Is the oil price pass-through to domestic inflation symmetric or asymmetric? new evidence from India based on NARDL

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Abstract

With 80% oil dependence, which is expected to further increase in coming years due to rapid expansion, and the reforms initiated to deregulate domestic oil market, the association between global oil prices and inflation in India has increased. Using the autoregressive distribution lag (ARDL) and the nonlinear and asymmetric autoregressive distribution lag (NARDL) framework, we investigate the association between global oil prices and inflation. The ARDL results indicate no association between the two, whereas NARDL findings not only point to long term association but also indicates asymmetric pass-through. Precisely, domestic prices increase with the increase in global oil prices but the decrease in global oil prices has no significant association with the domestic prices. These results are robust to the inclusion of additional variables, different proxy of oil prices (WTI crude) and different time period (January 2003 to January 2018). The contrasting results obtained from the ARDL and the NARDL modelling highlight the importance of using non-linear framework, especially in high oil dependence country with non-competitive market structure. The results have implications for welfare assessment and the effectiveness of monetary policy.

Keywords: Oil Prices; Inflation; India; non-linear ARDL

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1. Introduction and Motivation

The seminal contribution of Hamilton (1983) led to many studies linking oil price fluctuations to macroeconomic stability such as exchange rate, inflation, interest rate, industrial production/economic output and stock market activities (Narayan and Sharma, 2011; Narayan and Gupta, 2014; Wei and Guo, 2016; Cross and Nguyen, 2017; Salisu and Isah, 2017). The existing literature argues that the negative effect of oil price shocks is the result of oil dependency of an economy (Hamilton, 1996; Cunado and Perez de Gracia, 2003) as the increase in oil prices decreases the purchasing power of consumers and hence ultimately leads to lower economic output (Zhang and Yao, 2016). As oil is one of the important factors of production, any increase in it leads to higher costs and hence increase in domestic prices and eventually lower production (Kang and Ratti, 2013a; Du and He, 2015).

In this paper, we focus on the association between oil price fluctuation and domestic prices. Though the literature on oil price and inflation is voluminous but the question has been approached rather unsystematically and that could partially explain the mixed results obtained in the last two decades. With the notable exception of few studies on developed markets (US and Euro region) and a few single country studies on China and Taiwan (see for instance, Mork, 1989; Hamilton and Herrera, 2001; Du et al., 2010; Evgenidis, 2017; Long and Liang, 2018), most of these literature still model the association between them as linear. Precisely, most of the literature model the effect of oil price to be symmetric and hence presuming that the oil price increase/decrease would have similar effect on the inflation. This approach has serious shortcomings as it could be the case that the increase in oil price leads to higher domestic prices but the decrease in oil prices has lesser or no effect on inflation. The asymmetry could be due to several reasons such as market structure, public regulations, and cost structures (Ibrahim, 2015). Perhaps this could also explain the more recent findings in the literature which suggest little or negligible association between oil prices and domestic prices (Long and Liang, 2018). Precisely, the more recent findings indicate that the oil pass-through has declined over the years and this holds for industrialized and emerging economies (De Gregorio et al., 2007), US (Hooker, 2002; Barsky and Kilian, 2004; Valcarcel and Wohar, 2013), G7 countries (Killian, 2008) as well as Euro region (Alvarez et al., 2011).

In this paper, we revisit the debate between oil price and inflation for the case of India. However, we use the approach which allows us to segregate the effect of increase and decrease in oil prices. Precisely, we utilize the Non-linear ARDL (NARDL) approach of Shin et al. (2014) to examine whether domestic prices respond asymmetrically, in the long run as well as the short run, to changes in the oil prices. The examination in a non-linear context has direct relevance with the welfare cost. For instance, many emerging economies adopt policies to limit the oil pass-through to consumers but the policies would not achieve the desired results without the proper understanding of association between oil prices and inflation (Bouakez, and Vencatachellum, 2008). Moreover, the examination is vital with respect to the country's monetary policy as well. Among others, one of the main objectives of monetary policy is the price stability as it is generally accepted that the inflation below or above certain preconceived threshold can be detrimental to economic output and hence the principal objective of all the central banks is to stabilize the price around that threshold. However, in order to achieve the objective, it is important for the central banks to fully understand the aggregate fluctuations in the inflation and hence it is important to understand the oil pass-through phenomenon (Varghese, 2016), especially in a country like India. In other words, not having proper understanding of pass-through (as to whether it is symmetric or asymmetric) would make the monetary policy ineffective as it won't be able to stabilize the price levels (Cunado and Perez de Gracia, 2003).

We chose India for several reasons. First, India is the fourth largest oil consumer in the world and also ranked fourth among the largest oil importer in the world, therefore India's role has become important in the world oil market. The strong link between oil prices and domestic prices have implications for investors (domestic and global) as well as portfolio managers as Indian stock market may not provide a hedge against inflation.

Second, oil dependence of India has rapidly increased for the past several years and now stands at 80% of total crude oil requirement as at March 2018. Moreover, as the per capita energy consumption of India is already one third of global average and hence India's energy demand is only going to go up. And oil being one of the most important factors of production, any fluctuation in its price is expected to have significant effect on the India's manufacturing costs and ultimately the domestic prices. With 80% oil dependence and high energy consumption per capita, India is certainly more vulnerable to oil price fluctuations and hence it would be interesting to examine the relationship between the two.

Third, the association between domestic oil prices and global oil prices have become stronger. After 2002, in response to the increasing burden of subsidies during the phase of high oil prices, government initiated the reforms in the domestic fuel market and formally started to deregulate the retail oil market and has allowed the oil firms to set their prices.[34] However, the market structure of India's energy sector is still concentrated and most of the production and refining activities are mainly controlled by two state owned firms, Oil and Natural Gas Corporation (ONGC) and Oil India Limited (OIL). For instance, ONGC's production accounted for close to 69% in 2014. Though there are few private market players but their share of production is still not significant.[5] Given India's highly concentrated market, an increase and decrease in oil prices may lead to asymmetric transmission to domestic prices.

The findings based on monthly Brent Crude oil and inflation (January 1994 to March 2018) can be summarized as follows. The findings based on ARDL indicate insignificant association between oil prices and inflation suggesting global oil prices have no effect on the inflation in India. This is in line with the recent findings that the association between oil prices and inflation has either declined or diminished over the years (Long and Liang, 2018). However, the NARDL results are in sharp contrast with the ARDL findings as it indicates positive association between inflation and oil prices in the long run. However, the relationship is asymmetric as an increase in oil prices is associated with the increase in inflation but the decrease is oil prices has no effect on inflation. One of the reasons for such findings could be due to the non-competitive structure of the Indian oil industry. The results confirm the arguments of Meyer and Cramon-Taubadel (2004) and Long and Liang (2018) that in a non-competitive market, firms raise the prices during the upward trend in global oil prices but do not cut back the prices during downwards trends. The results are asymmetric in both short run as well as the long run.. The results highlight the importance of

[3] IHS Energy, "Indian diesel price liberalization could shake up domestic retail sector," November 18, 2014.
[4] Though the government still have considerable control over the domestic oil prices.
[5] International Energy Agency (IEA), World Energy Outlook, 2015.

modelling the relationship in a non-linear framework so that the asymmetric price adjustments can be captured. These results pose serious challenge to policymakers as it requires them to adopt more dynamic policies to fight inflationary pressures.

The results are robust to various sensitivity tests. In the first sensitivity test, we include other important variables such as industrial production and exchange, whereas in the second test we replace the Brent Crude oil with the West Texas Intermediate (WTI) Crude oil. In both the cases, our results remained similar to the main results. As the price control reforms started in 2002, therefore the global oil prices and domestic oil prices may be more strongly related only after this period. Therefore, to check the sensitivity of our results, we started our sample from 2003. The results are not sensitive to the sample period. Finally, we use the annual data of oil prices and inflation to test if the results are contingent on the frequency of data. Our results remained similar to main results.

2. Transmission channel

2.1 Theoretical relationship between oil prices and inflation

In case of oil exporting countries (OEC), the impact of increase in oil prices can be negative on domestic prices. During the phase where oil prices are on the rise, the foreign reserves of OEC will increase which would result in the appreciation of OEC currency and hence inflation would go down. However, if the country has diversified their energy needs and has little role of oil in an economy, the impact of increased or decreased in oil price will be insignificant. On the other hand, an economy like India which is the fourth largest oil consumer in the world with 80% dependence on the oil imports, any increase in global oil prices would put lot of inflationary pressures on the economy. In other words, country like India would certainly experience the rise in domestic prices with the increase in oil prices.

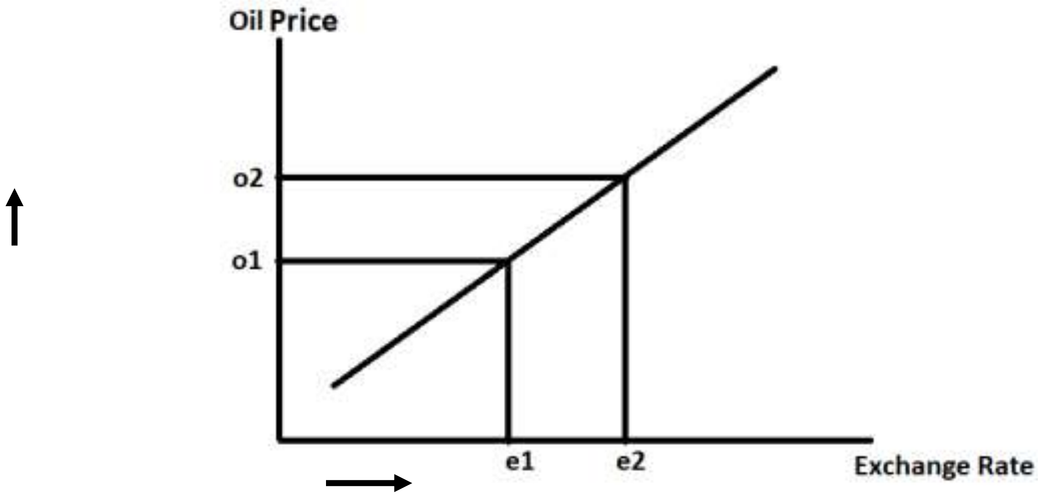
The above arguments are graphically summarized below:

Oil exporting Country

In figure 1, we can see that the increase in oil prices from o1 to o2 leads to appreciation of local currency from e1 to e2.

Oil Prices↑ → Exchange Rate ↑ → Inflation ↓

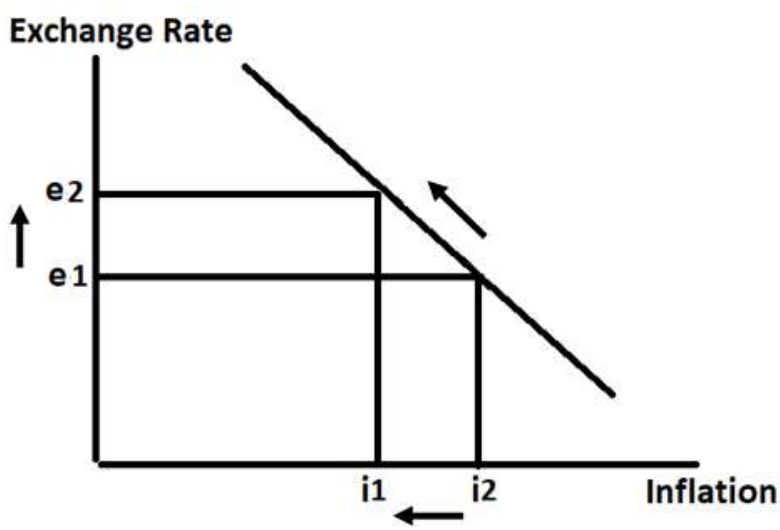
Figure 1 Relationship between Oil Prices and Exchange Rate



Source: Elaborated by authors

Below Figure 2 demonstrates that as exchange rate increases (appreciate) from point e1 to e2, the inflation decreases from point i2 to i1.

Figure 2 Relationship between Exchange Rate and Inflation



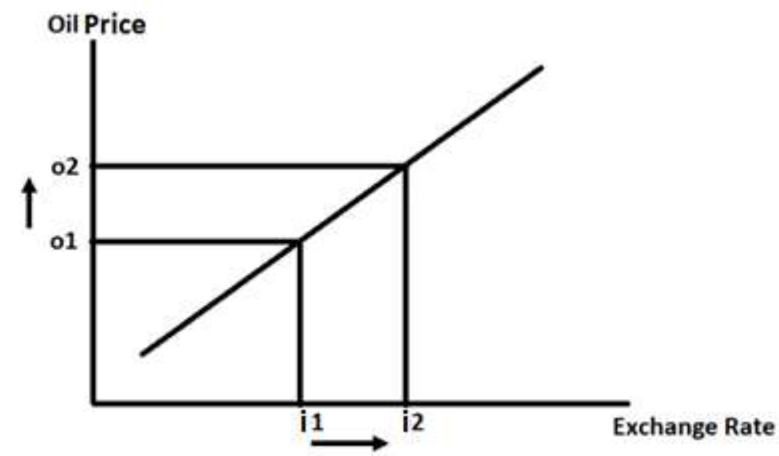
Source: Elaborated by authors

Exchange Rate ↑ → Inflation ↓

Oil Importing Country

Figure 3 shows as oil prices increase from o1 to o2 it leads to increase in inflation from i1 to i2.

Figure 3 Relationship between Oil price and Inflation

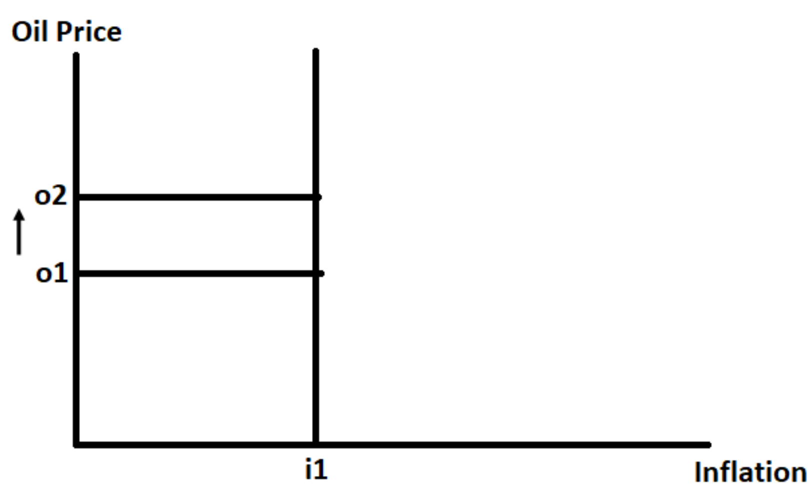


Oil Price↑ → Inflation↑

Country with less dependence on Oil

The below figure shows that increase in oil prices do not affect the inflation rate.

Figure 4 Relationship between Oil price and Inflation

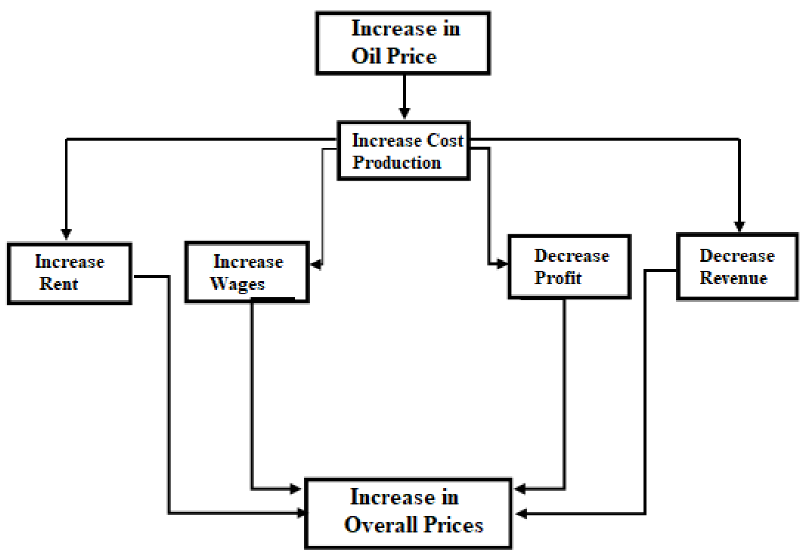


Oil Price↑ → Inflation

2.2 Cost-push inflation

Cost-push inflation is the increase in domestic prices triggered by the increase in input prices such as raw material, labors etc. This is one of the main transmission channel through increased oil prices are transferred to consumers. In response to increase in oil prices, firms adjust the prices upwards to cover the increased costs by transferring it to consumers. Below diagram illustrates the transmission mechanism.

Figure 5 Oil Price and Inflation Association (Cost push inflation)



Source: Elaborated by author

2.3 Asymmetric pass-through

There could be at least three scenarios where oil pass-through could be asymmetric: market competition, public regulations, and cost structures. For instance, an oligopoly structure has been argued to be the source of the asymmetry as the adjustment is found to be quicker in case of increase in oil prices while little or no change during declining trend in the oil prices (Meyer and

Cramon-Taubadel, 2004). In addition to this, policy measures such as price controls (price floor/ceilings) can also lead to price asymmetry behavior as there is a limit to which price can be adjusted (Ibrahim, 2015). Finally, the interaction between market power and the cost structure of firms can also result in long as well as short run asymmetric price behavior (Karantininis et al. (2011a, b).

Long and Liang (2018, pg 241) rightly points out, *"When the global oil price rises, the importing costs of domestic petroleum enterprises also rise. In order to maintain a certain profit, domestic petroleum enterprises will enhance refined oils prices and to greater extent, will rely on monopoly power. The refined oils are inputs and the raw materials of a variety of industrial products, so production cost of various products will increase and push up PPI to a large extent. It will also increase living costs, because households consume substantial refined oil products, and thus push up CPI. However, when the global crude oil prices decline, in order to make more profit, domestic petroleum enterprises can lower the refined oil prices to a small extent because of their monopoly power. This means the decline of PPI and CPI is also smaller too."* To reiterate the arguments, it can be argued that the oil pass-through could be asymmetric in a sense that the pass-through would be higher in case of increase in oil prices as compared to decrease in oil prices.

3. Data and Methodology

3.1 Data

We employ monthly data (1st April 1994 to 1st Jan 2018) on consumer price index (CPI) and oil price (Brent). The variables used for the robustness tests are Industrial Production (IP), exchange rate (ER) and West Texas Intermediate (WTI). All the variables are expressed in natural log. The oil prices are collected from Energy Information Administration (EIA).

3.2 Methodology

The following equations non-linear ARDL will be specified to study the asymmetric relationship between inflation (CPI) and oil price (Brent).

$$cpi_t = \beta_0 + \beta_1 b_t^+ + \beta_2 b_t^- + e_t \qquad (1)$$

In the above equation $(\beta_0, \beta_1, \beta_2)$ are the parameters capturing long run relationship.

where *cpi* is the consumer price index used as a proxy to represent inflation i.e. as the impact of oil price is transmit finally to *cpi*. Where b is the Brent used as a proxy for oil price. Similarly, $b_t^+ + b_t^-$ are the partial sums of negative as well as positive variations in oil price (b).

$$b_t^- = \sum_{i=1}^{t} \Delta b_t^- = \sum_{i=1}^{t} \min(\Delta b_i, 0) \qquad (2)$$

$$b_t^+ = \sum_{i=1}^{t} \Delta b_t^+ = \sum_{i=1}^{t} \max(\Delta b_i, 0) \qquad (3)$$

where $b_t = b_0 + b_t^+ + b_t^-$.

Where $\beta_1 and\ \beta_2$ capture long run asymmetric relationship between inflation and oil price.

If $\beta_1$is significant positive it predicts direct impact of oil price on inflation and vice versa as explain in figure 3. Similarly, positive significance of β_2 is a sign of reduction in oil price decrease inflation and vice versa. But is both $\beta_1 and\ \beta_2$ are insignificance it shows no impact of increase and decrease in oil price on inflation.

Following Shin et al. (2014), we develop the following NARDL equation to see long run.

$$\Delta cpi_t = \gamma_0 + \gamma_1 cpi_{t-1} + \gamma_2 b_{t-1}^+ + \gamma_3 b_{t-1}^- + \sum_{i=1}^{p} \lambda_i \Delta cpi_{t-i} + \sum_{i=0}^{q} (\lambda_i^+ \Delta b_{t-i}^+ + \lambda_i^- \Delta b_{t-i}^-) + e_t \qquad (4)$$

Where the lag orders are represented by p and q.

We got from equation (4) the long run parameters of equation (1) that is $-\gamma_2/\gamma_1 = \beta_1$ and $-\gamma_3/\gamma_1 = \beta_2$.

The Short run positive and negative effects of oil price can be apprehended by $\sum_{i=0}^{q} \gamma_i^+$ and $\sum_{i=0}^{q} \gamma_i^-$ in equation (4).

So, this equation (4) will give us long run and short run asymmetric relationship between oil price (b) and inflation (cpi).

Before estimate equation (4) of non-linear ARDL model you need to do three steps. Firstly, we need to OLS to estimate (4). From general to specific approach is used in order to remove insignificant lags and reach final specification of equation (4). Secondly, in order to see long run relationship between oil price and inflation, we apply cointegration test of ARDL. For this we use Wald F test of (Pesaran et al., 2001) symbolized by F_{PSS} where null i.e. $H_0: \gamma_1 = \gamma_2 = \gamma_3 = 0$. Thirdly, to find long run asymmetric relationship, the $H_0: -\gamma_2/\gamma_1 = -\gamma_3/\gamma_1$ while to discovery short run asymmetric relationship, the $H_0: \sum_{i=0}^{q} \lambda_i^+ = \sum_{i=0}^{q} \lambda_i^-$. In order to see this asymmetric relationship between oil price and inflation we graphically represent the relation based on the following equation (5):

$$m_h^+ = \sum_{j=0}^{h} \frac{dcpi_{t+j}}{db_t^+}, \quad m_h^- = \sum_{j=0}^{h} \frac{dcpi_{t+j}}{db_t^-}, \quad h = 0, 1, 2,3,4,5 \ldots$$

$$\text{as } h \rightarrow \infty, m_h^+ \rightarrow \beta_1 \text{and } m_h^- \rightarrow \beta_2 \qquad (5)$$

Table 1 and Table 2 presents the descriptive statistics of the variables.

Table 1 Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Inf	285	0.01	0.01	-0.02	0.04
B	286	52.92	34.00	9.82	132.72
E	286	109.24	10.59	89.54	129.63
Ip	286	75.57	29.73	30.68	131.19
wti	286	51.48	30.20	11.35	133.88

Table 2 Correlation

	inf	b	E	ip	Wti
inf	1				
B	0.10*	1			
E	-0.22*	-0.45*	1		
Ip	-0.01	0.75*	0.01	1	
Wti	0.11*	0.99*	-0.40*	0.74*	1

3.3 Testing stationary of the variables

In order to check that variable is stationary or not, we apply Augmented Ducky Filler (ADF), KPSS and PP. As wee see in the following tables 3, 4 and 5 that variables are found non-stationary at the level form and become stationary at difference form.

Table 3 ADF

Variable	Test Statistic	P- Value	Implication
		Level form	
CPI	1.414528	0.9991	non-stationary
B	-1.938	0.3147	non-stationary
E	-2.019911	0.2782	non-stationary
IP	0.817015	0.9942	non-stationary
WTI	-2.148191	0.2261	non-stationary
		Difference form	
CPI	-13.17139	0.0000	Stationary
B	-11.37611	0.0000	Stationary
E	-10.59752	0.0000	Stationary
IP	-16.40542	0.0000	Stationary
WTI	-11.19522	0.0000	Stationary

Table 4 KPSS

Variable	Test Statistic	Critical- Value	Implication
		Level form	
CPI	0.488840	0.119000	non-stationary
B	0.211140	0.119000	non-stationary
E	0.232501	0.119000	non-stationary
IP	0.258746	0.119000	non-stationary
WTI	0.241088	0.119000	non-stationary
		Difference form	
CPI	0.072384	0.119000	Stationary
B	0.051638	0.119000	Stationary
E	0.112898	0.119000	Stationary
IP	0.058932	0.119000	Stationary
WTI	0.048796	0.119000	Stationary

Table 5 PP

Variable	Test Statistic	P- Value	Implication
		Level form	
CPI	-0.547282	0.9808	non-stationary
B	-2.202287	0.4860	non-stationary
E	-1.771386	0.7162	non-stationary

IP	-2.320677	0.4209	non-stationary
WTI	-2.317665	0.4225	non-stationary
	Difference form		
CPI	-12.03384	0.0000	Stationary
B	-11.35394	0.0000	Stationary
E	-10.92124	0.0000	Stationary
IP	-26.79825	0.0000	Stationary
WTI	-11.21245	0.0000	Stationary

3.4 Testing ARDL Co-integration

The ARDL model requires a priori knowledge or estimation of the orders of the extended ARDL. This appropriate modification of the orders of the ARDL model is sufficient to simultaneously correct for residual serial correlation and the problem of endogenous regressors (Pesaran and Shin, 1998, p. 386). While NARDL is the extended version of ARDL where ARDL assume equal impact of independent variables on dependent variable in terms of increase and decrease in independent variables. Similarly, ARDL only take care of onside relationship among variables while NARDL is tasting statistically that how much is the impact of independent variables on dependent variable with respect to increase and decrease in independent variables. Similarly, NARDL also taking care of two side relationship among variables. The order of the distributed lag on the dependent variable and the regressors is selected using either the Akaike Information Criterion (AIC) or the Schwartz Bayesian Criterion (SBC). This study will use AIC as a lag selection criterion. Based on the previous discussion, a significant F-statistic for testing the joint level significance of the lagged level indicates the existence of long-run relationship.

Before we move to our NARDL results, we also present the results from ARDL estimation. In the following Table 6 we see that the coefficient of oil price (b) is insignificant which shows that there is no impact of oil price on inflation. This insignificant result of ARDL approach is in line with recent studies who predict that ARDL is not the suitable model to study oil-inflation association.

In the succeeding table 6 p value is greater than 0.10 which means that there is no co-integration using conventional ARDL approach. That is there might be asymmetric cointegration but there is no symmetric long run and short run cointegration. Therefore, we need to test asymmetric cointegration relationship by using advance non- linear ARDL technique.

Table 6 Long Run and Short Run Relationship using ARDL

D. cpi	Coef.	Std. Err.	t	p- value
Long Run				
b	63.633	641.356	0.10	0.922
Short Run				
b	-.0093	.00822	-1.13	0.259

3.5 Testing NARDL Co-integration

Now we are using nonlinear ARDL to see asymmetric relationship.

Table 7 NARDL Co-integration test statistics for (cpi) and (b) variables

Overall statistics	t_{BDM}	F_{PSS}
Overall values	**-4.5239**	**17.5353**

Table 7 give us result of non-linear ARDL. In order to estimate equation (4) of non-linear ARDL we employ ordinary lease square (OLS). By using general to specific method, insignificant lags of the first difference has been removed to get the final estimated model. Table 7 depicted, overall co-integration result. The presence of cointegration is noticed by rejecting H_0 of no-cointegration by using t_{BDM} and F_{PSS} tests.

Two sets of asymptotic critical values are provided by Pesaran (1997). If the computed F-statistics is greater than the critical value, then we reject the null hypothesis of no co-integration and conclude that there exists steady state equilibrium between the variables. If the computed F-statistics is less than the critical value, then we cannot reject the null of no co-integration. If the computed F-statistics falls within the lower and upper bound critical values, then the result is inconclusive. But our case F-statistics values is greater than F-statistics (critical value) i.e. 17.5353

> 3 therefore we reject null hypothesis of no cointegration and conclude that there is co-integration (long run association) among variables.

In table 8 and table 9 we report long run and short run non-linear ARDL result. As we see in table 8 the long run symmetric null hypothesis i.e. $\beta_1 = \beta_2$ has been rejected at 1% level of significance and concluded asymmetric relationship between oil price and inflation in long run. Similarly, the short run relationship between oil price and inflation is also found to be significant where the null hypothesis of symmetric relationship was $\sum_{i=0}^{q} \gamma_i^+ = \sum_{i=0}^{q} \gamma_i^-$ has been rejected at 5% level of significance. In table 8, the left-hand side shows that increase in oil price leads to boost up inflation where the coefficient (effect [+]) is significant at 1% level of significance. Which means that one dollar per barrel increase in oil price leads to 0.33 percentage point increase in an inflation. While on the right-hand side of table 8 we can predict that decrease in oil price has on significant impact on inflation as the coefficient (effect [-]) is insignificant. So the question is what is the message of this result? Our result conveys important message and are in line with importing country concept discussed above at figure 3.

Table 8 Nonlinear ARDL using two variables CPI and B

Long Run Asymmetry statistics

	effect [+]			**effect [-]**		
Variables	Coef.	F-Stat	P value	Coef.	F-Stat	P value
B	0.288	23.57	0.0000	-0.018	.09021	0.764

Table 9 Long Run and Short Run Asymmetric Significance

	Long Run Asymmetry statistics		**Short Run Asymmetry statistics**	
Variables	**F-Stat**	**P value**	**F-Stat**	**P value**
B	1329	0.000	9.516	0.002

In the following tables 10 and 11 we have used data from 2003 and onward as some studies pointed out that in case of India after 2002, oil prices have been deregulated. But the result is same with the data used from 1994.

Table 10 Nonlinear ARDL using two variables CPI and B and Data used from 2003-2018

Long Run Asymmetry statistics

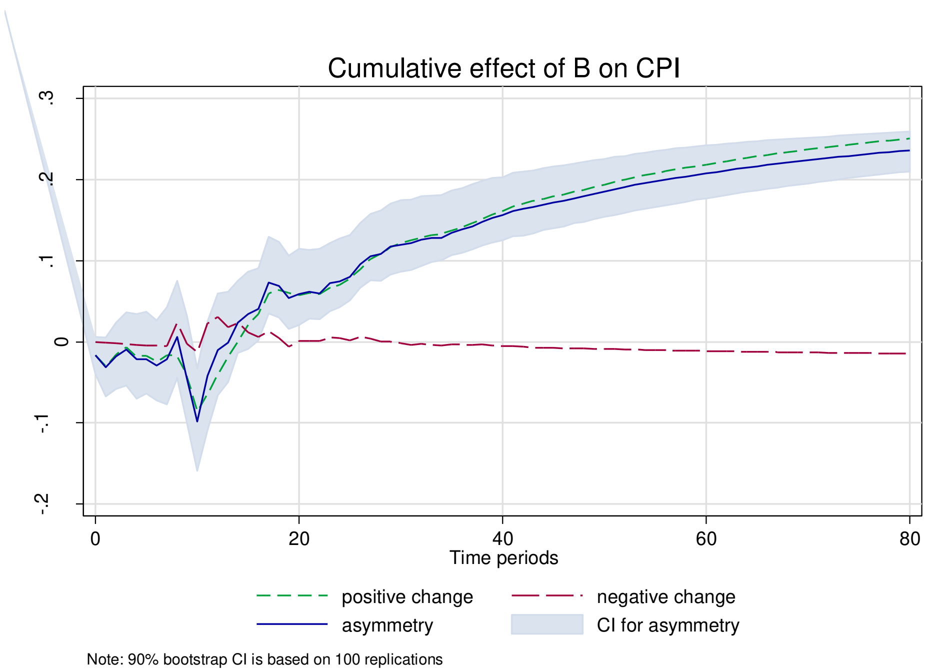
	effect [+]			**effect [-]**		
Variables	Coef.	F-Stat	P value	Coef.	F-Stat	P value
B	0.330	16.8	0.000	-0.047	.3635	0.547

Table 11 Nonlinear ARDL using two variables CPI and B and Data used from 2003-2018

	Long Run Asymmetry statistics		**Short Run Asymmetry statistics**	
Variables	**F-Stat**	**P value**	**F-Stat**	**P value**
B	586.9	0.000	2.224	0.138

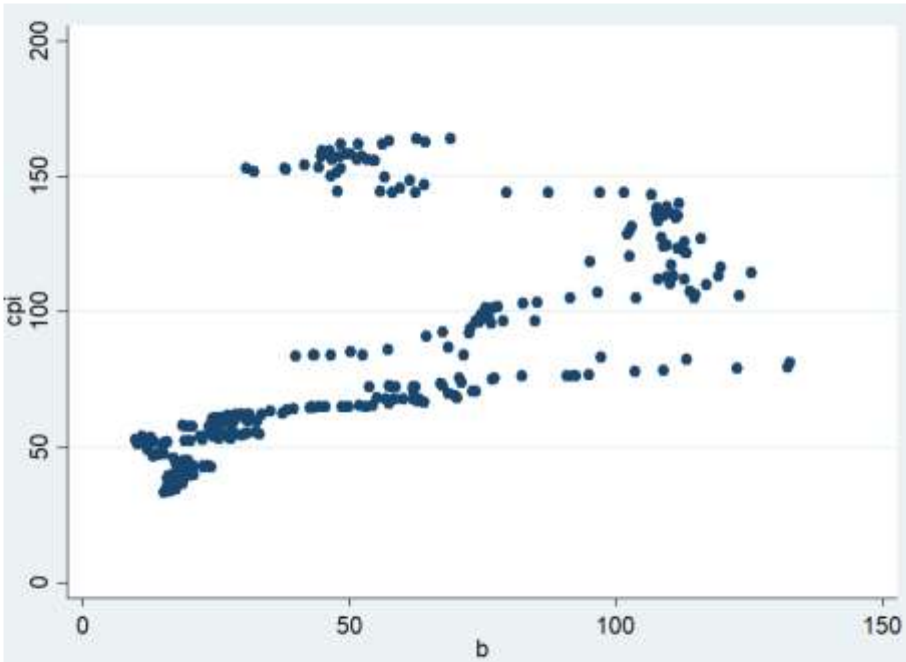
In the following figure 6 we see that an increase (positive change) in oil price increase inflation but negative change line is in line with 0 which show no impact in case of decrease in oil price.

Figure 6



In the following figure 7 we see that the relationship between inflation (cpi) and oil price (Brent) is not predictable and inconclusive in terms of positive and negative that is non-linear.

Figure 7



3.6 Error Correction Model (ECM)

Here we use Error Correction Model (ECM) applying ARDL approach. ECM choose optimal lags for each variable individually. The details of all i.e. coefficients, standard error, z statistics and p-value are provided below. For more details refer Appendix.

Table 12 RMSE

Equation	Parms	RMSE	R-sq	chi2	P>chi2
D_cpi	6	.686439	0.3999	185.2507	0.0000
D_b	6	4.52744	0.1866	63.78549	0.0000
D_e	6	1.23441	0.1819	61.82543	0.0000
D_ip	6	1.42525	0.2171	77.07074	0.0000

Table 13 Short Run relationship

Results of Error-Correction Model				
Variable	Coefficient	Standard Error	Z-Statistics	[P-Value]
Ecm(-1) CPI	0.0066897	0.0020856	3.21	0.001***
Ecm(-1) B	-0.0395137	0.0137556	-2.87	0.004***

Ecm(-1) E	0.0073457	0.0037505	1.96	0.050**
Ecm(-1) IP	-0.0033	0.00433	-0.75	0.451

***, **, * denote that coefficients are significant at 1%, 5% and 10% level.

In Co-integration, we study long-term relationship while ECM gives us short-run relationship. Sometime there may be short run huge variation between short run and long run. Therefore, ECM has be ability to capture short run relationship.

The variables which have significant coefficients of ecm(-1) are found to be dependent on other variables for short run values determination and is called endogenous and vice versa. In the above table we see that inflation (CPI), oil price (B), Exchange rate (E) are endogenous variables, while industrial production is exogenous variable.

As oil price and inflation are found endogenous variables. Therefore, the government of India should take care of these two variables.

3.7 Variance Decomposition (VDC)

If we see from the government policy perspective, all the endogenous variables can be influenced taking into consideration the fiscal or monetary policy of the government. But the question is which variables government should target? Because it is difficult for the government to focus on all variables simultaneously. Therefore, it is important to know the relative exogeneity and endogeneity. For this purpose, VDC is used. In the below table beta is exactly identified and see that the top ranking is oil price. If government control oil price it can influenced highly other variables related to it.

Table 14 Identification: beta is exactly identified

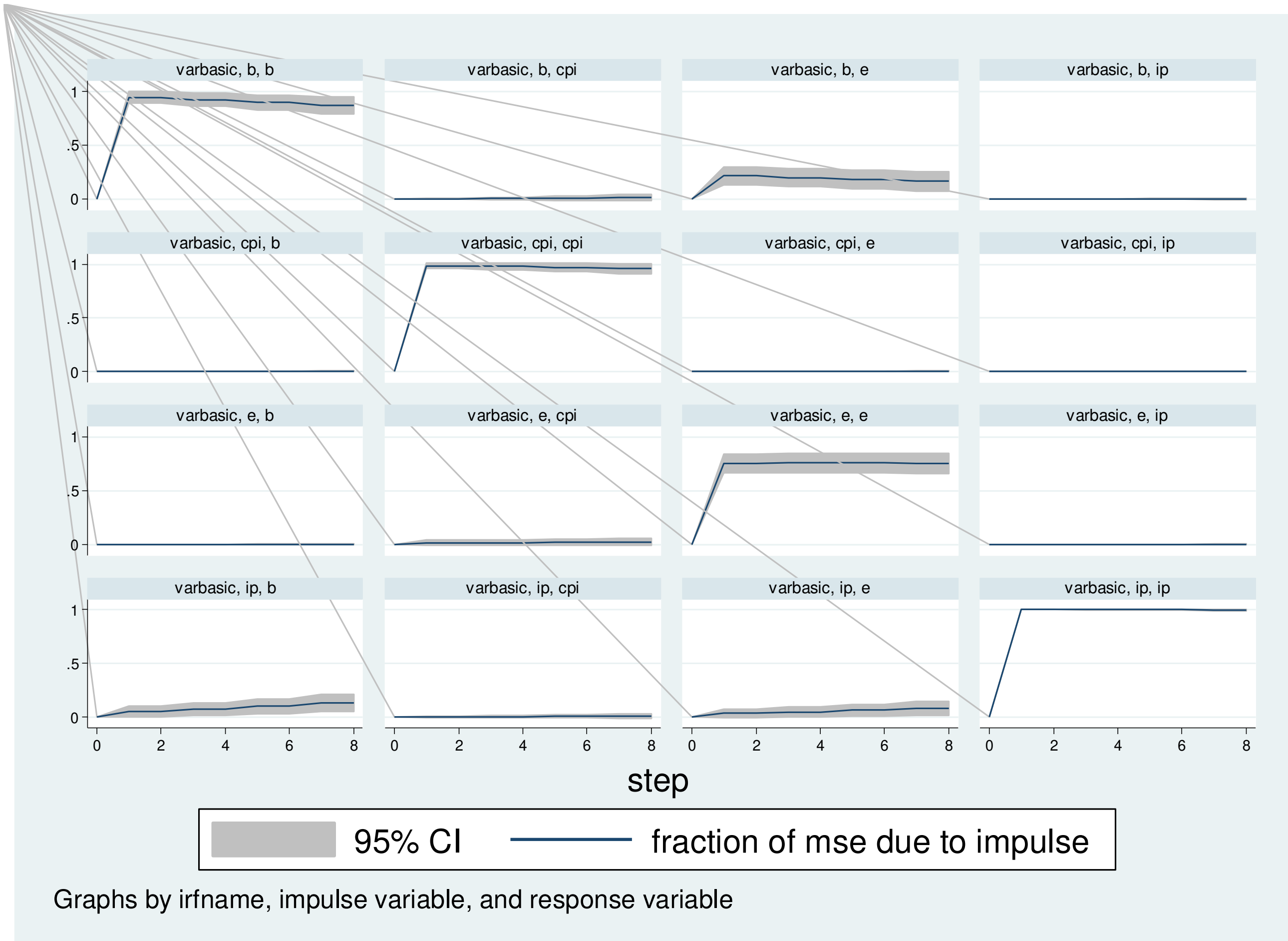
Johansen normalization restriction imposed				
beta	Coef.	Std. Err.	z	P>|z|
cpi	1	.	.	.
b	.8584133	.2591249	3.31	0.001
e	-.3090149	.543945	-0.57	0.570
ip	-1.638071	.2701905	-6.06	0.000
_cons	20.58773	.	.	.

Table 15 Ranking

maximum rank	parms	LL	eigenvalue	trace statistic	critical value
0	36	-2044.28	.	46.3533*	47.21

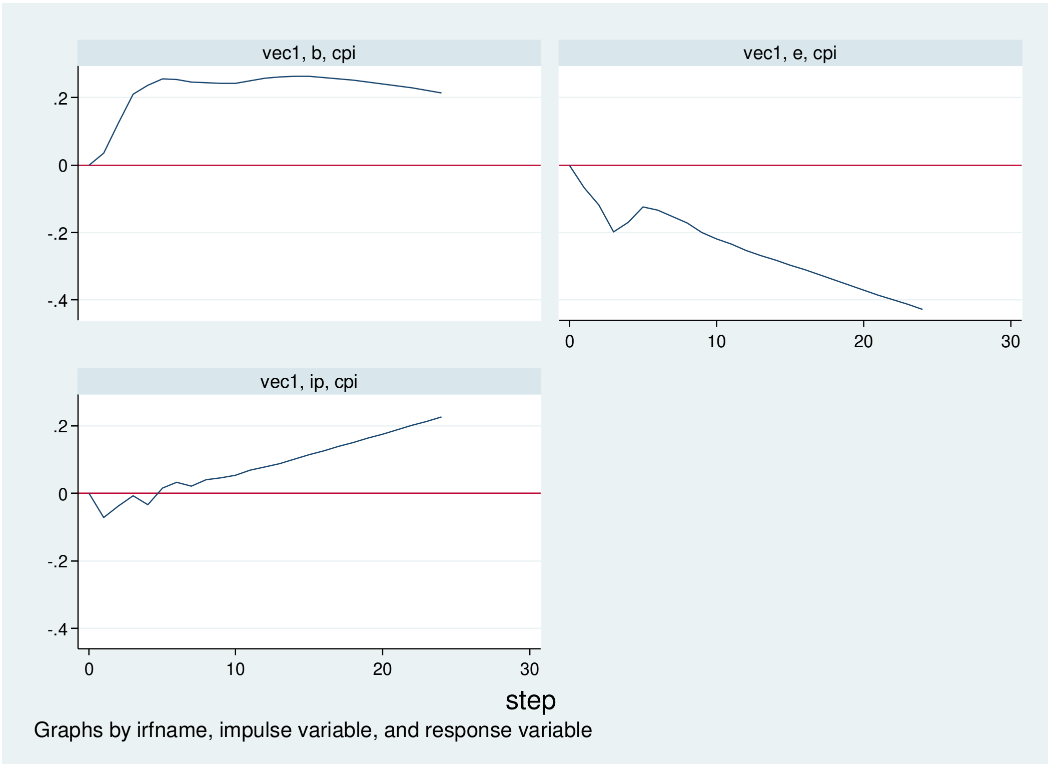
1	43	-2034.08	0.06955	25.9541	29.68
2	48	-2025.69	0.05758	9.171	15.41
3	51	-2021.45	0.02953	0.6884	3.76
4	52	-2021.1	0.00243		

Figure 8 Variance Decomposition



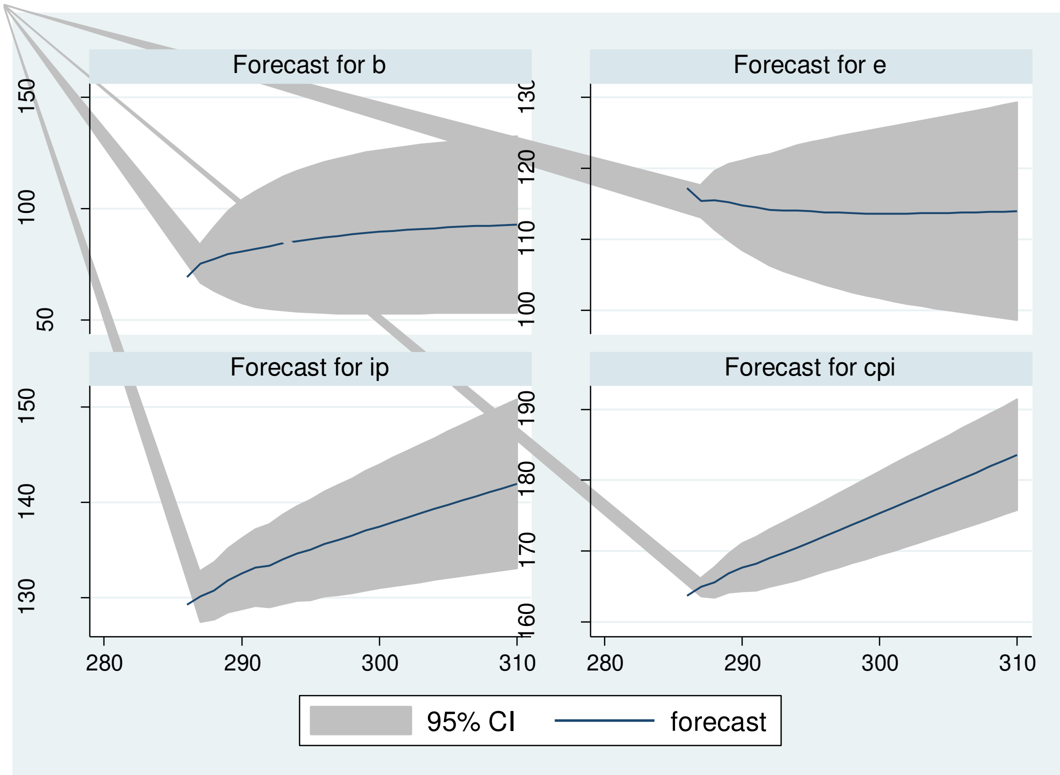
As we discussed before that oil is the main driver of the economy therefore the government should hit it so that control rest of other economic fundamentals. The oil should be the main policy target of the government.

Figure 9 Impulse response



The same result can be checked graphically by IR.

Figure 10 Forecasting with VECMs



In the following figure we have done VECM for all variables. As we see that the impact of oil price is expending with the passage of time. Therefore, it is should be the target of policy makers.

4. Conclusions and policy recommendations

Is oil pass-through symmetric or asymmetric? The examination of this question is not only relevant from the policy perspective but it also has implications for global investors. In this paper, we adopt the NARDL framework to examine the asymmetry in the oil pass-through. In other words, the main objective of this paper is to examine whether the increase/decrease in oil prices (Brent crude) have the similar effect, in terms of magnitude, on domestic prices. The sample spans from January 1994 to January 2018. For comparative purposes, we also estimated the association between oil price and domestic prices using the relationship with ARDL which does not take asymmetry into account. The results of ARDL indicates no long run relationship between oil prices and inflation. This is in sharp contrast with the NARDL findings which indicate long run relationship. Moreover, the results are asymmetric both in long run as well as short run. The main findings reveal that the oil price increase is associated with increase in inflation, whereas a decrease in oil prices has no significant association with inflation. These results highlight the importance of examining the relationship in non-linear framework. These results are robust to the inclusion of additional variables, different proxy of oil prices (WTI crude) and different time period (January 2003 to January 2018).

With 80% oil dependence, which is expected to further increase in coming years due to rapid expansion, and the reforms initiated to deregulate domestic oil market, the association between global and the domestic oil prices is only going to get stronger. The strong association between global and domestic oil prices have serious implications for the domestic price level, especially with oligopolistic market like India. Moreover, the evidence of asymmetric pass-through makes the situation more worrying for the policymakers as it causes the welfare loss to general consumers. Therefore, the policymakers are required to keep close watch on the global prices while addressing domestic prices. Moreover, the monetary policy should be more dynamic in nature so that it can be effective in curbing inflationary pressures. Furthermore, the government should also invite more players to make the market structure more competitive. This would help them address the asymmetric pass-through issues. Likewise, more emphasis on alternative energy resources such as coal and renewables would help the policymakers to diversify the energy demands and hence lowering the sensitivity of inflation to oil prices. Finally, India can also address domestic prices to certain extent by substituting imported fuels with domestic fuels like bio-deisel and ethanol.

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Appendices

Robustness

The following tables 1 and 2 confirm our results by adding other variables to the model.
Table 1 Nonlinear ARDL with all variables

Long Run Asymmetry statistics

	effect [+]			effect [-]		
Variables	Coef.	F-Stat	P value	Coef.	F-Stat	P value
B	0.333	9.365	0.002	-0.018	.157	0.692
e	0.102	1.447	0.230	-0.178	.9375	0.334
ip	-0.390	2.087	0.150	0.541	3.976	0.047

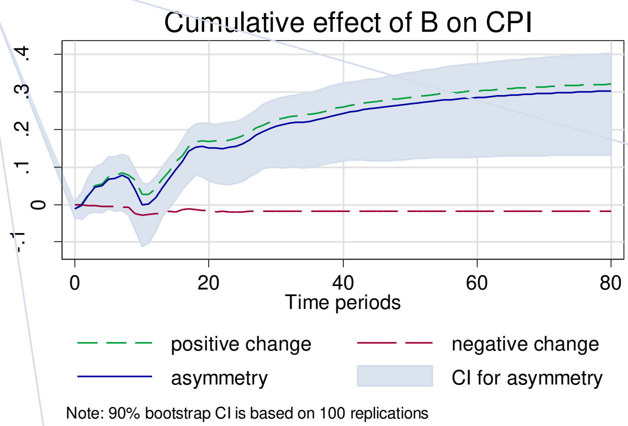
Table 2 Nonlinear ARDL with all variables

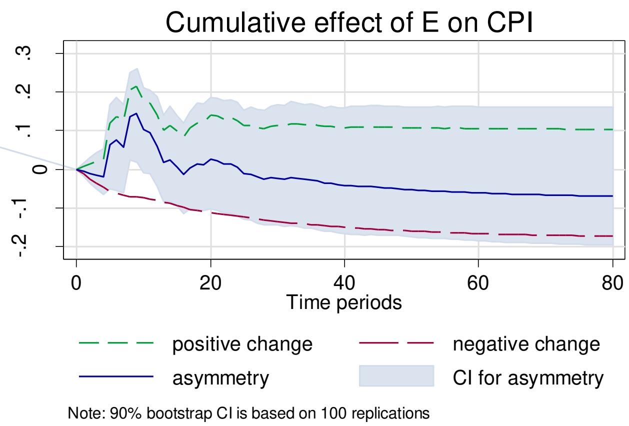
	Long Run Asymmetry statistics		Short Run Asymmetry statistics	
Variables	**F-Stat**	**P value**	**F-Stat**	**P value**
B	8.956	0.003	5.605	0.019
e	.2637	0.608	6.347	0.012
ip	.2566	0.613	3.622	0.058

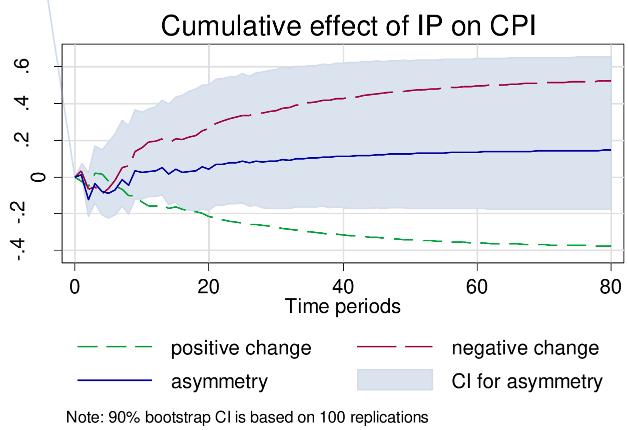
Robustness test by using wti

```
nardl cpi wti e ip, p(12) q (12) constraints(1/7)
Asymmetry statistics:
------------------------------------------------------------------------------
             |          Long-run effect [+] |          Long-run effect [-]
  Exog. var. |       coef.     F-stat     P>F |       coef.     F-stat     P>F
-------------+----------------------------------------------------------------
         wti |       0.406      11.68   0.001        -0.061      1.341   0.248
           e |       0.129      2.462   0.118        -0.197      1.285   0.258
          ip |      -0.562      4.254   0.040         0.764      9.202   0.003
-------------+----------------------------------------------------------------
             |            Long-run asymmetry |           Short-run asymmetry
             |                F-stat     P>F |                F-stat     P>F
-------------+----------------------------------------------------------------
         wti |                  11.4   0.001                  5.322   0.022
           e |                 .2453   0.621                  5.634   0.018
          ip |                 .5454   0.461                  2.746   0.099
------------------------------------------------------------------------------
Note: Long-run effect [-] refers to a permanent change in exog. var. by -1

  Cointegration test statistics:    t_BDM =      -3.7006
                                    F_PSS =      10.3120
```

Figure all variables (1994-2018)







Vector auto-regression

```
Sample:  3 - 286                                        Number of obs     =       284
Log likelihood =  -2549.578                             AIC               =  18.09562
FPE            =    849.059                             HQIC              =  18.19865
Det(Sigma_ml)  =   737.5022                             SBIC              =  18.35259
```

Equation	Parms	RMSE	R-sq	chi2	P>chi2
ip	5	1.72419	0.9967	84581.64	0.0000
b	5	7.89258	0.9468	5052.958	0.0000
e	5	2.16679	0.9582	6513.365	0.0000
cpi	5	1.13923	0.9992	341930.8	0.0000

```
-------------------------------------------------------------


------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
ip           |
          ip |
         L2. |   1.005768   .0177075    56.80   0.000     .9710617    1.040474
             |
           b |
         L2. |   -.005706   .0065557    -0.87   0.384     -.018555    .0071429
             |
           e |
         L2. |  -.0052955   .0124028    -0.43   0.669    -.0296046    .0190135
             |
         cpi |
         L2. |   .0007748   .0111172     0.07   0.944    -.0210145    .0225641
             |
       _cons |   1.070561   1.362069     0.79   0.432    -1.599045    3.740167
-------------+----------------------------------------------------------------
b            |
          ip |
         L2. |   .3826507    .081057     4.72   0.000     .2237819    .5415195
             |
           b |
         L2. |   .8592865   .0300091    28.63   0.000     .8004697    .9181033
             |
           e |
         L2. |  -.0609454   .0567746    -1.07   0.283    -.1722216    .0503308
             |
         cpi |
         L2. |  -.2135274   .0508895    -4.20   0.000     -.313269   -.1137858
```

```
             |
       _cons |   3.500798   6.234948     0.56   0.574    -8.719476    15.72107
-------------+----------------------------------------------------------------
e            |
          ip |
         L2. |  -.0896235    .022253    -4.03   0.000    -.1332386   -.0460083
             |
           b |
         L2. |   .0127961   .0082386     1.55   0.120    -.0033512    .0289435
             |
           e |
         L2. |   .9610184   .0155867    61.66   0.000     .9304691    .9915677
             |
         cpi |
         L2. |   .0604964    .013971     4.33   0.000     .0331137     .087879
             |
       _cons |   5.457074   1.711716     3.19   0.001     2.102173    8.811975
-------------+----------------------------------------------------------------
cpi          |
          ip |
         L2. |   .0080901      .0117     0.69   0.489    -.0148414    .0310216
             |
           b |
         L2. |   .0072405   .0043316     1.67   0.095    -.0012492    .0157303
             |
           e |
         L2. |  -.0128421    .008195    -1.57   0.117    -.0289039    .0032198
             |
         cpi |
         L2. |    .998772   .0073455   135.97   0.000     .9843751    1.013169
             |
       _cons |   1.427918   .8999671     1.59   0.113    -.3359853    3.191821
```

ECM

Selection-order criteria

Sample: 5 - 286 Number of obs = 282

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-5418.48				3.5e+10	38.4644	38.4903	38.529
1	-2666.44	5504.1	25	0.000	138.981	19.1237	19.2791	19.5111
2	-2564.27	204.33	25	0.000	80.4173	18.5764	18.8613*	19.2867*
3	-2535.39	57.779	25	0.000	78.2616*	18.5488*	18.9631	19.582
4	-2511.84	47.093*	25	0.005	79.1334	18.5591	19.1029	19.9152

Endogenous: ip wti b e cpi

Exogenous: _cons

ECM Rank

Johansen tests for cointegration

Trend: constant Number of obs = 283

Sample: 4 - 286 Lags = 3

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	36	-2044.2799	.	46.3533*	47.21
1	43	-2034.0803	0.06955	25.9541	29.68
2	48	-2025.6888	0.05758	9.1710	15.41
3	51	-2021.4475	0.02953	0.6884	3.76
4	52	-2021.1033	0.00243		

Vector error-correction model

Sample: 3 - 286 Number of obs = 284

AIC = 14.67066

Log likelihood = -2056.234 HQIC = 14.80975

Det(Sigma_ml) = 22.85144 SBIC = 15.01757

Equation	Parms	RMSE	R-sq	chi2	P>chi2
D_cpi	6	.686439	0.3999	185.2507	0.0000
D_b	6	4.52744	0.1866	63.78549	0.0000
D_ip	6	1.42525	0.2171	77.07074	0.0000
D_e	6	1.23441	0.1819	61.82543	0.0000

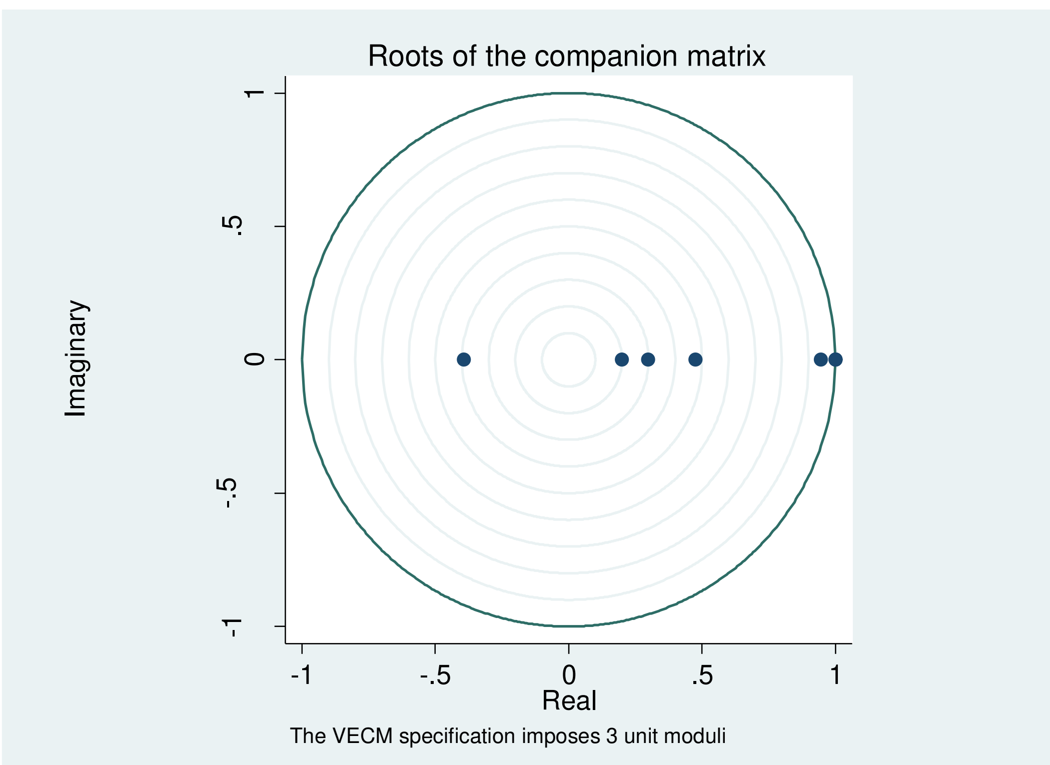
	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
D_cpi						
_ce1						
L1.	.0066897	.0020856	3.21	0.001	.0026021	.0107774
cpi						
LD.	.2823399	.0577358	4.89	0.000	.1691799	.3954999
b						
LD.	.0066791	.0093279	0.72	0.474	-.0116032	.0249614

```
             |
          ip |
         LD. |  -.0537892   .0268978    -2.00   0.046     -.106508   -.0010705
             |
           e |
         LD. |  -.0576292   .0340957    -1.69   0.091    -.1244556    .0091972
             |
       _cons |    .402865   .0541369     7.44   0.000     .2967586    .5089714
-------------+----------------------------------------------------------------
D_b          |
        _ce1 |
         L1. |  -.0395137   .0137556    -2.87   0.004    -.0664741   -.0125533
             |
         cpi |
         LD. |  -.1596138   .3807991    -0.42   0.675    -.9059663    .5867387
             |
           b |
         LD. |   .3383454   .0615224     5.50   0.000     .2177638    .4589271
             |
          ip |
         LD. |  -.3067036    .177406    -1.73   0.084    -.6544128    .0410057
             |
           e |
         LD. |  -.4712171   .2248801    -2.10   0.036     -.911974   -.0304603
             |
       _cons |   .0576296   .3570626     0.16   0.872    -.6422003    .7574595
-------------+----------------------------------------------------------------
D_ip         |
        _ce1 |
         L1. |  -.0032648   .0043303    -0.75   0.451     -.011752    .0052223
             |
         cpi |
         LD. |   .2111058   .1198764     1.76   0.078    -.0238476    .4460591
             |
           b |
         LD. |   .0185636   .0193674     0.96   0.338    -.0193958    .0565229
             |
          ip |
         LD. |  -.4223303   .0558478    -7.56   0.000    -.5317899   -.3128707
             |
           e |
         LD. |  -.0945065   .0707927    -1.33   0.182    -.2332576    .0442447
             |
       _cons |   .3762834   .1124041     3.35   0.001     .1559754    .5965913
-------------+----------------------------------------------------------------
D_e          |
        _ce1 |
         L1. |   .0073457   .0037505     1.96   0.050    -5.10e-06    .0146964
             |
         cpi |
         LD. |  -.0328311   .1038251    -0.32   0.752    -.2363245    .1706623
             |
           b |
         LD. |  -.0330702   .0167741    -1.97   0.049    -.0659468   -.0001935
             |
          ip |
         LD. |   .0585774   .0483698     1.21   0.226    -.0362257    .1533805
             |
           e |
         LD. |   .3496913   .0613137     5.70   0.000     .2295187    .4698639
             |
       _cons |   .1103516   .0973533     1.13   0.257    -.0804574    .3011606
------------------------------------------------------------------------------

Cointegrating equations

Equation           Parms    chi2     P>chi2
-------------------------------------------
_ce1                   3   58.19369   0.0000
-------------------------------------------
```

```
Identification:  beta is exactly identified

                 Johansen normalization restriction imposed
------------------------------------------------------------------------------
        beta |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
_ce1         |
         cpi |          1          .       .       .            .           .
           b |   .8584133   .2591249     3.31   0.001     .3505377    1.366289
          ip |  -1.638071   .2701905    -6.06   0.000    -2.167635   -1.108508
           e |  -.3090149    .543945    -0.57   0.570    -1.375127    .7570977
       _cons |   20.58773          .       .       .            .           .
------------------------------------------------------------------------------
```

vecstable, graph

```
   Eigenvalue stability condition
  +----------------------------------------+
  |        Eigenvalue         |   Modulus    |
  |--------------------------+-------------|
  |          1                |         1    |
  |          1                |         1    |
  |          1                |         1    |
  |   .9449168                |   .944917    |
  |   .4760878                |   .476088    |
  |  -.393173                 |   .393173    |
  |   .2967942                |   .296794    |
  |   .1992692                |   .199269    |
  +----------------------------------------+
   The VECM specification imposes 3 unit moduli.
```



Normality test

vecnorm

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_cpi	125.063	2	0.00000
D_b	62.442	2	0.00000
D_ip	181.889	2	0.00000
D_e	5.708	2	0.05760
ALL	375.102	8	0.00000

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_cpi	-.15416	1.113	1	0.29141
D_b	-.57846	15.671	1	0.00008
D_ip	.51091	12.225	1	0.00047
D_e	.06379	0.191	1	0.66243
ALL		29.200	4	0.00001

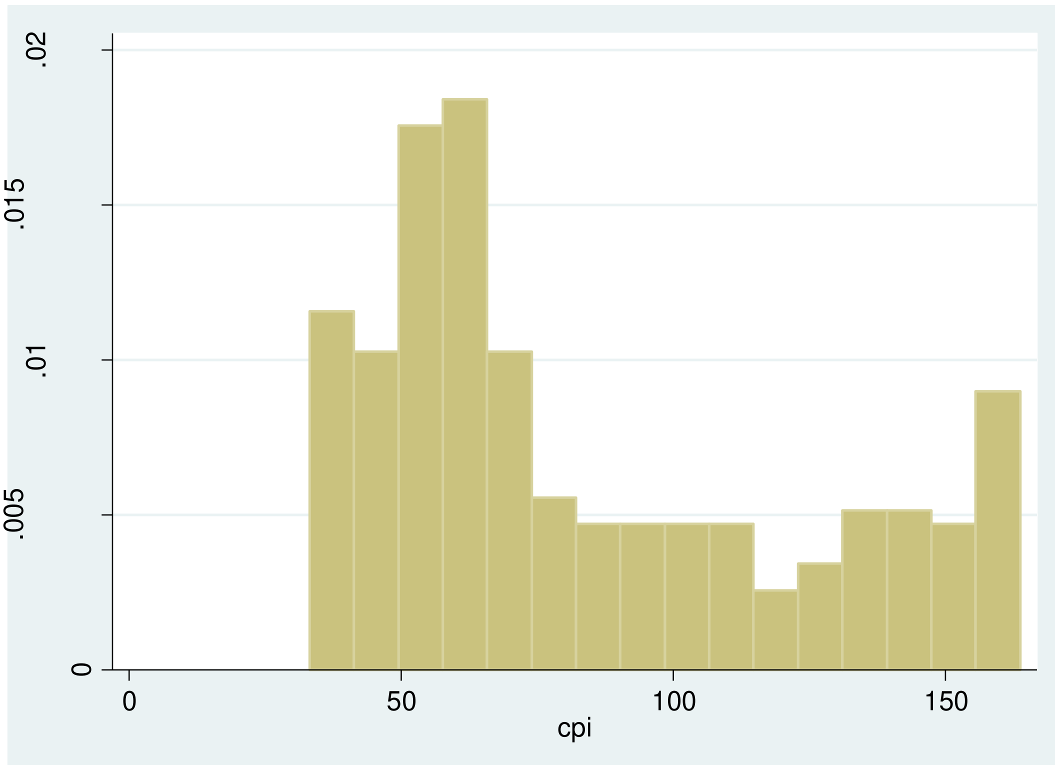
Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
D_cpi	6.2537	123.950	1	0.00000
D_b	4.9987	46.771	1	0.00000
D_ip	6.8067	169.663	1	0.00000

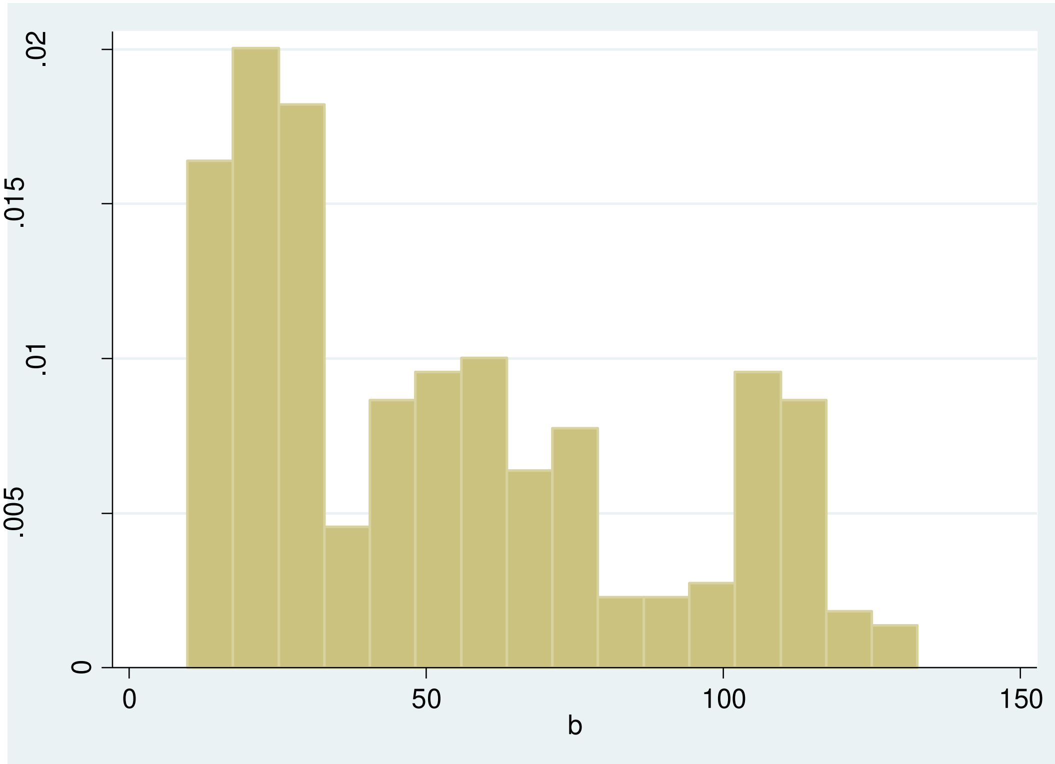
```
|               D_e |  3.6865    5.518   1    0.01882   |
|               ALL |          345.903   4    0.00000   |
+----------------------------------------------------+
```

Histogram

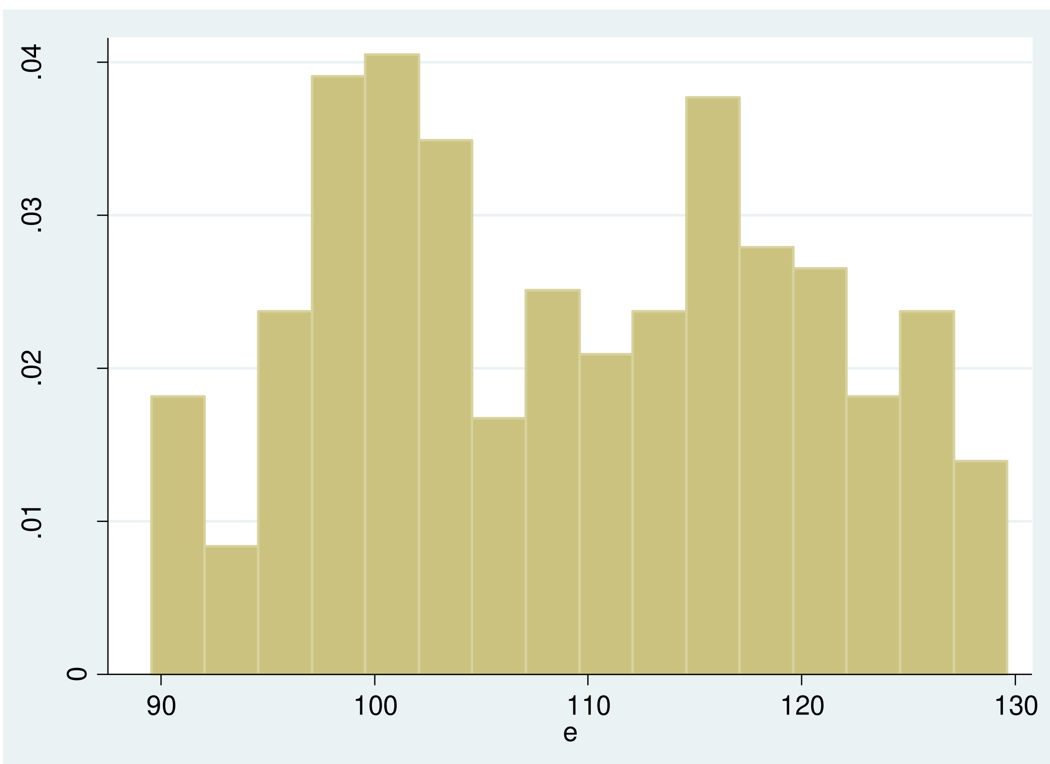
cpi



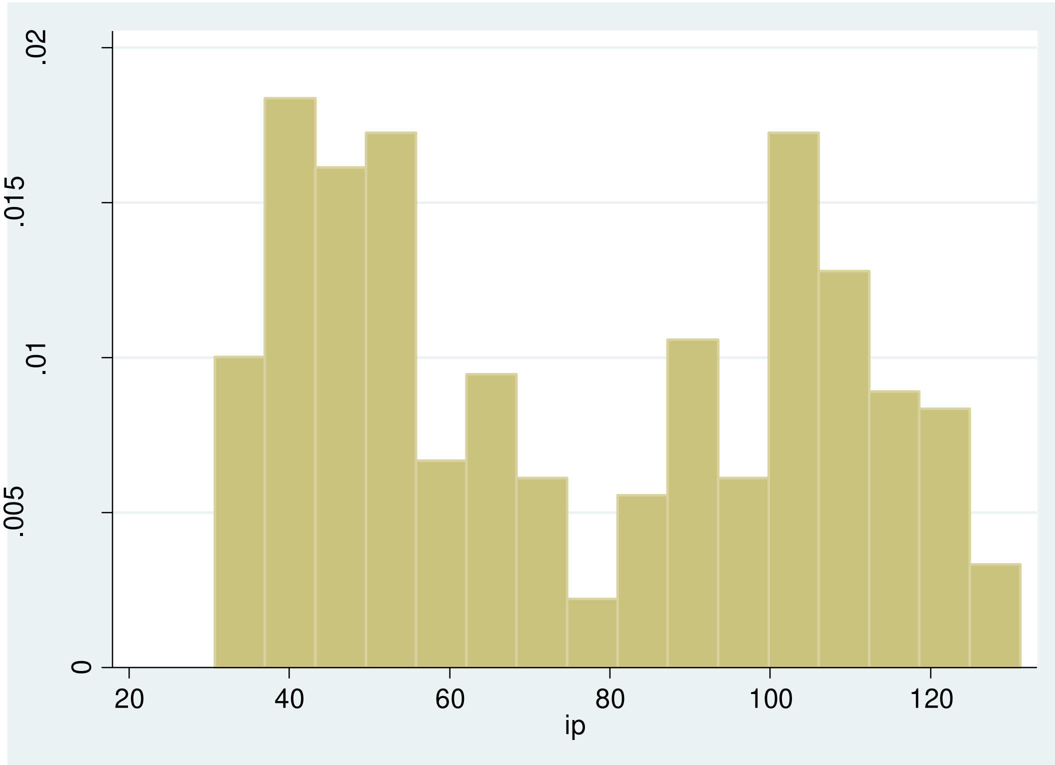
Oil price



Exchange rate

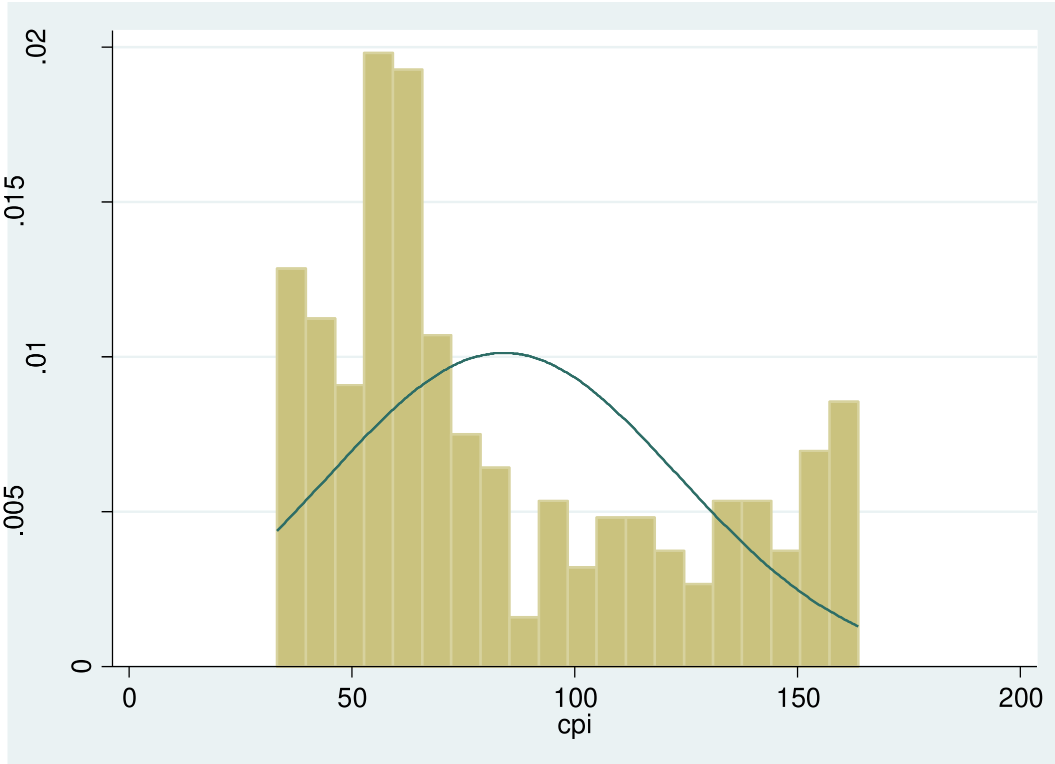


Industrial production

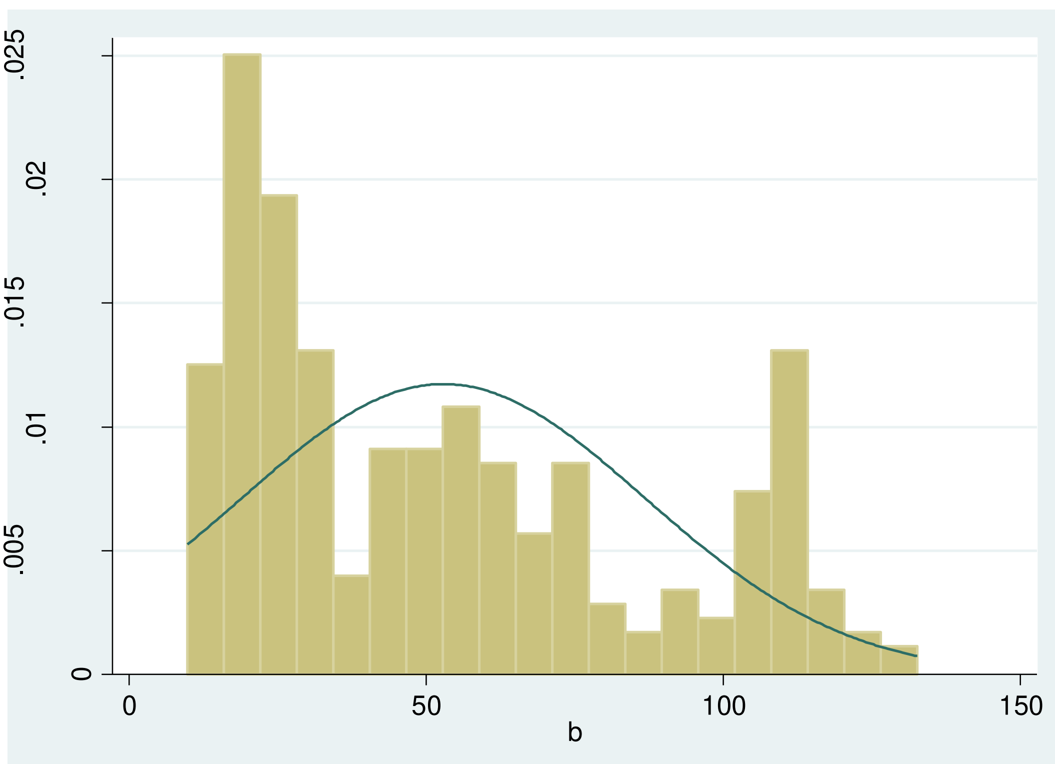


Normal distribution

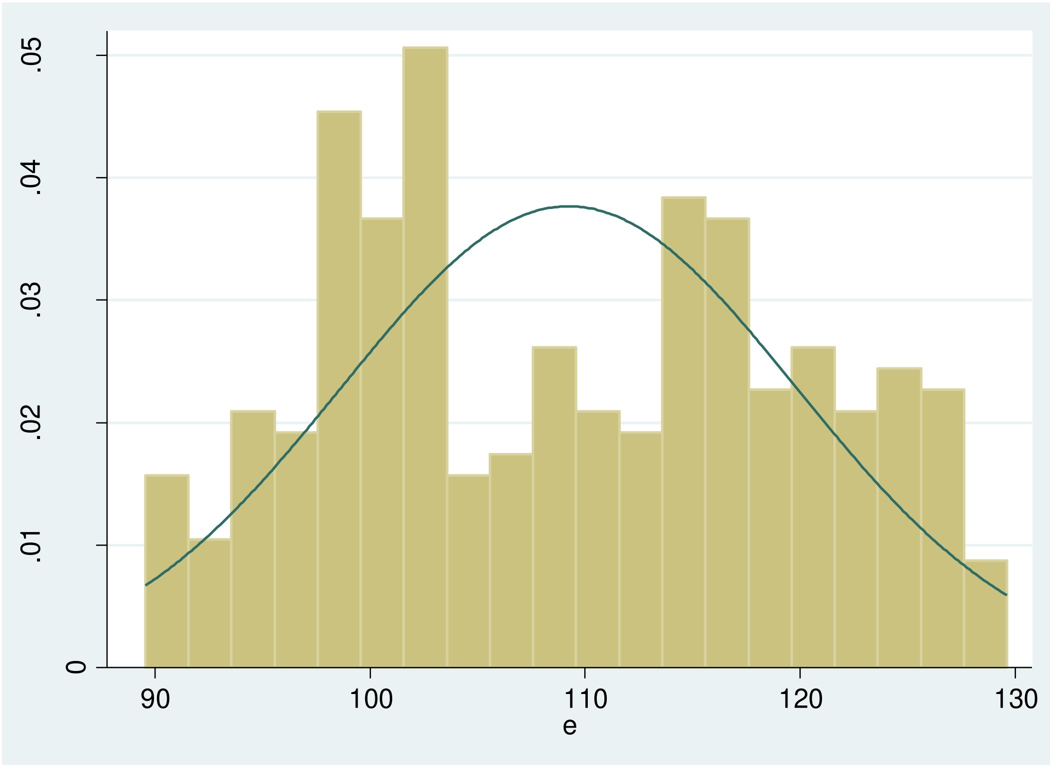
Inflation (cpi)


.02
.015
.01
.005
0
0
50
100
150
200
cpi

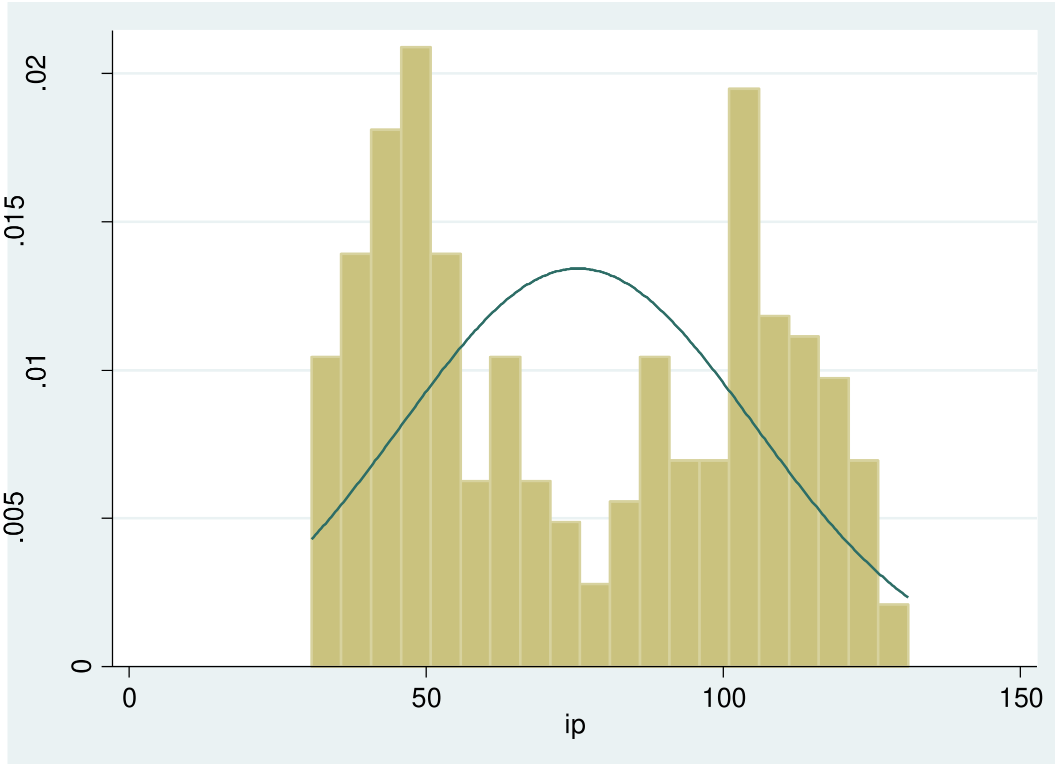
Oil price


.025
.02
.015
.01
.005
0
0
50
100
150
b

Exchange rate

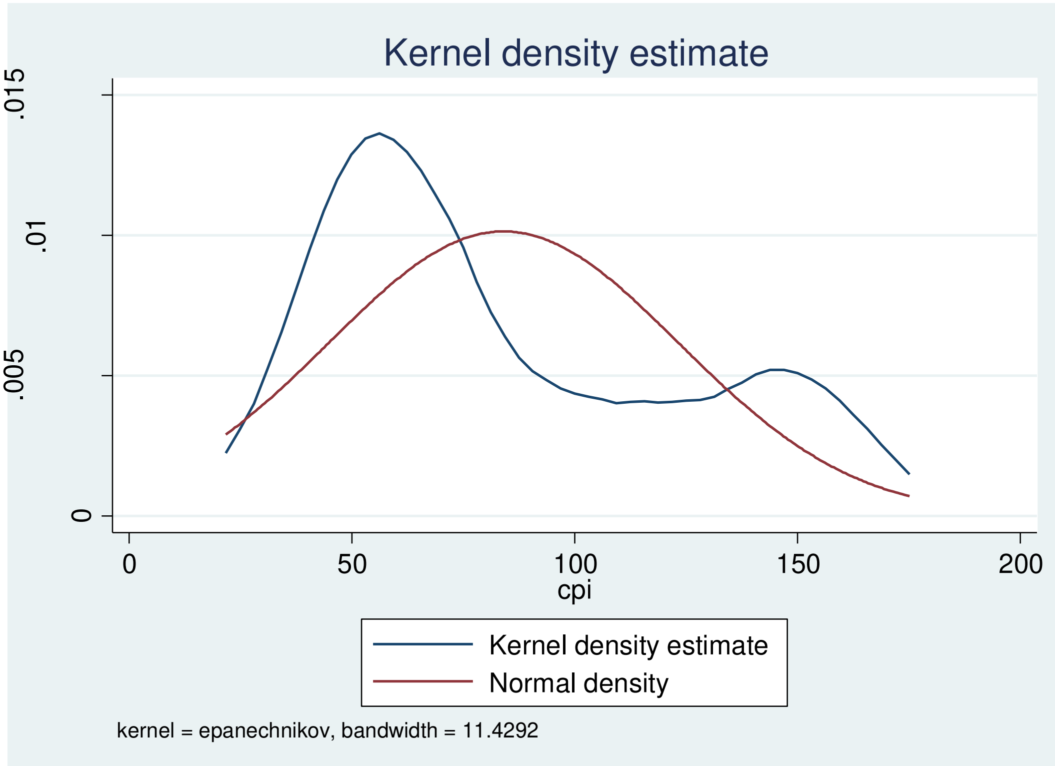


Industrial production



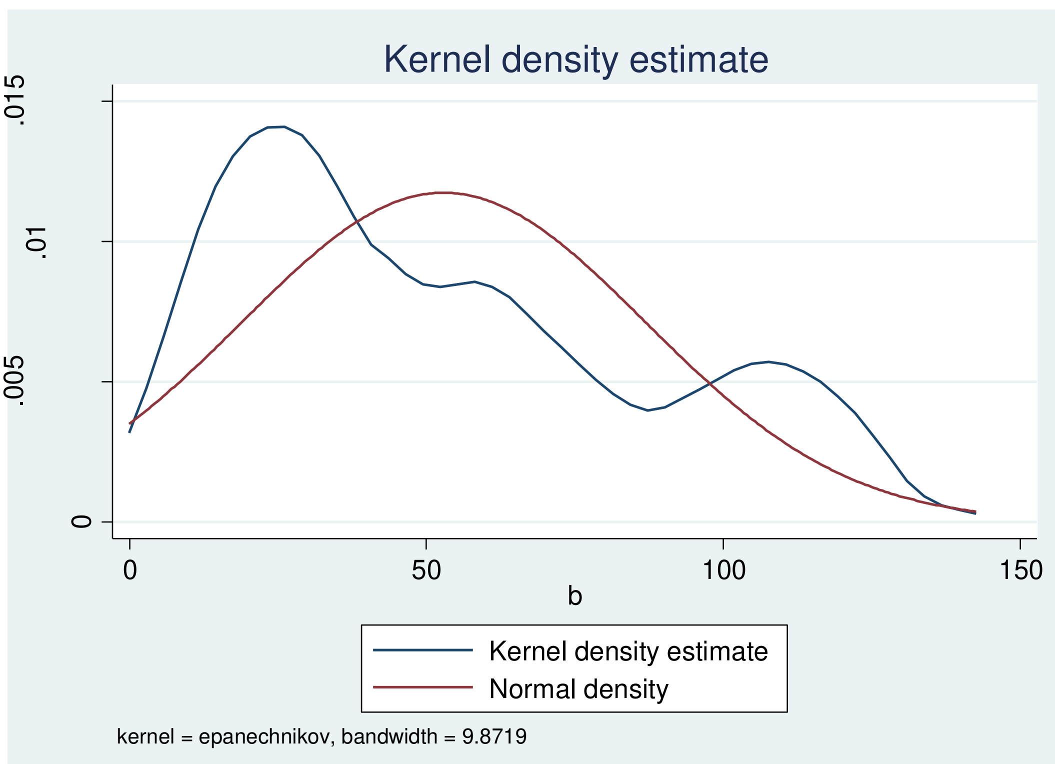
Kernel density distribution

Inflation (cpi)



Kernel density estimate
0
.005
.01
.015
0
50
100
150
200
cpi
Kernel density estimate
Normal density
kernel = epanechnikov, bandwidth = 11.4292

Oil price

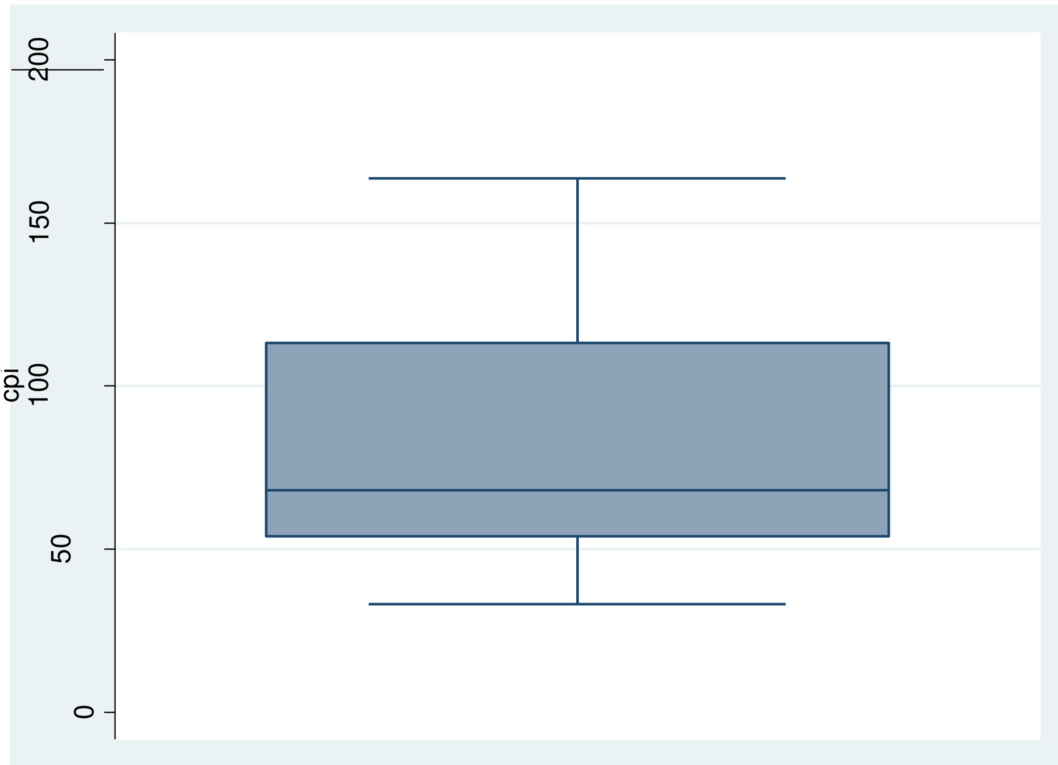


Kernel density estimate
0
.005
.01
.015
0
50
100
150
b
Kernel density estimate
Normal density
kernel = epanechnikov, bandwidth = 9.8719

All the kdensity plots indicate that all variables are not normally distributed.

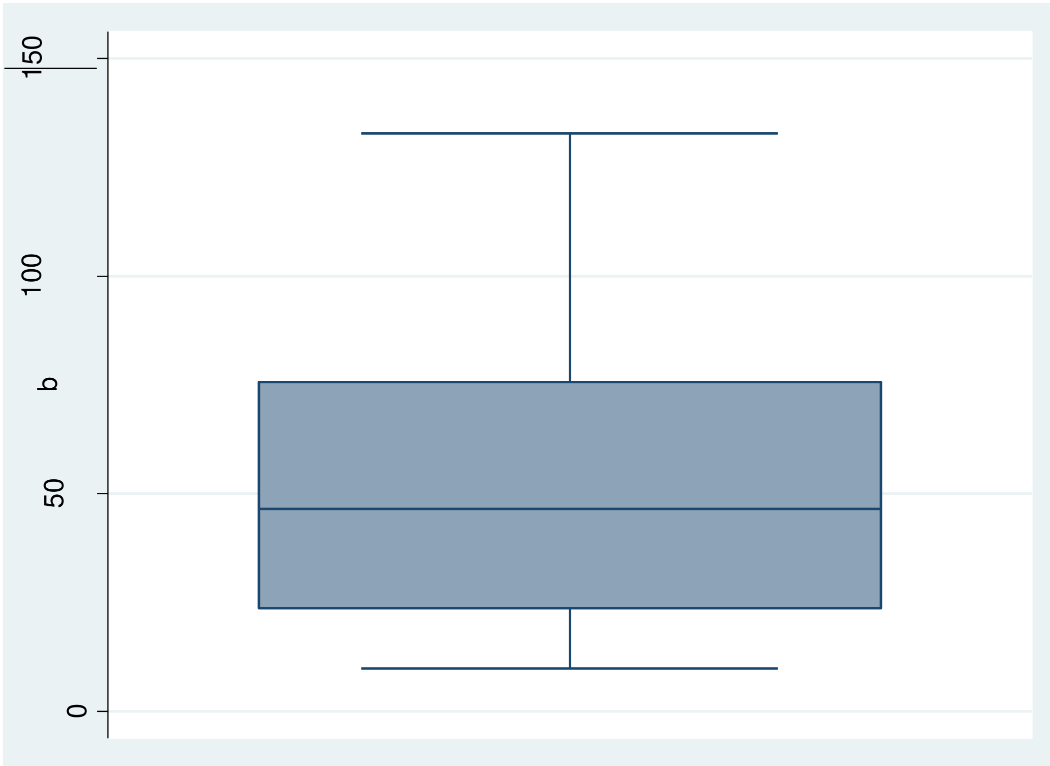
Graphic box

Inflation (cpi)

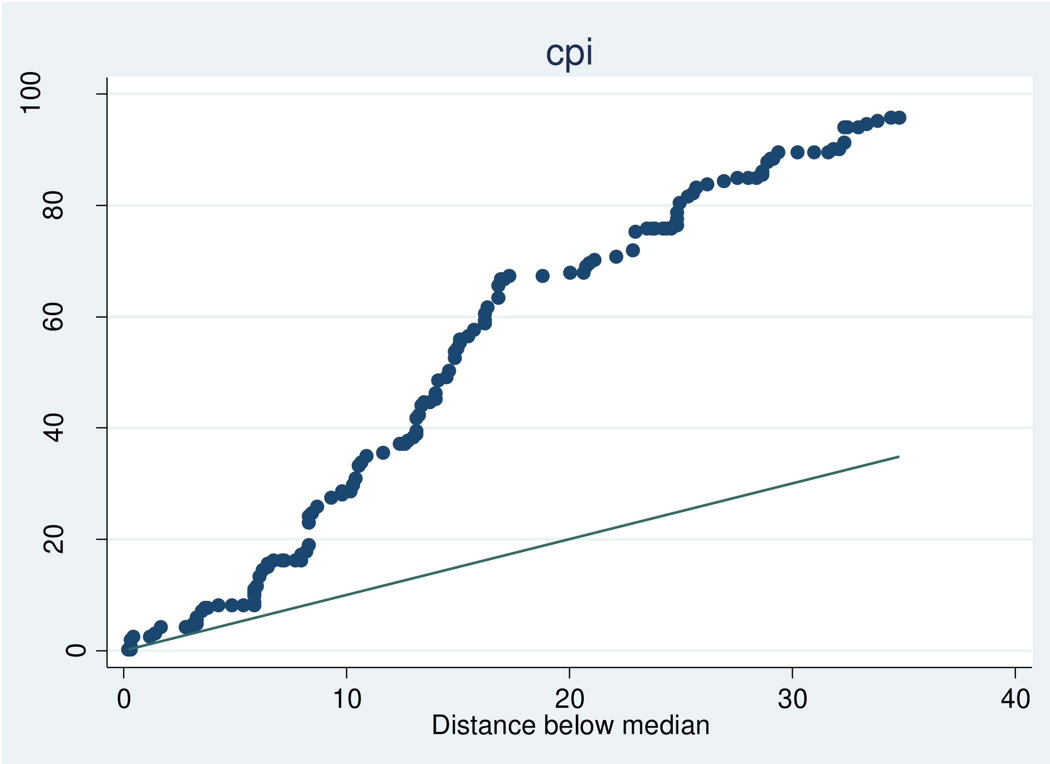


We see that there is no outlier in the cpi data

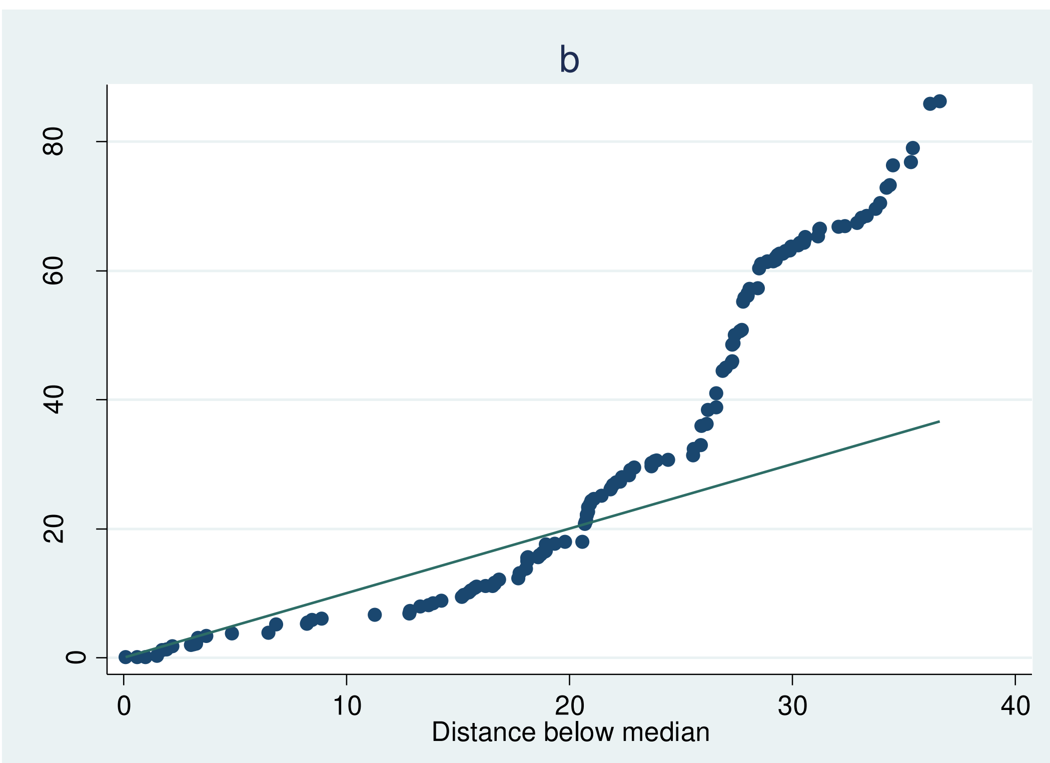
Oil price



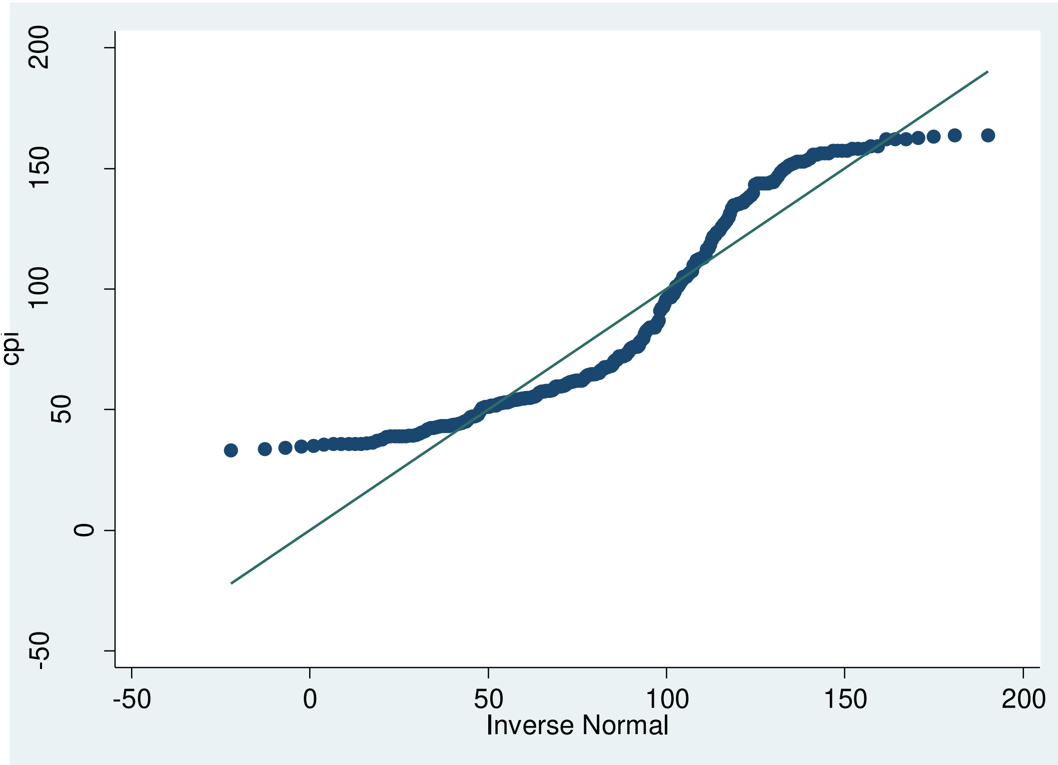
The below figure also show far away from median values of inflation


cpi
0
20
40
60
80
100
0
10
20
30
40
Distance below median

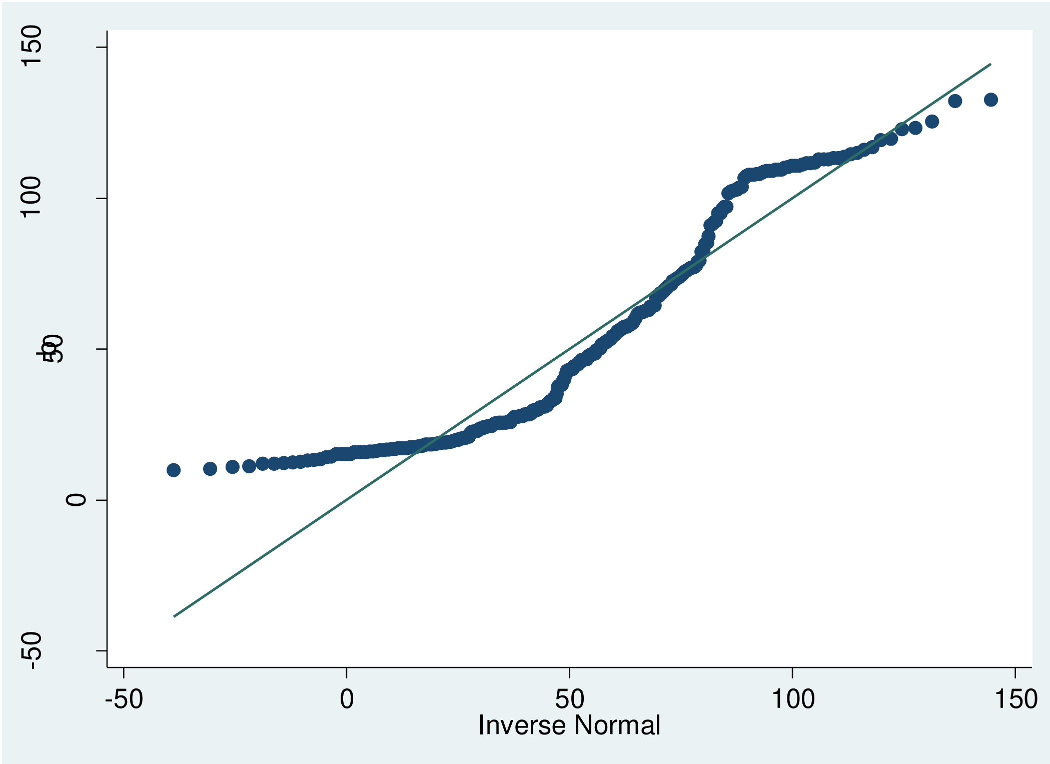
Oil price


b
0
20
40
60
80
0
10
20
30
40
Distance below median

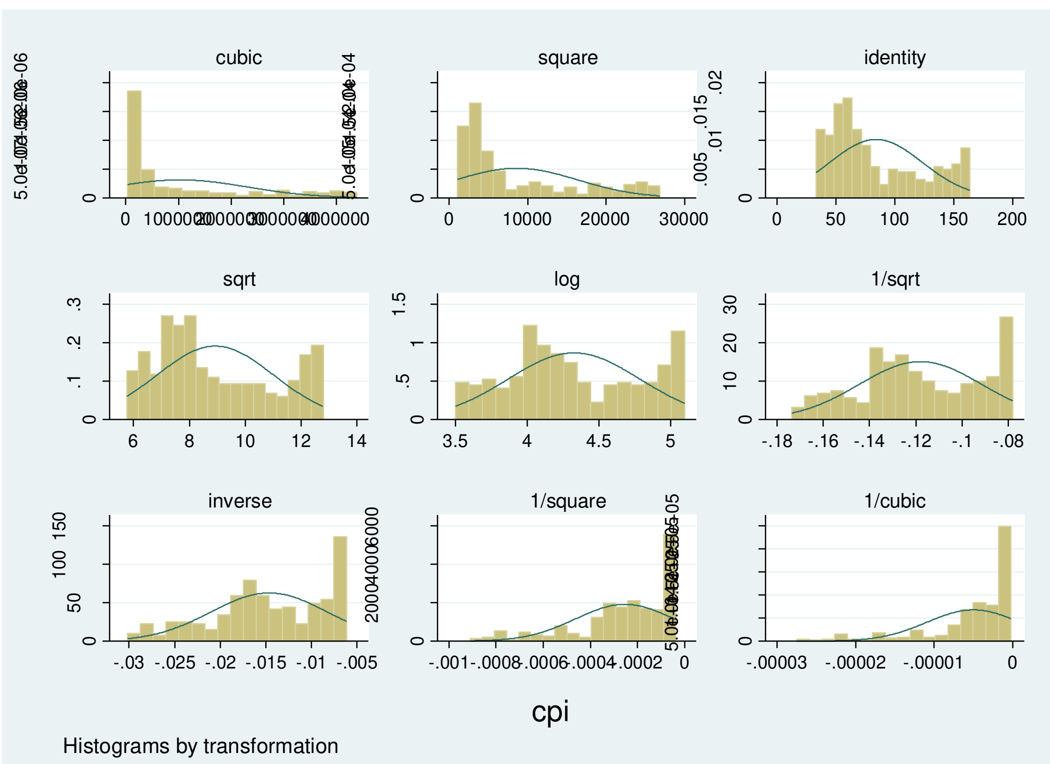
The blow figure shows inverse normality of inflation



Oil price



Overall picture of inflation



Overall picture of oil price