 concludes.

2. Country information

Azerbaijan is located in the South Caucasus region, bordering the Caspian Sea from the east, between Iran and Russia. GDP growth estimated at 10.8% in 2008, slowing from an average 29.3% during 2005-2007, which made Azerbaijan one of fast-growing countries in the world. The hydrocarbon sector dominates the economy in Azerbaijan. The oil and gas industry accounts for more than 80% of exports and about 50% of GDP. In 2007 oil and gas production increased by 30% and almost 50%, respectively. Oil production reached 450 million barrels in 2008. Oil revenues are expected to reach its peak in 2011. The country's oil and gas revenues are forecasted to be $200 billion until 2024. In the non-oil sector growth was led by construction, services, and agriculture. Non-oil GDP grew at almost 16% in 2008, the highest rate in the last 5 years. But non-oil GDP share shrank in total GDP due to vast growing oil sector (Figure 1). Non-oil sectors provided 43% of nominal GDP in 2007, down from 47% a year earlier and 58% in 2005. Economy's high dependence on oil sector creates a potential threat to the economy due the potential volatility in the world oil market.

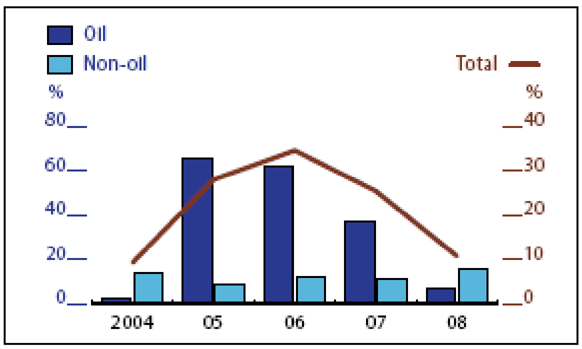
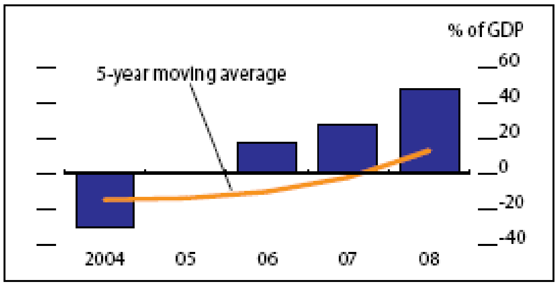


Figure 1. **GDP growth by sector**[1]

The central bank in March 2008 introduced a new exchange rate arrangement that pegs the manat to a dollar–euro currency basket. This was a step toward greater exchange rate flexibility. During 2008, the manat appreciated by 4.2% against the dollar, but the real effective exchange rate appreciated by 12.9% because of Azerbaijan's higher inflation.

[1] Source: Asian Development Outlook 2009

Figure 2. Current account balance[2]



Azerbaijan had a significant current account deficit until 2004, as it needed to import goods and services related to the construction and development of the oil and gas fields. As hydrocarbon production increased and oil prices rose, the current account balance switched to a surplus making 45% of GDP in 2008 (Figure 2). Gross international reserves, excluding State Oil Fund's assets, are estimated to have leaped from $4.3 billion in 2007 to about $6.5 billion at end-2008.

Consumer price inflation increased to an average of 20.8% from 16.7% in 2007. The increase was due to steeper prices of food mainly, which has a weight of over 30% in the consumer basket. Rapid monetary expansion and a near doubling of civil service salaries and social security payments also accelerated the inflation. In 2007 government expenditures grew by 50%, which is mostly directed to increase to public sector wages and financing infrastructure projects. Direct budget transfers from the State Oil Fund grew by 29.3% in 2008 accounting for about 40% of total state budget revenue. Continued substantial reliance on State Oil Fund reserves could lead to early depletion of its assets. Therefore, such fast spending of the oil revenues not only has the negative impact on the country's economy, but also leads to unfair intergeneration distribution of oil revenues.

[2] Source: Asian Development Outlook 2009

3. Literature Review

Vast number of empirical researches has been conducted both to analyze the effect of terms of trade on exchange rate and determine exchange rate misalignment from equilibrium level.

The potential role of oil shocks in driving terms of trade movements and effecting exchange rates received much attention. Krugman (1983) and Golub (1983) were the first to develop models analyzing the bilateral exchange rates between two or more oil importing countries. They find that effect of the oil price increase depends on the relative propensity to import oil and trade deficits against oil exporting countries. Empirical tests of the Krugman-Golub hypothesis were performed by Amano and van Norden (1998), which have found evidence of a long-run stable relationship between the real effective exchange rate of the US dollar and the oil price deflated by the US consumer price index over the post-Bretton Woods period. Amano and van Norden (1995) also have documented a robust relationship between the real domestic price of oil and real effective exchange rates for Germany, Japan and the United States in the long run.

Since the data become available for oil exporting countries, empirical studies focused on these countries. Indeed, many empirical studies find a significant and positive relationship between the oil price and the real exchange rate of oil exporting countries. Akram (2004) finds a non-linear asymmetric relationship between the nominal exchange rate and oil prices in Norway. He has found certain threshold for krone above which krone depreciates when oil price increases. Bergvall (2004) examines the determinants of the real exchange rates in Nordic countries and finds that exogenous terms of trade and productivity shocks explain most of the long-run variance of the real exchange rate in the case of Norway and also Denmark. Korhonen and Juurikkala (2007) estimate the real exchange rate in a panel of nine OPEC countries. Habib et al.

(2007) has found strong relationship between oil prices and REER in Russia and described its currency as "oil currency".

There is voluminous theoretical and empirical literature on the equilibrium exchange rate, which covers both developed and developing countries. Different methodologies such as Purchasing Power Parity Approach (PPP), Trade Equation Approach (TEA), and Structural Model Approach (SMA) were used by various authors[3]. MacDonald (1995) and Rogoff (1996) indicate that PPP is not an appropriate model for the determination of equilibrium exchange rates because of its slow mean reversion to a constant level implied by the PPP assumption. However, Yotopoulos and Sawada (2005) find that 132 countries out of 153 countries have achieved PPP within twenty years and 105 of them have attained it over the 1990-2000. Razin and Collins (1997) develop their estimation using a reduced form of the real exchange rate equation derived from a Mundell-Fleming model. Montiel (1999) suggests that the co-integration technique is a superior method of estimating the real exchange rate over the PPP methodology.

However, according to Hinkle and Montiel (1999) there is no consensus on the methodology to estimate the equilibrium exchange rate. Commonly used indicators include nominal and real effective exchange rates, productivity and other competitiveness measures, terms of trade, net foreign assets, current account, government expenditures, interest rate differentials, and parallel market exchange rates. A problem is that these indicators may not always allow policy-makers to identify the degree of misalignment precisely enough to pinpoint the appropriate timing and amount of intervention.

[3] World Bank Research Publication (1999) by Hinkle and Montiel give broad definition and empirical tests of these models.

4. Data Analysis

4.1. Theoretical Framework

In this subsection we sketch the theoretical framework underlying our empirical investigation. The model describes the real exchange rate as a function of terms of trade, relative productivity between the non-traded and traded sectors and real interest rate of home country and his trading partners. The model is a modified version of standard small open economy discussed in Cashin et al. (2004) by adding real interest rate to the framework.

We consider oil exporting small open economy, *D.* There are two different sectors in domestic economy: oil extraction and production as a primary export tradable good and production of a non-traded good. We consider several assumptions: (1) factor markets and final goods are competitive in both sectors, (2) production takes place under constant returns to scale, (3) labor is fully mobile between traded and non-traded good sector, and therefore wages are equalized across sectors, (4) firms both in domestic oil exporting country and its trading partners have access to the same technology, though productivities differ, and nontradable sector is more labor augmented.

Consequently, we describe algebraically the oil exporter's economy and foreign trading partner's economy so that, eventually, we can define the real effective exchange rate of the oil producing country. Simple static framework is adopted, since the focus is on the factors determining the real exchange rate. The theory is viewed holding in the long-run, so we omit time subscripts.

The oil producing country

In this subsection we describe the supply and demand sides of the economy of the oil exporter.

Firms

Capital and labor are supplied inelastically and employed in the production of tradable and nontradable goods. The two goods are produced according to Cobb-Douglas function[4]:

$$\Pi_T = P_T Y_T - (wL_T + RK_T) \xrightarrow[L,K]{} \max \qquad (1)$$

s.t. $Y_T = A_T L_T^{1-\alpha} K_T^{\alpha})$

and

$$\Pi_N = P_N Y_N - (wL_N + RK_N) \xrightarrow[L,K]{} \max \qquad (2)$$

s.t. $Y_N = A_N L_N^{1-\beta} K_N^{\beta})$

The subscript *T* and *N* stands for tradable and nontradable sector. Due to free labor movement, wages are equalized across sectors. Since the production in tradable sector is more capital augmented, we have $\alpha > \beta$. After substituting the constraints in objective functions and taking derivatives we get following first order conditions

$$R = P_T A_T \alpha (k_T)^{\alpha-1} \qquad (3)$$

$$R = P_N A_N \beta (k_N)^{\beta-1} \qquad (4)$$

$$w = P_T A_T (1-\alpha)(k_T)^{\alpha} \qquad (5)$$

$$w = P_N A_N (1-\beta)(k_N)^{\beta} \qquad (6)$$

where $k = K / L$

[4] For the sake of simplicity we omit superscript denoting domestic country for a while and derive for general case

We have 6 unknowns ($R, w, k_N, k_T, P_{N,} P_T$) and 4 equations. Taking real interest rate and price of tradable good (real petroleum price) as exogenous to the system lets us solve for other unknowns as a function of them. First, we obtain the tradable sector capital-labor ratio from (3)

$$k_T = \left(\frac{\alpha P_T A_T}{R} \right)^{1/(1-\alpha)} \quad (7)$$

Next, substitute (7) in (5) to get the wage rate

$$w = (1-\alpha)(P_T A_T)^{1/(1-\alpha)} \left(\frac{\alpha}{R} \right)^{\alpha/(1-\alpha)} \quad (8)$$

Substituting (8) in (6) we get

$$k_N = \left(\frac{1-\alpha}{1-\beta} \frac{(P_T A_T)^{1/(1-\alpha)} (\alpha / R)^{\alpha/(1-\alpha)}}{P_N A_N} \right)^{1/\beta} \quad (9)$$

Finally, plugging (9) into (4) we get the price of nontradable goods of domestic oil exporting country in terms of relative productivity between the sector, price of tradable good and real interest rate

$$P_N = \frac{(A_T P_T)^{(1-\beta)/(1-\alpha)}}{A_N} C(R \ )^{(\beta-\alpha)/(1-\alpha)} \quad (10)$$

where C is the positive constant. For the oil exporting domestic country and the nontradable price index will be as follows[5]

$$P_N^D = \frac{(A_O^D P_O)^{(1-\beta)/(1-\alpha)}}{A_N^D} C(R^D)^{(\beta-\alpha)/(1-\alpha)} \quad (11)$$

The elasticity of nontradable price $\partial \ln P_N^D / \partial \ln P_O = (1-\beta)/(1-\alpha) > 1$ is positive and more than unity. Hence, an increase in the price of oil will raise the price level of the non-traded sector by more percentage.

[5] We take into account that the fact that oil is the main tradable good of domestic country and *O* index describes it.

Households

A continuum of identical households maximizes their utility over the consumption of the non-traded good produced domestically and the *imported* tradable good. This tradable good is imported from the rest of the world and is not produced domestically. Our assumptions on preferences imply that the primarily exported commodity petroleum is also not consumed domestically. Households derive utility from the consumption of the nontradable goods produced at home and the imported good. Thus, the representative household is characterized by Cobb-Douglas preferences

$$U^D = \left(C_N^D\right)^\gamma \left(C_T^D\right)^{1-\gamma} \xrightarrow[C]{} \max$$

s.t. $P_N^D C_N^D + P_T^D C_T^D = W$

where C_N^D and C_T^D is the domestic consumption of domestic nontradables and traded goods imported from abroad, respectively. Solving the optimization problem yields composite consumption as $C^D = k\left(C_N^D\right)^\gamma \left(C_T^D\right)^{1-\gamma}$ with constant $k = 1/(\gamma^\gamma (1-\gamma)^{1-\gamma})$. The minimum cost of one unit of consumption C of the oil producing country is a geometric average, with weights γ and $1-\gamma$, of the prices of tradables and non-tradables:

$$P^D = \left(P_N^D\right)^\gamma \left(P_T^D\right)^{1-\gamma} \qquad (12)$$

where P_T^D is the price in local currency terms of one unit of the tradable good imported from abroad. Commonly, P is defined as consumer price index (CPI). The law of one price is assumed to hold for the imported good, so that $P_T^D = P_T^F / NER_{fc}$, where NER_{fc} is the nominal exchange rate in foreign currency terms (defined as the amount of foreign currency per unit of local currency), and P_T^F is the price of the tradable (imported) good in terms of foreign currency. We now specify the rest of the world.

Foreign trading partners

The economy of the foreign region consists of two sectors likewise. The imported oil is used production of intermediate goods. Similarly, as in the oil exporting country, the price of nontradables is

$$P_N^F = \frac{\left(A_T^F P_T^F\right)^{(1-\beta)/(1-\alpha)}}{A_N^F} C(R^F)^{(\beta-\alpha)/(1-\alpha)} \qquad (13)$$

Also, consumers in the foreign country are assumed to consume nontradable goods and final tradable goods as in the oil exporting country and, therefore the consumer price index of foreign country is given by

$$P^F = \left(P_N^F\right)^{\gamma} \left(P_T^F\right)^{1-\gamma} \qquad (14)$$

Real exchange rate determination

After the determination of price indices in domestic and foreign trading partner country it is straightforward to determine the real exchange rate. The real exchange is defined as the foreign price of the domestic basket of consumption relative to the foreign price of a foreign basket of consumption: $NER_{fc} P^D / P^F$. Using equations (11) to (14) we can determine the bilateral real exchange rate as follows

$$BRER_{fc} = \left(\left(\frac{A_O^D}{A_T^F} \frac{P_O}{P_T^F} \right)^{(1-\beta)/(1-\alpha)} \frac{A_N^F}{A_N^D} \left(\frac{R^D}{R^F} \right)^{(\beta-\alpha)/(1-\alpha)} \right)^{\gamma} \qquad \text{(A.15)}$$

Real effective exchange rate (REER) is defined as the geometric average of BRER with its trade partners

$$REER_{fc} = \prod_{i=1}^{m} BRER_{fc_i}^{w_{id}} \qquad \text{(A.16)}$$

where w_{id} is the share of i^{th} country in the total trade.

From last equation (15) we can find the coefficients of elasticity. To be consistent with the variables of our model, consider $TOT = \ln(\frac{P_O}{P_T^F})$, $RIRD = \ln(\frac{R^D}{P^F})$ and $PROD = \ln(\frac{A_O / A_N^D}{A_T^F / A_N^F})$.

As variables are in natural logs, the partial derivative of BRER with respect to each them means the elasticity of respective variable

$$\frac{\partial BRER}{\partial TOT} = \gamma(1-\beta)/(1-\alpha) > 0 \qquad (16)$$

$$\frac{\partial BRER}{\partial RIRD} = \gamma(\beta-\alpha)/(1-\alpha) < 0 \qquad (17)$$

$$\frac{\partial BRER}{\partial PROD} = \gamma > 0 \text{ if we have } \beta = \alpha \qquad (18)$$

Equations (16)-(18) predicts that increase in oil prices and productivity would lead to the appreciation of REER, while for real interest rate the contrary is true. Therefore, in this framework, an improvement in the terms of trade - the relative price of exports in terms of imports - produces an appreciation of the domestic currency. In this context, a positive shock to the terms of trade leads to an increase in wages in the exporting sector. Similarly to the dynamics of the Balassa-Samuelson model of exchange rate, under the assumption of wage equalization across the two sectors, this translates into an increase in wages and prices in the non-traded goods sector and an appreciation of the real exchange rate.

4.2. Data description

Our empirical investigation is based on the theoretical framework described in the previous subsection. The data set covers the period between 1997 M1-2001 M12. The data are expressed in logs. The source of the monthly data is the Central Bank of Azerbaijan. All variables are expressed in indexes and 1996 M12 is the base period for all indices[6].

The real exchange rate index (*REER*) is a CPI-based effective real exchange rate constructed as a competition weighted geometric average of the bilateral exchange rate series for main trading partners.

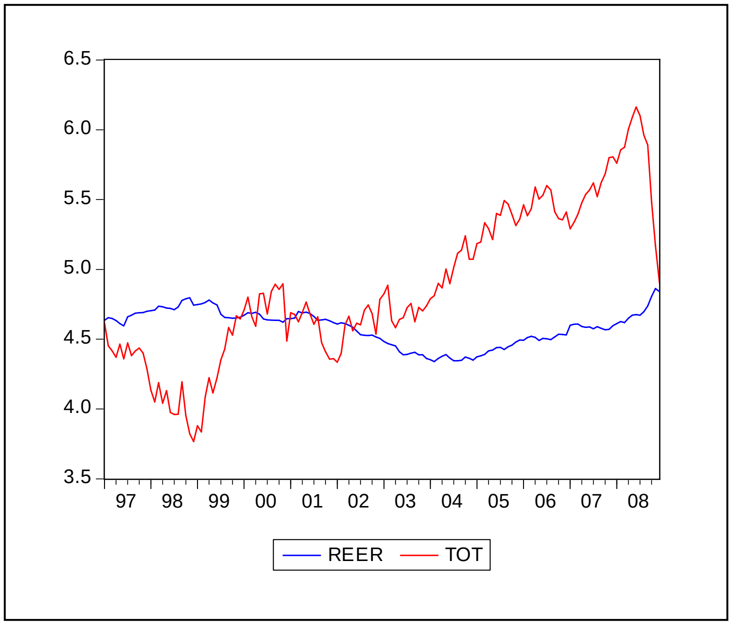
As a measure of relative productivity differential we use relative prices between traded and non-traded goods in both in Azerbaijan and his trade partners $(TPI_{aze}/CPI_{aze})/(TPI_F/CPI_F)$. As a proxy to non-tradables price index *CPI* is used. Likewise to real effective exchange rate, consumer price index and tradable price index is trade share weighted geometric average of the indices for each trade partner.

Real interest rates differential (*RIRD*)is the difference in logs (i.e. ratio in level) of CPI adjusted nominal short term interest rates, again in Azerbaijan and his trade partners.

As a measure of terms of trade (*TOT*), traditionally relative prices of export to import are used. We claim oil price to be the only exogenous factor causing changes in terms of trade of Azerbaijan. To capture the effect of exogenous changes in the export prices, we use the real price

6 All indices were adjusted to 100 in the base period.

Figure 3. The real exchange rate and terms of trade



of oil as a proxy to export prices. The real price of oil is calculated as US dollar price of crude oil[7] deflated by the efficient export price index, i.e. the export trade share weighted geometric average of the CPIs for export trade partners. In Figure 1 we compare real effective exchange rate against the UK Brent price. A preliminary inspection reveals the evidence of co-movement between them.

4.3. Unit root analysis

Following the descriptive analysis of the data, in this subsection we discuss the statistical features of our time series. An important issue in time series regression is the degree of integration of the variables, since integrated variables require a different empirical treatment from stationary variables, due to the well-know problem of spurious regression. In particular, the identification of the order of integration of the real exchange rate is a delicate task, as exchange rates usually display near-unit root behaviour. In general, the hypothesis of stationarity of real exchange rates is accepted over very long samples and rejected in shorter samples over the post-Bretton Woods period (Taylor 2003). As unit root tests have low power and may fail to distinguish between a unit root process and a near-unit root process, we compare the results of

[7] The price of *UK BRENT* barrel was used, others are almost the same.

the standard Augmented Dickey-Fuller (ADF) test with the null of non-stationarity and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test with the null of trend stationarity. In these tests a decision on the AR order or, equivalently, on the number of lagged differences of variables was based on the order specification criteria such as Akaike, Hannan&Quinn and Schwarz. The last two criteria estimate the order consistently under general conditions for both stationary and integrated processes[8]. Nevertheless, the limiting distribution of unit root test statistics does not depend on the coefficients or other characteristics of the short-term dynamics. For all series except REER both ADF and KPSS tests lead to the same conclusion of variables being I(1)[9]. The results are presented in Table 1:

Table 4. Unit root tests

	Levels		1st differences	
	KPSS $H_0 : x \sim \text{I}(0)$	*ADF* $H_0 : x \sim \text{I}(1)$	*KPSS* $H_0 : x \sim \text{I}(0)$	*ADF* $H_0 : x \sim \text{I}(1)$
Real exchange rate	1.21***	0.63	0.29***	-8.86***
Terms of trade	0.36***	-2.33	0.12	-11.82***
Real int. rate diff.	0.32***	-2.26	0.03	-6.89***
Relative productivity	0.25***	-3.17	0.05	-12.11***

Notes: Asterisks ** denote rejection of the null hypothesis at 5 percent level.

[8] However, the increase in efficiency of this criterion comes at the cost of a higher likelihood of serial correlation in the residuals. We choose the Akaike criteria and a richer lag structure when it was necessary to eliminate residual serial correlation.

[9] All unit root tests include a constant and a deterministic time trend in our series; additionally, the seasonal dummy variables are present in ADF test. Tests on the first differences of the variables reject the hypothesis of the presence of a unit root, therefore conclude that there are no I(2) variables in our sample.

In the case of real exchange rate tests applied to first differences gives contradicting results. The Quandt-Andrews breakpoint test indicates structural break in the first month of 2005 for the real effective exchange rate. This test seeks for one or more unknown structural breakpoints in the sample for a specified equation[10]. One econometric procedure to tests for unit roots in the presence of a structural break involves splitting the sample into two parts and using Dickey-Fuller tests on each part. The problem with this procedure is that the degrees of freedom for each of the resulting regressions' are diminished. It is preferable to have a single test based on the full sample. Perron (1989) goes on to develop a formal procedure to test for unit roots in the presence of a structural change. Following two hypotheses have been tested:

$$H_A : y_t = \alpha_0 + y_{t-1} + \mu_1 D_L + \varepsilon_t \qquad A_A : y_t = \alpha_0 + \alpha_1 t + \mu_2 D_T + \varepsilon_t$$

$$H_B : y_t = \alpha_0 + y_{t-1} + \mu_1 D_L + \mu_3 D_P + \varepsilon_t \qquad A_B : y_t = \alpha_0 + \alpha_1 t + \mu_1 D_L + \mu_2 D_T + \varepsilon_t$$

where D_P represents a pulse dummy variable such that $D_P = 1$ if t=T+1 and zero otherwise, D_L represents a level dummy variable such that $D_L = 1$ if t > T+1 and zero otherwise, and $D_T = t - T$ if t>T, zero otherwise. The specification (A) tests the null hypothesis of a permanent change magnitude of the drift term versus the alternative of a change in the slope of the trend.

A change in both the level and drift of a unit root process is represented by specification (B).

In order to test the null hypotheses, first, the regressions in alternatives were estimated, then augmented Dickey-Fuller test applied to residuals from those regressions, if the residuals do not appear to be white-noise. The t-statistics for the null hypothesis of ADF were compared to the critical values calculated by Perron (1989). As a time of structural change is taken January of 2005. Results from the test for Perron test are reported in Table A1 (Appendix). Both tests

[10] Basically, when structural break is present, the various test statistics are biased toward the non-rejection of a unit root, but we encounter the opposite problem.

confirm REER to be I(1). Unit root analysis show that all series underlying the empirical estimation are difference stationary processes.

5. Empirical analysis

5.1. Specifying the Cointegration Rank

In the light of the evidence from the panel unit root tests, we proceed with our cointegration analysis. Engle and Granger (1987) pointed out that a linear combination of two or more non-stationary series may be stationary. Appropriate lag order should be chosen before performing cointegration test. In order to determine the proper lag order the sequential modified LR test (Lutkepohl, 1991) is carried out starting from a model with some prespecified maximum lag length $p_{\max}$ and following sequence of null hypotheses are tested until the test rejects: $H_0 : \Phi_{p_{\max}} = 0$, $H_0 : \Phi_{p_{\max}-1} = 0$, and so forth. Table A2 (Appendix) reports the values of the Akaike (AIC), Schwarz (SC), and Hannan-Quinn (HQ) information criteria for different lag orders as well as the results from likelihood ratio (LR) tests for successive lag deletions. The LR test is implemented using the small-sample correction suggested in Sims (1980) and using a 5% significance level for the individual tests. The maximum lag-order is set to six[11]. The AIC suggests including three lagged differences, whereas HQ and SC favor a specification with only one lagged difference. The results of another test, so called lag exclusion tests, which tests the

[11] If a very large order $p_{\max}$ is used, a long sequence of tests may be necessary that will have an impact on the overall Type I error of the testing sequence, that is, the choice of $p_{\max}$ will have an impact on the probability of an inadequate selection of p (Lutkepohl, 2001).

joint significance of all endogenous variables at the lag reported for each equation separately, are consistent with these results.

Cointegration tests using the methodology developed in Johansen (1991, 1995) Saikkonen & Lutkepohl (2000 a, b) estimates the $\Pi = \alpha\beta'$ matrix from an unrestricted VAR and tests whether we can reject the restrictions implied by the reduced rank of Π [12]. We consider two specifications discussed in Johansen (1995). The first case considers a linear deterministic trend in the level data and, hence, $\mu_1 \neq 0$. But it is absent from the cointegration relations, we have $\beta'\mu_1 = 0$, that is, the trend parameter is orthogonal to the cointegration matrix:

$$\Delta y_t - \mu_1 = \Pi(y_{t-1} - \mu_0) + \sum_{i=1}^{p-1} \Gamma_i (\Delta y_{t-i} - \mu_1) + \varepsilon_t, \qquad (1)$$

where $\Delta(y_t - \mu_0 - \mu_1 t) = \Delta y_t - \mu_1$ and $\Pi(y_{t-1} - \mu_0 - \mu_1(t-1)) = \Pi(y_{t-1} - \mu_0)$. After collecting the constants we get:

$$\Delta y_t = \zeta_0 + \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \varepsilon_t, \quad \text{where } \zeta_0 = -\Pi\mu_0 + (\sum_{i=1}^{p} i\Phi_i)\mu_1, \qquad (2)$$

LR tests based test on the intercept version of the VECM in (2) is treated by Johansen (1995), which is known as trace and max eigenvalue tests. An alternative test based on the trend adjusted version (1) was proposed by Saikkonen&Lutkepohl (2000b). The constant and trend parameters

[12] Any VAR in the form $y_t = \mu_0 + \mu_1 t + \sum_{i=1}^{p} \Phi_i y_{t-i} + \varepsilon_t$ can be written in error-correction form as

$$\Delta y_t = \mu + \mu_1 t + \sum_{i=1}^{p-1} \Gamma_i (1-L) L^i y_t + \Pi y_{t-1} + \varepsilon_t \text{ where } \Gamma_i = -\sum_{j=i+1}^{p} \Phi_j \text{ and } \Pi = \sum_{i=1}^{p} \Phi_i - \mathrm{I}$$

Granger Representation Theorem (Engle and Granger, 1997 and Johansen, 1991) asserts that if the coefficient matrix Π has reduced rank r<k, then there exist $k \times r$ matrices α and β each with rank r such that $\Pi = \alpha\beta'$ and $\beta' y_t$ is stationary. r is the number of cointegrating relations, i.e. the cointegrating rank and each row of β' is the cointegrating vector.

are estimated in a first step by a feasible GLS procedure, the y_t was modified to yield $\tilde{y} = y_t - \hat{\mu}_0 - \hat{\mu}_1 t$, and then LR-type test based on reduced rank regression of (1) was applied.

The second case considers fully unrestricted linear trend term, which again gives two types VECMs:

$$\Delta y_t - \mu_1 = \Pi(y_{t-1} - \mu_0 - \mu_1(t-1)) + \sum_{i=1}^{p-1} \Gamma_i (\Delta y_{t-i} - \mu_1) + \varepsilon_t \qquad (3)$$

After rearranging, we get

$$\Delta y_t = \zeta_1 + \tilde{\Pi} \begin{bmatrix} y_{t-1} \\ t-1 \end{bmatrix} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \varepsilon_t , \qquad (4)$$

where $\zeta_1 = -\Pi\mu_0 + (I_k - \sum_{i=1}^{p-1}\Gamma_i)\mu_1$ and $\tilde{\Pi} = \alpha[\beta' : \eta]$ is a $K \times (K+1)$ matrix of rank r with $\eta = -\beta'\mu_1$. Here there is deterministic linear trend both in the levels and in the cointegration relations. The trend parameters are again estimated in a first step by a GLS procedure, details and critical values are presented in Lutkepohl& Saikkonen (2000). The results of the Johansen trace tests and the tests proposed by Saikkonen and Lutkepohl (S&L tests) are presented in Table 2[13]. Tests were performed at different lag orders for checking the robustness of the results.[14]

[13] As the results for maximum eigenvalue tests coincide with those of trace test, they are not included.
[14] As discussed before, low-order model that does not capture the serial dependence in the data well may lead to size distortions, whereas choosing an unnecessarily large lag order may spoil the power of the tests. So, using both lag orders offered by different information criteria are better strategy.

Table 5. Cointegration tests

Test	Deterministic terms	Lagged differences	$H_0 : r = r_0$	Test statistics	Critical values	
					5%	1%
Johansen	*c, tr, sd*	1	$r_0 = 0$	74.13	63.66	70.91
	c, tr, sd	1	$r_0 = 1$	33.99	42.77	48.87
	c, orth tr, sd	1	$r_0 = 0$	64.72	47.71	54.23
	c, orth tr, sd	1	$r_0 = 1$	28.02	29.80	35.21
	c, tr, sd	3	$r_0 = 0$	75.93	63.66	70.91
	c, tr, sd	3	$r_0 = 1$	39.67	42.77	48.87
	c, orth tr, sd	3	$r_0 = 0$	67.17	47.71	54.23
	c, orth tr, sd	3	$r_0 = 1$	31.15	29.80	35.21
S&L	*c, tr, sd*	1	$r_0 = 0$	64.48	45.32	51.45
	c, tr, sd	1	$r_0 = 1$	25.70	28.52	33.50
	c, orth tr, sd	1	$r_0 = 0$	54.65	35.76	41.58
	c, orth tr, sd	1	$r_0 = 1$	20.79	20.96	25.71
	c, tr, sd	3	$r_0 = 0$	64.83	45.32	51.45
	c, tr, sd	3	$r_0 = 1$	28.44	28.52	33.50
	c, orth tr, sd	3	$r_0 = 0$	51.31	35.76	41.58
	c, orth tr, sd	3	$r_0 = 1$	22.22	20.96	25.71

Notes: c-constant, *tr* -linear trend, *orth tr*-linear trend orthogonal to the cointegration relations, *sd*- seasonal dummies

Tests using SC in lag selection indicate one cointegration relation. As 11 seasonal dummies were included for monthly data, which considerably increases the number of parameters being estimated, the tests performs worse if we use lag ordered indicated by AIC criterion and estimated parameters become even more[15]. Although Monte Carlo studies by several authors show that efficiency loss from choosing a too long lag structure is small and a too short lag structure has a severe impact on maximum likelihood estimates, this strategy can not be favored unless we have long time series. As discussed in Johansen (2002) the increase of the quantity of estimated parameters considerable increases the Type I error and using standard critical value for testing may yield misleading results[16].

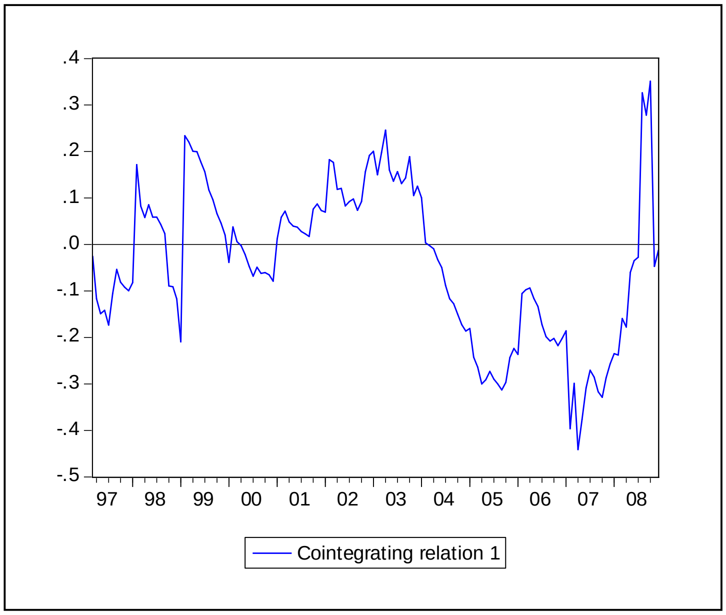
As cointegrating relation is present in our system of variables, the VAR form is not convenient model setup, therefore we directly step to estimation of vector error correction model (VECM) using Johansen procedure. Determining the cointegration rank is a prerequisite for estimating the model in an error-correction form. This allows us to distinguish between stationarity created by linear combinations of the I(1) variables and stationarity created by differencing (see footnote 4). Seasonal dummies are, also, used in estimation of VECM. Other deterministic terms, i.e. time trend and constant were excluded, though most empirical works have included despite the characteristics of the model. Hendry and Juselius (2000) discuss five cases for deterministic terms. They argue that intercept is generally needed to account for the initial level of measurements and if when the measurements start from zero, or when the measurements cancel

[15] In general, many remove seasonality by prefiltering the series using period-to-period differences or the X-11 methodology. According to Soto (2001) these methodologies have important pitfalls: using dummies treats the seasonality as a deterministic phenomenon, while filters either impose a particular stochastic structure (a unit root in the monthly or quarterly frequency) or induce excess persistence (X-11). Therefore, standard deseasonalizing methods are inappropriate

[16] Johansen (2002) shows that number of parameters per observation should be less than 0.2, standard tables of critical values give a reasonable result. If this ratio is 0.2 rejection probability of a nominal 5% test using asymptotic critical values is in fact close to 37%. The correction gives a test with rejection probability around 11%, which is much better than the direct use of the asymptotic tables. Using three lags in our tests yields ratio of 0.18 which is very close to 0.2, however it is 0.12 for one lag.

in the cointegrating relations, exclusion of constant is justified. In our model for all indices initial value is 100, but this value cancels in cointegration relation. Figure 2 shows that initial value is very close to zero.

Figure 4. Cointegration relation



Deterministic trend was neglected because no growth observed in the first differences and orthogonal trend restricted to cointegration space become very insignificant when included. In Table 3, we report the long-run cointegration relation after normalizing by the coefficient of the real effective exchange rate:

Table 6. Long-run equilibrium equation for real effective exchange rate

$$\begin{array}{lllllllll} REER_t = & 0.092 & TOT_t - & 0.121^{***} & RIRD_t + & 1.049^{***} & PROD_t + & ec_t \\ & (0.071) & & (0.035) & & (0.092) & & \end{array}$$

Estimation period: 1997 M4, 2008 M12 : T=141

Notes: Asterisks *** denote significance at 1% level. Standard errors reported in parentheses.

The results reveal that the national currency may be considered as an “oil currency” in the light of the elasticity of the real exchange rate to the oil price in the long-run, which is positive.

Increase in international oil prices improves terms of trade by the same percentage, since real oil price index was used as the export price index for Azerbaijan. This improvement subsequently causes the real exchange rate appreciation. For example, the long run effect of the increase of oil price 10% which was the common case until recent global financial crisis is the appreciation of real exchange rate by approx.1%. The elasticity for productivity differential is also positive and relatively larger. Thus, In Azerbaijan, the Balassa-Samuelson effect seems to play an important role in driving the real effective exchange rate along with the real oil price. Azerbaijan is a transition economy on its way to catch up with its developed trading partners. Therefore, one should expect the higher the domestic relative price increase of non-tradables compared to foreign countries and leading to an appreciation of the real exchange rate. Implication of this result to "Dutch Disease" in Azerbaijan will be discussed later.

5.2. Causality analysis

Besides identifying the cointegrating vector, it is important to control for the causal relationship between the variables[17]. If cointegrating relations do not enter a particular equation and thus that the corresponding left-hand variable is weakly exogenous for the cointegration parameters, then the corresponding element of the loading matrix α (the speed of adjustment of this variable to the long-run equilibrium level) will be zero. Therefore weak exogeneity of the presumed endogenous variables can be tested by testing the null of corresponding $\alpha = 0$.

[17] The χ^2 (Wald) statistics of pairwise Granger causality test indicates the joint insignificance of all other lagged endogenous variables in the equation for real interest rate differentials.

In our case, one would expect the rejection of the weak exogeneity for real effective exchange rate. This hypothesis is indeed supported by the empirical evidence, but is not rejected for the real interest rate differential (see Table 4).

Table 4. Test of weak exogeneity

Null Hypothesis:	LR statistics:	p-value:
$\alpha_{reer} = 0$	4.02	0.045
$\alpha_{prod} = 0$	6.01	0.014
$\alpha_{rird} = 0$	1.79	0.179
$\alpha_{tot} = 0$	9.40	0.002

Notes: The test statistics distributed asymptotically as $\chi^2(1)$. ** denote rejection of the null at the 5% significance level.

The implications of Granger causality test will be discussed later in the section of stability analysis.

5.3. Testing for restrictions and subset modeling

Asymptotic properties of the standard t-ratios reported are retained when they are applied to the short-run parameters in a VECM, whereas problems may occur for the standard t-ratios of integrated variables in the levels VAR representation. Restrictions in our model for individual parameters and groups of parameters in VARs or VECMs are based on model selection criteria.

We use sequential elimination of regressors (SER) strategy which sequentially deletes those regressors which lead to the largest reduction of the given criterion until no further reduction is possible. Bruggemann et al.(2001) have shown that this strategy is equivalent to sequentially eliminating those regressors with the smallest absolute values of t-ratios until all t-ratios (in absolute value) are greater than some threshold value γ. Note that a single regressor is eliminated in each step only. Then new t-ratios are computed for the reduced model. They argue that choosing $\gamma = \{[\exp(c_T / T) - 1](T - N + j - 1)\}^{1/2}$ in the jth step of the elimination procedure results in the same final model that is obtained by sequentially minimizing the selection criterion defined by the penalty term c_T. The threshold values for the t-ratios correspond to the critical values of the tests. We use $c_T(AIC) = 2$ which is relatively less restrictive and for an equation with 20 regressors and sample size of 100 corresponds to eliminating all regressors with t-values that are not significant at the 15–20% (Bruggemann et al., 2001). The outcomes of weak exogeneity tests are taken into account in subset modeling via sequentially eliminating regressors. Except real interest rate differentials, we assume that terms of trade is also unmodeled, therefore the corresponding coefficient in the loading matrix α is set to zero. As oil and oil products consist more than 80% of the export structure for Azerbaijan and export prices depend on the current oil price, the evidence that terms of trade is unmodelled, i.e. the cointegration part is excluded from the equation for terms of trade is reasonable.

Using the cointegration relation from Table 3 and after performing a model reduction, we estimate the final estimation by feasible GLS (FGLS), which is equivalent to 3SLS because the model is in reduced form (Lutkepohl 2004). Results of the estimation are presented in the Appendix (Equation A1). It is not straightforward the interpretation of seasonal dummies and there are not the point interest. For example, the significance of the seasonal dummy for the first month in PROD is most likely the result of the considerable price increases in the holidays' eve month before, so on. Results indicates two modeled equations and the equations that includes cointegration relation are reported in Table 5

Table 5. **Subset error correction model equations**

$$\Delta REER_t = -0.014(REER_{t-1} - 0.092^{***} TOT_{t-1} + 0.121^{***} RIRD_{t-1} - 1.049^{***} PROD_{t-1}) + 0.264^{***} \Delta REER_{t-1} + \lambda s_t + u_t$$

(0.009) (0.071) (0.035) (0.092) (0.078)

$$\Delta PROD_t = 0.042 \; (REER_{t-1} - 0.092^{****} TOT_{t-1} + 0.121^{***} RIRD_{t-1} - 1.049^{***} PROD_{t-1}) + 0.700^{***} \Delta REER_{t-1} - 0.093 \Delta PROD_{t-1} + \lambda s_t + u_t$$

(0.022) (0.071) (0.035) (0.092) (0.195) (0.072)

Note: Standard errors reported in parentheses.

From the values of loading vector it is possible to derive the half-life of deviations from the equilibrium following exogenous shocks. For Azeri manat it takes approximately 4 years to dissipate the half of the shock[18]. This is in line with standard PPP models estimating half-life of deviation as a result of shocks to the real exchange rate of more than three years in industrial countries.

5.4. Structural VECM

For analyzing instantaneous relations we consider structural vector error correction model based on the subset model:

$$A\Delta y_t = \Pi^* y_{t-1} + \Gamma_1^* \Delta y_{t-1} + v_t$$

Π^*, Γ^* are structural form parameter matrices and $(4 \times 4) v_t$ is zero mean structural form error with time invariant covariance matrix. The invertible (4×4) matrix A allows modeling instantaneous relations among the variables. Because the shocks are not directly observed,

[18] The half-life of deviations as a response to exogenous shocks is calculated according to the following formula: $\ln(0.5)/\ln(1-|\alpha|)$.

making assumption of orthogonality of the shocks is a consensus, so that we are able to identify them. As our model is 4-dimensional system 6 restrictions are necessary for orthogonalizing the shocks[19]. Restrictions made to the A matrix are in line with the weak exogeneity tests and the assumption that terms of trade is unmodeled. So we have rows of zeros for real interest rate differentials and terms of trade in the A matrix. The estimation results of structural VECM are reported in the Appendix (Equation A2)

The standard test statistics indicates relatively insignificance the estimated coefficients.

The converted equation for real effective exchange rate is presented below

$$\Delta REER_t = 0.225\Delta TOT_t - 0.013 RIRD_t + 0.254 PROD_t - 0.023(REER_{t-1} - 0.092 TOT_{t-1} + 0.121 RIRD_{t-1} - 1.049 PROD_{t-1}) + 0.408\Delta REER_{t-1} + \lambda s_t + u_t$$

As expected terms of trade and productivity growth has relatively more instantaneous effect on real exchange rate than real interest rate.

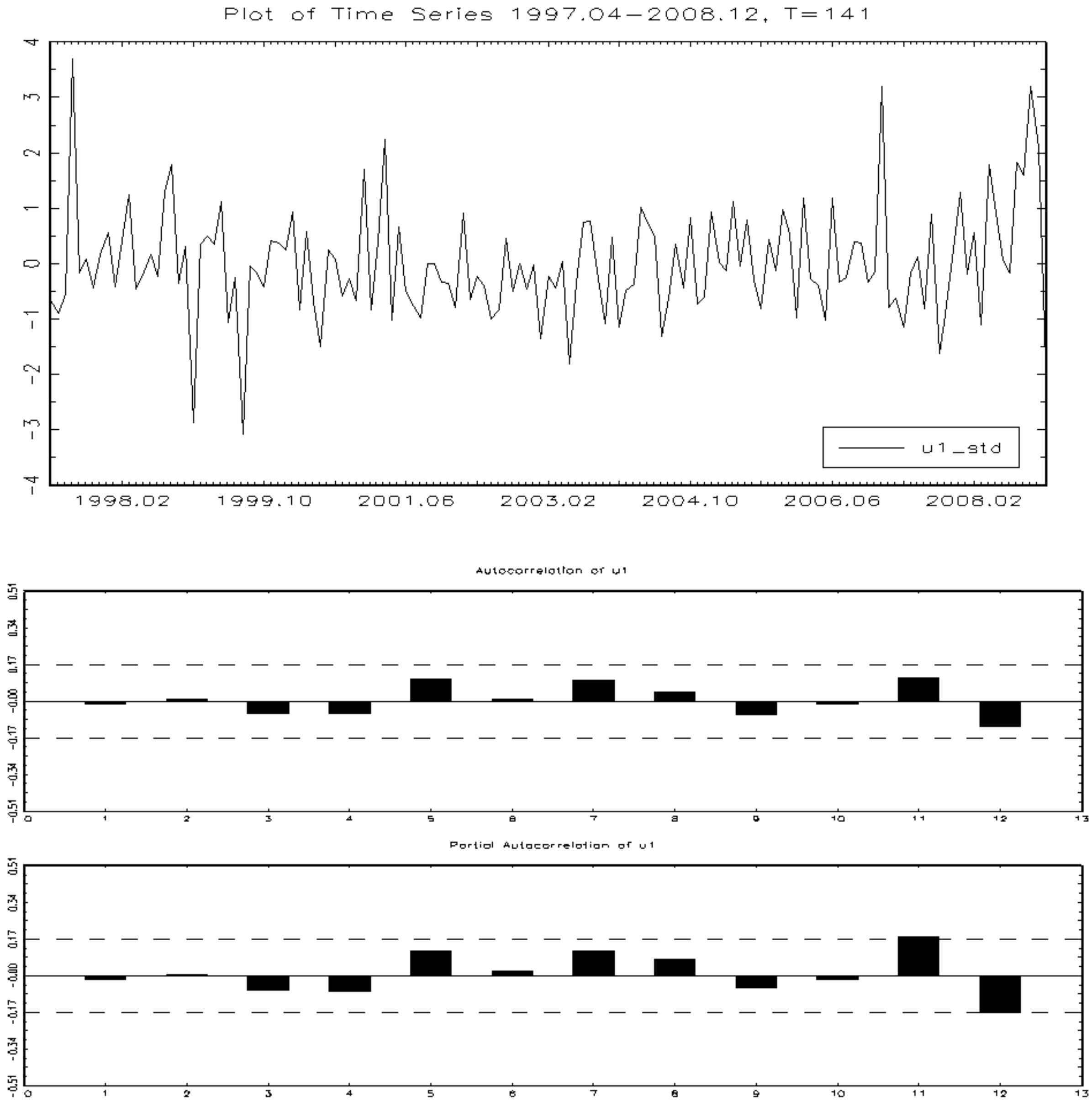
5.5. Model Checking

In this section we use statistical tools for checking how well estimated subset VECM provides an adequate representation of data generating process. We start with the descriptive analysis of the residuals. The standardized residuals and residual autocorrelations are plotted in Figure 3[20]

[19] There are $K(K-1)/2$ potentially different instantaneous covariances, where K is the dimension of the system.

[20] We focus here on the equations for REER. For reports about the other equations see Figure B.1. in Appendix B.

Figure 5. Residuals and residual autocorrelations of subset VECM for REER equation



Although some residual autocorrelations reach outside the $\pm 2/\sqrt{T}$ bounds, they do not give rise to concern, because the large autocorrelations are at high lags.

For diagnostic tests of residuals choosing the order of residual lag is very critical for the test results. Again, if it is chosen too small approximation of the test statistics to the null distribution may be very poor, whereas a large lag order may result in a loss of power. Therefore, in applying the test it is a good strategy to try different orders of lags:

Table 6. Tests for residual autocorrelations

	No. of lags	Test statistics	p-value
Portmanteau test	3	50.70	0.14
	6	92.23	0.39
Breusch-Godfrey test	3	60.65	0.10
	6	206.39	0.22

Notes: Null hypothesis for both tests is no autocorrelation. Test statistics have an asymptotic χ^2 distribution

Normality test reports the multivariate extensions of the *Jarque-Bera* residual normality test, which compares the third and fourth moments of the residuals to those from the normal distribution. Both the joint test and the univariate tests applied to the individual equation errors separately results in rejection of normality hypothesis.

Table 9 shows that multivariate ARCH test rejects its respective null hypothesis. In order to analyze the sources of the possible problem in more detail, univariate ARCH tests are performed for individual equations. This indicates the source of problem in the equation for real interest rate differentials, since it rejects the null hypothesis of no ARCH in the residuals.

Table 7. ARCH-LM test

Test	$ARCH_{LM}(u_1)$	$ARCH_{LM}(u_2)$	$ARCH_{LM}(u_3)$	$ARCH_{LM}(u_4)$	$MARCH_{LM}$
Test statistic	2.25	1.83	51.41	2.32	765.55
p-value	0.90	0.93	0.00	0.89	0.00

Notes: Null hypothesis for both tests is no ARCH in residuals. Test statistics have an asymptotic χ^2 distribution

Granger (1969) defines a variable to be casual for another time series variable, if the former helps to improve the forecasts of the latter. Different extensions have been considered since then. As cointegration rank $r = 1$, there must be Granger-causality in at least one direction because α and β both have rank one and, hence, cannot be zero. Wald tests for Granger causality may result in nonstandard limiting distributions depending on the cointegration properties of the system (Toda & Phillips, 1993). The nonstandard asymptotic properties of the standard tests on the coefficients of cointegrated VAR processes are due to the singularity of the asymptotic distribution of the estimators. Dolado and Lutkepohl (1996) propose that the singularity can be removed by fitting a VAR process whose order exceeds the true order. Instantaneous causality is characterized by nonzero correlation of residuals. Thus the null hypothesis is tested against the alternative of a nonzero covariance between the error vectors. Results reveal instantaneous causality for all variables except productivity differential. But null hypotheses for Granger causality have not been rejected in three direction in the system. As indicated above in order to get approximate limiting distribution for test statistics excess order VAR is estimated, then the last redundant lag ignored[21]. Thus the causality tests are based on fairly large models with many parameters. As discussed before in cointegration rank tests the not large sample information makes it difficult for such tests to reject the null hypothesis when many parameters are estimated. In other words, the causality tests apparently have a power problem in testing Granger causality between determinants of real exchange rate. Lutkepohl (2004) proposes that a cointegration analysis and a Granger-causality analysis look at the data from different angles. In such a situation the view from one direction often gives a much clearer picture than from another

[21] If true data generating process is VAR (p) process, then a VAR (p+1) with $\Phi_{p+1} = 0$ is also an appropriate model. And test is performed on the $\Phi_i, i = 1,..., p$, with the last redundant lag ignored

corner. This line of arguments shows that there is no conflict between the results from the cointegration analysis, weak exogeneity tests and the causality analysis.

5.5. Stability analysis

Further, stability analysis checks the time invariance of the model. *Chow tests* compare the variances for different time periods to decide on parameter constancy. Therefore, a volatility cluster in one of the subperiods may lead to the rejection of the constant parameter hypothesis and this result maybe misleading unless ARCH structure that has been taken into account. If the variability differs due to ARCH effects, this may then be diagnosed as parameter instability, however maybe the model parameters actually do not vary. As for some objective reasons MARCH have not been rejected, we can not rely on Chow test for testing the stability of our model. Instead, the stability test based on the *recursive eigenvalues* has been executed. Hansen and Johansen (1999) propose recursive statistics for stability analysis of VEC models stating that for a time invariant model i^{th} largest eigenvalue[22] based on the sample moments from the first τ observations should be within confidence interval, approximate 95% of which for the nonzero true eigenvalues corresponding to $\lambda_1^{(\tau)}, \lambda_2^{(\tau)}, ..., \lambda_r^{(\tau)}$ is

$$\left[\frac{\lambda_i^{(\tau)}}{\lambda_i^{(\tau)} + (1-\lambda_i^{(\tau)}) \exp(1.96\hat{\sigma}_{ii})}, \frac{\lambda_i^{(\tau)}}{\lambda_i^{(\tau)} + (1-\lambda_i^{(\tau)}) \exp(-1.96\hat{\sigma}_{ii})} \right]$$

where $\hat{\sigma}_{ii}$ is the statistics calculated on the base of covariance matrix.

In another stability test proposed by Hansen and Johansen (1999) recursive eigenvalues are used as the basis for formal tests of parameter constancy. Let

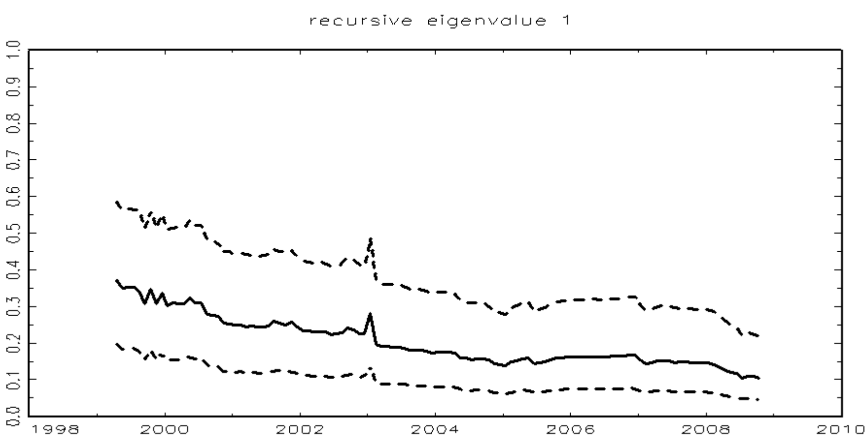
[22] for VEC models without parameter restrictions and without exogenous variables the eigenvalues from a reduced rank regression which are also used in the cointegration rank tests are computed recursively by the Johansen estimation procedure (Johansen , 1995).

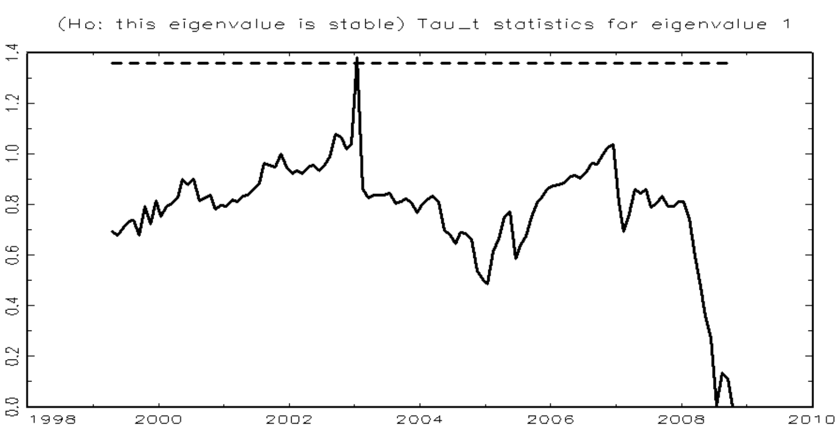
$$\xi_i^{(r)} = \log\left(\frac{\lambda_i^{(\tau)}}{1-\lambda_i^{(\tau)}}\right) \quad \text{and} \quad \tau(\xi_i^{(r)}) = \frac{\tau}{T}\left|(\xi_i^{(r)} - \xi_i^{(T)})/\hat{\sigma}_{ii}\right|$$

Stability is rejected if $\tau(\xi_i^{(r)})$ exceeds the critical value. Critical values for the limiting null distribution are tabulated by Ploberger et al.(1989).

Because the cointegrating rank is equal to one $r = 1$, there is one nonzero eigenvalue. Confidence intervals for that eigenvalue the tau statistic $\tau(\xi_1^{(r)})$ plotted show the recursive eigenvalue appears to be fairly stable and these diagnostic statistics do not indicate instability of the system. Figure 4 reports the results of these two stability tests presented in the graph form:

Figure 6. Recursive eigenvalue and Tau statistics





6. Real exchange rate misalignment and discussion of empirical findings

6.1. Exchange rate misalignment

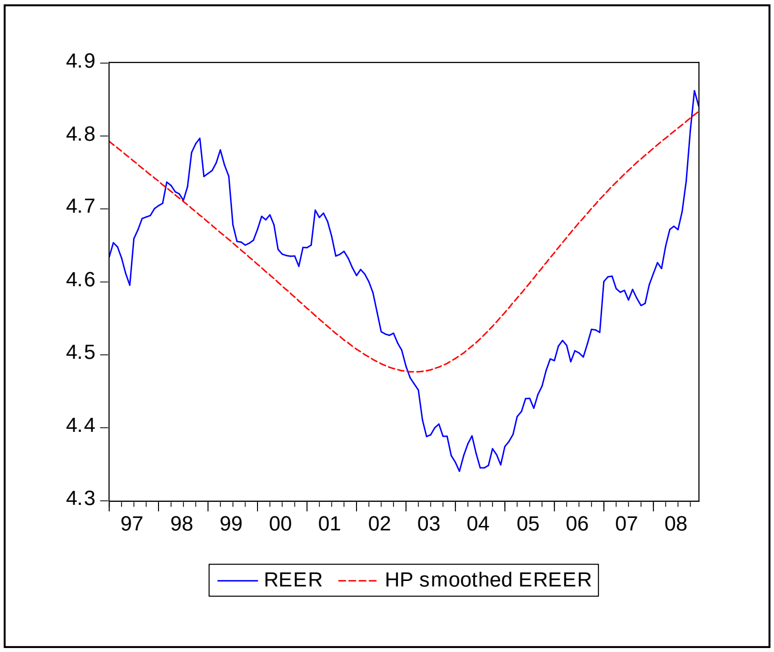
In section we give several measures of misalignment. The long run equilibrium level of real effective exchange rate (EREER) is estimated from the cointegration equation in Table 3. In Figure 6 we plot this measure against actual REER.

Figure 7. Equilibrium and actual real effective exchange rates

Misalignment is defined as actual values of real exchange rate and long-run equilibrium values estimated given current values of its determinants. Clark and Macdonald (1998) refer to this measure as *current misalignment.*

However, the current values may depart from sustainable values and separation of structural and cyclical components is needed. We calculate also the difference between actual real exchange rate and sustainable values, which is called *total misalignment.* Hodrick-Prescott (HP) filter was used to obtain smoothed series for generating long-run equilibrium values of real effective exchange rate.

Figure 8. **HP smoothed equilibrium and actual real effective exchange rates**



HP filter has been criticized because of the end-point bias. The last point of the series has an exaggerated impact on the trend at the end of the series. Therefore, for analyzing recent currency misalignment this may not be efficient way. Using the decomposition method discussed in Granger and Haldrup(1995) we can differentiate permanent and transitory effect. They propose $Y_t = P(Y_t) + T(Y_t)$ where $P(Y_t)$ is persistent or long memory component.

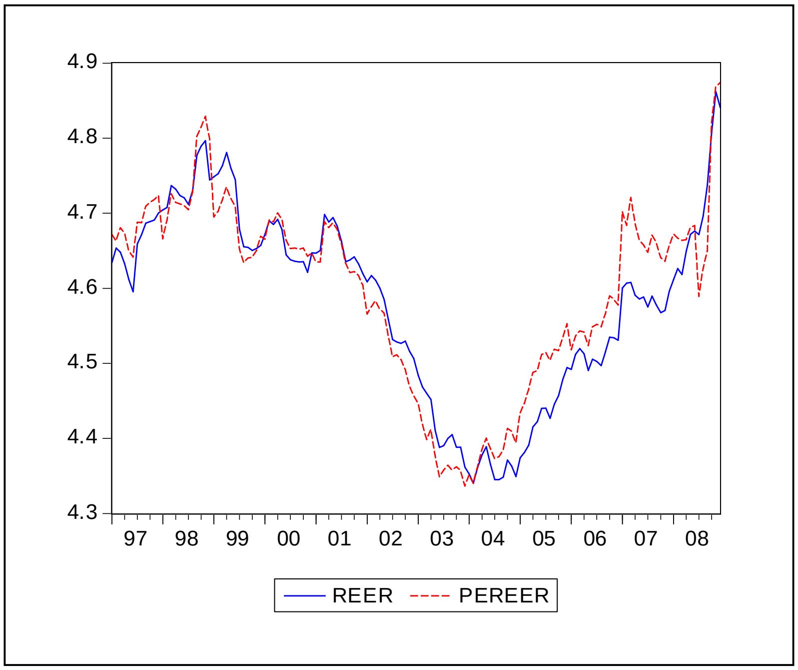
$P(Y_t) = A_1 f_t$ and $T(Y_t) = A_2 z_t$ with $f_t = \alpha'_{ort} Y_t$ and $z_t = \beta' Y_t$ and where $A_1 = \beta_\perp (\alpha'_\perp \beta_\perp)^{-1}$ and $A_2 = \alpha(\beta'_\perp \alpha_\perp)^{-1}$

Putting all together we get the following factorization

$$Y_t = \beta_{\perp t}(\alpha'_\perp \beta_\perp)^{-1} \alpha'_\perp Y_t + \alpha(\beta' \alpha \ \ )^{-1} \beta' Y_t$$

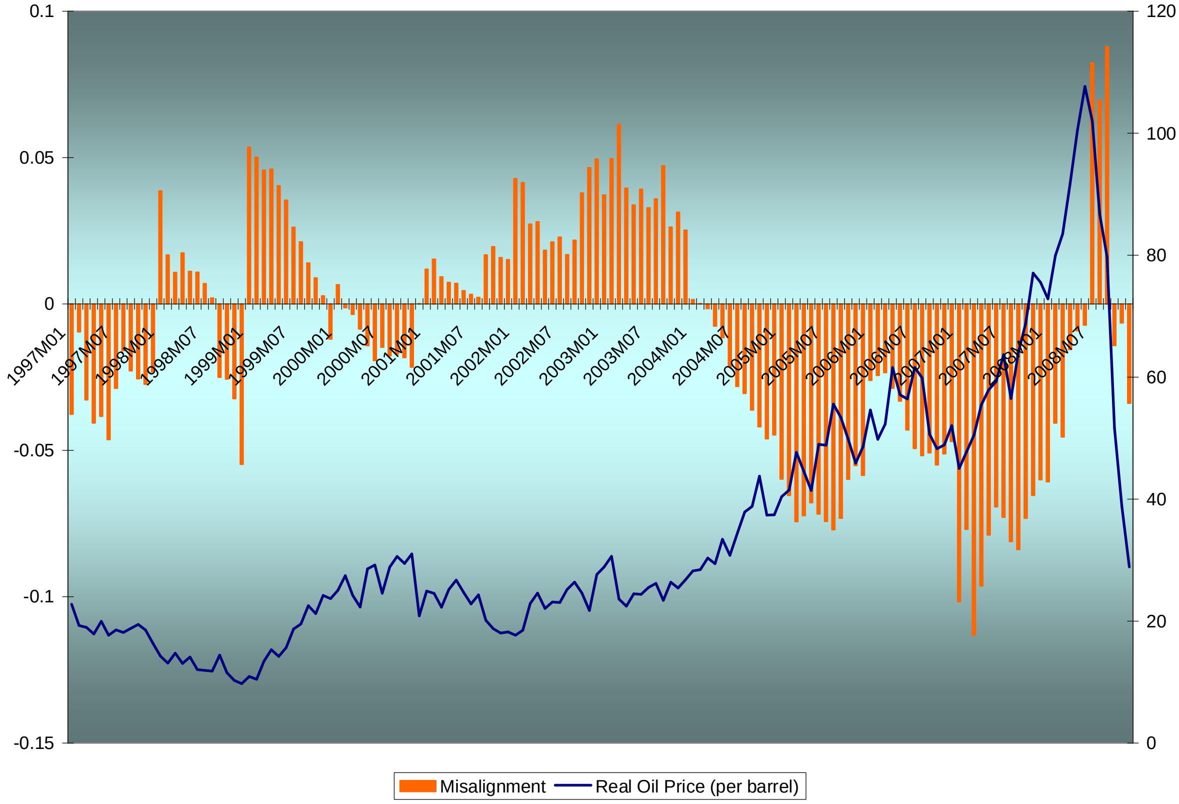
Using the above formula we estimate the permanent part using cointegration and loading vectors. After adjusting the cointegration equation we get permanent equilibrium real effective exchange rate (PEREER). Figure 8 describes the misalignment using permanent equilibrium rate. Comparing EREER with PEREER we see that the latter is less volatile, as reflects the permanent component of the REER.

Figure 9. Permanent equilibrium and actual real effective exchange rate



The real exchange rate has been appreciating between the years, 2004-2008, while still being undervalued. The convergence of the two rates coincides with increase of oil revenues and in the middle of 2008 when oil prices was in its peak, real exchange has become overvalued for several month. During global financial crisis mainly as the result of inflation sluggishness real effective exchange rate has slowed its temp of increment. Figure 9 represents co-movement between oil prices and misalignment of REER relative to PEREER. Structural VEC model shows that instantaneous effect of oil prices to REER is insignificant and one can observe from Figure 9 that misalignment change responds to oil price variation with delay. Habib et al. (2007) argue that real exchange rate response to oil shock depends whether nominal exchange rate is allowed to absorb the exogenous oil shock. In 2007 real and nominal effective exchange rate of manat appreciated respectively 27.7 and 17.7 percent in response to the oil price increase of 45.2 percent in 2006. However, in 2006 real exchange rate appreciated only 6.7 percent and nominal exchange rate even depreciated 5.2 percent.

Figure 10. Real oil price and exchange rate misalignment



Under the pegged exchange rate regime in Azerbaijan nominal exchange rate does not absorb the oil price shock and its appreciation is modest relative the oil price increase. Though rapid increase of oil revenues as a result of oil price increases, as well as quantity of oil exported has lead to real appreciation, the national currency is not overvalued.

6.2. Discussion of empirical results

In this section we discuss the results from our subset model. In Azerbaijan we identify a robust long-run relationship between the exchange rate and oil prices. Also, we find strong evidence of non-stationarity of the REER accounting on structural break in beginning of 2005. The rapid appreciation after several years of depreciation of manat is due to the boom of the oil revenues starting from 2005[23]. Other variables show similar pattern and increase of oil prices in world market also coincides with this period. Therefore, taking into account the similar changes in the series, we conclude that there is no break in the cointegration relation on this specific time period and shift dummy is not included.

The coefficients of cointegration relation are consistent with the elasticities (16)-(18).

The PPP puzzle indicating the high degree of persistence of the shocks to real exchange rate is present in our model. The negative coefficient of loading matrix for REER means the reversion to long run equilibrium. The speed of reversion of the real exchange rate to its long-run mean is measured by half-life of deviations ($\ln(0.5)/\ln(1-|\alpha|)$) and as discussed above for Azerbaijan it is approximately 4 years and reconciles with the consensus estimates of three to five years for the real exchange rates for industrial countries (Taylor, 2003). For structural model this period is shorter (2.5 years), but adjustment coefficient is insignificant.

The coefficient of RIRD in cointegration equation supports uncovered interest parity, which states that relative increase of interest rates would lead to depreciation in order to satisfy no arbitrage condition. Increases in monetary aggregates also reflect commercial banks' foreign borrowing, which has fueled a rapid expansion in their lending. Credit to the economy rose by 55.6% in 2008, much of it going to households and small businesses in lower interest rates in comparison to stringent credit terms previous years. In result created inflationary pressures made its contribution to appreciation. The negative coefficient of RIRD in cointegration equation is consistent with this implication.

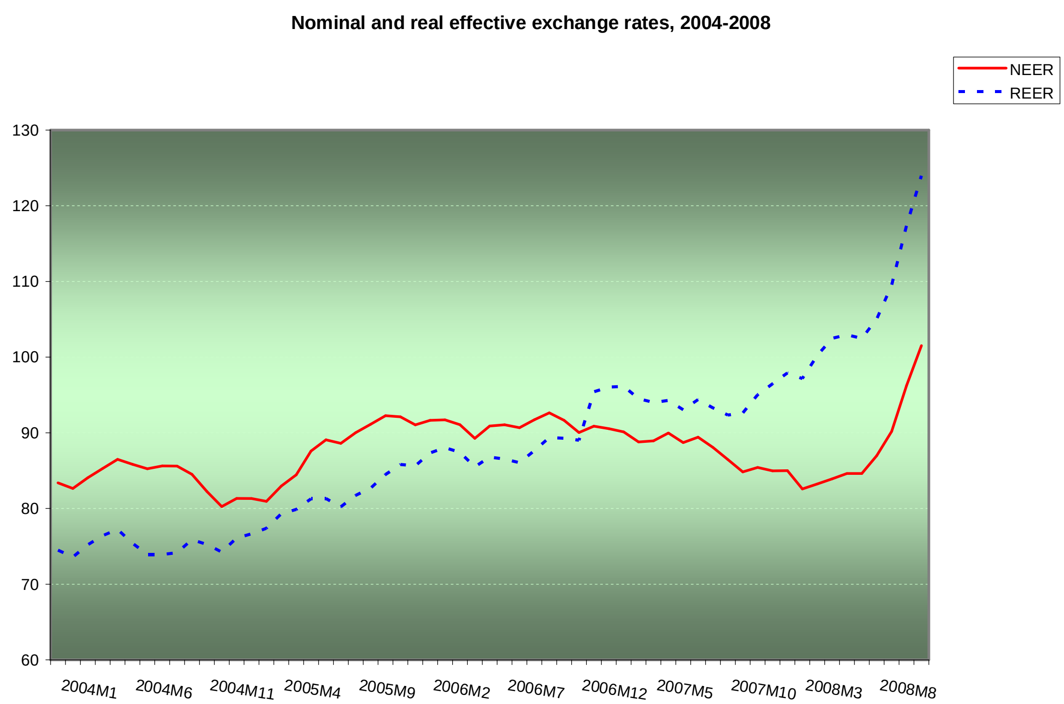
Cointegration relation predicts 0.09 % increase in REER in response to 1% improvement in terms of trade, i.e. increase in oil prices[24], which means 9% increase when oil prices double.

[23] The Baku-Tbilisi-Ceyhan (BTC) pipeline was launched in May, 2005.
[24] As discussed before this equivalence if fair once we take into consideration very little volatility of import prices.

Although managed exchange rate policy and accumulation of oil revenues in the State Oil Fund weakens the effect of oil price shock, in practice the considerable appreciation is observed. Government expenditures financed by the direct transfers from the State Oil Fund put pressure on appreciation through domestic price increases.

The large oil-related foreign currency inflows have created pressures for rapid growth in monetary aggregates. Central Bank has raised its purchases of foreign exchange to limit nominal appreciation of the manat. The manat appreciated only by about 4.5% in nominal terms against the United States dollar. However, the real appreciation was 17% against US dollar. As discussed in the previous subsection increasing oil revenues recent years correspond to more appreciation in real effective exchange rate rather than nominal exchange rate (Figure 5).

Figure 11. Effective exchange rates



Therefore, since 2004 the real exchange rate appreciation of Azeri manat mainly has been through an increase in domestic prices not through nominal appreciation. Central Bank has raised its purchases of foreign exchange to limit nominal appreciation of the manat. These interventions have been only partially sterilized, leading to expansion of broad money (M3) by 44.0% in 2008, though much less than the 71.4% expansion recorded in 2007. In turn resulted persistent inflationary pressures contributed to real appreciation.

Consistent with the Balassa-Samuelson hypothesis, we also find that real appreciation in Azerbaijan has been proportional to productivity differential growth yielding more than 1% appreciation in real exchange rate when prices of relative price of tradables to nontradables increase 1%. According to this hypothesis the real exchange rate will appreciate if productivity growth in the tradables sector exceeds that in the nontradables sector leading to an increase in the relative price of nontradables implies a rise in the overall price level and relative productivity growth. If this condition holds, then the inflation differential is positive and the real exchange rate appreciates. We find strong evidence of this impact on real effective exchange rate of Azeri manat. However, productivity increase mostly falls on oil sector. Instead, in small non-oil trade sector (agriculture, metallurgy, etc) have been deteriorated due to poor supply of technology and labor. On the other hand as oil extraction and export are ruled by oil contracts, this does not increase competitiveness of traded goods in world market.

These facts are consistent with the existence of "Dutch Disease" in Azerbaijan[25]. A rise in the oil price increases the demand for labor and capital in the oil sector, which leads to higher wages there and to a higher profitability. Factors are mobile and labor and capital to move from the manufacturing and service sectors to the oil sector. Oil sector output and employment will thus increase, while output and employment in manufacturing and services will decline. According to the 2007 conclusions, the share of oil products within the total pool of exported items was 85%. Global Competitiveness Report for the 2006-2007 ranked Azerbaijan's economy down to the

[25] Going back to Corden (1977) the "Dutch Disease" hypothesis is briefly summarized as the notion that an exogenous increase in resource prices or in resource output results in real exchange rate appreciation and a decline in the manufacturing sector. He distinguishes between a *resource movement effect* and a *spending effect*.

64th place for low competitiveness level among 125 participant countries. While tradable goods are pegged to the international market by the small country assumption, the price for tradable goods does not change. The decline in services output leads to excess demand for services and therefore to an increase in the price of services. The result is an increase in the price of nontradables relative to tradables, inducing an appreciation of the real exchange rate. USAID funded survey conducted by the Economic Research Center (ERC) in Azerbaijan reported 29% annual CPI increase in 2007. Thus, the inflation in Azerbaijan has been higher that its main trading partners, which contributed to the appreciation of the real effective exchange rate.

Summing up, in Azerbaijan, the positive oil shocks have been transmitted to the real exchange rate through a partial sterilization of oil revenues and a considerable increase in price levels.

The dependence of economy on oil industry has played an important role in the relationship between oil price and the real exchange rate.

7. Conclusion

We have used cointegration technique to estimate EREER for Azerbaijan. Based on the theoretical framework the main explanatory variables have been found to be terms of trade, productivity differentials and real interest rate differentials. We have found that the Azeri manat can be defined as an “oil currency”, since the real effective exchange rate shares a common stochastic trend with the real oil price. This relationship is robust to the inclusion of the productivity differential and real interest rate differentials as other determinants of long-run equilibrium of the real effective exchange rate. Using cointegration relation we have estimated permanent equilibrium level of real exchange rate and found undervaluation of national currency in the years of increasing oil revenues after 2005, though it was close to its equilibrium level in the last year of our sample period.

The magnitude of the error correction coefficients is consistent with the findings for other developing countries, indicating the gradual convergence of the exchange rate toward long-run equilibrium in approximately 4 years. The degree of exchange rate misalignment that the degree of misalignment and its volatility is higher than it would have been under the flexible exchange rate regime. The monetary expansion during the last four years was mainly driven by credit expansion to private sector in lower credit spread, which has started to create inflationary pressures in Azerbaijan and there is an emerging sign of real exchange rate appreciation due to increasing inflationary differential relative to trading partners.

These results yield the following important policy implications for exchange rate policy in Azerbaijan. First, the amount of transfers from the Fund into the State Budget in any year shouldn't be above the Fund's average portfolio profits that will additionally account the fluctuations of oil price in the world market. Second, no direct transfers should be allowed from the Fund into any public investment project or program and acceleration of domestic prices should be kept under control to prevent inflationary pressures on appreciation of REER and at the same time monetary expansion should provide enough liquidity to the development of non-oil sector. Last but not the least, since REER is not overvalued, Central Bank should continue with current pegged exchange rate regime and intervene in the market to prevent the depreciation of REER as a result of sharp decrease in oil prices in the late 2008.

References:

Akram, Q.F. (2004), "Oil prices and exchange rates: Norwegian experience", Econometrics Journal 7, 476-504

Amano, R.A. and S. van Norden (1995), "Terms of trade and real exchange rates: the Canadian evidence", Journal of International Money and Finance 14, 1, 83-104.

Amano, R.A. and S. van Norden (1998), "Oil prices and the rise and fall of the US real exchange rate", Journal of International Money and Finance 17, 299-316.

Balassa, B. (1964), "The Purchasing Power Parity Doctrine: a reappraisal", Journal of Political Economy, 72.

Bergvall, A. (2004), "What determines real exchange rates? The Nordic countries". Scandinavian Journal of Economics 106, 315-337.

Bruggemann, R. and Lutkepohl, H. (2001), "Lag selection in subset VAR models with an application to a U.S. monetary system", in Lutkepohl, H., and M. Kratzig (eds.) (2004), "Applied Time Series Econometrics" Cambridge University Press, Cambridge.

Caballero, R. and V. Corbo (1989), "How does Uncertainty about the Real Exchange Rate Affects Exports", Research Policy Series No. 221. Washington DC, World Bank.

Cashin, P.; L.F. Céspedes and R. Sahay (2004),"Commodity currencies and the real exchange rate", Journal of Development Economics 75, 239-268.

Clark, P and Macdonald, R. (1998), "Exchange Rates and Economic Fundamentals: A Methodological Comparison of BEERs and FEERs", IMF Working paper 98/67.

David F. Hendry and K. Juselius (2000), "Explaining cointegration analysis: Part II", Energy Journal 21.

De Gregorio, J. and H. Wolf (1994), "Terms of Trade, Productivity and Real Exchange Rates," NBER Working Paper N. 4807

Dolado, J. J. and Lutkepohl, H. (1996), "Making Wald tests work for cointegrated VAR systems", Econometric Reviews 15: 369–386.

Engle, Robert F. and C. W. J. Granger (1987), "Co-integration and Error Correction: Representation, Estimation, and Testing", Econometrica, vol 55, pp. 251–276.

Golub, S. (1983), "Oil prices and exchange rates", in Habib M. and M. Kalamova (2007), "Are the oil currencies? The real exchange rate of the oil exporting countries", ECB working paper series N.839.

Granger, C. W. J. and N. Haldrup (1995), "Separation in cointegrated systems, long memory components and common stochastic trends", University of California at San Diego, Economics Working Paper Series

Habib M. and M. Kalamova (2007), "Are the oil currencies? The real exchange rate of the oil exporting countries", ECB working paper series N.839.

Hinkle, Lawrence and Montiel, Peter (eds.) (1999), "Exchange Rate Misalignment: Concepts and Measurement for Developing Countries", World Bank, Oxford University Press, Oxford.

Johansen, S. (1991), "Estimating and hypothesis testing of cointegration vectors in Gaussian Vector Autoregressive Models", Econometrica 59, 1551-1580.

Johansen, S. (1995), "Likelihood-Based Inference in Cointegrated Vector Auto Regressive Models", Oxford University Press, Oxford.

Johansen, S. (2002), "A small sample correction for the test of cointegrating rank in the vector autoregressive model", Econometrica 70, 1929-1961

Korhonnen, I. and T. Juurikkala (2007), "Equilibrium exchange rates in oildependent countries". BOFIT Discussion Paper 8/2007, Bank of Finland Institute
for Economies in Transition.

Krugman, P.(1983), "Oil and the Dollar", in Habib M. and M. Kalamova (2007), "Are the oil currencies? The real exchange rate of the oil exporting countries", ECB working paper series N.839.

Lutkepohl, H. (1991), "Introduction to Multiple Time Series Analysis", Springer Verlag, Berlin.

Lutkepohl, H. & Saikkonen, P. (2000), "Testing for the cointegrating rank of a VAR process with a time trend", Journal of Econometrics 95: 177–198.

Lutkepohl, H., and M. Kratzig (eds.) (2004), "Applied Time Series Econometrics" Cambridge University Press, Cambridge.

MacDonald, R. (1995), "Long-run Exchange Rate Modeling: A Survey of Recent Evidence", IMF Staff Papers, 42: 437-98.

MacDonald, R. (2000), "Concepts to Calculate Equilibrium Exchange Rates: An Overview", Deutsche Bundesbank Economics Research Group Discussion Paper No.
3, Frankfurt.

Montiel, Peter (1999), "Determinants of the long-run equilibrium exchange rate: an analytical model", in Hinkle, Lawrence and Montiel, Peter (eds.) (1999), "Exchange Rate Misalignment: Concepts and Measurement for Developing Countries", World Bank, Oxford University Press, Oxford.

Montiel, P.(2003), “Macroeconomics in Emerging Markets”, Cambridge: Cambridge University Press.

Perron, P. (1989), “The Great Crash, the Oil Price Shock and the Unit Root Hypothesis”, Econometrica, 57, 1361–1401.

Ploberger, W., Kramer, W. and Kontrus, K. (1989), “A new test for structural stability in the linear regression model”, Journal of Econometrics 40: 307–318.

Razin, O. and S.Collins (1997), “Real Exchange Rate Misalignments and Growth”, NBER Working Paper 6174.

Rogoff, K. (1996), “The purchasing power parity puzzle”, Journal of Economic Literature 34, 647-668.

Saikkonen, P. & Lutkepohl, H. (2000a), “Asymptotic inference on nonlinear functions of the coefficients of infinite order cointegrated VAR processes”, in Lutkepohl, H., and M. Kratzig (eds.) (2004), “Applied Time Series Econometrics” Cambridge University Press, Cambridge.

Saikkonen, P. & Lutkepohl, H. (2000b), “Testing for the cointegrating rank of a VAR process with an intercept”, Econometric Theory 16: 373–406.

Samuelson, P. (1964), “Theoretical Notes on Trade Problems,” Review of Economics and Statistics, v. 46.

Soto, R. and M. Tapia (2001), “”Seasonal cointegration and the stability of the demand for money”, Central Bank of Chile working papers N. 103.

Sims, C. A. (1980), “Macroeconomics and reality”, in Lutkepohl, H., and M. Kratzig (eds.) (2004), “Applied Time Series Econometrics” Cambridge University Press, Cambridge.

Taylor, M.P. (2003), “Purchasing Power Parity”, Review of International Economics 11, 436-452.

Toda, H. Y. & Phillips, P. C. B. (1993), “Vector autoregressions and causality”, in Lutkepohl, H., and M. Kratzig (eds.) (2004), “Applied Time Series Econometrics” Cambridge University Press, Cambridge.

Yotopulos P.A. and Y. Sawada (2005), “Exchange rate misalighnment: A new test of long-run PPP based on cross country data”, University of Tokyo, CIRJE F-Series.

Appendix

Table A1. Perron tests for unit root of REER

Specification A

Levels		1st differences	
Test Statistics	Critical value 1%	Test statistics	Critical value 1%
-2.39	-4.57	-9.33	-4.57

Specification B

Levels		1st differences	
Test statistics	Critical value 1%	Test statistics	Critical value 1%
-2.42	-4.88	-9.50	-4.88

Notes: $\lambda = 0.6$. The critical values are taken from Perron (1989)

Table A2. Lag selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-38.45236	NA	4.20e-05	1.271358	2.299354	1.689110
1	622.6563	1166.662	3.19e-09*	-8.215533	-6.844872*	-7.658531*
2	638.0566	26.27109	3.23e-09	-8.206714	-6.493388	-7.510462
3	654.8862	27.71944*	3.21e-09	-8.218915*	-6.162923	-7.383412
4	665.9966	17.64587	3.49e-09	-8.147009	-5.748352	-7.172255
5	672.4005	9.794158	4.06e-09	-8.005889	-5.264567	-6.891885
6	681.7669	13.77412	4.55e-09	-7.908336	-4.824349	-6.655082
7	695.5412	19.44618	4.80e-09	-7.875606	-4.448954	-6.483102
8	708.4375	17.44787	5.15e-09	-7.829963	-4.060645	-6.298208

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Equation A1. Estimation results of the subset VECM

$$\begin{pmatrix}\Delta REER_t\\ \Delta TOT_t\\ \Delta RIRD_t\\ \Delta PROD_t\end{pmatrix}=\begin{pmatrix}-0.014\\ (0.009)\\ ---\\ ---\\ 0.042\\ (0.022)\end{pmatrix}\begin{pmatrix}1.000 & -0.092 & 0.121 & -1.049\\ --- & (0.071) & (0.035) & (0.092)\end{pmatrix}\begin{pmatrix}REER_{t-1}\\ TOT_{t-1}\\ RIRD_{t-1}\\ PROD_{t-1}\end{pmatrix}+$$

$$+\begin{pmatrix}0.264 & --- & --- & ---\\ (0.078) & --- & --- & ---\\ -1.270 & --- & --- & ---\\ (0.460) & --- & --- & ---\\ --- & --- & -0.132 & ---\\ --- & --- & (0.072) & ---\\ 0.700 & --- & --- & -0.093\\ (0.195) & --- & --- & (0.072)\end{pmatrix}\begin{pmatrix}\Delta REER_{t-1}\\ \Delta TOT_{t-1}\\ \Delta RIRD_{t-1}\\ \Delta PROD_{t-1}\end{pmatrix}+$$

$$+\begin{pmatrix}0.011 & -- & 0.009 & -- & -- & -- & -- & -- & 0.013 & 0.008 & --\\ -- & -- & 0.059 & -- & -- & -- & -- & -- & --- & -- & ---\\ -0.306 & -- & -- & -- & -- & -- & 0.270 & -- & -- & -0.250 & --\\ -0.083 & -- & --- & -- & --- & -- & -- & --- & -- & -- & ---\end{pmatrix}\begin{pmatrix}s_{1t}\\ s_{2t}\\ s_{3t}\\ s_{4t}\\ s_{5t}\\ s_{6t}\\ s_{7t}\\ s_{8t}\\ s_{9t}\\ s_{10}\\ s_{11}\end{pmatrix}+\begin{pmatrix}u_{1t}\\ u_{2t}\\ u_{3t}\\ u_{4t}\end{pmatrix}$$

Equation A2. Estimation results for structural VECM

$$\begin{pmatrix}1.000 & -0.225 & 0.013 & -0.254\\ -- & (0.433) & (0.022) & (0.229)\\ --- & 1.000 & ---- & ---\\ ---- & --- & --- & ---\\ --- & --- & 1.000 & ---\\ --- & --- & ---- & ---\\ -1.138 & 0.134 & -0.020 & 1.000\\ (0.853) & (0.199) & (0.032) & ---\end{pmatrix}\begin{pmatrix}\Delta REER_t\\ \Delta TOT_t\\ \Delta RIRD_t\\ \Delta PROD_t\end{pmatrix}=\begin{pmatrix}-0.023\\ (0.034)\\ ---\\ ---\\ 0.053\\ (0.031)\end{pmatrix}\begin{pmatrix}1.000 & -0.092 & 0.121 & -1.049\\ --- & (0.071) & (0.035) & (0.092)\end{pmatrix}\begin{pmatrix}REER_{t-1}\\ TOT_{t-1}\\ RIRD_{t-1}\\ PROD_{t-1}\end{pmatrix}+$$

$$+\begin{pmatrix}0.408 & --- & --- & ---\\ (0.593) & --- & --- & ---\\ -1.267 & --- & --- & ---\\ (0.460) & --- & --- & ---\\ --- & --- & -0.128 & ---\\ --- & --- & (0.077) & ---\\ 0.201 & --- & --- & -0.088\\ (0.435) & --- & --- & (0.075)\end{pmatrix}\begin{pmatrix}\Delta REER_{t-1}\\ \Delta TOT_{t-1}\\ \Delta RIRD_{t-1}\\ \Delta PROD_{t-1}\end{pmatrix}+DS_t+u_t$$

Figure A1. Standardized residuals

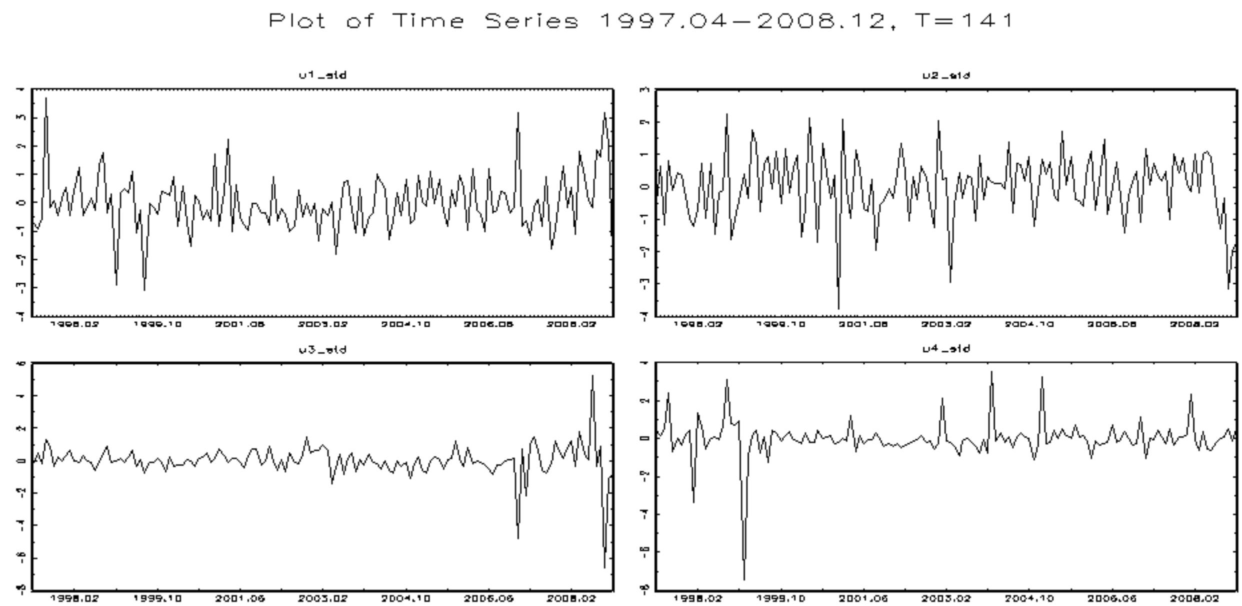
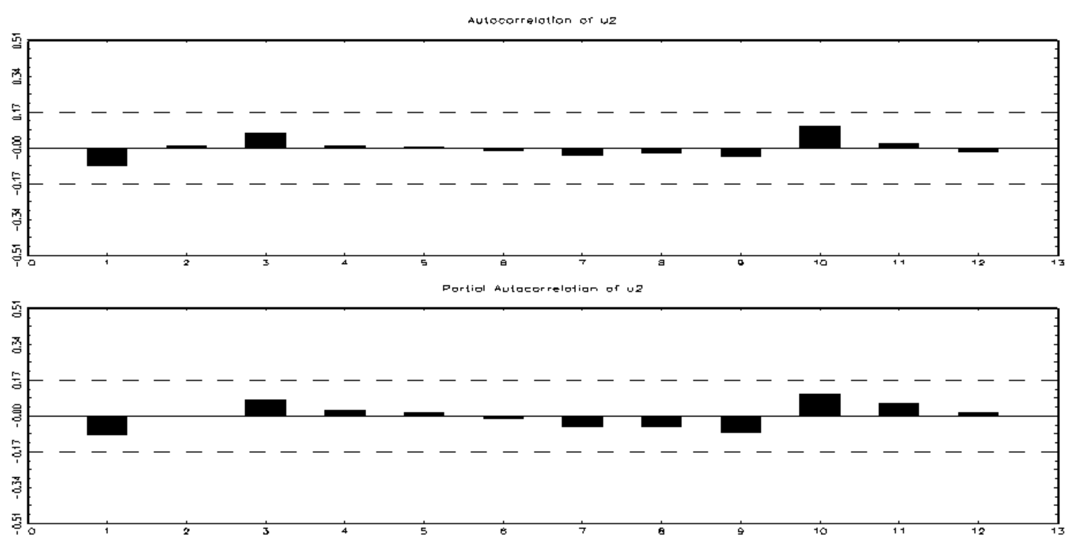
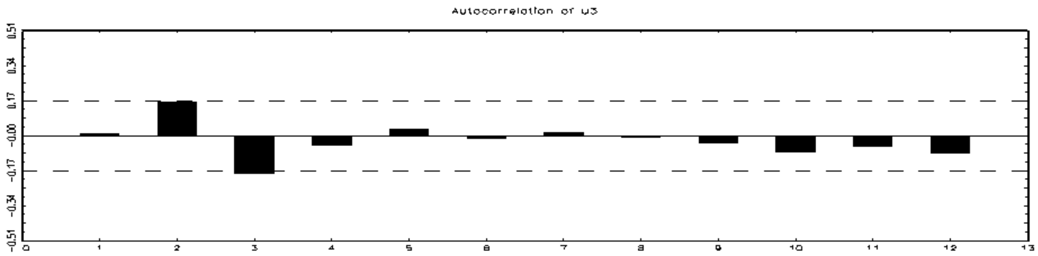
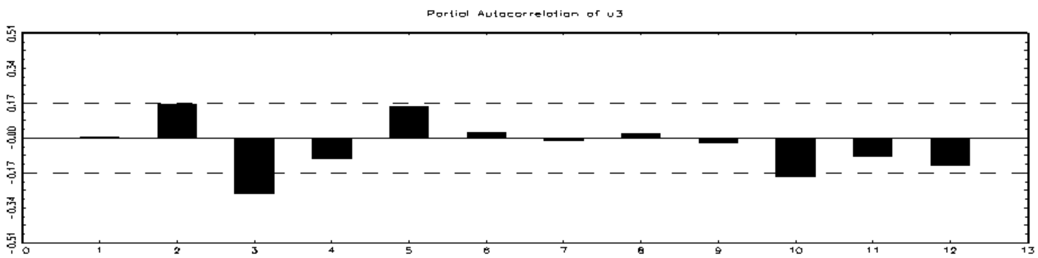


Figure A2.Residual autocorrelations




Autocorrelation of u3
0.51
0.34
0.17
-0.00
-0.17
-0.34
-0.51
0 1 2 3 4 5 6 7 8 9 10 11 12 13


Partial Autocorrelation of u3
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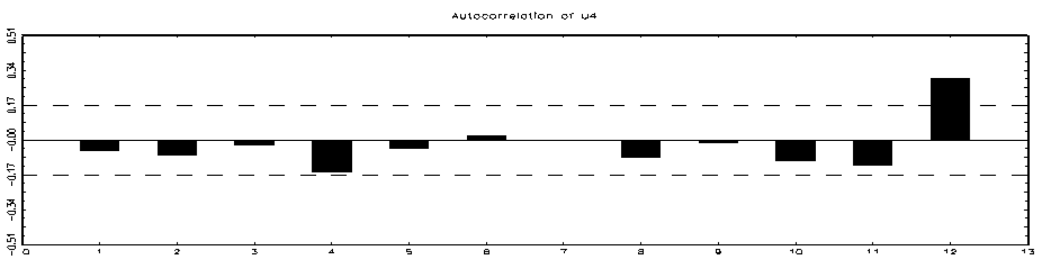
0.34
0.17
-0.00
-0.17
-0.34
-0.51
0 1 2 3 4 5 6 7 8 9 10 11 12 13


Autocorrelation of u4
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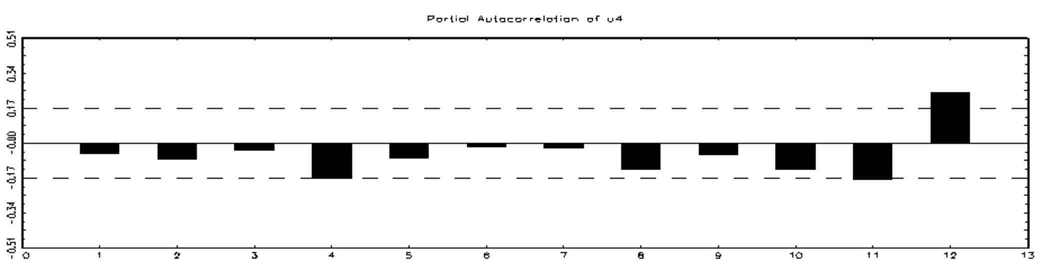
0.34
0.17
-0.00
-0.17
-0.34
-0.51
0 1 2 3 4 5 6 7 8 9 10 11 12 13


Partial Autocorrelation of u4
0.51
0.34
0.17
-0.00
-0.17
-0.34
-0.51
0 1 2 3 4 5 6 7 8 9 10 11 12 13