Interest Rate, Exchange Rate and Uncovered Interest Parity between China and USA.

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Abstract

The uncovered interest parity (UIP) puzzle concerns the empirical regularity that high interest rate countries tend to have high expected returns on short time deposits. We test whether UIP holds between China and USA. If it holds, this could partially explain that China is not an exchange rate manipulation country. Using Fama regression, our results reject UIP holds between China and USA.

1 Introduction

The interest rate parity in foreign exchange markets finds that over short time horizons(from a week to a quarter) when the interest rate (one country relative to another) is higher than average, the short-term deposits of the high-interest rate currency tend to earn an excess return. That is, the high interest rate country tends to have the higher expected return in the short run, hence the price of foreign currency should be lower than average. Standard exchange rate models, such as Mundell-Fleming model or the well-known Dornbusch(1976) model shows that interest rate holds: that there are no ex ante excess returns from holding deposits in one country relative to another.

Following the previous empirical literatures, I investigate the behavior of exchange rates and interest rates for the United States relative to China using different time series tools, specifically, I test whether the interest rate parity holds between China and USA. This project is interesting because in a long time, China has been criticized for manipulating exchange rate. If China manipulated the exchange rate, this will definitely distorts the exchange rate market, hence the interest rate parity will not hold between China and USA.

The remainder of this paper is presented as follows: , section 2 is the discussion of data used in this paper, and also analyzes the statistics results. Section 3 describes the model specication and related econometric theories. Section 4 presents empirical results. The last section summarizes the empirical findings and conclusions.

2 Data

I use the monthly data. Exchange rate (expressed yuan per dollar), and inflations for China and USA are all from The Organisation for Economic Co-operation and Development (OECD) Website. Nominal interest rates for China and USA are both from Reserve Bank at Saint Louis. The whole time range is from Feb.1993 to Oct.2016. Our data covers 284 observations after adjustment.

I first calculated the real interest rate from the nominal interest rate and inflation (nominal interest rate minus inflation), and then take the difference of real interest rates between China and USA as the net real interest rates(NI). Following the previous literature, we take log of exchange rate as our exchange rate.

Table 1 summarizes the variables we used and their definitions.

Table 2 gives the summary statistics of these variables.

It shows that over 1993 to 2016, the average exchange rate is 7.49 Renminbi per dollar, and on average China has a higher inflation and nominal interest rate than US. And also the net interest rate is positive, which means on average China has a higher real interest rate than US.

Figure 1 shows the trend graph of inflation, nominal interest rate and real interest rates of China and USA over period 1993 to 2016. We can see that the above results still holds. Specifically, China's nominal and real interest rate is decreasing over time, however USA's nominal and real interest rate is fluctuating before 2008 and quite flat after that.

Figure 2 shows the trend graph of the level of exchange rate and the net interest rate between China and USA. Clearly, exchange rate is decreasing over time, from the highest about 8.8 to about 6.3. However the trend pattern for net interest rate is not very clear, specifically, we know that after the 2008 global financial crisis, the rate is quite flat, and is about 2%. Moreover, for the most time during this period, net interest rate keeps positive.

3 The Econometric Models

3.1 Unit Root Test

The assumption of the classical regression model is that both the sequences should be stationary and that the errors have a zero mean and a finite variance. Non-stationary could cause the regression to be a spurious regression, which has a high R square and t-statistics that appear to be significant but the results are meaningless. The method used for unit root test is Augmented Dickey Fuller(ADF) test which includes additional lags.

The null hypothesis of at least one unit root is

$$y_t = \sum_{i=1}^{k} \alpha_i * y_{t-i} + \epsilon_t, \qquad \sum_{i=1}^{k} \alpha_i = 1$$

Alternative hypothesis:

$$y_t = \alpha_0 + \sum_{i=1}^{k} \alpha_i * y_{t-i} + \epsilon_t, \qquad |\sum_{i=1}^{k} \alpha_i| < 1$$

In general, we estimate the equation as shown below:

$$\Delta y_t = \alpha + \beta * t + (\rho - 1) * y_{t-i} + \sum_{i=1}^{k-1} \theta_i * y_{t-i} + \epsilon_t$$

where $\Delta = 1 - L$, y_t is the variable such as the exchang rate or net interest rate between China and USA, ϵ is a white noise term. The null hypothesis is $\rho = 1$ and the alternative hypothesis is $\rho \neq 1$. If we fail to reject H_0 it means there is at least one unit root

3.2 Cointegration Test

By the definition of cointegration that two variables with one or more units are cointegrated if a linear combination of the wo variables has fewer unit roots than the original variables. So we apply the Johansen test and get estimate of cointegrating matrix in VAR to capture the long-run equilibrium relationship between exchange rate and net interest rate. The vector equation is

$$\Delta x_t = \pi x_{t-1} + \sum_{i=1}^{k} \pi \Delta x_{t-i} + \nu_t$$

The null hypothesis is $\pi = 0$, if we can not reject the null hypothesis, it implies that there are not cointegrated relation between variables. Also the rank of π is the number of cointegrating vectors. There are two ways for Johansen test, the first is maximum eigenvalue test and another is Johansen trace test. The statistic for the maximum eigenvalue is

$$LR(r, r+1) = -Tln(1 - \lambda_{r+1})$$

The statistic for trace test is

$$LR(r, n) = -T \sum_{i=r+1}^{n} ln(1 - \lambda_i)$$

The null hypothesis of both tests are the same, which is there is no cointegration. The difference between them is the altervative hypothesis.

3.3 Vector Errow Correction and Granger Causality Test

When the variables are non-stationary and are cointegrated, we can apply the Vector Error Correction Model (VECM), which can capture both the short-run dynamic and the long-run equilibrium relationship between variables. The Vector Error Correction Model (VECM) is a Vector Autoregressive Model (VAR) in first differences with the addition of a vector when there exists cointegraion, the Granger Causality is:

$$\Delta y_{1t} = \alpha_0 + \delta_1(y_{1,t-1} - \gamma y_{2,t-1}) + \sum_{i=1}^{k} \alpha_{1,i}\Delta y_{1,t-i} + \sum_{i=1}^{k} \alpha_{2,i}\Delta y_{2,t-i} + \epsilon_{1,t}$$

$$\Delta y_{2t} = \beta_0 + \beta_2(y_{1,t-1} - \gamma y_{2,t-1}) + \sum_{i=1}^{k} \beta_{1,i}\Delta y_{1,t-i} + \sum_{i=1}^{k} \beta_{2,i}\Delta y_{2,t-i} + \epsilon_{2,t}$$

Where y_{1t} represents stock prices and y_{2t} represents exchange rates.

According to Engle and Granger(1987), we estimate the error correction term using the residual from a cointegrating regression on In(EX) and NI, δ_1 and δ_2 are the speeds of adjustment. The null hypothesis H_o :

$$\alpha_{21} = \alpha_{22} = ... = \alpha_{2k} = 0, and \delta_1 = 0$$

If we fail to reject the null hypothesis, it implies that exchange rate does not Granger cause net interest rate.

The null hypothesis H_0:

$$\beta_{11} = \beta_{12} = ... = \beta_{1k} = 0, and \delta_2 = 0$$

If we fail to reject the null hypothesis, it implies that net interest rate does not Granger Cause exchange rate.

4 The Empirical Results

4.1 ACF and PACF

The ACF and PACF of LOGEX is reported in Figure 3, Figure 3 shows the autocorrelation and partial autocorrelation function for LOGEX (log exchange rate). The first order autocorrelation is 0.975, and autocorrelations declines very slowly, which implies there may be unit root. Figure 4 shows the autocorrelation and partial autocorrelation function for DLOGEX (the difference of log exchange rate), here clearly ACF and PACF is 0, which means there is no unit root for DLOGEX. However, we still need to test whether there is unit root for LOGEX.

The ACF and PACF of NI is reported in Figure 5, Figure 5 shows the autocorrelation and partial autocorrelation function for NI (net interest rate). The first order autocorrelation is 0.898, and autocorrelations declines very slowly, which implies there may be unit roots. Figure 6 shows the autocorrelation and partial autocorrelation function for D(NI) (the difference of interest rate), here there is no special pattern of ACF and PACF, which mean that there is no unit root for D(NI). However, we still need to test whether there is unit root for NI.

4.2 Unit Root Test

We use ADF method described above to test the existence of unit root for LOGEX. Figure 7 shows that the P values is 0.1875, which means we could not reject the null hypothesis: LOGEX has a unit root. We continue using ADF method to test whether DLOGEX has a unit root. Figure 8 shows that the P value is almost 0, hence we can reject the null hypothesis: DLOGEX has a unit root. In conclusion, there is a unit root for LOGEX and no unit root for DLOGEX.

We use ADF method described above to test the existence of unit root for NI. Figure 9 shows that the P values is 0.0306, which means we could reject the null hypothesis: NI has a unit root at 5% level. In conclusion, there is no unit root for NI.

4.3 ARMA Model for LOGEX

According to Figure 3, we try AR1 for LOGEX. The output is shown on Figure 10. The coefficient for LOGEX(-1) is 0.98 and very significant. Moreover, Figure 11 plots the ACF and PACF of the residuals. It shows that there is no clear relationship between residuals. Figure 12 plots the ACF and PACF of the squared residuals. It shows that there is no clear relationship between squared residuals. In a word, the outcome shows that AR1 is a good model to estimate LOGEX. Combining with the unit root test, we can see that LOGEX is a random walk process.

4.4 ARCH and GARCH for NI

After trying some other models to estimate NI, we use ARMA(1,1) to estimate the level of NI and GARCH(1,1) to estimate the residuals. The outcome is shown in Figure 13. All the coefficients except constant are significant. Specifically, the coefficient for NI(-1) is 0.948 and it seems that there is a unit root for NI, however, we already tested that there is no unit root. Figure 14 plots the ACF and PACF for residuals. Cleary there is no significant correlation in the residuals except for the lag12. Figure 15 plots the ACF and PACF for squared residuals. Clearly there is no significant correlation in the squared rediduals except for the lag12. Combining Figure13, Figure 14 and Figure 15 together, we can conclude that even there is some correlation among rediduals, we still think ARMA(1,1) and GARCH(1,1) is a good model to estimate net interest rate.

4.5 Cointegration Test, VAR and ECM

We apply the Johansen cointegration test to test whether there is cointegration between LOGEX and NI. The test outcome is shown in Figure 16. Figure 16 shows that 3 out of 5 methods show that there are cointegration between LOGEX and NI. Hence an error correction term should be included in the bivariate autoregressions.

Figure 18 shows the outcome of the model of Vector Error Correction. The absolute value of t-statistics of CointEq1 for D(LOGEX) and D(NI) are around 2 and hence are marginal significant. Hence Figure 18 shows that there is long-run relationship between the two variables.

4.6 Test Granger Causality

To better capture their relationship, we do the Granger Causality test. Since Granger causality test requires that all data series involved are stationary, we use the first differences of log level series of exchange rate and the level series of net interest rate.

Figure 19 shows the outcome for lag 1. We could not reject NI does not Granger Cause DLOGEX, however, we could reject DLOGEX Granger Cause NI at 5% level.

Figure 20 shows the outcome for lag 2. In this case we conclude that NI Granger Cause DLOGEX and DLOGEX Granger Cause NI.

4.7 Impulse Responses

The impulse response function shows in Figure 21 describes how exchange rates and net interest rate react over time to exogenous innovation shock. The exchange rate and net interest rate are responding to the future value of themselves but not each other. Figure 21 and Figure 22 give more direct view about how the exchange rate and net interest rate response to themselves and to each other. The response of exchange rates by net interest rate fluctuate across periods, some of the period they have negative signs while some period they have positive signs. The similar results hold for the response of net interest rate by exchange rate.

5 Fama Regression

The Famma regression(see Fama 1984) is the basis for thw forward premium puzzle. It is usually reported as a regression of the change in the log of the exchange rate between time t and t+1 on the time t interest differential:

$$-1 * DLOGEX_t = \alpha + \beta * NI_{t-1} + \epsilon_{t-1}$$

Where$DLOGEX$ means the difference change of log of exchange rate between China and USA(exchange rate is expressed as RMB per dollar).Under uncovered interest parity, $\alpha = 0$ and $\beta = 1$

Figure 23 shows the Fama regression. The coefficient for NI(-1) is -0.000876 and not significant. The intercept coefficient, on the other hand is very near zero. Hence we can conclude that the uncovered interest rate does not hold between China and USA.

6 Conclusions

In this paper, we study the relationship between exchange rates and net interest rates, by using monthly data. We employ the Johansen maximum likelihood cointegration tests and get the conclusion that there exists cointegration between exchange rates and net interest rate. Based on cointegration, we estimate the Vector Error Cointegration Model to capture the long-run equilibrium relationship between the variables.

Firstly, evidence suggests that there exists significant long-run relationship between the exchange rates and net interest rate. Secondly, Granger causality seems to exist. Also from the impulse response function, the results are not quit consistent with the idea that both net interest rate and exchange rates can serve as instruments to predict the future path of each other. In terms of uncovered interest rate parity, our Fama regression does not support.

This paper only uses the data from China and USA, which I think it maybe helpful to understand the dynamic relationship between net interest rate and exchange rate between China and USA. And it could be useful for both countrys' monetary policy.

7 Reference

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8 Appendix

Table 1: Variables and Definitions

Variables	Definitions
EX	Exchange rate between China and USA(RMB per dollar)
LOGEX	Log of exchange rate between China and USA(RMB per dollar)
DLOGEX	Difference change of log of Exchange rate between China and USA
INCN	China's inflation (%)
INUS	USA's inflation (%)
NICN	China's nominal interest rate (%)
NIUS	USA's nominal interest rate (%)
RICN	China's real interest rate (%)
RIUS	USA's real interest rate (%)
NI	net interest rate between China and USA (China's minus USA's) (%)

Table 2: Summary Statistics

Sample: 1993M02 2016M10								
	EX	INCN	INUS	NICN	NIUS	RICN	RIUS	NI
Mean	7.49	0.32	0.19	4.63	2.95	4.30	2.76	1.54
Median	8.08	0.20	0.19	3.25	3.00	3.29	2.65	1.94
Maximu	8.70	4.05	1.22	10.44	6.25	1.27	6.79	7.77
Minimum	5.71	-1.40	-1.92	2.70	0.50	0.92	-0.36	-4.25
Std. Dev.	0.94	0.90	0.34	2.66	2.00	2.50	1.98	2.38
Skewnes	-0.45	1.04	-0.99	1.33	0.18	1.22	0.18	-0.33
Kurtosis	1.52	5.01	8.23	3.01	1.45	3.18	1.54	2.81
Observations	285	285	285	285	285	285	285	285

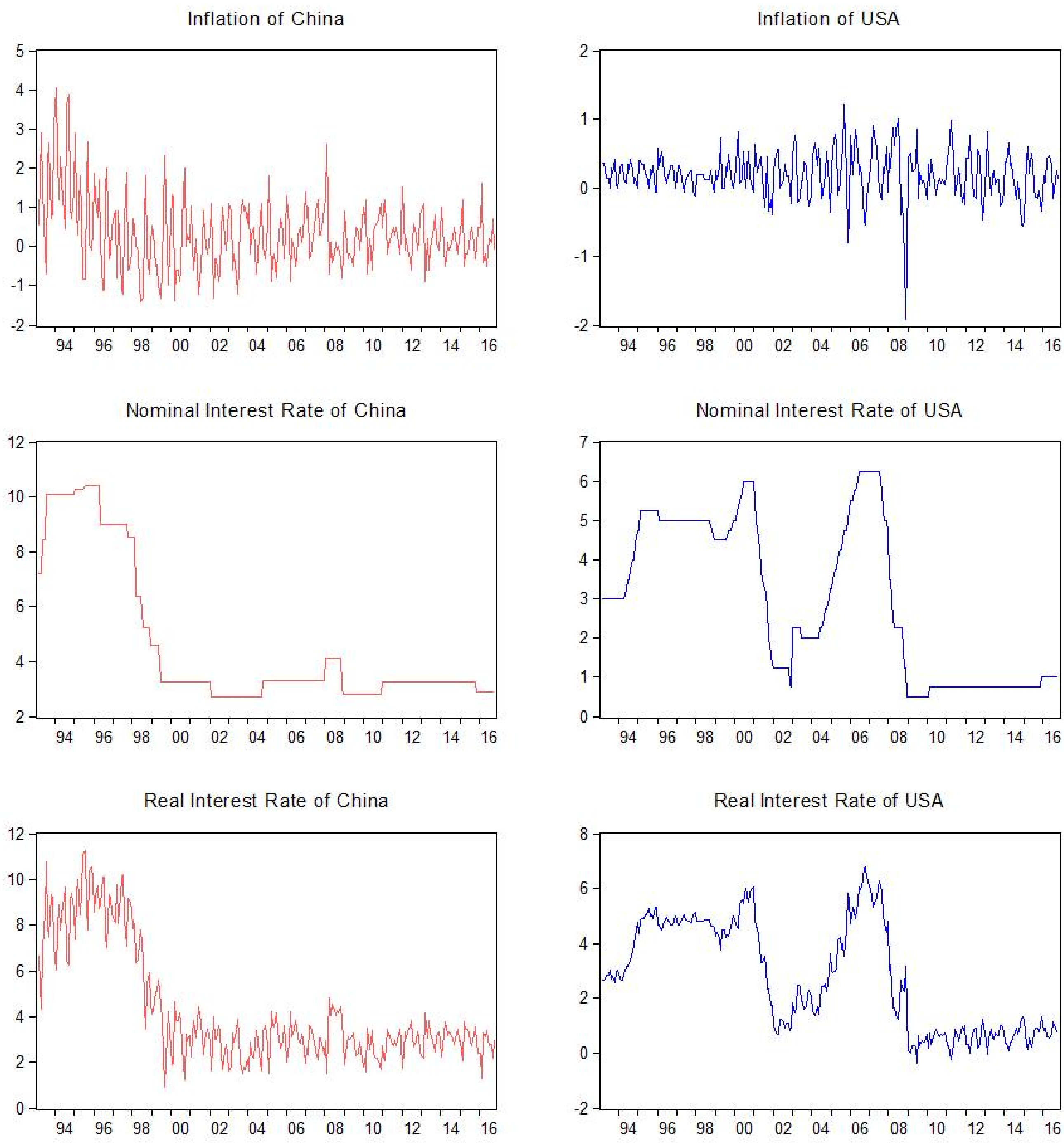

Inflation of China
Inflation of USA
Nominal Interest Rate of China
Nominal Interest Rate of USA
Real Interest Rate of China
Real Interest Rate of USA
94 96 98 00 02 04 06 08 10 12 14 16

Figure 1:

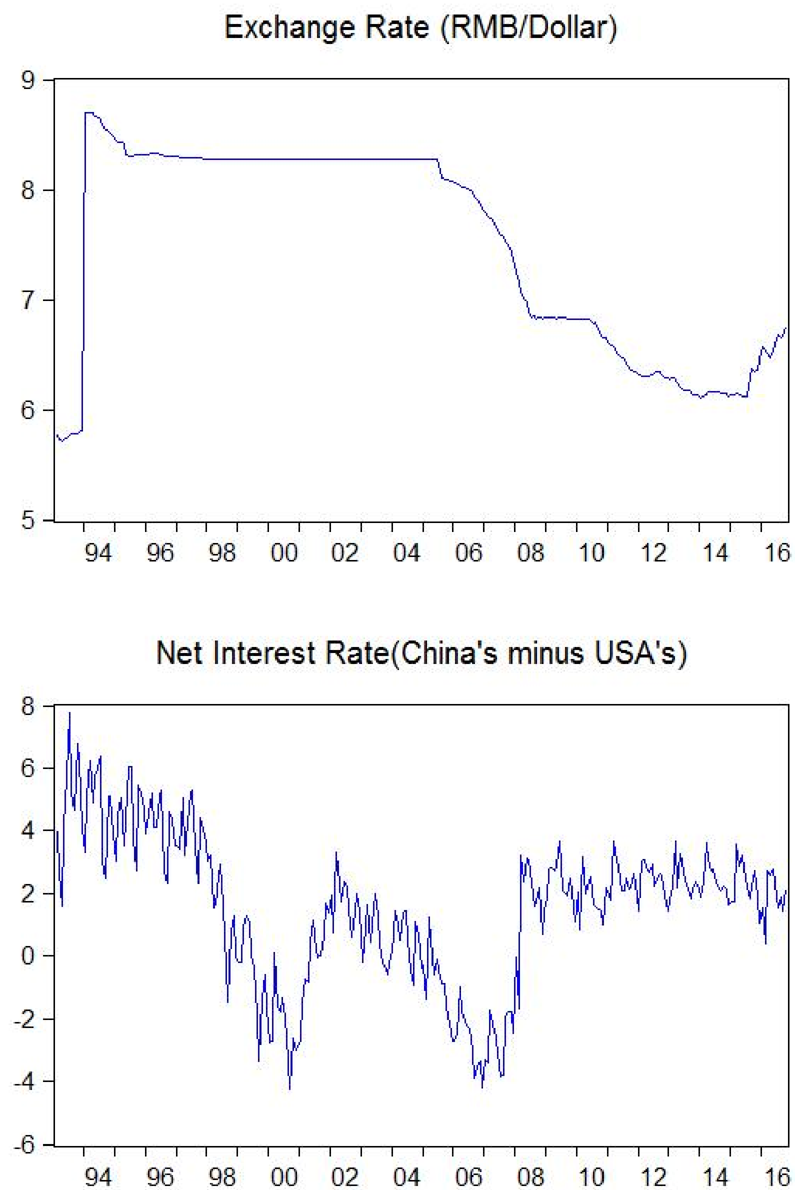

Exchange Rate (RMB/Dollar)
9
8
7
6
5
94
96
98
00
02
04
06
08
10
12
14
16
Net Interest Rate(China's minus USA's)
8
6
4
2
0
-2
-4
-6
94
96
98
00
02
04
06
08
10
12
14
16

Figure 2:

Correlogram of LOG(Exchange Rate)

Date: 03/22/17 Time: 20:01
Sample: 1993M02 2016M10
Included observations: 285

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.975	0.975	273.57	0.000
		2	0.948	-0.039	533.28	0.000
		3	0.921	-0.027	779.06	0.000
		4	0.893	-0.013	1011.3	0.000
		5	0.865	-0.022	1230.1	0.000
		6	0.837	-0.026	1435.5	0.000
		7	0.808	-0.025	1627.8	0.000
		8	0.780	-0.010	1807.3	0.000
		9	0.751	-0.011	1974.7	0.000
		10	0.724	-0.009	2130.4	0.000
		11	0.696	-0.014	2274.9	0.000
		12	0.689	0.411	2417.3	0.000
		13	0.683	-0.025	2557.7	0.000
		14	0.677	-0.020	2696.0	0.000
		15	0.671	-0.014	2832.2	0.000
		16	0.663	-0.034	2965.9	0.000
		17	0.657	0.001	3097.5	0.000
		18	0.650	-0.022	3226.9	0.000
		19	0.643	-0.012	3354.0	0.000
		20	0.635	-0.011	3478.6	0.000
		21	0.628	-0.010	3600.7	0.000
		22	0.620	-0.015	3720.2	0.000
		23	0.612	0.202	3837.0	0.000
		24	0.603	-0.025	3951.0	0.000
		25	0.595	-0.019	4062.2	0.000
		26	0.586	-0.013	4170.6	0.000
		27	0.577	-0.039	4276.2	0.000
		28	0.567	-0.012	4378.6	0.000
		29	0.557	-0.022	4477.9	0.000
		30	0.548	-0.013	4574.0	0.000
		31	0.538	-0.012	4667.1	0.000
		32	0.527	-0.011	4757.0	0.000
		33	0.517	-0.017	4843.9	0.000
		34	0.507	0.102	4927.6	0.000
		35	0.497	-0.023	5008.3	0.000
		36	0.486	-0.017	5086.0	0.000

Figure 3:

Correlogram of D(LOGEX)

Date: 03/22/17 Time: 20:05
Sample: 1993M02 2016M10
Included observations: 284

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.020	0.020	0.1140	0.736
		2	0.010	0.010	0.1439	0.931
		3	0.005	0.005	0.1520	0.985
		4	0.007	0.007	0.1680	0.997
		5	0.016	0.016	0.2451	0.999
		6	0.013	0.012	0.2964	1.000
		7	-0.003	-0.004	0.2989	1.000
		8	-0.004	-0.004	0.3033	1.000
		9	-0.007	-0.007	0.3164	1.000
		10	-0.012	-0.012	0.3590	1.000
		11	-0.002	-0.002	0.3606	1.000
		12	-0.009	-0.008	0.3840	1.000
		13	0.004	0.005	0.3893	1.000
		14	0.004	0.005	0.3951	1.000
		15	0.003	0.004	0.3983	1.000
		16	-0.024	-0.024	0.5768	1.000
		17	0.000	0.001	0.5769	1.000
		18	0.004	0.005	0.5829	1.000
		19	0.005	0.005	0.5917	1.000
		20	0.006	0.006	0.6044	1.000
		21	0.003	0.004	0.6079	1.000
		22	0.002	0.003	0.6098	1.000
		23	0.003	0.003	0.6130	1.000
		24	0.004	0.003	0.6182	1.000
		25	0.002	0.001	0.6194	1.000
		26	0.008	0.007	0.6397	1.000
		27	0.004	0.004	0.6455	1.000
		28	0.003	0.002	0.6482	1.000
		29	0.003	0.003	0.6504	1.000
		30	0.003	0.004	0.6543	1.000
		31	0.002	0.002	0.6558	1.000
		32	0.003	0.002	0.6585	1.000
		33	0.002	0.002	0.6600	1.000
		34	0.004	0.004	0.6657	1.000
		35	0.005	0.005	0.6729	1.000
		36	0.003	0.003	0.6757	1.000

Figure 4:

Correlogram of NI

Date: 03/22/17 Time: 20:09
Sample: 1993M02 2016M10
Included observations: 285

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.898	0.898	232.50	0.000
		2	0.833	0.135	433.17	0.000
		3	0.821	0.278	628.86	0.000
		4	0.828	0.218	828.33	0.000
		5	0.788	-0.089	1009.9	0.000
		6	0.731	-0.119	1166.4	0.000
		7	0.735	0.205	1325.3	0.000
		8	0.729	-0.035	1482.1	0.000
		9	0.687	-0.097	1621.8	0.000
		10	0.649	0.031	1747.1	0.000
		11	0.667	0.189	1879.8	0.000
		12	0.681	0.047	2018.8	0.000
		13	0.602	-0.356	2127.7	0.000
		14	0.529	-0.168	2212.3	0.000
		15	0.510	-0.025	2291.0	0.000
		16	0.494	-0.095	2365.3	0.000
		17	0.457	0.103	2429.1	0.000
		18	0.395	-0.054	2476.9	0.000
		19	0.391	0.068	2523.9	0.000
		20	0.383	0.032	2569.2	0.000
		21	0.348	0.025	2606.6	0.000
		22	0.323	0.077	2639.1	0.000
		23	0.329	0.008	2673.0	0.000
		24	0.361	0.217	2713.9	0.000
		25	0.298	-0.187	2741.8	0.000
		26	0.232	-0.166	2758.9	0.000
		27	0.214	-0.016	2773.4	0.000
		28	0.208	-0.081	2787.2	0.000
		29	0.181	0.005	2797.6	0.000
		30	0.132	0.041	2803.1	0.000
		31	0.134	0.063	2808.9	0.000
		32	0.138	0.007	2815.1	0.000
		33	0.112	-0.026	2819.1	0.000
		34	0.095	0.064	2822.1	0.000
		35	0.112	0.019	2826.2	0.000
		36	0.145	0.053	2833.1	0.000

Figure 5:

Correlogram of D(NI)

Date: 03/22/17 Time: 20:10
Sample: 1993M02 2016M10
Included observations: 284

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.171	-0.171	8.4171	0.004
		2	-0.260	-0.298	27.951	0.000
		3	-0.110	-0.248	31.470	0.000
		4	0.216	0.059	45.014	0.000
		5	0.076	0.061	46.714	0.000
		6	-0.293	-0.237	71.767	0.000
		7	0.057	0.019	72.722	0.000
		8	0.168	0.073	81.027	0.000
		9	-0.020	-0.052	81.148	0.000
		10	-0.261	-0.189	101.27	0.000
		11	0.020	-0.052	101.40	0.000
		12	0.456	0.343	163.40	0.000
		13	-0.041	0.127	163.91	0.000
		14	-0.257	-0.007	183.75	0.000
		15	-0.027	0.070	183.96	0.000
		16	0.107	-0.108	187.45	0.000
		17	0.120	0.061	191.85	0.000
		18	-0.267	-0.059	213.61	0.000
		19	0.024	-0.044	213.78	0.000
		20	0.122	-0.043	218.34	0.000
		21	-0.056	-0.114	219.30	0.000
		22	-0.144	-0.045	225.72	0.000
		23	-0.123	-0.251	230.45	0.000
		24	0.466	0.167	298.24	0.000
		25	0.009	0.139	298.26	0.000
		26	-0.227	-0.017	314.50	0.000
		27	-0.069	0.066	315.99	0.000
		28	0.094	-0.036	318.81	0.000
		29	0.110	-0.049	322.64	0.000
		30	-0.243	-0.062	341.56	0.000
		31	0.001	-0.020	341.56	0.000
		32	0.129	0.009	346.92	0.000
		33	-0.043	-0.094	347.51	0.000
		34	-0.164	-0.063	356.28	0.000
		35	-0.076	-0.089	358.16	0.000
		36	0.489	0.200	436.44	0.000

Figure 6:

Augmented Dickey-Fuller Unit Root Test on LOGEX

Null Hypothesis: LOGEX has a unit root
Exogenous: Constant
Lag Length: 4 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.255190	0.1875
Test critical values:	1% level	-3.453567	
	5% level	-2.871656	
	10% level	-2.572233	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOGEX)
Method: Least Squares
Date: 03/22/17 Time: 20:07
Sample (adjusted): 1993M07 2016M10
Included observations: 280 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOGEX(-1)	-0.026398	0.011706	-2.255190	0.0249
D(LOGEX(-1))	0.027839	0.059991	0.464045	0.6430
D(LOGEX(-2))	0.018489	0.060013	0.308084	0.7583
D(LOGEX(-3))	0.013927	0.060025	0.232017	0.8167
D(LOGEX(-4))	0.017009	0.060054	0.283224	0.7772
C	0.053597	0.023564	2.274482	0.0237

R-squared	0.018779	Mean dependent var	0.000580
Adjusted R-squared	0.000874	S.D. dependent var	0.024557
S.E. of regression	0.024546	Akaike info criterion	-4.555302
Sum squared resid	0.165093	Schwarz criterion	-4.477413
Log likelihood	643.7422	Hannan-Quinn criter.	-4.524060
F-statistic	1.048800	Durbin-Watson stat	2.000681
Prob(F-statistic)	0.389301		

Figure 7:

Augmented Dickey-Fuller Unit Root Test on D(LOGEX)

Null Hypothesis: D(LOGEX) has a unit root
Exogenous: Constant
Lag Length: 4 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.142421	0.0000
Test critical values:	1% level	-3.453652	
	5% level	-2.871693	
	10% level	-2.572253	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOGEX,2)
Method: Least Squares
Date: 03/22/17 Time: 20:08
Sample (adjusted): 1993M08 2016M10
Included observations: 279 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LOGEX(-1))	-0.943208	0.132057	-7.142421	0.0000
D(LOGEX(-1),2)	-0.037443	0.118612	-0.315680	0.7525
D(LOGEX(-2),2)	-0.027751	0.103174	-0.268973	0.7882
D(LOGEX(-3),2)	-0.022951	0.084828	-0.270557	0.7869
D(LOGEX(-4),2)	-0.015950	0.060567	-0.263351	0.7925
C	0.000538	0.001487	0.361932	0.7177

R-squared	0.490199	Mean dependent var	2.60E-05
Adjusted R-squared	0.480862	S.D. dependent var	0.034440
S.E. of regression	0.024814	Akaike info criterion	-4.533509
Sum squared resid	0.168102	Schwarz criterion	-4.455418
Log likelihood	638.4245	Hannan-Quinn criter.	-4.502183
F-statistic	52.50066	Durbin-Watson stat	1.999797
Prob(F-statistic)	0.000000		

Figure 8:

Augmented Dickey-Fuller Unit Root Test on NI

Null Hypothesis: NI has a unit root
Exogenous: Constant
Lag Length: 13 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.063398	0.0306
Test critical values:	1% level	-3.454353	
	5% level	-2.872001	
	10% level	-2.572417	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(NI)
Method: Least Squares
Date: 03/22/17 Time: 20:11
Sample (adjusted): 1994M04 2016M10
Included observations: 271 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
NI(-1)	-0.070845	0.023126	-3.063398	0.0024
D(NI(-1))	-0.314007	0.061465	-5.108744	0.0000
D(NI(-2))	-0.122843	0.059621	-2.060413	0.0404
D(NI(-3))	-0.119594	0.060000	-1.993244	0.0473
D(NI(-4))	0.007483	0.059765	0.125205	0.9005
D(NI(-5))	0.062250	0.059637	1.043817	0.2976
D(NI(-6))	-0.057576	0.059725	-0.964013	0.3359
D(NI(-7))	0.038283	0.059698	0.641273	0.5219
D(NI(-8))	0.003094	0.059447	0.052053	0.9585
D(NI(-9))	-0.017316	0.058764	-0.294671	0.7685
D(NI(-10))	-0.086452	0.058517	-1.477395	0.1408
D(NI(-11))	0.082947	0.056764	1.461255	0.1452
D(NI(-12))	0.440864	0.055754	7.907305	0.0000
D(NI(-13))	0.195348	0.058185	3.357382	0.0009
C	0.078054	0.059183	1.318864	0.1884

R-squared	0.418368	Mean dependent var	-0.015154
Adjusted R-squared	0.386560	S.D. dependent var	1.023444
S.E. of regression	0.801586	Akaike info criterion	2.449310
Sum squared resid	164.4902	Schwarz criterion	2.648689
Log likelihood	-316.8815	Hannan-Quinn criter.	2.529363
F-statistic	13.15293	Durbin-Watson stat	2.013125
Prob(F-statistic)	0.000000		

Figure 9:

Dependent Variable: LOGEX
Method: Least Squares
Date: 03/29/17 Time: 10:24
Sample (adjusted): 1993M03 2016M10
Included observations: 284 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.047682	0.022353	2.133185	0.0338
LOGEX(-1)	0.976507	0.011119	87.82492	0.0000

R-squared	0.964729	Mean dependent var	2.006735
Adjusted R-squared	0.964604	S.D. dependent var	0.128849
S.E. of regression	0.024241	Akaike info criterion	-4.594493
Sum squared resid	0.165716	Schwarz criterion	-4.568796
Log likelihood	654.4180	Hannan-Quinn criter.	-4.584190
F-statistic	7713.217	Durbin-Watson stat	1.943959
Prob(F-statistic)	0.000000		

Figure 10:

Correlogram of Residuals

Date: 04/15/17 Time: 13:50
Sample: 1993M03 2016M10
Included observations: 284

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.027	0.027	0.2137	0.644
		2	0.017	0.016	0.2974	0.862
		3	0.012	0.011	0.3376	0.953
		4	0.014	0.013	0.3920	0.983
		5	0.022	0.021	0.5365	0.991
		6	0.019	0.017	0.6421	0.996
		7	0.002	0.001	0.6439	0.999
		8	0.001	-0.000	0.6442	1.000
		9	-0.002	-0.003	0.6457	1.000
		10	-0.008	-0.009	0.6633	1.000
		11	0.016	0.016	0.7406	1.000
		12	0.010	0.009	0.7682	1.000
		13	0.022	0.022	0.9187	1.000
		14	0.023	0.021	1.0729	1.000
		15	0.022	0.020	1.2146	1.000
		16	-0.006	-0.009	1.2247	1.000
		17	0.018	0.016	1.3256	1.000
		18	0.022	0.019	1.4760	1.000
		19	0.023	0.019	1.6337	1.000
		20	0.024	0.020	1.8057	1.000
		21	0.020	0.018	1.9349	1.000
		22	0.019	0.016	2.0499	1.000
		23	0.020	0.016	2.1705	1.000
		24	0.020	0.016	2.2996	1.000
		25	0.018	0.014	2.4025	1.000
		26	0.024	0.019	2.5823	1.000
		27	0.020	0.016	2.7031	1.000
		28	0.018	0.014	2.8063	1.000
		29	0.018	0.014	2.9043	1.000
		30	0.018	0.014	3.0112	1.000
		31	0.017	0.012	3.1025	1.000
		32	0.018	0.012	3.2014	1.000
		33	0.017	0.012	3.2899	1.000
		34	0.018	0.013	3.4004	1.000
		35	0.019	0.014	3.5147	1.000
		36	0.017	0.012	3.6071	1.000

Figure 11:

Correlogram of Residuals Squared

Date: 04/15/17 Time: 13:51
Sample: 1993M03 2016M10
Included observations: 284

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.004	-0.004	0.0039	0.950
		2	-0.004	-0.004	0.0077	0.996
		3	-0.004	-0.004	0.0114	1.000
		4	-0.004	-0.004	0.0155	1.000
		5	-0.004	-0.004	0.0197	1.000
		6	-0.004	-0.004	0.0241	1.000
		7	-0.004	-0.004	0.0283	1.000
		8	-0.004	-0.004	0.0325	1.000
		9	-0.003	-0.003	0.0355	1.000
		10	-0.003	-0.003	0.0379	1.000
		11	-0.000	-0.000	0.0379	1.000
		12	-0.000	-0.000	0.0379	1.000
		13	-0.000	-0.000	0.0380	1.000
		14	-0.000	-0.000	0.0380	1.000
		15	-0.000	-0.000	0.0380	1.000
		16	0.000	0.000	0.0380	1.000
		17	-0.000	-0.000	0.0381	1.000
		18	-0.000	-0.000	0.0381	1.000
		19	-0.000	-0.000	0.0381	1.000
		20	-0.000	-0.000	0.0382	1.000
		21	-0.000	-0.000	0.0382	1.000
		22	-0.000	-0.000	0.0383	1.000
		23	-0.000	-0.000	0.0383	1.000
		24	-0.000	-0.000	0.0384	1.000
		25	-0.000	-0.000	0.0384	1.000
		26	-0.000	-0.000	0.0385	1.000
		27	-0.000	-0.000	0.0385	1.000
		28	-0.000	-0.000	0.0386	1.000
		29	-0.000	-0.001	0.0387	1.000
		30	-0.000	-0.001	0.0387	1.000
		31	-0.001	-0.001	0.0388	1.000
		32	-0.001	-0.001	0.0389	1.000
		33	-0.001	-0.001	0.0390	1.000
		34	-0.001	-0.001	0.0391	1.000
		35	-0.001	-0.001	0.0392	1.000
		36	-0.001	-0.001	0.0393	1.000

Figure 12:

Dependent Variable: NI
Method: ML - ARCH (Marquardt) - Normal distribution
Date: 04/15/17 Time: 14:05
Sample (adjusted): 1993M03 2016M10
Included observations: 284 after adjustments
Convergence achieved after 226 iterations
MA Backcast: 1993M02
Presample variance: backcast (parameter = 0.7)
GARCH = C(4) + C(5)*RESID(-1)^2 + C(6)*GARCH(-1)

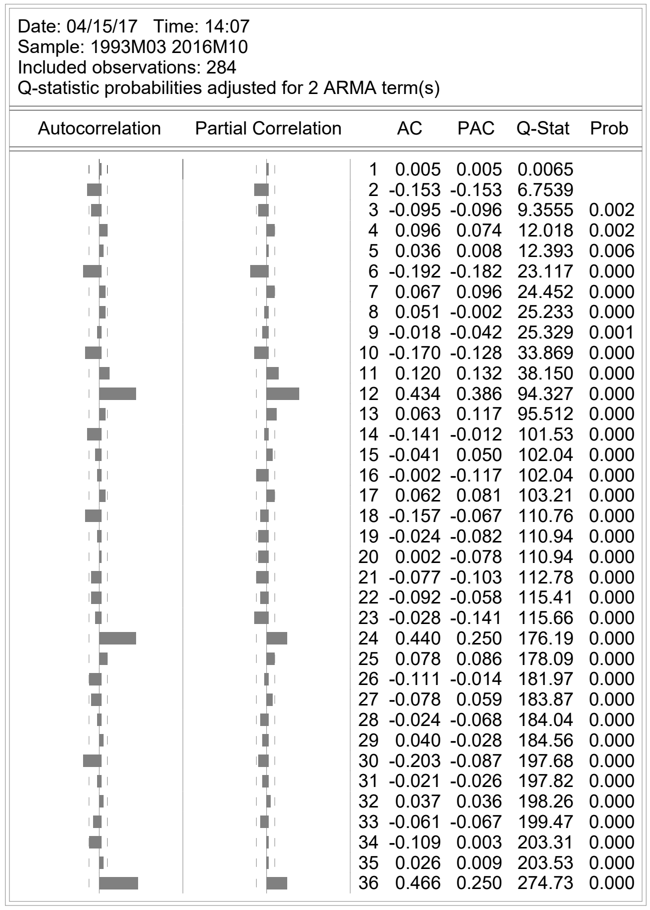
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	1.073913	0.765139	1.403552	0.1605
AR(1)	0.947854	0.018449	51.37786	0.0000
MA(1)	-0.297504	0.009227	-32.24424	0.0000
Variance Equation				
C	0.010323	0.002482	4.159387	0.0000
RESID(-1)^2	-0.046871	0.009406	-4.982855	0.0000
GARCH(-1)	1.028300	0.009102	112.9776	0.0000

R-squared	0.818537	Mean dependent var	1.534408
Adjusted R-squared	0.817245	S.D. dependent var	2.380053
S.E. of regression	1.017468	Akaike info criterion	2.696986
Sum squared resid	290.9027	Schwarz criterion	2.774077
Log likelihood	-376.9721	Hannan-Quinn criter.	2.727894
Durbin-Watson stat	1.891594		

Inverted AR Roots	.95
Inverted MA Roots	.30

Figure 13:

Correlogram of Standardized Residuals

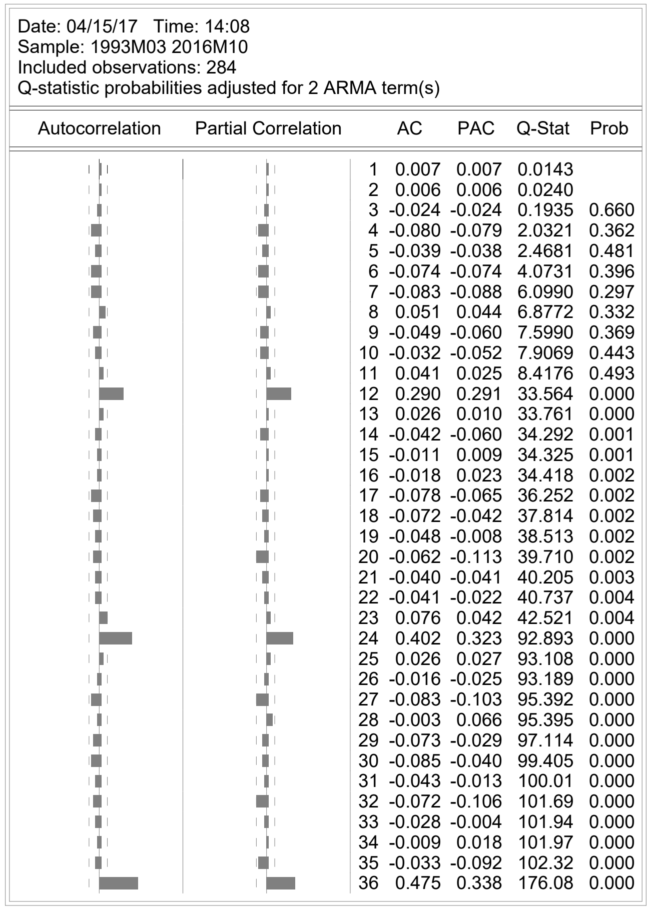


Date: 04/15/17 Time: 14:07
Sample: 1993M03 2016M10
Included observations: 284
Q-statistic probabilities adjusted for 2 ARMA term(s)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.005	0.005	0.0065	
		2	-0.153	-0.153	6.7539	
		3	-0.095	-0.096	9.3555	0.002
		4	0.096	0.074	12.018	0.002
		5	0.036	0.008	12.393	0.006
		6	-0.192	-0.182	23.117	0.000
		7	0.067	0.096	24.452	0.000
		8	0.051	-0.002	25.233	0.000
		9	-0.018	-0.042	25.329	0.001
		10	-0.170	-0.128	33.869	0.000
		11	0.120	0.132	38.150	0.000
		12	0.434	0.386	94.327	0.000
		13	0.063	0.117	95.512	0.000
		14	-0.141	-0.012	101.53	0.000
		15	-0.041	0.050	102.04	0.000
		16	-0.002	-0.117	102.04	0.000
		17	0.062	0.081	103.21	0.000
		18	-0.157	-0.067	110.76	0.000
		19	-0.024	-0.082	110.94	0.000
		20	0.002	-0.078	110.94	0.000
		21	-0.077	-0.103	112.78	0.000
		22	-0.092	-0.058	115.41	0.000
		23	-0.028	-0.141	115.66	0.000
		24	0.440	0.250	176.19	0.000
		25	0.078	0.086	178.09	0.000
		26	-0.111	-0.014	181.97	0.000
		27	-0.078	0.059	183.87	0.000
		28	-0.024	-0.068	184.04	0.000
		29	0.040	-0.028	184.56	0.000
		30	-0.203	-0.087	197.68	0.000
		31	-0.021	-0.026	197.82	0.000
		32	0.037	0.036	198.26	0.000
		33	-0.061	-0.067	199.47	0.000
		34	-0.109	0.003	203.31	0.000
		35	0.026	0.009	203.53	0.000
		36	0.466	0.250	274.73	0.000

Figure 14:

Correlogram of Standardized Residuals Squared



Date: 04/15/17 Time: 14:08
Sample: 1993M03 2016M10
Included observations: 284
Q-statistic probabilities adjusted for 2 ARMA term(s)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.007	0.007	0.0143	
		2	0.006	0.006	0.0240	
		3	-0.024	-0.024	0.1935	0.660
		4	-0.080	-0.079	2.0321	0.362
		5	-0.039	-0.038	2.4681	0.481
		6	-0.074	-0.074	4.0731	0.396
		7	-0.083	-0.088	6.0990	0.297
		8	0.051	0.044	6.8772	0.332
		9	-0.049	-0.060	7.5990	0.369
		10	-0.032	-0.052	7.9069	0.443
		11	0.041	0.025	8.4176	0.493
		12	0.290	0.291	33.564	0.000
		13	0.026	0.010	33.761	0.000
		14	-0.042	-0.060	34.292	0.001
		15	-0.011	0.009	34.325	0.001
		16	-0.018	0.023	34.418	0.002
		17	-0.078	-0.065	36.252	0.002
		18	-0.072	-0.042	37.814	0.002
		19	-0.048	-0.008	38.513	0.002
		20	-0.062	-0.113	39.710	0.002
		21	-0.040	-0.041	40.205	0.003
		22	-0.041	-0.022	40.737	0.004
		23	0.076	0.042	42.521	0.004
		24	0.402	0.323	92.893	0.000
		25	0.026	0.027	93.108	0.000
		26	-0.016	-0.025	93.189	0.000
		27	-0.083	-0.103	95.392	0.000
		28	-0.003	0.066	95.395	0.000
		29	-0.073	-0.029	97.114	0.000
		30	-0.085	-0.040	99.405	0.000
		31	-0.043	-0.013	100.01	0.000
		32	-0.072	-0.106	101.69	0.000
		33	-0.028	-0.004	101.94	0.000
		34	-0.009	0.018	101.97	0.000
		35	-0.033	-0.092	102.32	0.000
		36	0.475	0.338	176.08	0.000

Figure 15:

Johansen Cointegration Test Summary

Date: 04/15/17 Time: 15:02
Sample: 1993M02 2016M10
Included observations: 280
Series: NI LOGEX
Lags interval: 1 to 4

Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	0	0	2	1	2
Max-Eig	0	0	0	1	2

*Critical values based on MacKinnon-Haug-Michelis (1999)

Information Criteria by Rank and Model

Data Trend:	None	None	Linear	Linear	Quadratic
Rank or	No Intercept	Intercept	Intercept	Intercept	Intercept
No. of CEs	No Trend	No Trend	No Trend	Trend	Trend
	Log Likelihood by Rank (rows) and Model (columns)				
0	262.9614	262.9614	263.0674	263.0674	264.3809
1	268.1052	268.1077	268.1087	280.8707	281.5352
2	268.1096	271.3410	271.3410	285.5707	285.5707
	Akaike Information Criteria by Rank (rows) and Model (columns)				
0	-1.764010	-1.764010	-1.750481	-1.750481	-1.745578
1	-1.772180	-1.765055	-1.757919	-1.841934*	-1.839537
2	-1.743640	-1.752436	-1.752436	-1.839791	-1.839791
	Schwarz Criteria by Rank (rows) and Model (columns)				
0	-1.556308*	-1.556308*	-1.516816	-1.516816	-1.485950
1	-1.512552	-1.492446	-1.472329	-1.543362	-1.527983
2	-1.432086	-1.414919	-1.414919	-1.476312	-1.476312

Figure 16:

Vector Autoregression Estimates

Vector Autoregression Estimates
Date: 04/15/17 Time: 15:05
Sample (adjusted): 1993M04 2016M10
Included observations: 283 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	LOGEX	NI
LOGEX(-1)	0.993241	3.889443
	(0.05930)	(2.52552)
	[16.7496]	[1.54005]
LOGEX(-2)	-0.013775	-4.618292
	(0.05918)	(2.52032)
	[-0.23278]	[-1.83243]
NI(-1)	-0.002560	0.780223
	(0.00139)	(0.05908)
	[-1.84555]	[13.2064]
NI(-2)	0.003502	0.118550
	(0.00138)	(0.05894)
	[2.53041]	[2.01138]
C	0.040310	1.612504
	(0.02350)	(1.00087)
	[1.71529]	[1.61110]
R-squared	0.965185	0.817453
Adj. R-squared	0.964684	0.814826
Sum sq. resids	0.161199	292.3929
S.E. equation	0.024080	1.025560
F-statistic	1926.741	311.2231
Log likelihood	655.5251	-406.1798
Akaike AIC	-4.597351	2.905864
Schwarz SC	-4.532944	2.970271
Mean dependent	2.007656	1.530295
S.D. dependent	0.128136	2.383258

Determinant resid covariance (dof adj.)	0.000608
Determinant resid covariance	0.000586
Log likelihood	249.8746
Akaike information criterion	-1.695227
Schwarz criterion	-1.566412

Figure 17:

Vector Error Correction Estimates

Vector Error Correction Estimates
Date: 04/15/17 Time: 15:06
Sample (adjusted): 1993M05 2016M10
Included observations: 282 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1	
LOGEX(-1)	1.000000	
NI(-1)	0.355762	
	(0.10413)	
	[3.41661]	
C	-2.551675	
Error Correction:	**D(LOGEX)**	**D(NI)**
CointEq1	0.003513	-0.216251
	(0.00185)	(0.07556)
	[1.89464]	[-2.86181]
D(LOGEX(-1))	-0.008085	2.558747
	(0.06030)	(2.45767)
	[-0.13408]	[1.04113]
D(LOGEX(-2))	0.008358	3.153533
	(0.05983)	(2.43847)
	[0.13969]	[1.29324]
D(NI(-1))	-0.003980	-0.187304
	(0.00144)	(0.05858)
	[-2.76896]	[-3.19741]
D(NI(-2))	-0.001767	-0.258406
	(0.00142)	(0.05798)
	[-1.24226]	[-4.45659]
C	0.000564	-0.003820
	(0.00145)	(0.05895)
	[0.39029]	[-0.06480]
R-squared	0.033383	0.149169
Adj. R-squared	0.015872	0.133755
Sum sq. resids	0.162645	270.1776
S.E. equation	0.024275	0.989396
F-statistic	1.906402	9.677729
Log likelihood	651.4507	-394.1020
Akaike AIC	-4.577664	2.837603
Schwarz SC	-4.500177	2.915090
Mean dependent	0.000595	0.001899
S.D. dependent	0.024470	1.063040
Determinant resid covariance (dof adj.)		0.000573
Determinant resid covariance		0.000549
Log likelihood		258.2332
Akaike information criterion		-1.732150
Schwarz criterion		-1.551346

Figure 18:

Pairwise Granger Causality Tests
Date: 04/17/17 Time: 18:57
Sample: 1993M02 2016M10
Lags: 1

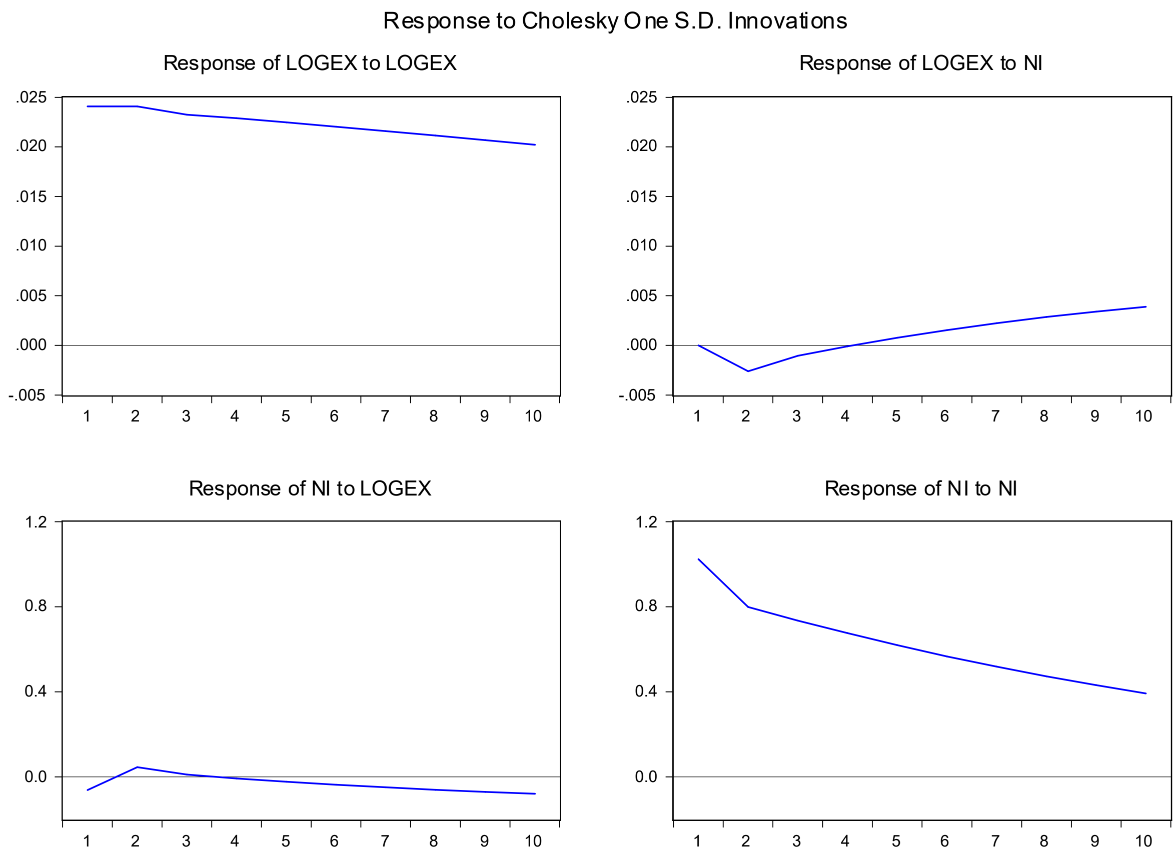
Null Hypothesis:	Obs	F-Statistic	Prob.
NI does not Granger Cause DLOGEX	283	2.07570	0.1508
DLOGEX does not Granger Cause NI		3.35264	0.0682

Figure 19:

Pairwise Granger Causality Tests
Date: 04/17/17 Time: 18:58
Sample: 1993M02 2016M10
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
NI does not Granger Cause DLOGEX	282	4.50126	0.0119
DLOGEX does not Granger Cause NI		2.39151	0.0934

Figure 20:



Response to Cholesky One S.D. Innovations
Response of LOGEX to LOGEX
Response of LOGEX to NI
Response of NI to LOGEX
Response of NI to NI
.025
.020
.015
.010
.005
.000
-.005
1.2
0.8
0.4
0.0
1
2
3
4
5
6
7
8
9
10

Figure 21:

Impulse Response to Cholesky (d.f. adjusted) One S.D. Innovations

Response of LOGEX: Period	LOGEX	NI
1	0.024080	0.000000
	(0.00101)	(0.00000)
2	0.024078	-0.002621
	(0.00176)	(0.00142)
3	0.023249	-0.001063
	(0.00179)	(0.00143)
4	0.022892	-0.000103
	(0.00178)	(0.00168)
5	0.022471	0.000754
	(0.00185)	(0.00200)
6	0.022036	0.001533
	(0.00195)	(0.00232)
7	0.021592	0.002229
	(0.00207)	(0.00263)
8	0.021140	0.002850
	(0.00220)	(0.00291)
9	0.020681	0.003403
	(0.00233)	(0.00316)
10	0.020218	0.003893
	(0.00247)	(0.00339)
Response of NI: Period	LOGEX	NI
1	-0.062662	1.023644
	(0.06091)	(0.04303)
2	0.044768	0.798671
	(0.07716)	(0.06917)
3	0.009940	0.734302
	(0.06666)	(0.05810)
4	-0.007709	0.675571
	(0.06296)	(0.06418)
5	-0.023172	0.618657
	(0.06198)	(0.07131)
6	-0.037313	0.566189
	(0.06190)	(0.07812)
7	-0.049929	0.517573
	(0.06264)	(0.08410)
8	-0.061168	0.472535
	(0.06389)	(0.08899)
9	-0.071141	0.430834
	(0.06541)	(0.09277)
10	-0.079948	0.392238
	(0.06703)	(0.09549)

Cholesky Ordering: LOGEX NI
Standard Errors: Analytic

Figure 22:

Dependent Variable: -DLOGEX
Method: Least Squares
Date: 04/17/17 Time: 18:24
Sample (adjusted): 1993M03 2016M10
Included observations: 284 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000798	0.001721	0.463519	0.6434
NI(-1)	-0.000876	0.000607	-1.443041	0.1501

R-squared	0.007330	Mean dependent var	-0.000552
Adjusted R-squared	0.003810	S.D. dependent var	0.024389
S.E. of regression	0.024343	Akaike info criterion	-4.586143
Sum squared resid	0.167105	Schwarz criterion	-4.560446
Log likelihood	653.2324	Hannan-Quinn criter.	-4.575841
F-statistic	2.082368	Durbin-Watson stat	1.981473
Prob(F-statistic)	0.150119		

Figure 23: