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# Sources of Asymmetry and Non-linearity in Pass-Through of Exchange Rate and Import Price to Consumer Price Inflation for the Turkish Economy during Inflation Targeting Regime

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# Sources of Asymmetry and Non-linearity in Pass-Through of Exchange Rate and Import Price to Consumer Price Inflation for the Turkish Economy during Inflation Targeting Regime

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Some recent studies indicate that exchange rate pass-through and import price pass-through are better characterized in a non-linear way. Having a better understanding of non-linearity of exchange rate pass-through (ERPT) and import prices pass-through (IPPT) under different conditions will contribute to the critical decisions on the proper role and magnitude of the exchange rate movements in the monetary policy. In this paper, we implement a state based non-linear method (Markov process) to identify, decompose, quantify and analyze the nonlinearities for both types of concurrent (same period) pass-through for the years between 2003 and 2014 for the Turkish economy. According to the results, both ERPT and IPPT are lower during appreciation and low volatility periods of nominal exchange rate. Even though ERPT does not differ depending on the level of business activity, IPPT is lower during contractionary periods compared to expansionary periods. The findings in this paper will allow for more nuanced monetary policy approaches to deal with pass-through stemming from different sources.

**Key words:** Asymmetry; Non-linearity; Inflation Targeting; Pass-Through of Exchange Rate and Import Price; Markov Switching Regression

**JEL Classification:** C22; C52; E52; E58; F31

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## 1. Introduction

The degree to which exchange rates and import prices are reflected in the domestic prices is a necessary question to be answered by monetary policy makers. However a deeper understanding the nature and characteristics of exchange rate pass-through (hence forth ERPT) and import prices pass-through (hence forth IPPT) is required for optimal conduct of monetary policy with fine tunings. In the literature, both ERPT and IPPT have long been considered as symmetric and linear. Only recently, empirical literature began providing evidence indicating non-linearity and asymmetry in both types of pass-through supporting observations that exchange rate and import price fluctuations are not passed to the domestic prices in a linear and symmetric way.

Following situations and explanations are cited in the literature as possible causes of asymmetry and non-linearity of ERPT and IPPT:

- Direction of Exchange Rate Movements: Pricing behavior of importing and exporting firms may show stickiness and vary depending on market share objectives, capacity constraints, switching and menu costs; hence exchange rate fluctuations with different directions may not be reflected in the domestic prices in a linear and symmetric way.

-Volatility of Nominal Exchange Rate: Uncertainty generated by volatility of nominal exchange rates may affect price adjustments of exporters and importers causing asymmetry and non-linearity in the formation of ERPT and IPPT.

-Level of Business Activity: Exporters and importers act differently in passing exchange rate variations to the prices depending on the level of business activity of the economy. Some empirical evidence suggest that during the expansionary periods exporters and importers reflect depreciation of the local currency to the prices, but during recessionary periods they do not reflect depreciation of the local currency to the domestic prices with the same magnitude and the speed at the expense of reducing their markups due market share concerns. On the other hand, there is also evidence suggesting the opposite of this pricing pattern.

In this study we identify, decompose, quantify and analyze ERPT and IPPT with state base non-linear method: Markov regime switching process. This nuanced analysis helps to design better and fine-tuned monetary policy responses. Our results report that concurrent (same quarter) ERPT and IPPT for the quarterly core inflation in Turkey between 2003 and 2014 vary during appreciation and depreciation periods of nominal exchange rate; high and low volatile periods of nominal exchange rate and level of business activity.

It is important to state that analysis of ERPT and IPPT in this study is limited to the concurrent pass-through which implies changes in core inflation in the same quarter and ERPT and IPPT coefficients do not represent the pass-through that adds up cumulatively during the course of multiple periods. So, one must be careful when comparing the pass-through findings of this study with other studies most of which compute pass-through that occurs through more than one period.

The remainder of this paper is organized as follows: Section 2 provides brief literature review. Section 3 explains the data and methodology. Section 4 discusses the empirical results under different regimes and Section 5 concludes.

## 2. The Literature Review

The literature on asymmetry and non-linearity of ERPT is relatively recent. The following papers provide evidence on existence and importance of non-linear behavior of ERPT: Marston (1990), Goldberg and Knetter (1997), Pollard and Coughlin (2004), Yang (2007), Bussière (2007), Delatte and López-Villavcencio (2012). Majority of these papers[2] in non-linear ERPT literature investigate ERPT non-linearity caused by the direction and the magnitude of exchange rate fluctuations. In this context, Delatte and López-Villavcencio (2012) investigate asymmetric ERPT effect over the short and long run for major developed countries and find evidence that depreciations pass through to prices more than appreciations. Ben Cheikh (2012), using non-linear smooth transition model, tests asymmetry in ERPT with respect to direction and magnitude of exchange rates for 12 EU countries and he reports strong evidence suggesting that ERPT responds asymmetrically to the size of exchange rate movements, while he cannot find a clear evidence of asymmetry for the direction of exchange rate movements.

Level of the business activity is also cited as another factor causing asymmetry in ERPT. Goldfajn and Werlang (2000) find strong correlation between economic activity and the degree of pass-through; they also report an asymmetric reaction of the ERPT over the business cycle, i.e. the transmission of exchange rate changes would be higher when the economy is booming than in periods of recession. Correa and Minella (2010) provide evidence that ERPT responds to business cycle in a non-linear way. Nogueira Jr. and Leon-Ledesma (2008) examine the role of business cycle in generating asymmetry by implementing a logistic STR model. Ben Cheikh

[2] Herzberg et al. (2003), Marazzi et al. (2005), Pollard and Coughlin (2004), Khundrakpam (2007) , Bussière (2007) and Yang (2007).

and Rault (2014) investigate, whether ERPT responds non-linearly to economic activity along the business cycle for the Finnish economy. They find that the long-run pass-through coefficient as 0.15 % (weakly significant), when GDP growth is below 3% and as 0.47 % if the growth rate is above 3%. Using band-pass spectral regression, Chew et al. (2011) find asymmetric ERPT in Singapore economy over the business cycles with importers passing on small share of exchange rate movements during boom periods as compared with recessions. In their seminal article, Devereux et al. (2003) investigate whether acceptance of euro will alter the responsiveness of consumer prices to exchange rate changes. Their central conjecture is that the acceptance of the euro will lead European prices to become more insulated from exchange-rate volatility. They find that this affects both the volatility and "levels" of macroeconomic aggregates in both the U.S. and Europe.

The literature regarding the effects of exchange rate volatility on ERPT is very little and evidence is mixed. Corsetti et al. (2008) develop a quantitative framework which generates high exchange-rate volatility and low ERPT. In their model, the combination of distribution services, price discrimination and local currency pricing with nominal rigidity can account for the variable degree of ERPT over different horizons. Ghosh and Rajan (2007) examine the evolution of exchange rate pass-through into India's consumer price index (CPI) at the aggregate level over the period 1980Q1-2006Q4. They investigate whether or not the extent of ERPT is affected by common macro fundamentals such as inflation and exchange rate volatility. They calculate dynamic ERPT elasticities using the Rupee-USD rate and examine the impact of common macroeconomic variables on the elasticities. They find that exchange rate volatility is the only variable that consistently has a negative effect on ERPT elasticities. De Souza et al. (2013) also find evidence that strongly supports time-varying pass-through.

Due to its importance for inflation dynamics, there are quite a number studies on ERPT for the Turkish economy, yet the number of studies on nonlinear dynamics of ERPT for the Turkish economy are few. Leigh and Rossi (2002) investigate ERPT in Turkey using a recursive vector auto regression. Compared to other emerging markets, they find a larger ERPT completed in shorter run and more pronounced on whole sale prices than on consumer prices. Using the McCarthy's (2000) method Kara and Öğünç (2005) estimated pass-through for Turkey and find evidence that ERPT has decreased after adoption of floating exchange rate regime. By making some case study analysis of time varying ERPT coefficients, Kara et al. (2005) state that ERPT is higher in the depreciation periods than it is in the appreciation periods and it is higher during boom periods than recessionary periods. Arbatlı (2003) find that recessions, higher levels of depreciations, lower levels of inflation and bigger changes in exchange rates were associated with lower pass-through. However, she estimated a TVAR with two regimes due to lack of long data series and the estimated system was linear within the particular regime but it was non-linear across regimes. Çatık and Güçlü (2012) found evidence confirming Taylor (2000)'s suggestion of low inflation environment itself lowers the pass-through. Cömert and Benlialper (2013) suggested that the appreciation of the TL was related to the deliberate asymmetric policy stance of the Central Bank of Turkey with respect to the exchange rate. In other words, they stated that appreciation of the Turkish lira was tolerated during the period under investigation whereas depreciation was responded aggressively by the Bank, and they named this policy stance under the inflation targeting (IT) regimes as "implicit asymmetric exchange rate peg". Doğan (2013) analyzed the asymmetric behavior of the ERPT to manufacturing prices in Turkey and found that pass-through was affected positively by the aggregate demand conditions. Contrary to our results that she found no evidence of asymmetry in ERPT regarding the size of exchange rate changes, volatility of exchange rates, or inflation level. Kal et al. (2014) investigated the asymmetry which was caused by the stages of business cycles and concluded that even though ERPT was powerful during boom periods, it did not exist during recessionary periods. Arslaner et al. (2014) made a detailed dynamic analysis of ERPT for Turkey for the period 1986-2014, in which it is shown that alternative ERPT coefficients can be found depending on the choice of methods, specifications, data frequencies, time spans and price deflators used to estimate. Even though their various estimates approach to 15.9 % on average, the estimation results show a great deal of variety under the mentioned alternatives.

Yüncüler (2011) estimate ERPT and IPPT with monthly data using Vector Auto Regression (VAR) model based on pricing along a distribution chain frame work developed by McCarthy (2000). He finds higher cumulative pass-through on producer prices than consumer prices and lower cumulative pass-through after IT. He also detects that between years 2007 and 2009, due to external factors counter movements of ERPT and IPPT offset the impact of each other. Kara and Öğünç (2012) also using the same methodology calculated ERPT and IPPT.

Within the context of the ERPT and IPPT literature for Turkish economy summarized above, this paper uses single equation models like Kara et al. (2005), Kal et al. (2014) and decomposes pass-through into ERPT and IPPT like Yüncüler (2011) and Kara and Öğünç (2012), however different than these two, it utilizes a non-linear state based method to decompose, identify and quantify ERPT and IPPT. This methodology helps a deeper and richer understanding of ERPT and IPPT and makes an important contribution to the literature and provides richer instruments for policy making purposes.

## 3.The Methodology, the Data and Testing the Model

In this section, the methodology, the data and the adequacy tests of the model will be explained:

### 3.1. The Methodology

As baseline model, we used log difference inflation regression model (Goldberg and Knetter, 1997). Since it will serve better to the purpose of decomposing, detecting and quantifying non-linearity of ERPT and IPPT, a reduced form of the standard model only with the relevant variables will be employed:

$$\Delta log(\text{core\_}h_t) = \beta_0 + \beta_1 \Delta \text{log}((\text{core\_}h_t)(\text{L})) + \beta_2 \Delta log(\text{exc}_t) + \beta_3 \Delta \text{log}(\text{exc}_t(\text{L})) + \beta_4 \Delta \text{log}(\text{impx}_t) + \beta_5 \Delta \text{log}(\text{impx}_t(\text{L})) + \varepsilon_t \qquad (1)$$

where $\text{core\_h}_t$ is core CPI-inflation; $\text{exc}_t$ is the exchange rate (TL/US$); $\text{impx}_t$ is import price index excluding energy in terms of US $ and L is the lag operator.

A general-to-specific approach is followed in order to develop the linear baseline model with the relevant explanatory variables and their appropriate lags; in other words, initial estimates of the linear baseline are reduced to a parsimonious model by successively removing the insignificant variables and/or their insignificant lags. This process of the model selection is guided by two principles: One, each model is tested by a set of statistical tests for model adequacy: Breusch-Godfrey Serial Correlation LM test for detecting serial auto correlation, White test for detecting heteroscedasticity, Jarque-Berra test for normality and RESET test as a regression specification test for functional adequacy. And this process is finalized by using

Hannan-Quin (HQ) information criterion, the Schwartz criterion (SC) and Akaike information criterion (AIC).

Once the baseline model with relevant variables and their appropriate lags is determined, a two state Markov regime switching method is implemented to decompose, identify and quantify non-linearity in CPT. Here, for the situations that are analyzed (direction of the exchange rate movement, level of volatility and level of business activity), it is assumed that the observed changes in inflation between two consecutive periods are random draws from two distributions with different means and standard deviations. Regime variables ($s_t$) determine the distribution for the period.

In more technical terms, when $s_t = 1$; the observed changes $h_t$ is a random draw from a $h_t / s_t = 1 \sim N(\mu_1, \sigma^2{}_1)$ distribution and when $s_t = 2$; the observed changes $h_t$ is a random draw from a $h_t / s_t = 2 \sim N(\mu_2, \sigma^2{}_2)$ distribution. The unobserved regime variable evolves according to Markov chain and the probability of switching from one state to the other state is called transition probability.

In this setting, the regimes refer to the different states of the economy such as high volatility state, low volatility state; expansionary and contractionary state, etc. as described in the previous section. In this context, Equation 1 (Table 1) is now converted to the following two equations for two states:

$$\Delta\log(core\_h_{1t}) = \beta_{10} + \beta_{11}\Delta\log((\mathrm{core}\_h_{1t})(\mathrm{L})) + \beta_{12}\Delta log(\mathrm{exc}_{1t}) + \beta_{13}\Delta\log(\mathrm{exc}_{1t}(\mathrm{L})) + \beta_{14}\Delta\log(\mathrm{impx}_{1t}) + \varepsilon_{1t} \quad (2)$$

$$\Delta\log(core\_h_{2t}) = \beta_{20} + \beta_{21}\Delta\log((\mathrm{core}\_h_{2t})(\mathrm{L})) + \beta_{22}\Delta log(\mathrm{exc}_{2t}) + \beta_{23}\Delta\log(\mathrm{exc}_{2t}(\mathrm{L})) + \beta_{24}\Delta\log(\mathrm{impx}_{2t}) + \varepsilon_{2t} \quad (3)$$

### 3. 2. The Data

Quarterly data is used and the data span is between 2002 Q3 and 2014 Q4. As the inflation measure seasonally adjusted H (core inflation index) index is used. According to the definition provided by Turkish Statistical Institution (TurkStat), H price index excludes energy, unprocessed food items, alcoholic beverages, tobacco products and gold. The import price index, which excludes energy prices, is based on US dollar terms and obtained from the CBRT. Exchange rate defined as Turkish Lira per US Dollar is also obtained from the CBRT. Quarterly seasonally adjusted real GDP series is also obtained from the CBRT. Exchange rate volatility variable used as state variable is defined as quarterly average of monthly volatility computed from daily nominal exchange rate.

### 3. 3. Testing the Model

Testing the Markov model with two states against a linear one state alternative is not a simple task. Following Engel and Hamilton (1990), Wald test is employed to test whether relationship between explanatory variables and dependent variable are statistically different from each other in the states.

Null hypothesis state that the coefficients of explanatory variables in the State 0 are equal to the coefficients of explanatory variables in State 1:

$$\begin{matrix} H_0:\beta_{10} = \beta_{20} & H_0:\beta_{11} = \beta_{21} & H_0:\beta_{12} = \beta_{22} & H_0:\beta_{13} = \beta_{23} & H_0:\beta_{14} = \beta_{24} \\ H_1:\beta_{10} \neq \beta_{20}, & H_1:\beta_{11} \neq \beta_{21}, & H_1:\beta_{12} \neq \beta_{22}, & H_1:\beta_{13} \neq \beta_{23}, & H_1:\beta_{14} \neq \beta_{24} \end{matrix}$$

Wald statistics used is:

$$\frac{(\hat{\beta}_{10} - \hat{\beta}_{20})^2}{\mathrm{var}(\hat{\beta}_{10}) + \mathrm{var}(\hat{\beta}_{20}) - 2\,\mathrm{cov}(\hat{\beta}_{10}, \hat{\beta}_{20})} \approx \chi^2 \tag{4}$$

**4. Empirical Results**

**4.1. Linear Specification**

With the procedures described in Section 3, the following baseline model as the core inflation equation for the Turkish economy between 2002 Q3 and 2014 Q4 is obtained:

$$\Delta\log(core\_h_t) = \beta_0 + \beta_1\Delta\log((\mathrm{core\_}h_t)(\mathrm{L})) + \beta_2\Delta log(\mathrm{exc}_t) + \beta_3\Delta\log(\mathrm{exc}_t(\mathrm{L})) + \beta_4\Delta\log(\mathrm{impx}_t) + \varepsilon_t \tag{5}$$

The summary of the baseline model and its diagnostic tests are presented at Tables 1&2 and Figure 1. As indicated in Table 1, due to the heteroscedasticity, the model is estimated with White heteroscedasticity consistent standard errors. Serial correlation, normality of the error terms and speciation tests suggests that the baseline model is according to these measures valid between 6-15% significance levels.

**4.2. Non-Linear Specifications**

After linear ERPT and IPPT specifications are obtained by following the procedure detailed above, we determined that the quarterly core inflation of Turkey conditioned on the three situations mentioned can be characterized by two distributions with two distinct means and standard deviations. Thus, as a final step a two state Markov process is implemented to Equation 5.

The non-linear specification is slightly different than the linear specification; the lag of exchange rate is not included in non-linear model due to the fact that the states are determined depending on the current value of the state variable; in other words the ERPT coming from the lag of exchange rate from the previous period does not depend on this period’s state variable and it is not relevant in this context. So, including lagged variable would not serve the purpose of analyzing the non-linearity of the current period; on the contrary, it may blur the results. Thus, the lagged value of exchange rate is not included in the non-linear specification in all of the three cases.

Markov regime switching processes assumes that the quarterly core inflation conditioned on appreciation (depreciation) and high (low) volatility of the nominal exchange rate and seasonally adjusted real GDP change follows a distribution with two different means and standard deviations. Analysis of the data supports this assumption for all of the three situations and we determined threshold values between the states depending on this analysis.

The threshold values, which separate data into two parts with distinct means and standard deviations, imply two sets of relations between the quarterly core inflation, the exchange rate and the import price index. To test this implication, Wald test is utilized as a model adequacy measure to check whether the quarterly relationship between the nominal exchange rate, the import price index and the core inflation are different across these states. Results of these tests are also reported along with the model.

### 4.2.1. Direction of Exchange Rate Movement

The exchange rate is defined as Turkish Lira per US Dollar, so increase of the exchange rate indicates depreciation of TL and decrease of the exchange rate indicates appreciation of TL. We found that the quarterly core inflation conditioned on appreciation and depreciation of TL shows distinct patterns in terms of mean and standard deviation. Specifically, during depreciation periods of TL, the mean and the standard deviation of the core inflation are 0.0200 and 0.0085 and during appreciation periods the mean and the standard deviation of the core inflation are 0.0150 and 0.0063. Thus, appreciation and depreciation of TL can be considered as two states since appreciation and depreciation of TL/USD exchange rate is Markovian as seen in Figure 2.

So, we run a two state Markov process and the findings are reported in Table 3. It is clear that ERPT is very low (0.5 %) during appreciation periods, whereas during depreciation periods it is comparatively bigger and with very high statistical significance (9.4 %). On the other hand, IPPT in both states are significant and 10.6 % and 13.6 % during appreciation and depreciation periods respectively.

It is also important to notice that during the depreciation periods of TL against US Dollar, current core inflation highly depends on the previous period's inflation (coefficient of lagged inflation is 0.9639), while for the appreciation periods this is not valid. So, inflation is difference stationary during the depreciation state and it is stationary during the appreciation state. States in Markov process are not sequential; as seen in the third graph of the Figures 2-3-4 so, one state may not be followed by the same state in the next period; hence an explosive state is not always followed by an explosive state. This fact suggests that an explosive coefficient in one of the states does not indicate explosiveness of the series. As a matter of fact, this pattern is a well-known situation and discussed in the literature.[4]

Wald test results prove existence of two states especially for lag of inflation and current value of exchange rate. The model explains 55.95 % of the variation in the core inflation.[5]

### 4.2.2. Low and High Nominal Exchange Rate Volatility

We used quarterly average of monthly volatility of daily exchange rate as the volatility measure. 2.7 % quarterly volatility emerged as the threshold level. During the tranquil periods, where exchange rate volatility is less than 2.7 % (State 1), the mean and the standard deviation of quarterly core inflation are 0.0156 and 0.0040 and during the volatile periods, where exchange rate volatility is greater than 2.7 % (State 2), the mean and the standard deviation of the quarterly core inflation are 0.0192 and 0.0085.

The coefficients reported in Table 4 indicate that IPPT during tranquil periods is around 7.4 % and it is 16.2 % during volatile periods. Similarly ERPT is 2.4 % during tranquil periods and 7.6 % during volatile periods. These results imply higher pass-through for both types for volatile periods of nominal exchange rate. The model explains 59.57 % of the variation in the core inflation.

[4] See Murray et al. (2008)
[5] We have to state that coefficient of determination is not very well defined for Markov models.

### 4.2.3 Business Cycle

During contractionary state (State 1) where seasonally adjusted real GDP growth is negative, the mean and the standard deviation of the quarterly core inflation are 0.0166 and 0.0055 and during expansionary state (State 2), the mean and the standard deviation of the quarterly core inflation are 0.0193 and 0.0087.

The results of this case are reported in Table 5. According to this, during contractionary business cycle periods IPPT is 7.2 %. On the other hand, during expansionary periods, it is 16.6 %. On the other hand, ERPT does not vary much between the states and around 7.7 % to 8.4 % respectively.

It is noteworthy that although ERPT does not vary substantially between expansionary and recessionary periods (8.4 % vs. 7.7 %), IPPT is substantially lower during recessionary periods compared to expansionary periods. This may be due to the fact that recessionary (expansionary) periods of Turkish economy generally overlaps with global recessionary (expansionary) periods during which commodity prices and other imported goods prices decrease (increase).

### 4.2.4 Discussion of the Results

In this section, we will analyze quarterly concurrent ERPT and IPPT for all three cases in terms of the sources and compare them with the other findings in the literature:

As mentioned earlier, this study uses single equation as Kara et al. (2005), Doğan (2012) and Kal et al. (2014), but it differs from them by analyzing two types of pass-through separately instead of lumping them into one; namely ERPT and IPPT are differentiated in this study. Using both components in the model allowed to identify the sources of pass-through leading to a deeper and richer analysis.

Kara et al. (2005) also look at asymmetry of ERPT due appreciation and depreciation of TL without differentiating it to exchange rate and import price index for the period of 1997-2004. They find that on average ERPT during appreciation periods of TL is 14% and it is 26 % during depreciation periods of TL. Our findings indicate statistically significant ERPT (9.4%) and IPPT (13.6%) during depreciation periods and statistically significant IPPT (10.57%) and statistically non-significant ERPT (0.5%) during appreciation periods.

Doğan (2013) uses threshold regression model to investigate whether ERPT to the manufacturing price index varies depending on business cycles, volatility, exchange rate movements and inflationary environments. She reports that ERPT due to exchange between positive and negative business cycle periods differs substantially (5% vs 31%), but she fails to find any difference for the other situations. Our results for the case of business activity indicate 8.4 % to 7.7 % ERPT and 16.6 % to 7.2 % IPPT to the quarterly core inflation between expansionary and contractionary states. Results of these two papers may not be comparable, since different price indexes with different natures and different data frequencies are used in each paper. Kal et al (2014) investigated inflation dynamics vary between expansionary and recessionary periods using money supply, industrial production index, nominal exchange rate and import price index using daily data for the period between 2003 and 2014. Their findings provide evidence that inflation dynamics including inflation pass-through from exchange rate as nominal effective exchange rate and import price index differ between expansionary and recessionary periods indicating higher pass-through during expansionary periods.

## 5. Conclusion

Pass-through to domestic inflation due to exchange rates and import prices is a major part of inflationary process. Therefore a deeper grasp of the characteristics of both types of pass-through is crucial in understanding and controlling the inflationary dynamics. Specially, for the IT economies with current account deficit this issue becomes more vital. In this study, we analyze some sources of non-linearity in ERPT and IPPT and quantify them by using Markov process for Turkey between 2003 and 2014. Findings of this paper provide evidence for the asymmetric nature of ERPT and IPPT in Turkey under appreciation (depreciation), high (low) volatility of nominal exchange rate (defined as TL per US dollar) and positive (negative) change of real GDP.

According to the results ERPT varies depending on the conditions mentioned above. Specifically, our findings indicate very low and statistically not significant ERPT during appreciation periods of nominal exchange rate and high and statistically significant ERPT during depreciation periods. We also found that volatility does not affect the statistical significance of ERPT, yet it is higher during volatile periods compared to tranquil periods. Level of business activity on the other hand does not affect statistical significance and the magnitude of ERPT.

On the other hand pass-through coming from import prices, IPPT is statistically significant under all circumstances mentioned above, but we found higher IPPT during depreciation, highly volatile and expansionary periods.

This paper contributes to the empirical literature by implementing a new approach to identify, quantify and analyze non-linearity of ERPT and IPPT. In addition to this, the state based non-linear method implemented in this paper allows better characterization of both types of pass-through under different economic conditions. Hence, the results of this paper provide more comprehensive analysis of pass-through which will be crucial for monetary policy decision making process.

The sources non-linearity of ERPT and IPPT may not be limited with the situations studied in this paper. Besides the situations studied in this paper, other economic conditions may also cause asymmetric behavior. Real exchange rate can be considered as one such condition; namely level and volatility of real exchange rate may lead non-linearity in ERPT and IPPT due to the fact that IT economies attempt to control inflation by maintaining lengthen periods of unsustainable high real exchange rate levels which eventually end with sudden depreciation of the domestic currencies. Long periods of high level of real exchange rate may alter the pricing behavior of the exporters and the importer causing non-linearities. Thus, this case also deserves to be studied on its own sake. Furthermore, we also think that two state Markovian process may not be sufficient to characterize non-linear behavior of IPPT in the cases that we studied, however since we used quarterly data, a three state process will be hard to implement due to the small number of observations. Thus, for future studies, these two issues may be suitable ways to proceed in this literature.

## Tables and Figures

**Table 1.** Least Square Regression Coefficients, White Heteroskedasticity-consistent Standard Errors of the Baseline Model, 2002Q3 - 2014Q4

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| **constant** | 0.0031 | 0.0028 | 1.0790 | 0.2863 |
| **$core\_h_{t-1}$** | 0.7295*** | 0.1551 | 4.7027 | 0.0000 |
| **$exc_t$** | 0.0725*** | 0.0238 | 3.0423 | 0.0039 |
| **$exc_{t-1}$** | 0.0297 | 0.0244 | 1.2154 | 0.2306 |
| **$impx_t$** | 0.1395*** | 0.0352 | 3.9636 | 0.0003 |
| **$R^2$** | 0.7211 | **Akaike info criterion** | | -6.5921 |
| **Log likelihood** | 169.8022 | **Schwarz criterion** | | -6.4009 |
| **F-statistic** | 29.0992 | **Hannan-Quinn criterion** | | -6.5193 |
| **Prob (F-statistic)** | 0.0000 | **D-W statístic** | | 2.5379 |
| **Prob (Wald F-statistic)** | 0.0000 | **Wald F-statistic** | | 9.3578 |

***, **, and * represent the level of significance at 0.01, 0.05 and .10 respectively by t-test.

**Table 2.** Breusch-Godfrey Serial Correlation LM Test and Model Selection Criterion Results, 2002Q3 - 2014Q4

| | | | | |
|---|---|---|---|---|
| **F-statistic** | 2.7328 | **Prob. F(2,43)** | | 0.0763 |
| **Obs*R-squared** | 5.6387 | **Prob. Chi-Square(2)** | | 0.0596 |

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| **constant** | -0.0022 | 0.0025 | -0.8580 | 0.3957 |
| **$core\_h_{t-1}$** | 0.0944 | 0.1025 | 0.9211 | 0.3621 |
| **$exc_t$** | 0.0012 | 0.0209 | 0.0576 | 0.9544 |
| **$exc_{t-1}$** | 0.0002 | 0.0197 | 0.0091 | 0.9928 |
| **$impx_t$** | 0.0127 | 0.0316 | 0.4011 | 0.6903 |
| **$residual_{t-1}$** | -0.3821 | 0.2034 | -1.8786 | 0.0671 |
| **$residual_{t-2}$** | 0.0275 | 0.1829 | 0.1501 | 0.8814 |
| **$R^2$** | 0.1128 | **Akaike info criterion** | | -6.6317 |
| **Log likelihood** | 172.7936 | **Schwarz criterion** | | -6.3641 |
| **F-statistic** | 0.9109 | **Hannan-Quinn criterion** | | -6.5299 |
| **Prob (F-statistic)** | 0.4963 | **D-W statístic** | | 1.9539 |

**Table 3.** Estimated Coefficients and Wald Test Results on Depreciation and Appreciation of Exchange Rate

| **Depreciation (∆exc>0)** | **Coefficients** | **t-ratios** | | **Wald Test** |
|---|---|---|---|---|
| **Constant** | -0.0007 | -0.1788 | **Constant** | 10.2209** |
| **core_h$_{t-1}$** | 0.9639*** | 5.2900 | **core_h$_{t-1}$** | 20.8263*** |
| **exc$_t$** | 0.0936*** | 4.0068 | **exc$_t$** | 12.5619** |
| **impx$_t$** | 0.1355*** | 5.1237 | **impx$_t$** | 1.0046 |
| **Appreciation (∆exc<0)** | **Coefficients** | **t-ratios** | **$R^2$** | 0.5595 |
| **Constant** | 0.0124*** | 15.2523 | **#of obs.(1/2)** | 21/ 21 |
| **core_h$_{t-1}$** | 0.1225*** | 3.3927 | **Mean (1/2)** | 0.0200/0.0150 |
| **exc$_t$** | 0.0046 | 0.4102 | **Stdv. (1/2)** | 0.0085/0.0063 |
| **impx$_t$** | 0.1057*** | 8.3193 | | |

***, **, and * represent the level of significance at 0.01, 0.05 and .10 respectively by t-test and by Chi-Square Test.

**Table 4.** Estimated Coefficients and Wald Test Results on High and Low Exchange Rate Volatility

| **Low Volatility (<2.7%)** | **Coefficients** | **t-ratios** | | **Wald Test** |
|---|---|---|---|---|
| **constant** | 0.0128*** | 33.9044 | **Constant** | 11.7819** |
| **core_h$_{t-1}$** | 0.1511*** | 7.3556 | **core_h$_{t-1}$** | 19.1778*** |
| **exc$_t$** | 0.0237*** | 7.4482 | **exc$_t$** | 6.1432* |
| **impx$_t$** | 0.0738*** | 33.8702 | **impx$_t$** | 8.1851* |
| **High Volatility (>2.7%)** | **Coefficients** | **t-ratios** | **$R^2$** | 0.5957 |
| **Constant** | 0.0003 | 0.4246 | **# of obs.** | |
| **core_h$_{t-1}$** | 0.9126*** | 5.4068 | **State 1 / 2** | 15 / 27 |
| **exc$_t$** | 0.0763*** | 4.0704 | **Mean (1/2)** | 0.0156/0.0192 |
| **impx$_t$** | 0.1623*** | 4.7549 | **Stdv. (1/2)** | 0.0040/0.0085 |

***, **, and * represent the level of significance at 0.01, 0.05 and .10 respectively by t-test and by Chi-Square Test.

**Table 5.** Estimated Coefficients and Wald Test Results on Level of Business Activity

| **Contractionary** | **Coefficients** | **t-ratios** | **Wald Test** | |
|---|---|---|---|---|
| **constant** | 0.0047*** | 3.7130 | **Constant** | 1.5234 |
| **core_h$_{t-1}$** | 0.5197*** | 7.5654 | **core_h$_{t-1}$** | 0.1231 |
| **exc$_t$** | 0.0774*** | 6.9864 | **exc$_t$** | 0.0286 |
| **impx$_t$** | 0.0715*** | 4.5153 | **impx$_t$** | 4.0403 |
| **Expansionary** | **Coefficients** | **t-ratios** | **$R^2$** | 0.5958 |
| **Constant** | 0.0098*** | 2.6014 | **# of obs.** | |
| **core_h$_{t-1}$** | 0.4580*** | 2.9920 | **State 1 / 2** | 21/ 21 |
| **exc$_t$** | 0.0841*** | 2.3751 | **Mean (1/2)** | 0.0166/0.0193 |
| **impx$_t$** | 0.1657*** | 3.8641 | **Stdv. (1/2)** | 0.0055/0.0087 |

***, **, and * represent the level of significance at 0.01, 0.05 and .10 respectively by t-test and by Chi-Square Test.

**Figure 1.** Descriptive statistics and Normality Test for the Baseline Model

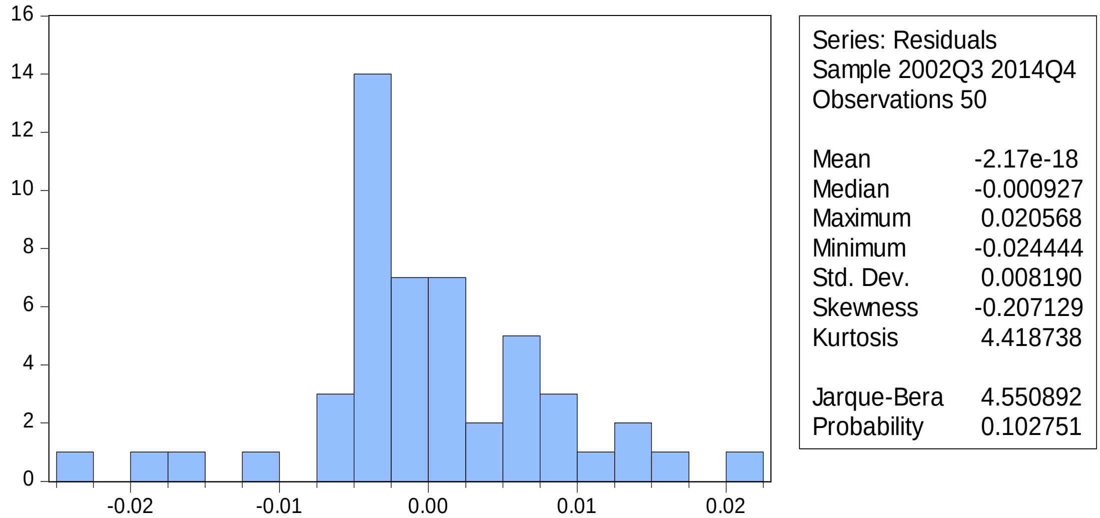


**Figure 2. Model I: States Determined Depending on Depreciation and Appreciation of Nominal Exchange Rate**

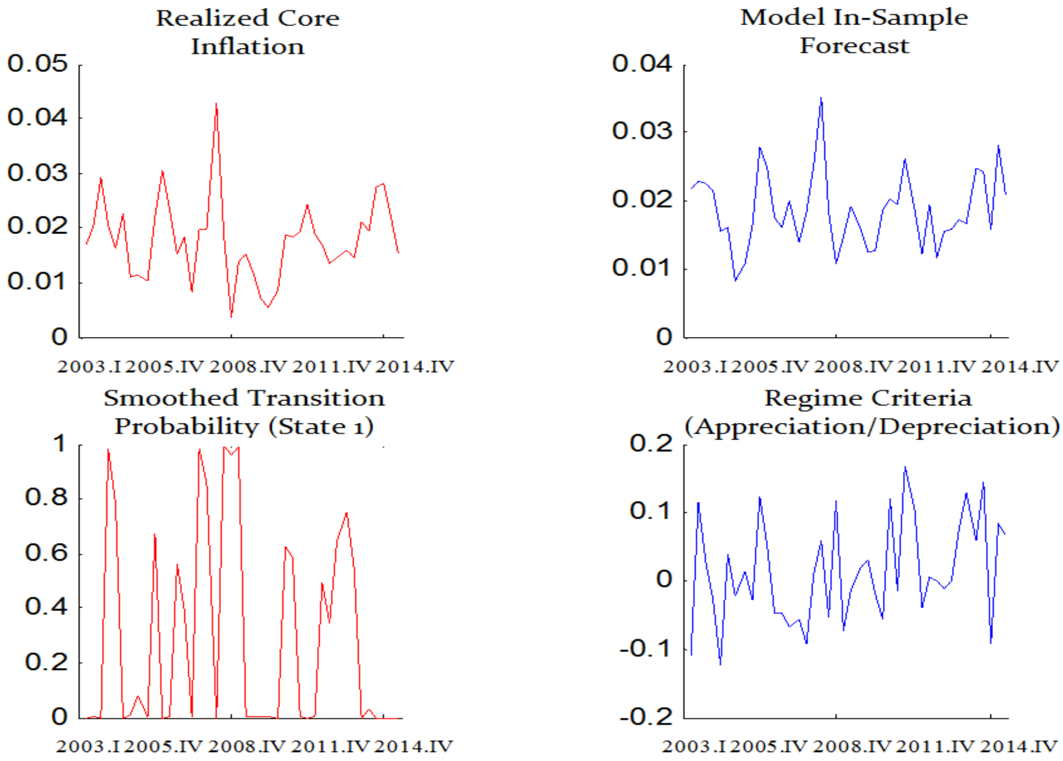



**Figure 3. Model II: States Determined Depending on High and Low Nominal Exchange Rate Volatility**

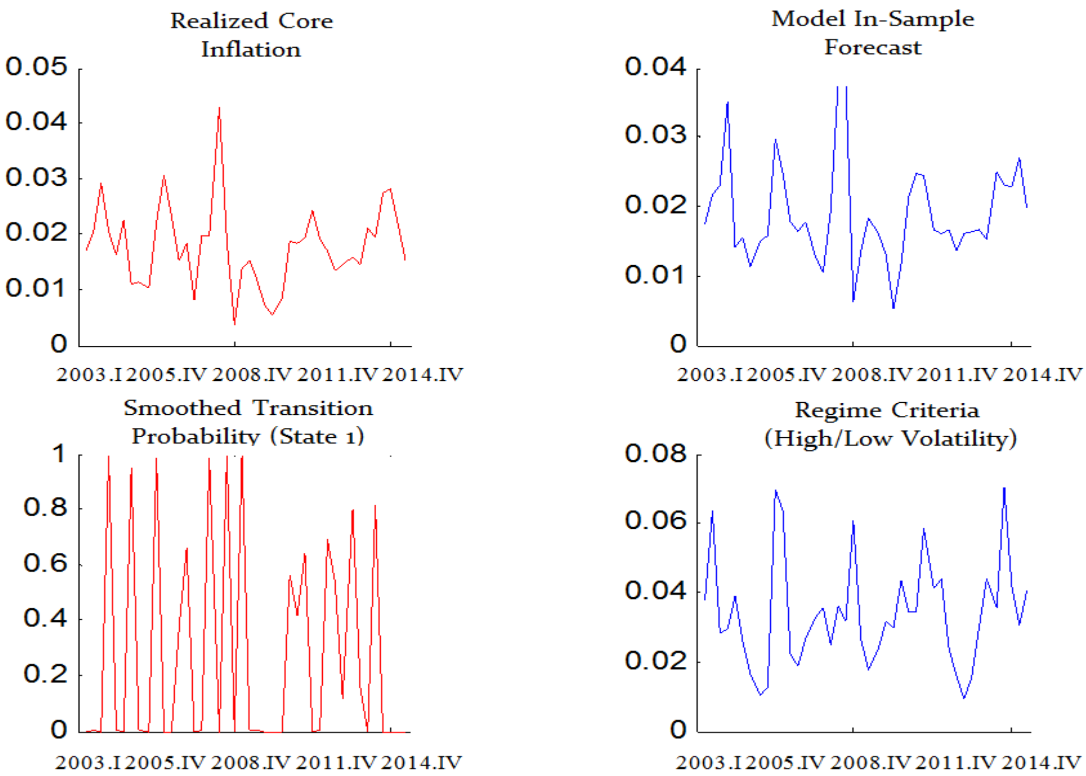
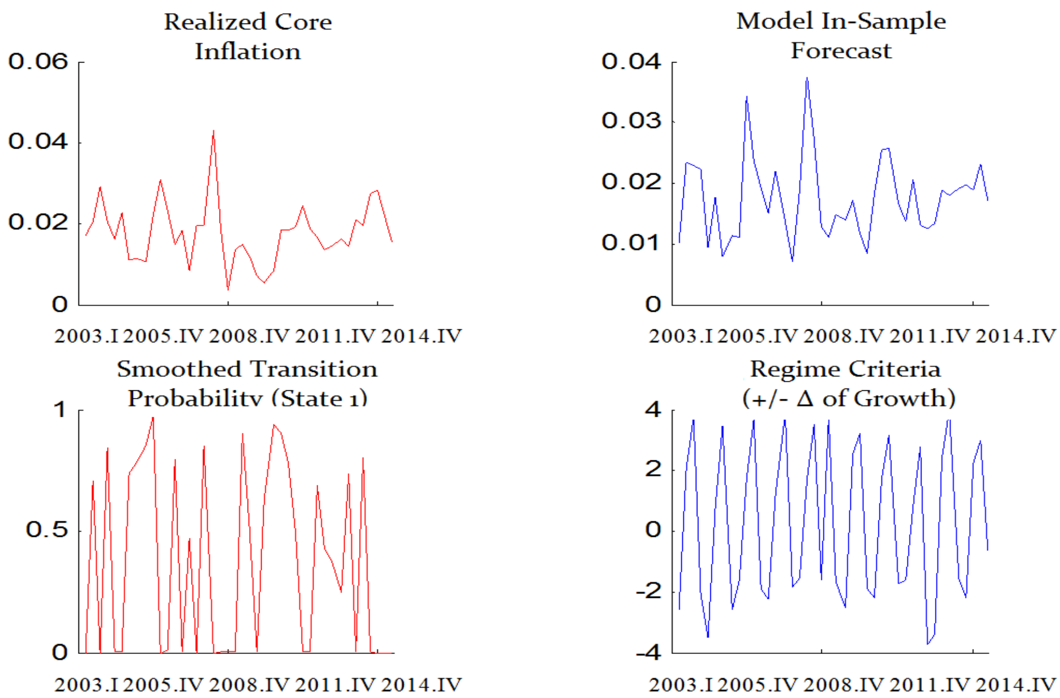


**Figure 4. Model III: States Determined Depending on Negative/Positive Real GDP Growth**



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