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Exchange Rate Pass-Through In Turkey: Looking for Asymmetries

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Abstract

This paper uses the VAR framework introduced in McCarthy (1999) to investigate the nature and extent of pass-through to prices in Turkey. Furthermore, Threshold VAR (TVAR) models are used to assess the possibility of asymmetries in the pass-through. Annual change in the industrial production index, exchange rate and inflation as well as deviation of the change in annual exchange rate from its sample mean are used as threshold variables. The latter variable is used to capture asymmetric effects of small versus big changes in exchange rates on the extent of pass through. Estimating several TVAR models imply significant asymmetries in the relationship between exchange rate and inflation as measured by Wholesale and Consumer Price Indices. More specifically, we find that pass-through to prices is lower during significant economic contractions, periods with higher exchange rate depreciation and periods with lower inflation. Evidence for asymmetries that arise from the magnitude of the change in exchange rates is weaker and quantitatively not very significant.

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1. Introduction

1.1. Literature on Exchange Rate Pass-Through

Exchange rate pass-through to domestic inflation can simply be defined as the percentage change in domestic price levels (as measured by an appropriate price index) arising from one percentage change in the exchange rate. What is generally understood as exchange rate pass-through is the mechanism through which prices of imports in the local currency change due to exchange rate fluctuations. A rise in the exchange rate (meaning a depreciation of the currency) implies that imports become more expensive and one would expect the prices to adjust to reflect this change. For small open economies pass-through to other prices such as wholesale and consumer prices are also potentially important since a change in the prices of imports will have a direct effect in the domestic price index in proportion to the share of imports in the index. Furthermore, changes in import prices will lead to changes in the prices of domestically produced goods to the extent that they constitute a change in the costs of domestic producers. This mechanism is especially important in small open economies where imports are used more extensively as intermediate goods. Another mechanism that is important for small open economies with high and persistent inflation experience is the "indexation" mechanism. In countries like Turkey, changes in the exchange rate influence expectations of future inflation and one observes a close relationship between exchange rates and the prices of goods and services that should not normally be affected by changes in exchange rates.

There are a number of studies that estimate the pass-through to import and domestic prices in various industrialized countries such as McCarthy (1999), Burstein, Eichenbaum and Rebelo (2002), Campa and Goldberg (2002) and Carranza, Galdón-Sánchez and Gómez-Biscarri (2004). A conclusion common to most such studies is the incompleteness of the pass-through. Several reasons have been suggested to explain this phenomenon. Usually models from industrial organization are used to explain pricing behavior in terms of market concentration, product homogeneity and market shares of domestic and foreign firms. Dornbusch (1985) and Krugman (1987) are some of the early papers that adopt this kind of framework to investigate the relationship between exchange rates and prices. Krugman (1987) suggests that the notion of "pricing-to-market" can explain the little pass through to prices. The "pricing-to-market" phenomenon is the idea that in international markets with imperfect competition, foreign firms adjust their markups differently in different countries and market conditions and fail to reflect the changes in exchange rates in their prices. "Pricing-to-market" behavior can be generated by models with sticky prices or wages, models that incorporate fixed costs associated with adjusting supply in response to price changes and by models where demand does not immediately respond to changes in prices. The extent of "pricing to market" depends on how long ago the exchange rate has changed, how long this change is expected to last and hence indirectly on the volatility and persistence of the exchange rate and import price shocks. All of these factors determine whether the firms will base their pricing decisions on long term costs versus short run fluctuations.[1]

Another explanation for the low pass-through is suggested in Burstein, Eichenbaum and Rebelo (2002) where they study the relationship between exchange rates and prices in several countries that have experienced large devaluations. They argue that when there is a depreciation the inclination to substitute for the cheaper domestic products (or "flight from quality") might explain the incomplete pass-through. This implies an asymmetry in the way different levels of depreciation affect pass-through. Another explanation by Taylor (2000) relates the inflationary environment to the level of exchange rate pass-through. The main idea is that in an inflationary environment, increases in costs tend to be more persistent and hence firms will choose to update their prices in response to a change in the exchange rate whereas the opposite is true in a low inflation environment. This implies that policies that target a low inflation rate will also reduce the level of exchange rate pass-through. Choudhri and Hakura (2001) test this hypothesis and find that there is a positive relationship between the pass-through and the average inflation rates across countries and periods. On the other hand, Campa and Goldberg (2002) find that macroeconomic factors such as inflation and exchange rate volatility cannot explain changes in the extent of import price pass-through in their cross-country and time-series analysis of 25 OECD countries.

The literature on asymmetries in the structure of the economy is quite extensive[2], however, asymmetries in the behavior of prices in response to exchange rate changes is not explored in too much detail especially at an empirical basis. Leiderman and Bar-Or (2002) explores the asymmetries in the extent of pass-

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[1] See Goldberg and Knetter (1997) for a review of the literature on exchange-rate pass-through and pricing to market.

[2] Cover (1992) examines asymmetric effects of positive versus negative money supply shocks. Ravn and Sola (1995) finds evidence for asymmetric effects of small versus big money supply shocks. Garcia and Schaller (2002) use a Markow Switching model to test whether monetary policy have different effects in expansions versus recessions.

through for Israel using a reduced-form estimate of the quarterly rate of inflation. They find that extent of pass-through is slightly less during a slowdown than in full employment and also that the pass-through is spread almost equally over the current and previous periods during a slow down whereas during full-employment the effects of pass-through is felt more quickly. Another source of asymmetry that they consider is the size of the exchange rate shock.[3] They conclude that when the exchange rate shock is sizable the pass-through to prices is faster. Other dimensions of asymmetries include whether the level of exchange rate changes matter. This kind of asymmetry can emerge from the "flight from quality" behavior discussed in Burstein, Eichenbaum and Rebelo (2002). Also Carranza, Galdón-Sánchez and Gómez-Biscarri (2004) discuss the possibility of such an asymmetry emerging from the balance-sheet effects of an exchange rate depreciation. The idea is that an exchange rate depreciation causes a drop in investment expenditures since it increases the financial costs of firms especially in highly dollarized economies. This decline in investment triggers a fall in prices. Carranza, Galdón-Sánchez and Gómez-Biscarri (2004) show that one can observe this phenomenon in various countries where there exists a certain level of depreciation beyond which pass-through is smaller. They also show that this effect is more prevalent during periods of lower output and in more dollarized economies. Although there is mixed empirical evidence for the quantitative significance of the inflationary environment on the extent of pass-through, another asymmetry that one can consider is between periods of high versus low inflation as suggested in Taylor (2000).

In general one would expect pass-through to be large in small open economies where imports constitute a large fraction of the consumption bundle and are used more intensively as intermediate products. However, several studies indicate that the pass through to prices in small open economies such as the United Kingdom and Canada are not significantly larger than that in a relatively more closed economy such as the U.S. There are very few studies on the pass-through in developing, high-inflation economies such as Turkey. Leigh and Rossi (2002) use a VAR model similar to McCarthy (1999) and calculate the pass-through coefficients from the estimated impulse response functions using data from January 1994 until April 2002. Leigh and Rossi (2002) conclude that the exchange rate pass-through to wholesale and consumer prices are incomplete (only 60 and 45 percent of the initial exchange rate shock is passed to prices respectively) and that the impact of

[3] They test for this asymmetry using a dummy variable for the periods in which there was a big change in the exchange rate.

exchange rate changes are over in 11 months which they conclude is somewhat shorter than the results obtained for other countries that has gone through similar devaluations. Another research project on the exchange rate pass-through is going on in the Central Bank of the Republic of Turkey where the approach is to estimate the pass-through coefficient as a time varying parameter and investigate the factors that explain the change in the pass-through coefficient over time.

This paper estimates the exchange rate pass-through in Turkey using a VAR model similar to McCarthy (1999). The benchmark results obtained in this study are different from studies that use a similar VAR framework such as Leigh and Rossi (2002) since it uses data from the period after the flotation of the Turkish Lira in order to tract structural differences that might have occurred in the exchange rate pass-through. Furthermore, this paper considers potential asymmetries in the behavior of exchange rate pass-through depending upon the nature and size of the exchange rate changes, whether the economy is in an expansion or contraction and the inflationary environment. The existence of such asymmetries can be very important for policy. For this end, the author will use a threshold vector autoregression (TVAR) model that builds upon the benchmark VAR from McCarthy (1999). TVAR models as applied in Tong (1980, 1990), Potter (1995) and Choi (1999) have been used extensively to test for asymmetries in many contexts but to the author's knowledge they have not been used to test asymmetries in the extent and nature of exchange rate pass-through to prices.

1.2. Exchange Rate and Inflation Trends in the Turkish Data

Looking at the historical evolution of annual inflation in Turkey since the early 1990s (Figure 1) one observes persistently high inflation rates throughout the 90s. During the two crises experienced in 1994 and 2000-2001 we observe inflation rates well above 50 percent. The evolution of the annual change in effective nominal U.S. $/TL exchange rate also show big depreciations during these two crises (Figure 2). During 1991 we observe that the uncertainty associated with the Gulf Crisis has led to a depreciation of Turkish Lira and an increase in inflation. On the other hand, the period between 1992 and the 1994 crisis can be characterized by high growth, high public sector borrowing and the appreciation of Turkish Lira. In early 1994 we observe a large depreciation of the Turkish Lira due to the currency crisis that took place in early 1994. The inflation rates during this period are well above 70 percent. After the 1994 crisis an economic program that suggests major structural reforms was announced. The exchange rate policy during this period can be characterized as a managed float policy where the Central Bank had exchange rate stabilization as one of its objectives. This program has worked well during 1995-1996 but starting in 1997 we observe increases in inflation rates. In December 1999 an IMF-backed disinflation and structural adjustment program with an exchange-rate peg that crawled with the targeted inflation was adopted. Soon after, in November 2000 there was a financial crisis and in February 2001 floating of the Turkish Lira took place. Since the adoption of the IMF-backed economic program after the 2001 crisis we observe a consistent decline in inflation rates. For the first time during the past decade we observe inflation rates below 10 percent in May 2004. Exchange rate depreciation is also at a declining trend during this period. A quick glance at the figures of inflation and percentage change in exchange rates indicates a persistent decline in both of these variables after the flotation of the Lira to levels that were not observed during the past decade. Therefore it is interesting to consider the possibility of a structural change in the way exchange rate movements pass to prices during this period. The small size of the sample and frequent crises make working with Turkish data difficult. It is therefore hard to make strong inferences but nevertheless some important conclusions emerge regarding the nature of pass-through to domestic prices which might be especially relevant for conducting policy.

The next section discusses the empirical methodology used including the TVAR approach and the threshold variables used. Section 3 presents the results including the estimated impulse responses and pass-through coefficients for the benchmark and asymmetric models. Section 4 provides a discussion of the results and Section 5 concludes.

2. Empirical Methodology

2.1. The VAR Framework and The Threshold VAR (TVAR) Approach

As mentioned before we adopt a VAR framework similar to McCarthy (1999) to asses exchange rate pass through in Turkey. Eq. 1 shows the general structure and the elements of the VAR in the order that they appear in the actual estimation. Δp_t^{oil} is the oil price inflation in US dollars[4], Δip_t is the change in industrial

[4] In the original McCarthy (1999) framework this variable is in terms of the domestic currency. However, using this variable expressed in terms of the domestic currency would make the first equation in the VAR endogenous to the rest of the equations in the VAR and hence one cannot obtain the correct identification of the structural shocks and their coefficients using the Cholesky decomposition. The author is grateful to the anonymous referee for bringing up this issue.

production index[5], Δe_t is the change in nominal exchange rate, Δp_t^m is the import price index inflation, Δp_t^w is the wholesale price index inflation, Δp_t^c is the consumer price index inflation and i_t is the short term interest rate. The last variable is included to take into account the impact of monetary policy on the rest of the system since monetary policy is known to react to fluctuations in exchange rates and output. The system is estimated using a constant and also a set of exogenous variables denoted by x_t. In particular two period dummy variables, $Dum94$ and $Dum01$, are used as exogenous variables to take into account the two crises experienced during 1994 and 2000-2001. The periods are identified as the first 4 months of 1994 and 2000:11-2001:3 for $Dum94$ and $Dum01$ respectively. ε_t is the vector of errors which are assumed to be serially uncorrelated.

$$y_t = c_1 + \psi_1 y_{t-1} + \psi_2 y_{t-2} + ...\psi_p y_{t-p} + \chi x_t + \varepsilon_t \qquad (1)$$

$$y_t' = \left[\Delta p_t^{oil}, \Delta ip_t, \Delta e_t, \Delta p_t^m, \Delta p_t^w, \Delta p_t^c, i_t\right]$$

All of the variables are in log differences except the interest rate. Performing Augmented Dickey-Fuller Unit Root Test for the variables in the VAR show that one can reject the null hypothesis of a unit root at the 1 percent level for all of the variables except CPI inflation. For CPI inflation one can reject the null hypothesis of a unit root at the 5 percent confidence level. As one can see the VAR is constructed such that the ordering of the variables reflects pricing along a distribution chain. To confirm that the ordering in the VAR is such that exchange rate changes come before changes in different domestic price indices, we run pairwise Granger causality tests between the monthly change in exchange rate and the import price index inflation, wholesale price index inflation and consumer price index inflation. The results of the causality tests show that we can reject the null hypothesis of exchange rate does not Granger cause import price index inflation at 3 percent, wholesale price index and consumer price index inflations at the 1 percent confidence levels.[6] Impulse responses are used to study the implications of a one standard deviation shock to exchange rate. The structural shocks in the model are identified from the VAR residuals through Cholesky decomposition. The variables in the VAR identify supply, demand, exchange rate, import price, wholesale price, consumer price and monetary policy shocks respectively. Therefore we assume that there is no contemporaneous impact of monetary policy shocks on the rest of the

[5] The same VAR was estimated using capacity utilization instead of industrial production index. The results were very similar.

[6] The sample period used for the Granger Causality Tests is the same as the sample used in estimating the VAR (1994:1-2004:5).

system.[7] The VAR structure given in Eq. 1 will be referred to as the benchmark case since it assumes that there is no non-linearity in the pass-through to various price indices. The number of lags used in the estimation of the benchmark model is 1 which is determined by Schwarz Information Criteria (SIC).[8]

Threshold Autoregression (TAR) models and their corresponding VAR versions (TVAR) can be classified along with Smooth Transition Autoregression (STAR) and Markow Switching (MS) models. These models introduce non-linearity in the conditional expectation of a series or system through making it behave differently under different regimes which are in turn determined by the value of some random variable or variables (Pagan (2004)). In TAR and STAR models the regime depends upon an observable random variable whereas in Markow Switching Models the regime shift depends upon a latent variable. The difference between STAR and TAR models is that the former models the regime switch as a smooth process where the estimated system changes slowly as the random variable changes. In TAR models the regime switch happens in a more abrupt fashion where if the random variable exceeds a certain threshold a regime shift takes place.[9] Notice that the system we estimate is linear within the particular regimes but is non-linear across regimes. In this paper, we estimate a TVAR with two regimes mainly due to lack of long data series to be able to capture efficiently the existence of more than two regimes. Furthermore, in other TVAR models estimated with larger data samples it has been concluded that estimating models with more than two regimes has not provided more insight into the implications of asymmetries and has generated noisy responses.[10] Eq. 2 shows the structure of the TVAR estimated to capture possible asymmetries in the pass-through to different price indices.

$$y_t = c_1 + \psi_1 y_{t-1} + ...\psi_p y_{t-p} + (c_2 + \phi_1 y_{t-1} + ...\phi_p y_{t-p}) I(\tau_t \geq \tau^*) + \chi x_t + \varepsilon_t \qquad (2)$$

One can rewrite the system in Eq. 2 in a more compact way as:

$$y_t = \psi L(y) + \phi L(y) I(\tau_t \geq \tau^*) + \chi x_t + \varepsilon_t \qquad (3)$$

$$L(y)' = \left[1, y_{t-1}, y_{t-2} ... y_{t-p}\right]$$

$$\psi = \left[c_1, \psi_1, \psi_2, ...\psi_p\right] and \phi = \left[c_2, \phi_1, \phi, ...\phi_p\right]$$

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[7] Note that the ordering of the variables in the VAR might change the results when one uses Cholesky decomposition to identify the structural shocks to the system. We find no difference in the impulse responses when the ordering of the VAR is changed.

[8] When working with small samples, SIC is usually a better criterion for lag selection when the objective is to obtain more accurate impulse responses. For more on this topic, see Ivanov and Kilian (2002).

[9] Actually, the threshold does not need to be a single value. It can be a range defined by two values.

[10] For example, see Alessandrini (2003).

ψ and ϕ are $q\times((q\times p)+1)$ and $L(y)$ is $((q\times p)+1)\times 1$ matrices where q is the number of variables included in the VAR. The observed random variable determining the regimes is τ_t and all of the variables are defined as before. When τ_t exceeds some threshold τ^* the system behaves like a VAR with coefficient matrix $\psi+\phi$ and otherwise like a VAR with coefficient matrix ψ. Notice that we implicitly assume a homogenous error variance-covariance matrix across regimes. We also assume that the regime effects are contemporaneous. In other words we could also consider lags of the threshold variable in determining regimes.

The parameters that needs to be estimated in this system are the coefficient matrices ψ , ϕ and χ as well as the value of the threshold τ^*. Non-linear estimation methods cannot be employed in this setting since existence of the indicator function makes the conditional mean non-differentiable in τ and therefore numerical methods cannot be used. However, given a certain value for τ^* the model is linear and the optimal method for estimation is applying OLS to all of the equations in the system. For this end we include a dummy variable to identify the regime and its interactions with the lags of variables in the VAR. We then employ a grid search on the value of τ that minimizes the determinant of the variance-covariance matrix of the model as in Alessandrini (2003). As suggested in Hansen (1999) it is also possible to identify some percentile α such that the grid search is performed over the range of values of the threshold variable that remain within the α th and $(1-\alpha)$ th percentiles of the sample. This is to make sure that in the grid search process, all of the regimes considered contain at least α percent of the sample. Alessandrini (2003) uses the values of the threshold variables that remain within the 33rd-66th percentiles of his sample for that particular variable. We employ a larger set of values for the range of τ for the grid search process and use $\alpha=25$.

In light of previous theoretical work on the possible asymmetries in the exchange rate pass through, we identify the following threshold variables: annual change in industrial production index, annual change in exchange rate, annual change in inflation as measured by CPI and the deviation of annual change in exchange rates from its mean. For all of the variables we use annual changes since they are not as volatile and hence do not lend themselves to frequent regime changes. The first three threshold variables are used to capture regime changes in levels of these variables whereas the last threshold variable tries to capture whether there are asymmetric effects of big versus small changes in exchange rates.

2.2. Data

All of the series used are in monthly frequency and are obtained from the Central Bank of the Republic Of Turkey Electronic Data Delivery System.[11] The sample period for all of the estimations is 1994:01 to 2004:05 as import price index data is only available starting in 1994. All of the series excluding interest rates and exchange rates are seasonally adjusted using X12 method of the U.S. Census Bureau. The oil price index is the barrel price in U.S. $ of oil imported by Turkey.[12] All of the other price indices are aggregate price indices unless indicated otherwise. The interest rate used is the monthly average of simple overnight rate. The exchange rate used is the nominal effective U.S. $/TL exchange rate.[13]

3. Results

3.1. Testing Linearity

In order to assess the results obtained from the asymmetric estimation one needs to first test the null hypothesis of linearity of the model against the alternative of non-linearity. Under a standard estimation framework, one can use a Wald test to test $H_o : \phi = 0$. However, in TVAR models such as the one used in this paper, the estimated parameter τ^* does not exist under the null hypothesis. If τ^* were determined ex-ante then this problem would disappear since the regimes would be given exogenously rather than determined endogenously with the data. Andrews and Ploberger (1994), Hansen (1996) and Hansen (1999) show that in such additively non-linear models, the Wald statistic does not follow the standard chi-square distribution and suggest a methodology based upon simulations to approximate the unknown asymptotic distribution of the Wald statistic and obtain approximate p-values for testing the null hypothesis. In this paper we adopt the methodology laid out in Hansen (1996) to test for linearity. The procedure is to calculate test statistics which are all functions of the Wald statistics over the grid space of values that τ can take and also obtain the asymptotic distributions of these statistics using simulation techniques. Comparing the asymptotic distributions of the test statistics with the actual test statistic we obtain asymptotic p-values for inference. Three such test statistics will be reported: supremum, average and

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[11] Non-tradable and tradable components of CPI and oil price index were obtained from the staff of Central Bank of the Republic of Turkey.

[12] This data is published in the Main Economic Indicators by the Republic of Turkey Prime Ministry, State Planning Organization.

[13] The same estimation was performed using a currency basket (1 dollar + 0.77 Euro) with 1 Euro=1.95 DM before 2000. The impulse responses were almost identical.

exponential average.[14,15] Appendix explains the methodology as laid out in Hansen (1996) as well as its application to the particular estimation used in this paper. The tests for linearity are performed for the two equations of interest for this paper: Equations for wholesale price index inflation and consumer price index inflation. Table 1 shows the values of the thresholds, relevant test statistics and the associated p-values for all of the four threshold variables. The results of the linearity tests clearly show that we can reject the null hypothesis of the linearity in the behavior of WPI and CPI inflation at all confidence levels for the first three threshold variables. For the last threshold variable we can reject the hypothesis of linearity at the 5 percent confidence level for CPI inflation equation using the majority of test statistics[16], whereas for the WPI inflation it is not possible to reject hypothesis of linearity with reasonable confidence.

3.2. Impulse Responses and Pass-Through Coefficients

In this section we analyze the impulse response functions of inflation as measured by different price indices due to a one standard deviation innovation to the exchange rate. Looking at the impulse responses we can trace the dynamic effects of exchange rate shocks on inflation rates over time. We will also calculate the pass-through coefficients at different points after the shock which show the cumulative response of the inflation rates to the cumulative change in the exchange rate. More specifically we define pass-through coefficient for j periods after a shock that takes place at time t as:

$$PTC_j = \frac{\sum_{i=t}^{t+j} \Delta p_i}{\sum_{i=t}^{t+j} \Delta e_i} \qquad (4)$$

3.2.1. Benchmark Model

Figure 3a shows the impulse response functions for Wholesale Price Index (WPI) and Consumer Price Index (CPI) inflation in response to a one standard deviation innovation to exchange rate. The two dashed lines show the two standard error band for the impulse responses which are calculated by Monte Carlo simulations with 1000 repetitions. The first thing to notice is that the impact response of WPI inflation is higher than that of CPI inflation. This is intuitively

[14] For the Wald statistics we impose no assumptions regarding the homoskedasticity of the error terms. Therefore we use the heteroskedasticity robust Wald test.
[15] Andrews and Ploberger (1994) derive optimality results for the last two statistics.
[16] For the average test statistic it is possible to reject the null hypothesis at 10 percent confidence level.

plausible since one would expect to see a more direct effect of import prices on wholesale prices as well as a larger share of imported products in the wholesale price index. For both measures of inflation the peak of the response to the exchange rate shock is observed in the first period and during subsequent periods the impulse responses slowly tend towards zero. Figure 3b plots the pass-through coefficients for different time periods after the shock. For WPI inflation, contemporaneous pass-through is approximately 30 percent of the immediate exchange rate change. For CPI inflation the same measure is 21 percent. After about eight months the effects of exchange rate shock is over for both measures of inflation and only 49 percent and 39 percent of the exchange rate shock is passed to WPI inflation and CPI inflation respectively. Fraction of tradables in the CPI used is 58 percent which can be treated as an upper bound for the pass-through to this index.

Given the pass-through estimates for CPI inflation, it is useful to consider pass-through to tradable and non-tradable components of this index. Figure 4a shows the impulse responses for inflation rates measured by the non-tradable and tradable components of CPI. The impact effect of non-tradable monthly CPI inflation is lower at 0.4 percent whereas for tradable CPI inflation it is at 0.76 percent. The response of tradable CPI inflation is higher at all points after the shock. In terms of the persistence of the responses we observe no significant difference between the two components. The pass-through coefficients (Figure 4b) show that in the month of the shock, the pass-through to tradable and non-tradable CPI inflation are 18 percent and 9 percent respectively. The difference in pass-through coefficients between the two components increase especially during the second and third months. For the tradable component of CPI the effects of the exchange rate shock are reflected in prices after 7 months whereas for the non-tradable component it takes 12 months. For tradable CPI inflation 39 percent of the cumulative exchange rate shock is passed to prices and for non-tradable CPI inflation it is as low as 20 percent.

In addition to the pass-through to CPI and WPI, one might want to look at the implications of an exchange rate shock for Import Price Index (MPI). Figure 5 shows the impulse responses for the general MPI and some of its components. The impulse responses obtained for MPI inflation are somewhat disappointing since the impulse effect is of the wrong sign and after about three months the response is close to zero for all the components. Another thing to notice about the responses for these different import price indices is that the impulse responses are estimated with a significantly higher standard error. For many of them it is not possible to identify the sign of the immediate impulse.

One of the questions of interest for Turkey is whether there is a structural change in the pass-through to prices after the flotation of the Turkish Lira in February of 2001. Although there is relatively small amount of data for the post flotation period it might still be instructive to estimate the same VAR using only data from pre and post flotation periods and analyze any differences across these periods in the impulse responses and pass-through coefficients. Figure 6 compares the impulse responses of WPI and CPI inflation for the two periods. The first thing to notice is that the response of both WPI and CPI inflation is higher for the pre-flotation period. The post-flotation period is not estimated with high accuracy especially the impulse response of CPI inflation is not very reliable even for the shorter horizon. In terms of persistence of the effects we observe no significant differences. Another difference between these two periods is the fact that for both WPI and CPI inflation the peak effect is observed in the second month for the post-flotation period whereas in the pre-flotation period the peak effect is observed in the first month. Looking at the pass-through coefficients we observe that for both WPI and CPI the eventual pass-through to prices is lower and more gradual for the post-flotation period. The eventual pass-through is 55 and 39 percent for WPI and CPI inflation during the pre-flotation period. For the post-flotation period the same measures are only 42 and 12 percent respectively. The pass-through is complete in 10 and 27 months for WPI and CPI for the post-flotation period whereas for the pre-flotation period the pass-through is complete within 10 months for both WPI and CPI inflation.

3.2.2. Non-Linear Model

In this section we will discuss the nature and extent of pass-through to prices estimated using the non-linear model discussed in Section 2.1. As mentioned before we consider 4 different threshold variables that identify two different regimes. We present the impulse response functions and pass-through coefficients for WPI and CPI inflation under the two regimes.

Annual Change in Industrial Production Index

The first threshold variable that we consider is the annual percentage change in industrial production index. The value of the threshold is estimated to be -3.28 percent. At some time t the economy is in the high output regime if

$\Delta_{annual} ip_t \geq -3.28$. All other periods where annual change in industrial production is lower than the threshold is identified as a low output regime. The fact that the threshold that is estimated is significantly low implies that the behavior of the pass-through is not asymmetric across periods of positive and negative economic growth. A threshold of -3.28 percent annual change in industrial production index captures the differences in the pass-through during periods of significant economic contractions. Looking at Figure 7 one can see that if the economy is in the low regime associated with a significant economic contraction the effects of an exchange rate shock are much less persistent. In the low regime the impulse responses for both WPI and CPI inflation reach zero by the sixth month whereas in the high regime the exchange rate shock still has an impact on prices even after one year. The pass-through coefficients also reflect this fact. Furthermore, the level of eventual pass-through to CPI is significantly higher in the high regime. Eventual pass-through to CPI is 31 percent and 24 percent in the high and low regimes respectively. For WPI the pass-through for the two regimes are not very different with 38 percent for the low regime and 35 percent for the high regime. An interesting implication of this is the fact that the discrepancy between the extent of pass-through to WPI versus CPI is much larger in the low regime. In other words in the high regime the pass-through to WPI and CPI are not significantly different from each other whereas in the low regime the pass-through to CPI is lower than that in WPI. Asymmetries in the pass-through to prices across periods of positive and negative economic growth are also investigated in Carranza, Galdón-Sánchez and Gómez-Biscarri (2004) for various countries. Their estimate for Turkey indicate no major difference in the pass-through coefficients between periods of contractions and expansions. Their results for Turkey confirm with the results from this analysis since the threshold variable estimated is not very close to zero percent. The advantage of the approach that is used in this study is the fact that it estimates the threshold variable and can detect differences in the behavior of the pass-through during other periods such as significant economic expansions or contractions as in the case of Turkey.

Annual Change in Exchange Rate

The second threshold variable that we consider is the annual change in exchange rate. The value of the threshold is estimated to be 52.2 percent. Therefore we identify the high regime as one in which the depreciation of the Turkish Lira is higher than 52.2 percent. Looking at Figure 8 the first thing to notice is the fact that in the low regime the effects of the exchange rate shock are more persistent. The peak of the impact for CPI is reached in the second period and for WPI the impulse responses decline very slowly. Looking at the pass-through coefficients, one of the differences across regimes is the fact that the pass-through to CPI is higher than WPI for the low depreciation regime. Also the cumulative pass-through to CPI is the highest observed for all of the regimes so far at around 73 percent of the cumulative change in exchange rate. In contrast, in the high depreciation regime we observe that the pass-through is quick (the effect of exchange rate shock is transmitted to prices in 4 months under the high depreciation regime whereas the effects of exchange rate shock on prices are still present after 2 years under the low depreciation regime) and that it is markedly lower (the pass-through is only 28 percent for CPI and 41 percent for WPI). The nature of this asymmetry can be explained through the "flight from quality" and "balance sheet effects" concepts discussed in Section 1 where when there is a sizable depreciation, the observed pass-through to prices do not reflect the bigger size of the depreciation.

Annual Change in Inflation

The third threshold variable that we consider is the annual change in inflation as measured by CPI. The threshold is estimated as 57.31 percent. The high inflation regime in this case is observed when the annual inflation rate is higher than 57.31 percent. Looking at the impulse responses depicted in Figure 9 we see that in the high inflation regime the response of WPI and CPI inflation are lower than those in the low inflation regime. In the second month after the shock there is a marked decline in responses in the high inflation regime. The pass-through coefficients show that the cumulative pass-through is higher for both WPI and CPI in the low inflation regime. This is in contradiction with the hypothesis put forth in Taylor (2000) regarding the asymmetric effects of exchange rates during periods of high and low inflation. One explanation for this result is that the threshold obtained with the inflation variable might actually be capturing the effect of another variable that is correlated with inflation.

Magnitude of Annual Change in Exchange Rate

The last threshold variable that we use tries to capture the magnitude of the annual change in exchange rate. This is to investigate whether one observes different effects of exchange rates on prices during periods of big versus small changes in exchange rates. The particular variable that is used in this paper measures the deviation of the annual change in exchange rates at a particular time t from its sample mean measured in terms of the standard deviation of changes in exchange rate observed in the sample. The value of the threshold estimated is 0.73. We identify a big change regime as one where the deviation of the annual change in exchange rate is more than 0.73 standard deviations from the mean. This implies a regime switch when the annual change in exchange rate is more than 70.64 percent or less than 22.12 percent. Figure 10 shows the impulse responses for WPI and CPI under big and small change regimes. The response of WPI inflation is somewhat more persistent under the low regime where the pass-through is complete in 10 months. For CPI inflation larger exchange rate changes pass through to prices over a longer time period of 11 months. Approximately 80 percent of the cumulative exchange rate change is passed to WPI and 62 percent of it is passed to CPI in the small change regime. The same measures for the big change regime are 50 percent and 37 percent respectively. The lower pass-through coefficients for larger exchange rate changes can be explained to the extent that firms might be identifying large changes as temporary changes. Furthermore, as mentioned earlier it is not possible to reject the null hypothesis of linearity at reasonable confidence levels for this threshold variable.

4. Discussion

Table 2 compares the results obtained regarding the nature of pass-through across different specifications. Looking at the benchmark specification the eventual pass-through to WPI and CPI is calculated as 49 percent and 39 percent of the change in exchange rate. This is somewhat lower than the estimates obtained in Leigh and Rossi (2002). One of the reasons behind the lower pass-though estimated in this paper is the fact that we take into account the impact of monetary policy on pass-through with the inclusion of interest rate in the VAR. This lowers the calculated pass-through. We also include data after 2002 which contributes to this difference. The variation in the measured pass-through across different regimes is striking for both WPI and CPI. For both WPI and CPI, the biggest quantitative differences in the amount of pass-through across regimes is observed for the regimes determined by annual change in exchange rate and annual inflation. Differences in the amount of time it takes for the changes in exchange rates to be reflected in prices are more striking between regimes determined by the annual change in exchange rate and the annual change in industrial production index.

Figures 11 through 14 plot the threshold variables across time for the sample period used in the estimation. This helps one detect the particular regimes corresponding to different periods. For example one can compare the classification of a particular time period under different threshold variables. Looking at the first threshold variable, the first thing to notice is that this variable only identifies the big economic contractions. More specifically the one year period immediately following the 1994 and 2001 crises are captured as low pass-through periods. The period between the two crisis and the period after 2002 are classified as the high pass-through regimes. Consider now the historical regimes identified with the annual inflation variable. This variable divides the sample as pre-1999 and post-1999 in identifying 2 major regimes. Here pre-1999 period is classified as a low pass-through period and the opposite is true for the post-1999 period. As mentioned before the inflation variable could be capturing the effect of another variable that is correlated with inflation. Another thing to notice about this figure is the fact that the post-flotation period can be characterized as a somewhat distinct period in terms of the behavior of inflation. We also know that the pass-through estimated for this particular period is lower than the pre-flotation period. Assuming that inflation will continue to decrease over the next couple of years, an interesting experiment would be to estimate a TVAR containing three regimes with two or three more years of data. It is very likely that one would find strong evidence for the existence of three distinct regimes. The annual change in exchange rate variable identify the post crisis periods as periods with low pass-through and similar to the divide in the sample period through the inflation threshold one can identify the post-1999 period as a period with relatively higher pass-through. Looking at the regimes identified through big versus small changes in exchange rate we observe a split in the sample after the flotation of the Turkish lira. Here the post-flotation period is associated with lower pass-through.

To summarize, the kind of asymmetries observed in the exchange rate pass-through to WPI and CPI inflation in Turkey indicate that periods of significant contractions in output, higher levels of depreciation, higher levels of inflation and bigger changes in exchange rates are associated with lower pass-through. Quantitative differences across regimes are not very significant for the regimes identified through the change in industrial production index. For the latter threshold variable it is not possible to reject the null hypothesis of linearity in the WPI inflation equation at reasonable significance levels.

5. Conclusion

5.1. Modeling Asymmetries

This paper provided evidence for the existence of asymmetries in the exchange rate pass-through to domestic prices as measured with Wholesale Price Index and Consumer Price Index. The empirical model used in this paper looked for asymmetries using a TVAR model with two regimes. As mentioned in Section 2, TVAR models constitute only one of the possibilities available for the researcher interested in investigating asymmetries. Indeed some of the results obtained in this paper hint that looking for more than two regimes can be more appropriate especially as more recent data becomes available. Furthermore, it would be instructive to consider a wider and less restrictive modeling approach. For example, one can use lags of the variables used as thresholds to determine regimes, allow for a heterogeneous variance-covariance matrix of the error terms across regimes, consider other threshold variables such as the degree of openness and the current account deficit and finally one can use Smooth Transition VAR models in modeling the asymmetries in nature and extent of pass-through to prices. Overall, the main conclusion that emerges from this paper is the fact that future work on exchange rate pass-through in Turkey should consider the possibility of asymmetries in the pass-through as well as other options for modeling asymmetries.

5.2. Implications for Policy

Another conclusion that emerge from this paper concerns optimal policy as it relates to the nature of pass-through to prices. The degree and intensity of the pass-through is clearly important for the conduct of monetary policy. For example, Ball (1999) argues that optimal policy in an open economy should use a "monetary conditions index" that contains exchange rates and interest rates. He asserts that inflation targets and Taylor rules are suboptimal in an open economy framework since monetary policy affects the economy through the exchange rate as well. Although Ball (1999) uses a model that assumes full and immediate pass-through, the point that exchange rates and their effects on prices are important for policy especially in a small open economy remains. Ball (2002) raises an interesting issue regarding whether the policy makers should care about the volatility of the exchange rates as an additional factor to consider in formulating policy. As Ball (2002) posits there might be real costs associated with exchange rate fluctuations that are not reflected in our current model frameworks. One possible source of inefficiency is the fact that changes in exchange rates imply reallocations between tradable and non-tradable sectors of the economy which might lead to inefficiencies. In exploring these questions the extent and nature of pass-through will also be important.

There are several studies that demonstrate that the nature and level of exchange rate pass-through is important for determining optimal policy rules including those that embody some form of inflation targeting. Hunt and Isard (2003) consider the implications of uncertain exchange rate pass-through on the conduct of optimal monetary policy using IMF's MULTIMOD model. They conclude that under uncertainty regarding the strength of the exchange rate pass-through, the optimal policy is to overestimate the strength of the pass-through and respond more to exchange rate movements. Another systematic investigation of this topic is Cunningham and Haldane (2002). They use a small macroeconomic model to study how the optimal horizon for targeting inflation forecasts change under different time dependent and state dependent pass-through assumptions. They find that inflation forecast based policies[17] perform better than policies that target current inflation under various types of assumptions regarding the nature of pass-through, however there are some differences across these alternative specifications regarding the optimal horizon for inflation forecasts.

Investigating the nature of optimal policy under different types of asymmetries in the pass-through to prices is a natural extension to the research on estimating the asymmetries in pass-through. For example, a lower level of pass-through and smaller asymmetries in the pass-through would make implementing policy easier. Frequency of regime switches would also be important in the implications of asymmetries for policy. Furthermore, one can extend the existing literature on optimal policy rules under model and parameter uncertainty to uncertainty regarding the nature and extent of asymmetries in the pass-through.

[17] See Svensson (1997), Rudebusch and Svensson (1999) and Batini and Haldane (1999) for a discussion of rules that target inflation forecasts.

6. Appendix

1. Testing for Linearity: Derivation of The Test Statistics and Their Asymptotic Distributions

Consider again the system estimated in Eq. 2:

$$y_t = c_1 + \psi_1 y_{t-1} + ...\psi_p y_{t=p} + (c_2 + \phi_1 y_{t-1} + ...\phi_p y_{t-p}) I(\tau_t \geq \tau^*) + \chi x_t + \varepsilon_t$$

For any one of the equations in the VAR, we want to test whether $\phi_i = \left[c_2 \phi_1 ... \phi_p \right] = 0$ where i is the number of the particular equation in the VAR. Hansen (1996) applies a local to null reparameterization of the null hypothesis to facilitate the distributional theory in which he uses $\phi_i = c/\sqrt{n}$ where c is a vector of constants. More specifically with this reparameterization the null hypothesis becomes $H_o : c = 0$. Under the null τ^* does not exist and it is necessary to use statistics that do not require ex-ante knowledge of τ^*.

The three test statistics suggested in Hansen (1996) are: $\sup T_n = \sup_{\tau \in G} T_n(\tau)$, $aveT_n = \int_G T_n(\tau) dW(\tau)$ and $\exp T_n = \ln(\int_G \exp(\frac{1}{2} T_n(\tau)) dW(\tau))$ where G is the set of values that τ can take and the particular T_n considered is the heteroskedasticity robust Wald test given by:

$$T_n(\tau) = n\hat{\beta}(\tau)' R (R \hat{V}_n^*(\tau) R')^{-1} R \hat{\beta}(\tau)$$

R is the selector matrix for the coefficient restrictions, $\hat{\beta}(\tau)$ is the OLS coefficient estimates of the equation under the alternative for a given value of the threshold, $\hat{V}_n^*(\tau) = M_n(\tau,\tau)^{-1} \hat{V}_n(\tau) M_n(\tau,\tau)^{-1}$

with $M_n(\tau,\tau) = \frac{1}{n} \Sigma_{t=1}^n x_t(\tau) x_t(\tau)'$, $\hat{V}_n(\tau) = \frac{1}{n} \Sigma_{t=1}^n \hat{s}_t(\tau) \hat{s}_t(\tau)'$

and $\hat{s}_t(\tau) = x_t(\tau) \hat{\varepsilon}_t(\tau)$.

Hansen (1996) derives the asymptotic distribution of these test statistics under the null hypothesis and the local alternative. Furthermore, he shows that using a test based upon the test statistics (denote by g_n) and $p_n = 1 - F^o(g_n)$ where $F^o(\cdot)$ is the distribution function of g_o are equivalent and that the asymptotic null distribution of p (denoted as p^o) is uniform on $[0,1]$ which makes the test of rejecting the null hypothesis if $p \leq \alpha$, where α is the size of the test, free of nuisance parameters. As a final step, Hansen (1996) shows that one can generate the conditional distribution functions of the test statistics using simulation techniques where one generates a random sample $(g_n^1, ... g_n^j)$ with j elements and one can simply calculate the percentage of the observations in this sample that exceed the actual test statistic and use this measure to conduct inference.[18] In this paper we follow other literature that employs the same inference methodology and use $J = 1000$. In practice one can make J arbitrarily large to obtain an even better estimate of the actual p-value statistic.

[18] For more details on the asymptotic distribution of the test statistics and the particular identities used in simulations, see Hansen (1996).

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Table 1
Linearity Tests

Threshold Variable	Eq. for	SupW	Prob	ExpW	Prob	AveW	Prob	Threshold
$\Delta_{annual} ip_t$	WPI	40.811	0.000	16.93	0.000	29.566	0.000	-3.28
	CPI	66.69	0.000	30.304	0.000	45.623	0.000	-3.28
$\Delta_{annual} e_t$	WPI	59.681	0.000	27.033	0.000	45.578	0.000	52.2
	CPI	87.844	0.000	41.273	0.000	65.343	0.000	52.2
$\Delta_{annual} p^c{}_t$	WPI	49.03	0.000	21.097	0.000	32.336	0.000	57.31
	CPI	88.831	0.000	39.056	0.000	61.13	0.000	57.31
$dev.\ of\ \Delta_{annual} e_t$	WPI	16.608	0.170	6.816	0.137	9.224	0.312	0.73
	CPI	22.105	0.026	9.342	0.021	12.427	0.099	0.73

Table 2
Summary of Results

	Time Frame		P-T	
	WPI	CPI	WPI	CPI
Benchmark	8	8	0.49	0.39
CPI-Traded	7	7	0.49	0.39
CPI-Non-Traded	5	12	0.48	0.20
Pre-Flotation	9	10	0.55	0.39
Post-Flotation	10	27	0.42	0.12
TV 1				
High Regime	12	14	0.35	0.31
Low Regime	6	5	0.38	0.24
TV 2				
High Regime	4	4	0.41	0.28
Low Regime	29	30	0.63	0.73
TV 3				
High Regime	5	5	0.39	0.26
Low Regime	6	11	0.59	0.46
TV 4				
High Regime	7	11	0.50	0.37
Low Regime	10	8	0.80	0.62

Fig. 1. Annual Inflation (CPI) in Turkey

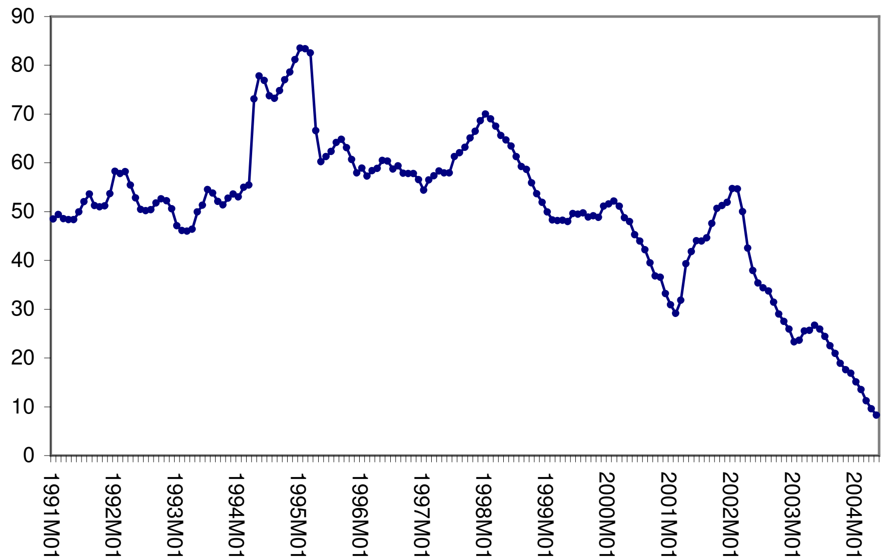


Fig. 2. Annual Change in Exchange Rate (%) ($/TL)

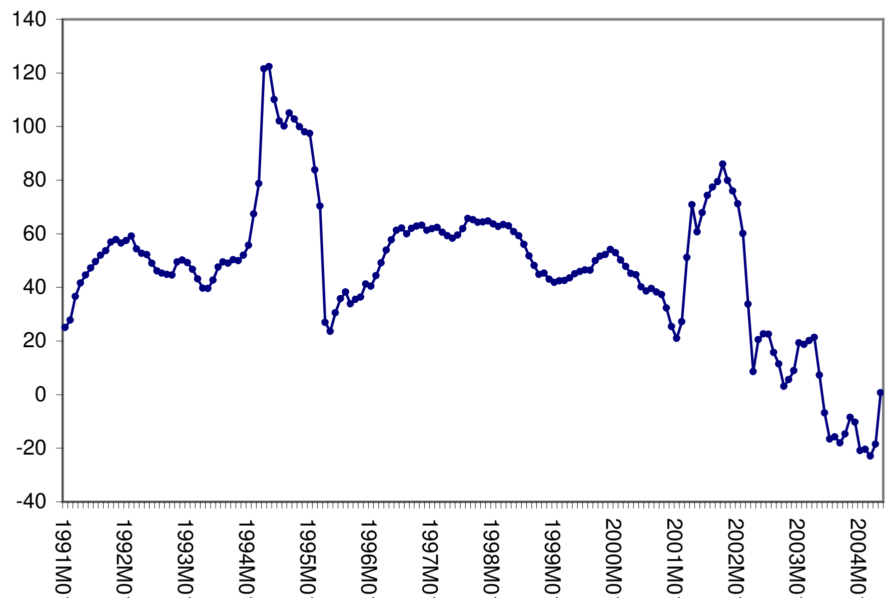


Fig. 3.a. Impulse Responses

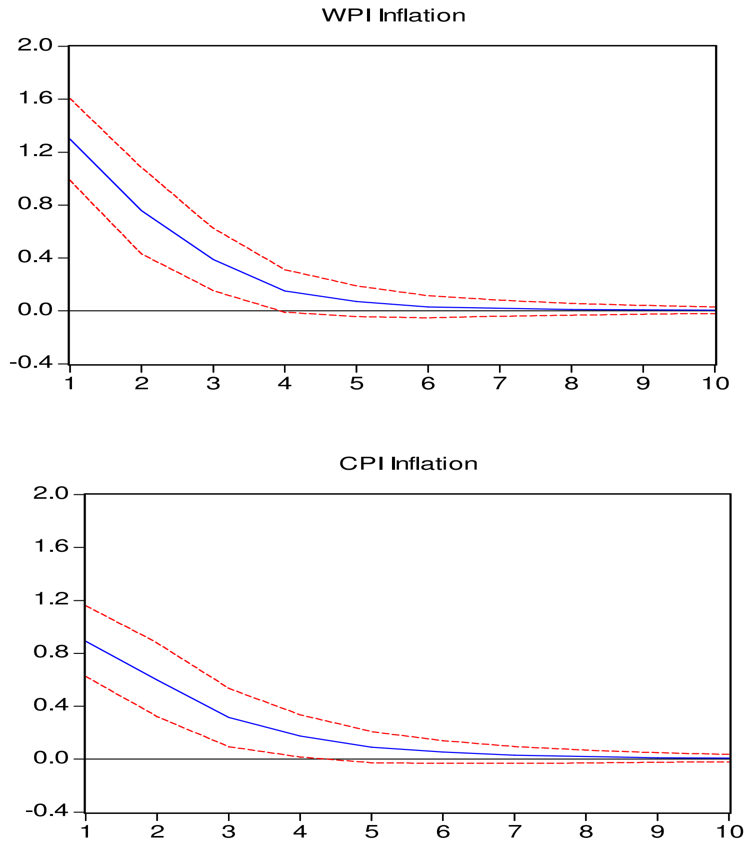


Fig. 3.b. Pass-Through Coefficients

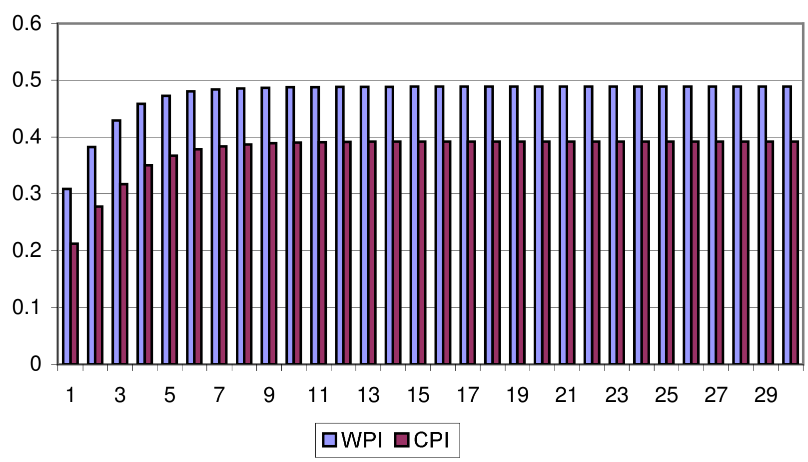
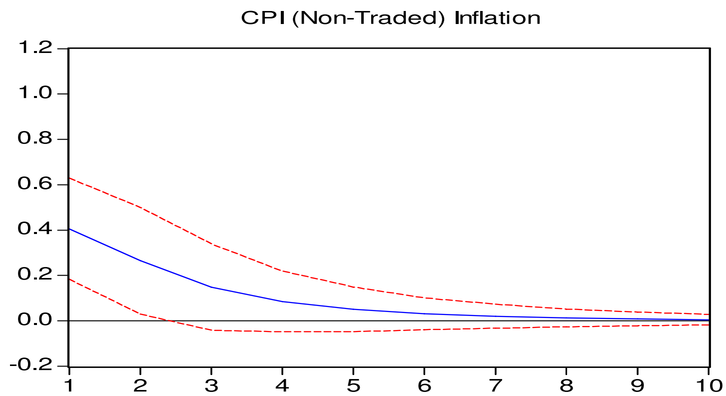


Fig. 4.a. Impulse Responses



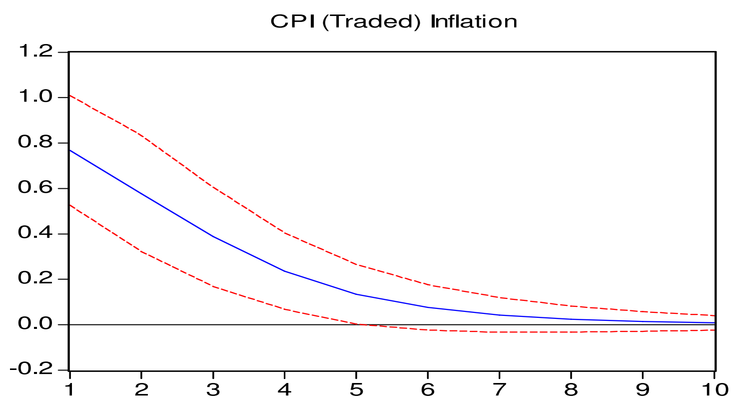


Fig. 4.b. Pass-Through Coefficients

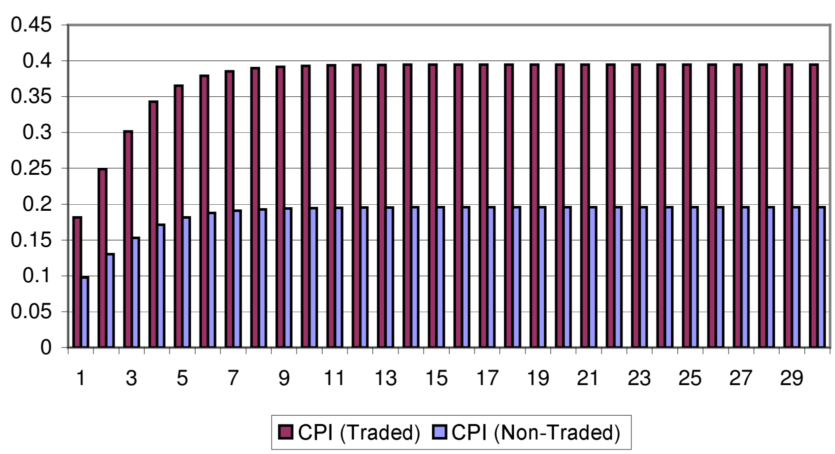


Fig. 5. Import Price Index Inflation (MPI)

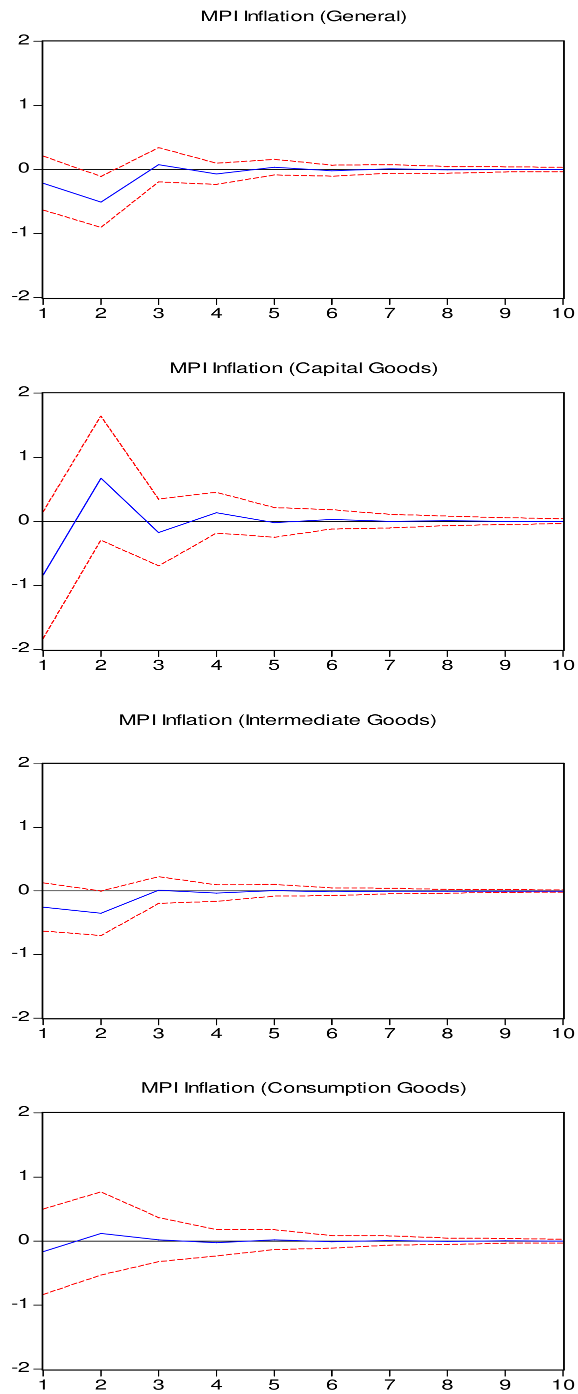


Fig. 6.a. Impulse Responses for WPI and CPI

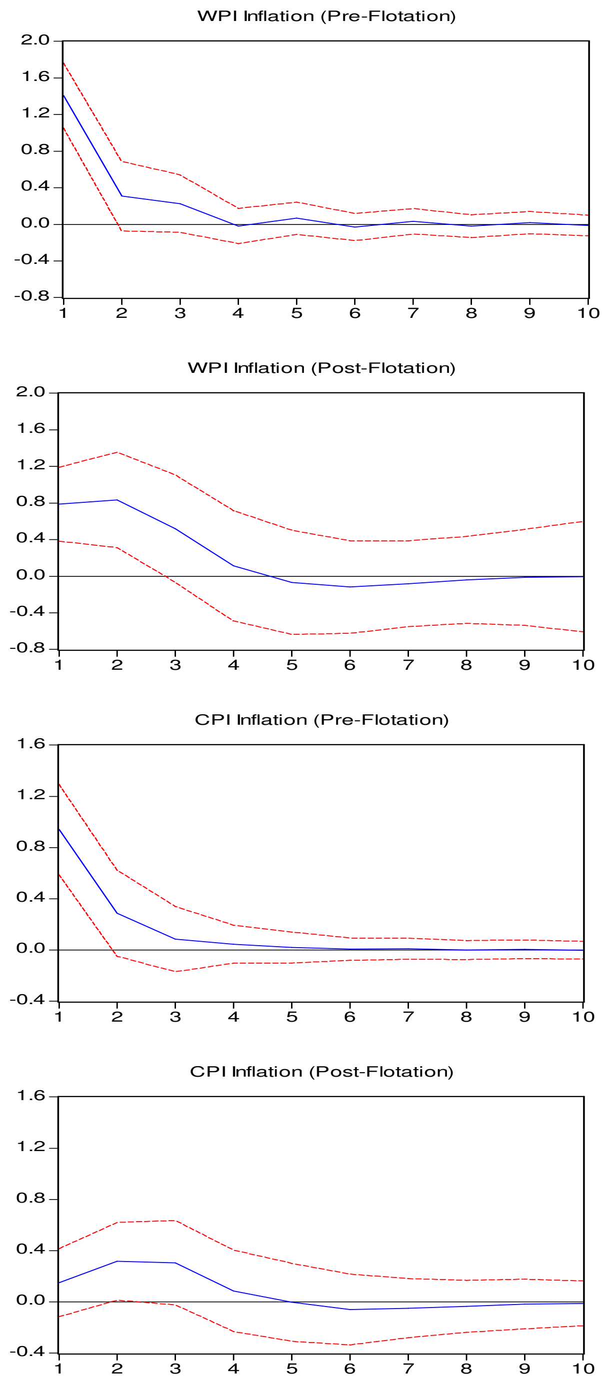


Fig. 6.b. Pass-Through Coefficients for WPI and CPI

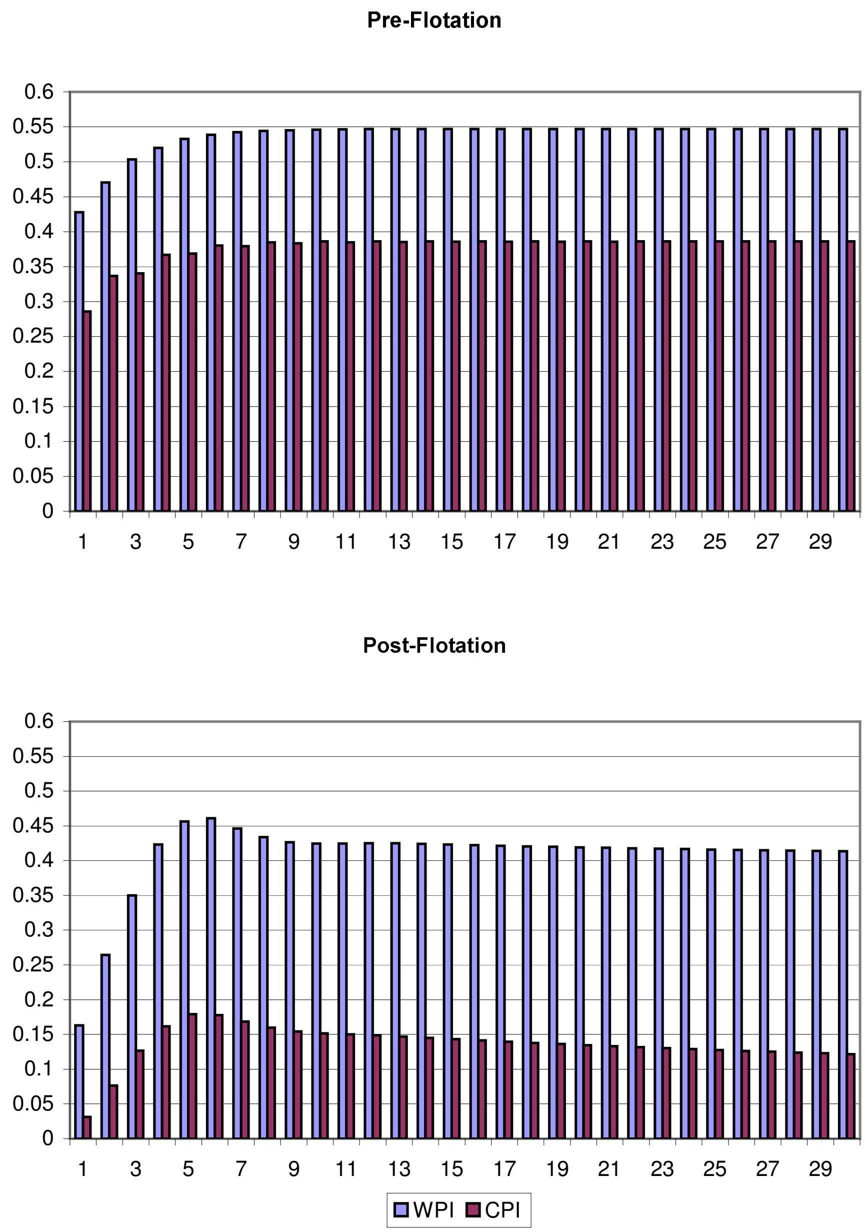


Fig. 7. a. Impulse Responses for WPI and CPI

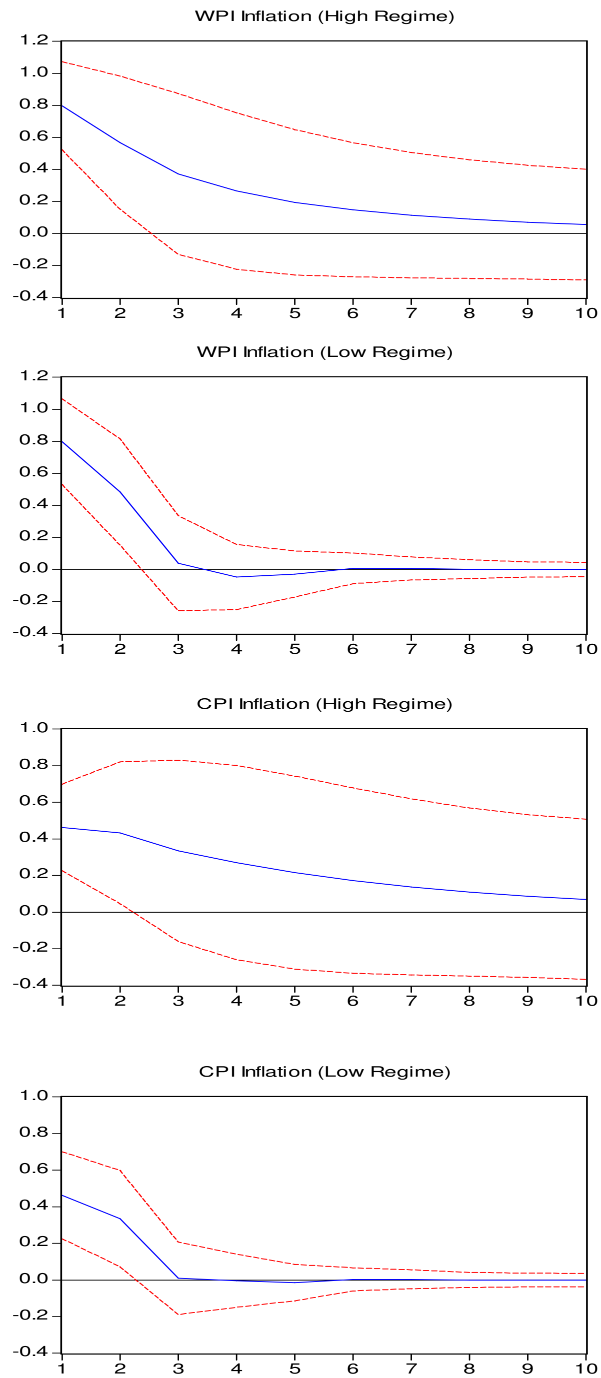
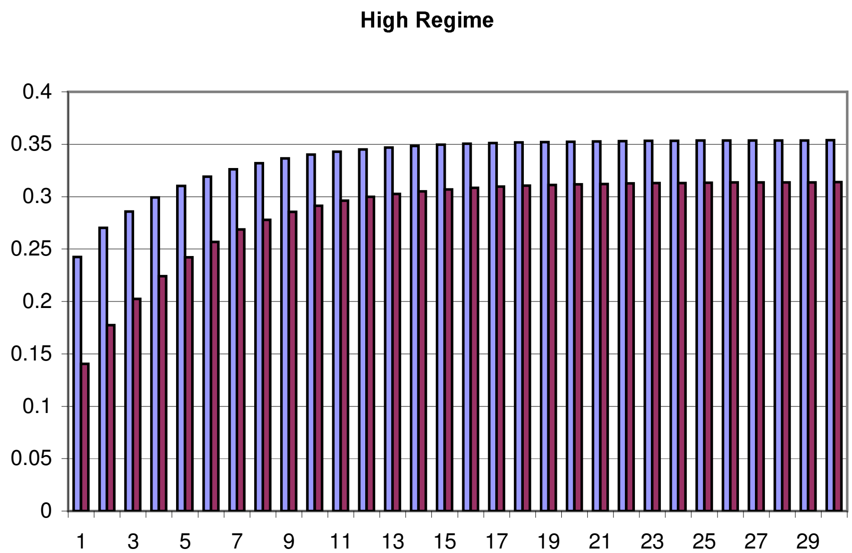


Fig. 7.b. Pass-Through Cofficients for WPI and CPI



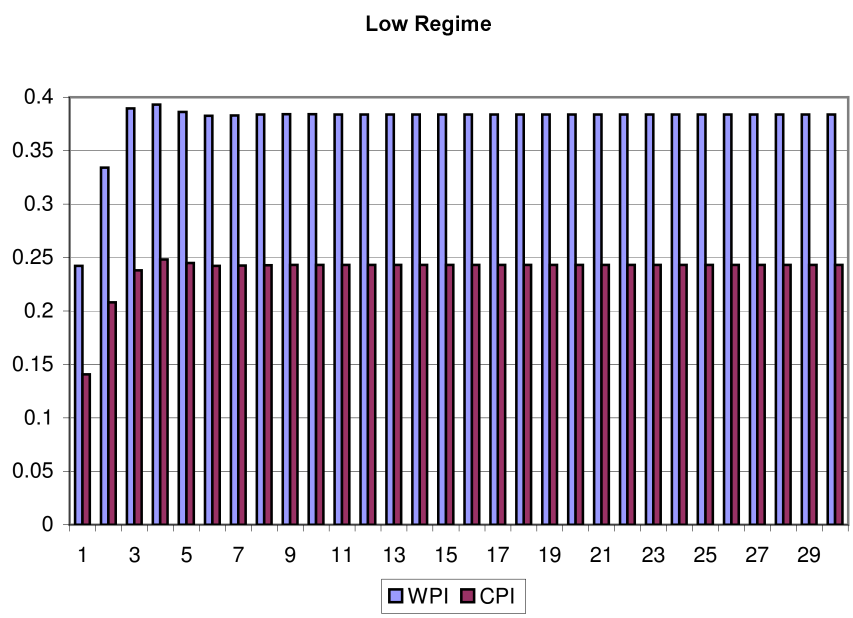


Fig. 8.a. Impulse Responses for WPI and CPI

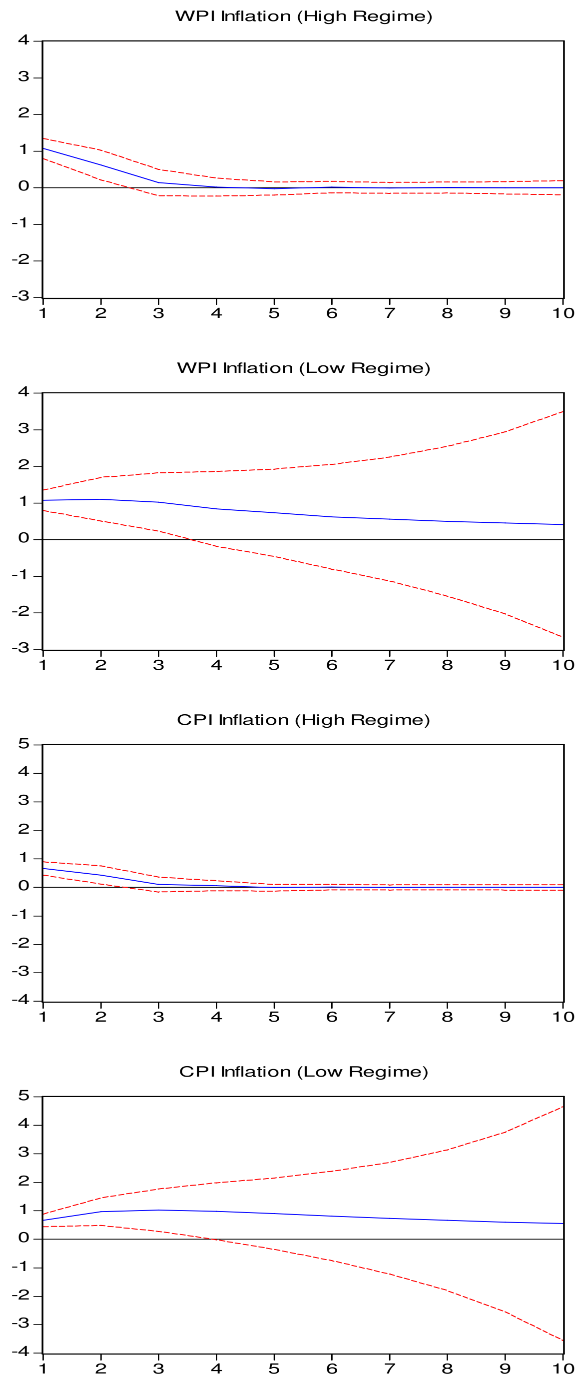


Fig. 8.b. Pass-Through Coefficients for WPI and CPI

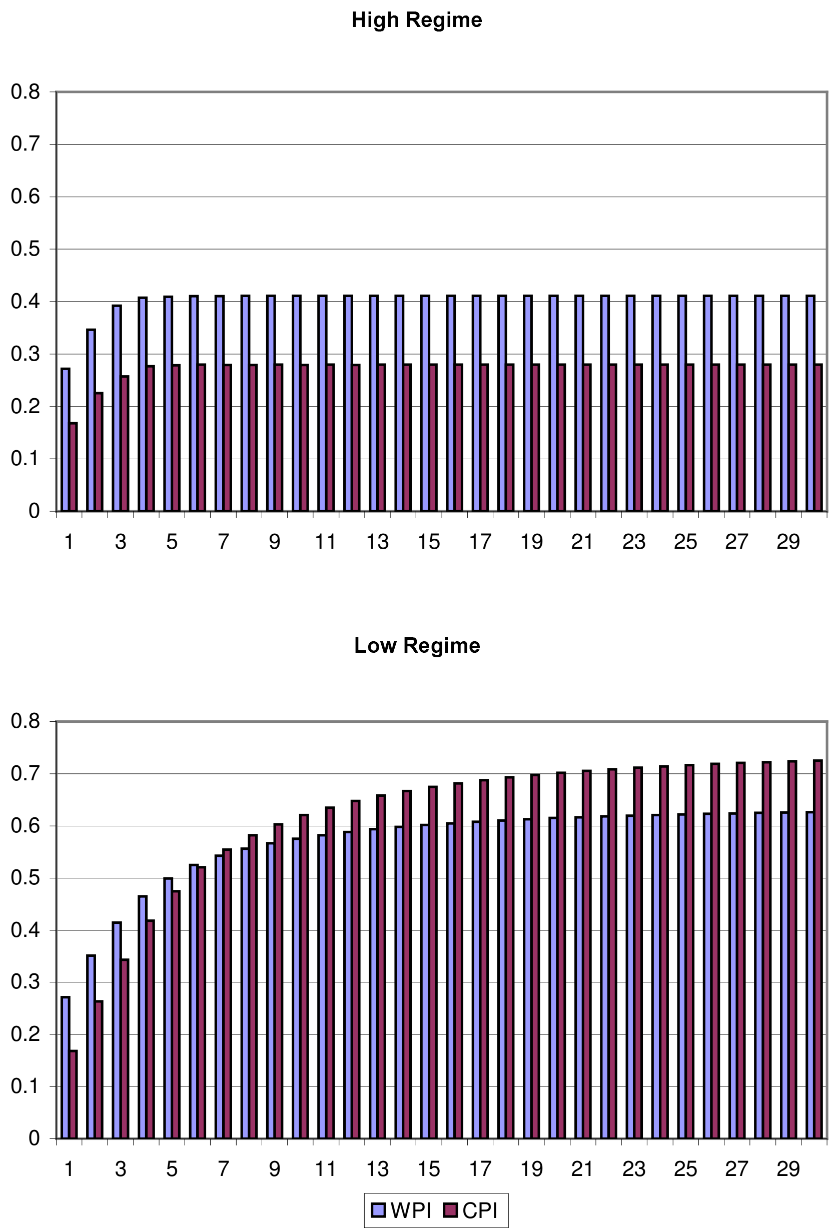


Fig. 9.a. Impulse Responses for WPI and CPI

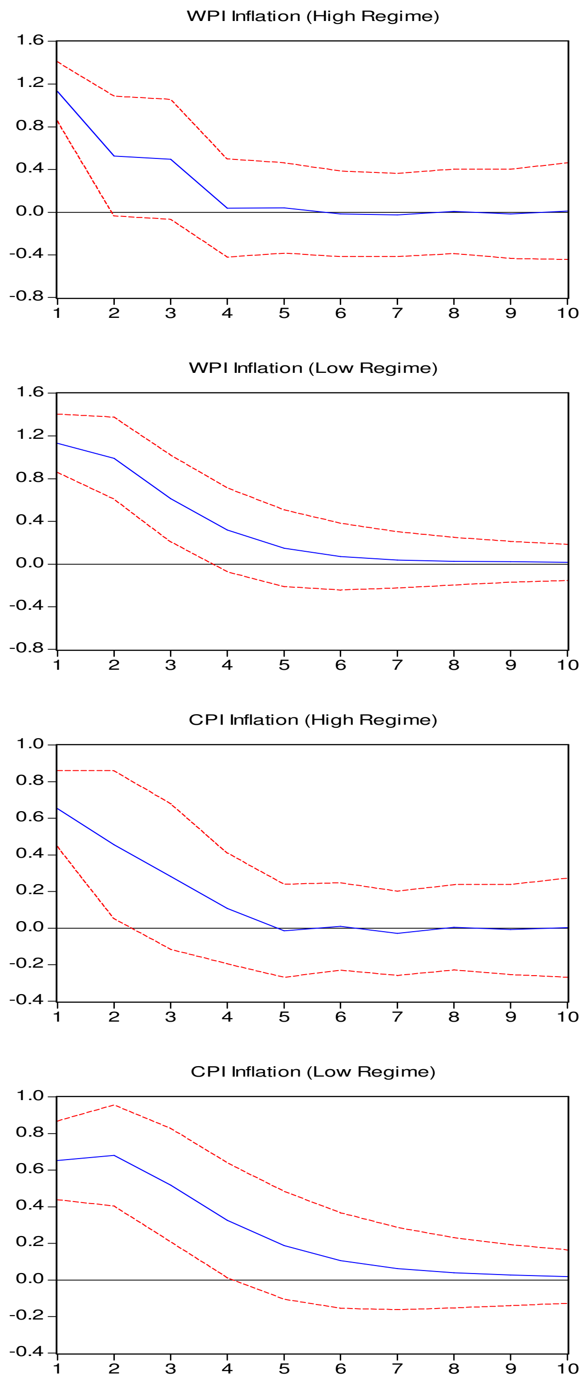


Fig. 9.b. Pass-Through Coefficients for WPI and CPI

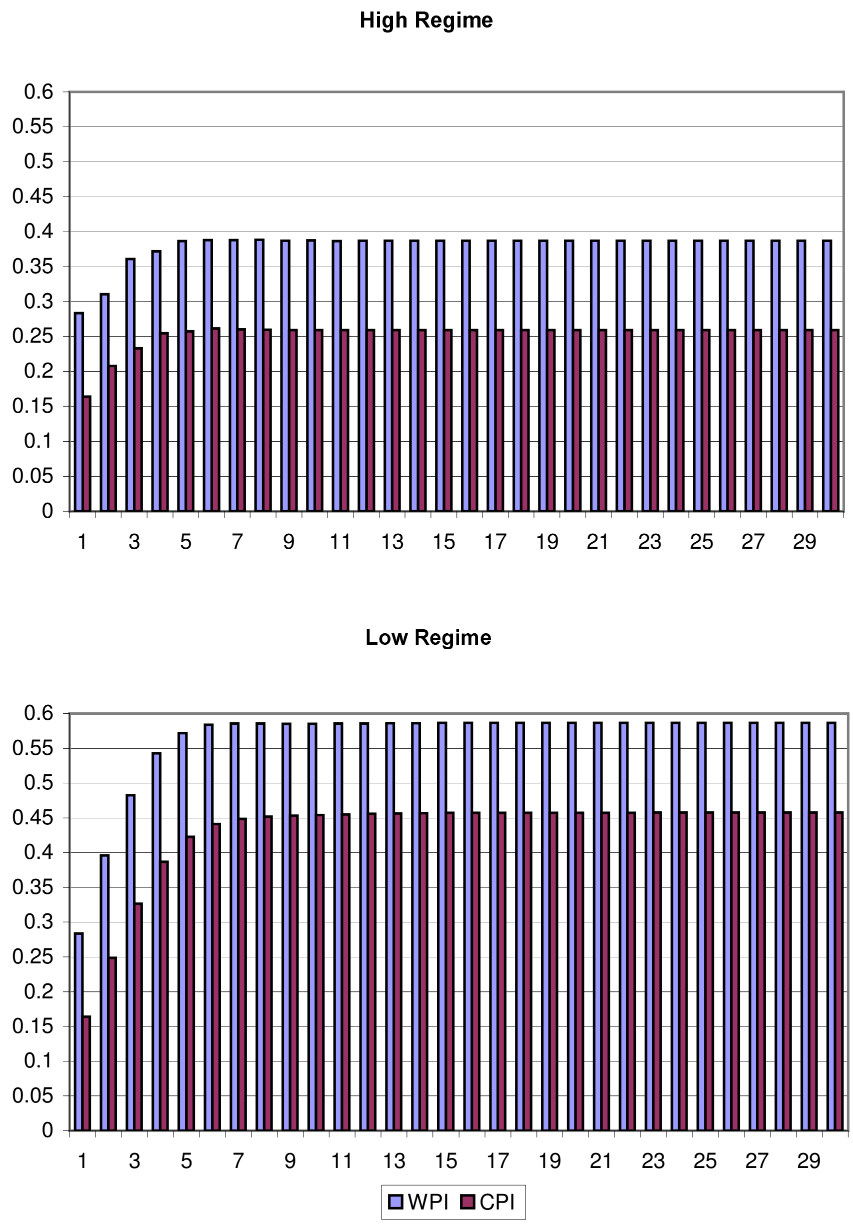


Fig. 10.a. Impulse Responses for WPI and CPI

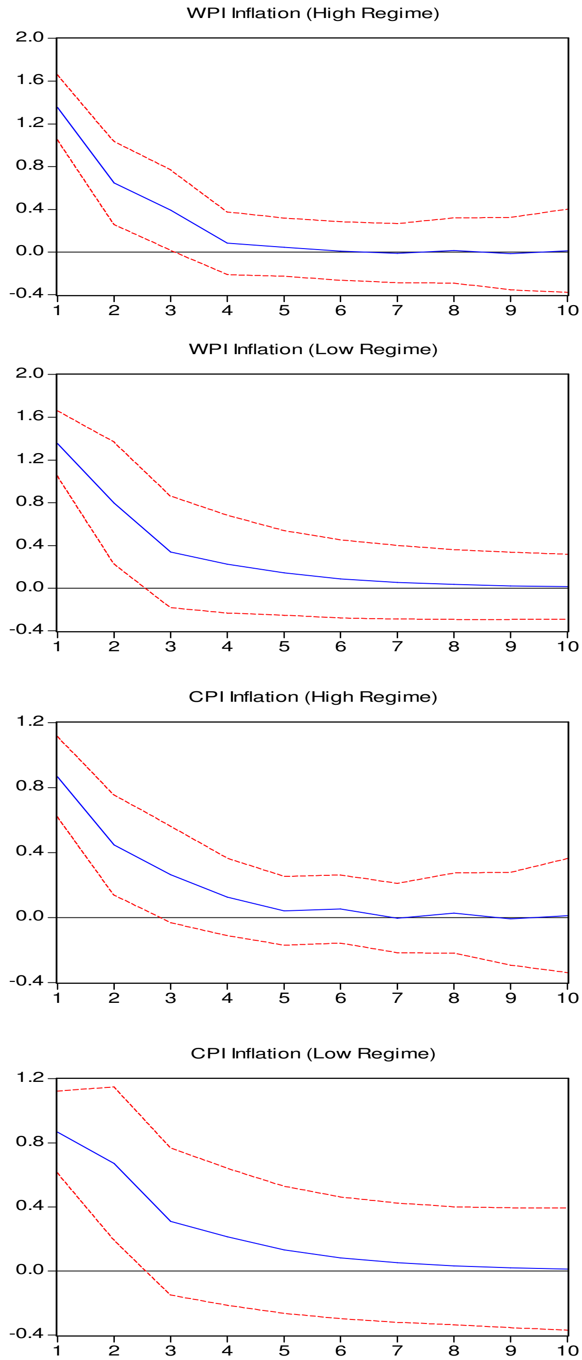


Fig. 10.b. Pass-Through Coefficients for WPI and CPI

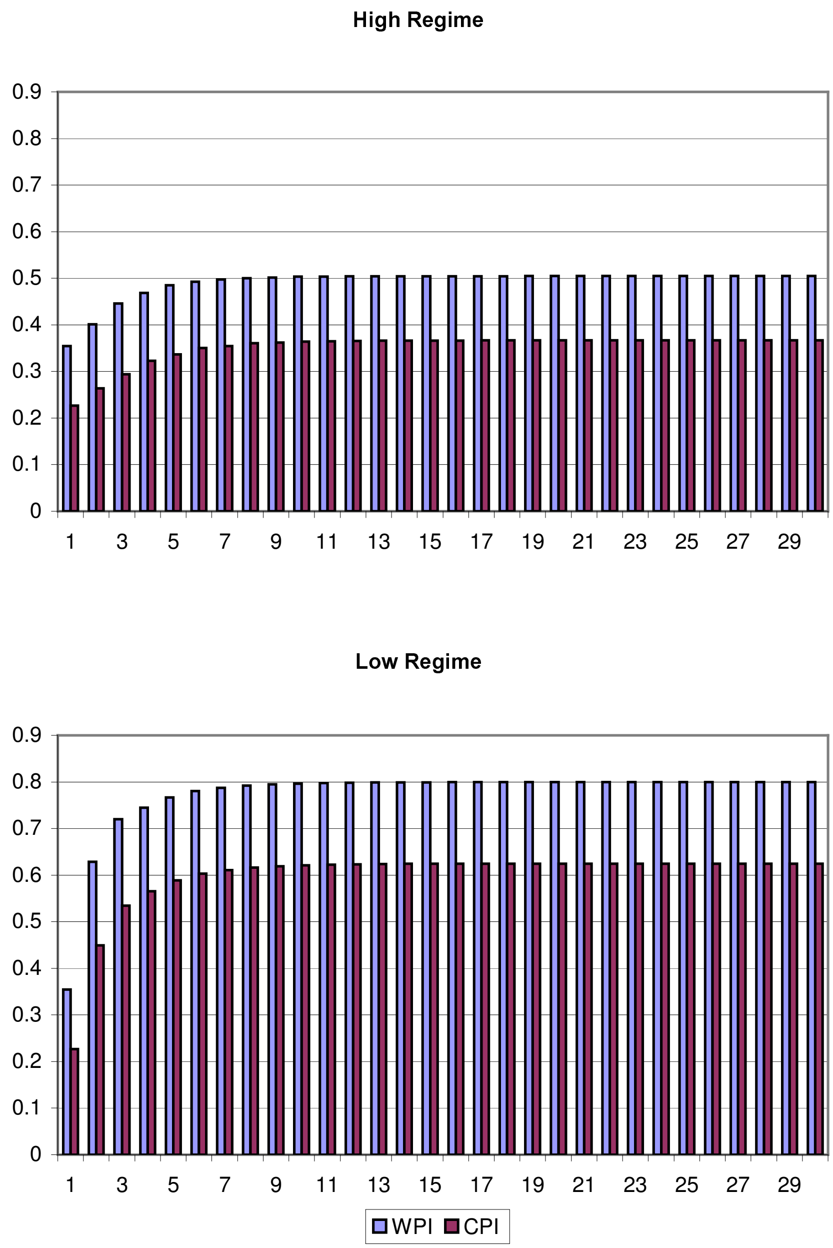


Fig. 11. Annual Change in IP

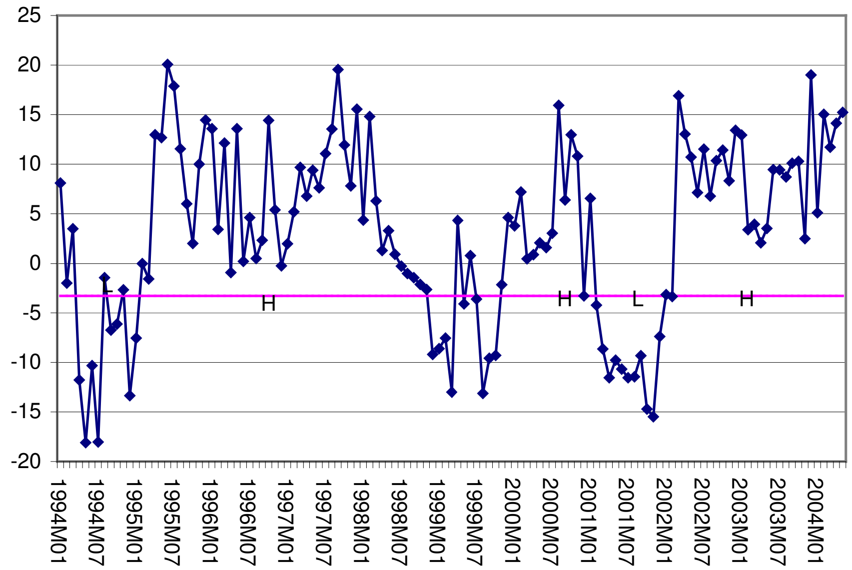


Fig. 12. Annual Change in Exchange Rate

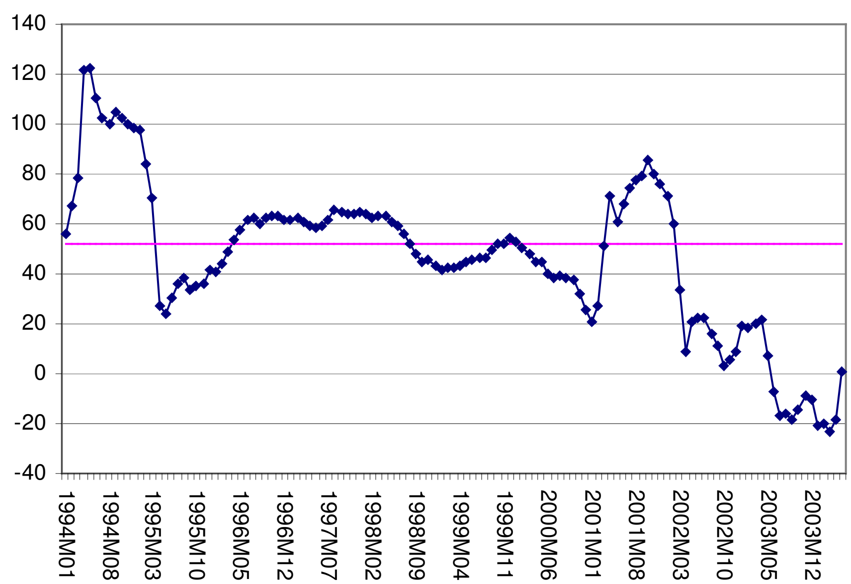


Fig. 13. Annual CPI Inflation

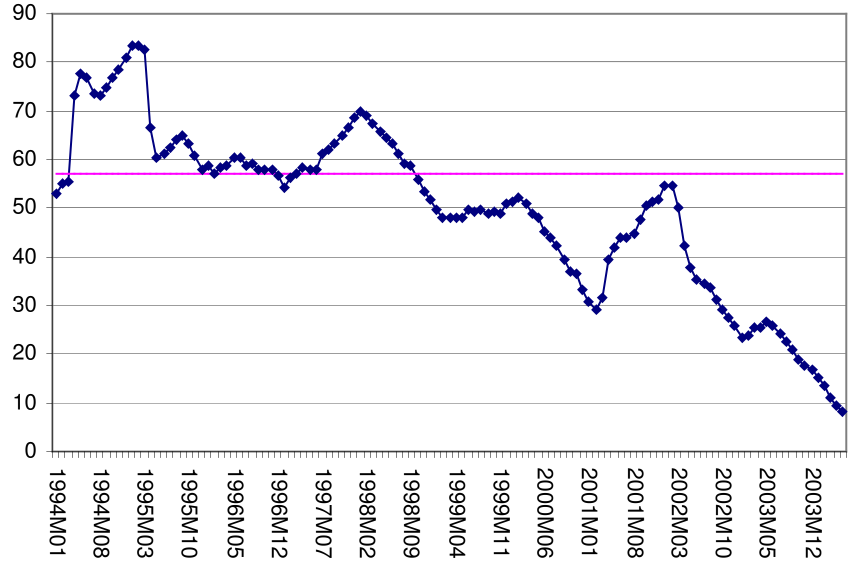


Fig. 14. Deviation of Annual Exchange Rate Change