10. TIME-VARYING EXCHANGE RATE PASS-THROUGH TO DOMESTIC PRICES: EVIDENCE FROM TURKEY

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Abstract

Exchange rate fluctuations have decisive effects on inflation dynamics and monetary policy in emerging market economies. This paper analyzes exchange rate pass-through to domestic prices in Turkey by employing the TVP-VAR model for the period from 2002:01 to 2019:12. Our findings indicate that exchange rate pass-through varied throughout the relevant period. Specifically, the pass-through coefficients decreased considerably after adopting the inflation targeting regime, whereas it accelerated significantly following the exchange rate depreciations, especially after 2013. This upward trend was probably due to structural problems and policy choices. Rising pass-through coefficients may imply the exchange rate pass-through has an impact during inflation targeting. However, it should be noted that inflation targeting has underperformed in Turkey due to policy preferences in the last decade.

Keywords: *Exchange rate, exchange rate pass-through, domestic prices, TVP-VAR model, Turkey*

JEL Classification: *C32, E31, E52, E58*

1. Introduction

Exchange rate pass-through (ERPT) refers to the impact of changes in exchange rates on domestic prices.[4] ERPT is critical for monetary authorities to maintain price and financial stability objectives. In the new open economy macroeconomics literature, ERPT is explained by two main approaches; micro and macro. The micro approach argues that various microeconomic factors that are exogenous to monetary policy determine ERPT. The main factors are sensitivity of

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4 Kara et al. (2007) claim that the ERPT has different definitions for advanced and emerging market economies. For developed countries, ERPT is defined as the exchange rate pass-through to import prices in domestic currency (Goldberg and Knetter, 1997). In emerging market economies, where pricing to market is low, ERPT is the impact of exchange rate changes on domestic prices.

demand elasticity in the exchange rate, competitiveness and market structure, the weight of imported intermediate goods in the production of domestic commodities (Campa and Goldberg, 2002), the composition of the import basket (Campa and Goldberg, 2005), and firms' pricing behaviors (Betts and Devereux, 2000).

While the macro approach can also explain ERPT based on microeconomic factors, such as market imperfections and nominal rigidities, it also emphasizes the degree of ERPT in the design and implementation of monetary policy (Smets and Wouters, 2002; Monacelli, 2005). The degree of ERPT can affect the expenditure-switching[5] role of flexible exchange rates as shock absorbers (Edwards and Yeyati, 2005). A low ERPT reduces the contribution of exchange rates to adjusting the external balance (Ito and Sato, 2008) whereas, it increases the effectiveness of monetary policy responses to real shocks (Campa and Goldberg, 2005). Furthermore, low pass-through expands the room for monetary policy maneuver by reducing the difficult trade-offs between price and output stability (Devereux *et al.*, 2006). The size of ERPT is a function of the monetary policy stance because it affects price stickiness. Therefore, ERPT should be regarded as endogenous to inflation performance (Devereux and Yetman, 2010).

Taylor (2000) argues that a credible monetary policy helps anchor inflationary expectations and reduces the effect of ERPT on inflation. Inflation impacts the price adjustment sentiments of firms exposed to cost pressures due to exchange rate fluctuations. In low inflation environments, firms tend to perceive exchange rate fluctuations as temporary, which reduces the effect of exchange rate shocks on price fluctuations. Taylor's (2000) pioneering hypothesis, which was tested in several empirical studies, was confirmed for both developed and emerging market economies (EMEs). Bailliu and Fujii (2004), Gagnon and Ihrig (2004), Sekine (2006), and Choudhri and Hakura (2006) all report that ERPT declined in developed countries that achieved price stability. Mishkin and Schimdt-Hebbel (2007), Noguiera Jr. (2007), Noguiera Jr. and León-Ledesma (2009), Coulibaly and Kempf (2010), Prasertnukul *et al.* (2010), Winkelried (2014), Baharumshah *et al.* (2017), López-Villavicencio and Mignon (2017), and López-Villavicencio and Pourroy (2019) demonstrated all that ERPT decreased after EMEs switch to an inflation targeting regime.

The macroeconomic environment since the global financial crisis (GFC) has led to a re-evaluation of the effect of exchange rates on domestic prices in inflation targeting regimes. The exchange rate shocks due to the unconventional monetary policies implemented by developed country central banks and the low inflation environment have caused trade-offs between price and financial stability in EMEs (Obstfeld, 2015). The abundance of global liquidity has had varying effects, which in turn have led to differences in the findings of studies investigating ERPT for the post-GFC period. For example, Jašová *et al.* (2019) found that ERPT had declined in EMEs since the GFC in line with Taylor's (2000) hypothesis. In contrast, Forbes *et al.* (2020) revealed that ERPT had risen in some developed countries and EMEs implementing inflation targeting regime. This finding is consistent with Siklos' (2018) argument that inflation targeting cannot isolate economies from all external shocks. These mixed results have led to exploring the argument that exchange rate shocks have no permanent effect on inflation dynamics and that the inflation targeting is omnipotent in eliminating the effects of ERPT.

Turkey is one of the EMEs where ERPT threatens price and financial stability. ERPT declined significantly in Turkey after inflation targeting was adopted after the November 2000 and February 2001 crises. However, the exchange rate has fluctuated and inflation has risen, especially since the taper tantrum began in May 2013. After 2013, the Central Bank of the Republic of Turkey (CBRT) gradually moved away from price stability and inflation targeting, although this was not

[5] *The expenditure-switching effect of exchange rate increases during ERPT to import prices is rapid and intense (Obstfeld, 2002). This effect helps change the direction of consumption and investment due to depreciation of the domestic currency caused by an import-induced trade deficit. The domestic currency depreciation leads to a new equilibrium with the expenditure-switching effect (Bailliu, 2010).*

announced officially. The bank's weakening commitment to price stability was replaced by an unorthodox monetary policy that prioritizes growth (Gürkaynak *et al.*, 2022). Indeed, the results of such a monetary policy became visible with the currency shock in August 2018. Furthermore, the erosion of CBRT independence (Demiralp and Demiralp, 2019) and the loose monetary policy needed as a policy response to the COVID-19 pandemic have left inflation out of control. The homemade currency shock in December 2021 and the effect of the Russia-Ukraine war on food and energy prices led inflation to jump to over 85% by October 2022.

However, Turkey's current inflation performance cannot be explained only by developments in the last few years because the country entered this period with already high inflation and rising exchange rates. Furthermore, the use of the policy rate to stimulate growth rather than react to exchange rate changes or inflation led to a dysfunctional monetary policy. Therefore, our analysis excludes recent monetary policy behavior and external shocks. Instead, our motivation is to examine the role of ERPT in inflation before the loss of inflation control.

This paper aims to investigate ERPT to domestic prices in the Turkish economy from 2002:01 to 2019:12. We analyze ERPT to import prices, producer prices, and consumer prices by employing the time-varying parameters vector autoregressive (TVP-VAR) model. By doing so, ERPT is examined in a time-varying manner for the pre-and post-GFC period.

By providing recent evidence on Turkey as an EME, our study contributes to the literature in three main ways. First, ERPT to domestic prices exhibits a time-varying pattern in Turkey, which reflects the nonlinear nature of ERPT and is consistent with other studies on the Turkish economy. Second, the low and stable inflation environment following the transition to inflation targeting led to considerably reduced ERPT, which confirms Taylor's (2000) hypothesis. Finally, ERPT to domestic prices has risen since 2010, which shows that ERPT may have an impact during inflation targeting and flexible exchange rates. However, it should be noted that inflation targeting could not be implemented successfully due to policy choices prioritizing financial stability and growth in the relevant period.

The rest of the paper is organized as follows. The next section explains the relationship between the exchange rate and inflation in Turkey's inflation targeting regime. Section 3 reviews empirical studies related to ERPT on the Turkish economy. Section 4 introduces the model, data, and the TVP-VAR methodology. Section 5 presents the empirical findings. The following section concludes the paper.

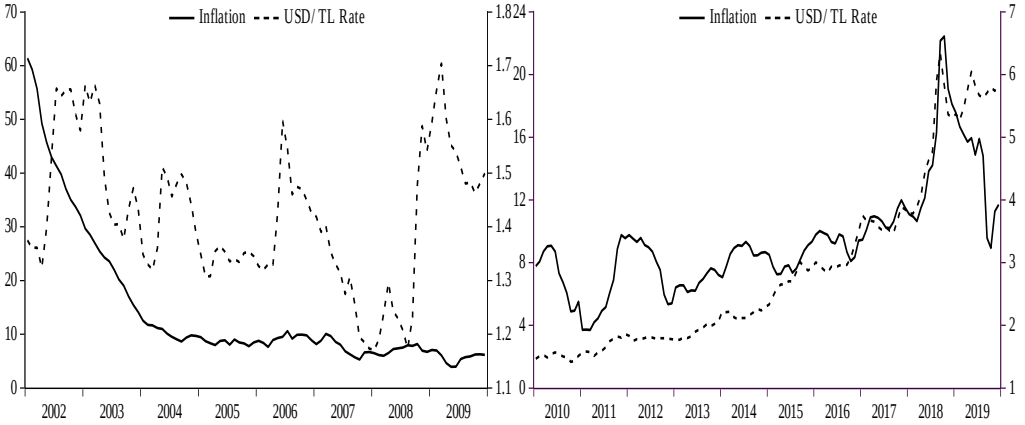
2. Exchange Rate and Inflation in the Turkish Economy

Turkey adopted inflation targeting, and a flexible exchange rate regime after its exchange rate peg collapsed during the November 2000 and February 2001 crises.[6] The CBRT then became legally independent. During the early stages of the inflation targeting regime, when fiscal dominance[7] was evident, exchange rate and financial market volatility decreased. At the same time, the risk premium fell as the credibility of monetary policy improved (Akyurek and Kutan, 2008). Following the most successful disinflation in the Turkish economy's history (Gurkaynak *et al.*, 2023), a low and stable inflation environment was achieved (see Figure 1(a)).

[6] *Turkey initially adopted implicit inflation targeting before switching to full-fledged inflation targeting in 2006 (Kara, 2008; Kara and Öğünç, 2008).*

[7] *Fiscal dominance refers to decreasing the effectiveness of monetary policy and impairing the functioning of transmission mechanisms due to the high level of the government's short-term debt stock (Kara and Orak, 2008).*

Figure 1. Inflation and exchange rate in the Turkish economy



(a) 2002:01-2009:12 **(b)** 2010:01-2019:12

Source: Authors' construction based on data from FRED, 2021
Notes: The left axis shows inflation, while the right axis is for the USD/TL rate. The annual percentage change in the consumer price index is used for inflation.

Before the GFC, variations in the exchange rate did not pose a threat to low inflation and price stability. According to Kara *et al.* (2007), the decline in ERPT was due to weakening indexation behavior after 2001. Kara and Öğünç (2008) showed that ERPT decreased because of changing expectations following a successful disinflation process, improved CBRT credibility, and the floating exchange rate regime.

External dominance[8] resulting from the characteristics of the post-GFC policy environment has led to a realization that price stability and financial stability are both important. Exchange rate fluctuations and financial instability risks emerged due to changing directions in developed countries' monetary policies (İlhan and Özdemir, 2019). The CBRT, therefore, implemented in November 2010 a framework called the new policy mix based on a multiple-goals and multiple-instruments framework (Başçı and Kara, 2011). However, the presence of the financial stability objective reduced the effectiveness of the price stability-oriented monetary policy (Özatay, 2014).

In the new policy mix, especially since 2013, inflation increased substantially following the sharp depreciation of the Turkish Lira (TL) (see Figure 1 (b)). After domestic and external shocks in 2016, the exchange rate rose gradually, while inflation reached double digits in 2017. The Turkish economy faced currency shocks in the second half of 2018, and the depreciation of the TL in September 2018 exceeded 80% compared to the same month of the previous year. Exacerbating uncertainties and increasing expectations of inflation pushed inflation above 25% in October 2018. Although rapid and strong monetary tightening brought the upward trend in inflation under control in 2019, it remained far higher than the CBRT's inflation targets. Indeed the average inflation in 2017-2019 was above 14%, which was almost double the average of 2010-2016.

[8] *External dominance occurs when a sudden stop in capital flows increases exchange rate and interest rate volatility, making it difficult to achieve inflation targets and reducing monetary policy credibility (Fraga et al., 2004).*

3. Literature Review

This review includes studies examining the magnitude of ERPT for the Turkish economy. Early studies showed the impact of the transition to inflation targeting on ERPT. Kara *et al.* (2007) analyzed ERPT to domestic prices from 1995:01 to 2004:12 with the TVP model. They found that ERPT changed over time and declined with the decrease in indexation behavior after 2001. Investigating the period from 1994:01 to 2014:12 with the VAR method, Kara and Öğünç (2008) reported that ERPT declined considerably after the adoption of inflation targeting. Çatık and Güçlü (2012) explored ERPT to domestic inflation between 1986:01 and 2009:10 using the Markov Regime Switching Vector Autoregressive (MS-VAR) model. They demonstrated that Taylor's (2000) hypothesis held for the Turkish economy, with inflation targeting contributing to a decrease in ERPT. Similarly, Çatık *et al.* (2016) used TVP-VAR to demonstrate that ERPT declined substantially after the adoption of inflation targeting.

Studies of the post-GFC period have reported an increase in ERPT. Kara *et al.* (2017a) investigated the dynamics of consumer prices between 2006 and 2016 using the TVP model. They showed that import price pass-through decreased considerably in later years, whereas ERPT remained relatively stable. In addition, while short-run ERPT was stable at around 13%, long-run ERPT was around 18%. Applying Kara *et al.*'s (2017a) method to the period 2006Q3 and 2021Q3, Kara and Sarıkaya (2021) showed that ERPT increased after 2017. Gayaker *et al.* (2021) used a threshold regression model to examine ERPT in relation to CBRT credibility between 2002:01 and 2020:02. They demonstrated that ERPT increased after 2011, with a higher pass-through coefficient during periods of lower credibility and rising exchange rate uncertainty.

Some studies found that changes in ERPT depended on the state of the transition variable. For example, using the MS method, Kal *et al.* (2015) explored ERPT from 2002Q3 to 2014Q4. While ERPT was quite low and statistically insignificant during appreciation periods, it was statistically significant and high when the domestic currency depreciated. Analyzing 2003:01 and 2017:01 with smooth transition regression models, Çiftçi and Yılmaz (2018) reported that ERPT to consumer prices was high during a large import shock. Fendoğlu *et al.* (2020) explored the relationship between external debt and ERPT in manufacturing industry sub-sectors from 2007:01 to 2016:12. They demonstrated that ERPT to producer prices was stronger when external indebtedness was high. Bilgili *et al.* (2022) used MS models to examine the asymmetric determinants of domestic prices from 1998Q1 to 2019Q2. They found that the exchange rate had a positive nonlinear impact on consumer price inflation in both low- and high-inflation volatility periods. Finally, Türel and Orhan (2022) used a threshold VAR model to investigate ERPT between 2005:01 and 2021:09. Using inflation and exchange rate movements as threshold variables, they showed that ERPT to domestic inflation was stronger in the higher than lower regime.

Although many studies have examined ERPT coefficients for Turkey using various methods, only a few studies have adopted a time-varying approach. In the present study, we therefore employ a TVP-VAR model similar to Çatık *et al.* (2016). However, we also compare the implementation of orthodox inflation targeting and unorthodox monetary policy period.

4. Data and Methodology

4.1. Data

We analyze ERPT to domestic prices in Turkey for the period 2002:01 to 2019:12. The starting date marks Turkey's adoption of an inflation targeting regime, while the sample ends with the last month of 2019 to exclude the effects of the COVID-19 pandemic.

Following Hahn (2003), McCarthy (2007), and Ito and Sato (2008), the model specification includes exchange rate and domestic prices as well as external shocks. The vector of endogenous variables is defined as follows:

$$Y_t' = [oil_t, ip_t, ner_t, imp_t, ppi_t, cpi_t] \quad (1)$$

where oil_t represents the global price of Brent crude in US dollars per barrel and ip_t shows the production index of total industry (2015=100). We use oil_t and ip_t to reflect supply and demand shocks, respectively. ner_t stands for the nominal USD/TL rate; imp_t denotes the import unit value index in TL (2010=100); ppi_t indicates the producer price index for domestic industrial activities (2015=100); and cpi_t represents the consumer price index excluding food and energy (2015=100). The series showing a seasonal effect are seasonally adjusted using the Census X-13 method. All variables are used as annual percentage changes. The import unit value index is retrieved from the Turkish Statistical Institute (TURKSTAT), whereas all the other series were obtained from Federal Reserve Economic Data (FRED).

The ordering of endogenous variables in the model indicates which variables are contemporaneously affected by which shocks. Since reduced-form residuals of supply shocks affect all variables in the system simultaneously, oil price is ordered first in our model, while production is ordered second because demand shocks are only affected by supply shocks. The nominal exchange rate is placed third while domestic prices, which are ordered regarding the distribution chain,[9] are last since they are affected simultaneously by previous shocks (Hahn, 2003; Ito and Sato, 2008). Table 1 presents the descriptive statistics and time series properties of the variables.

Table 1. Descriptive statistics and unit root tests

Descriptive statistics					
Variables	**Mean**	**Min.**	**Max.**	**Std. Dev.**	**JB**
oil_t	11.160	-54.990	86.559	33.550	2.943 (0.229)
ip_t	6.202	-20.221	24.213	7.377	77.720 (0.000)
ner_t	10.456	-20.640	104.896	18.344	214.377 (0.000)
imp_t	12.816	-14.229	86.569	17.218	103.467 (0.000)
ppi_t	13.392	-3.753	91.929	13.790	1373.168 (0.000)
cpi_t	11.619	3.705	61.398	9.362	1366.598 (0.000)

[9] *The distribution chain reduces the impact of domestic currency depreciation on consumer inflation through nominal rigidities and distribution costs (Winkelried, 2014). According to the distribution chain of pricing, ERPT is expected to be the highest in import prices and lowest in consumer prices due to the weight of imported input use (Ito and Sato, 2008).*

Unit root tests			
ADF		PP	
Intercept	Trend & Intercept	Intercept	Trend & Intercept
-4.186***	-4.409***	-3.544***	-3.707**
-3.734***	-3.916**	-4.140***	-4.347***
-3.371**	-6.742***	-5.881***	-6.691***
-3.848***	-4.674***	-5.196***	-5.310***
-5.038***	-4.867***	-6.465***	-6.199***
-5.145***	-6.246***	-8.996***	-8.987***

*Notes: The descriptive statistics are presented in the annual percentage change form of the series. JB is the Jarque and Bera test for normality. ADF is the Augmented Dickey-Fuller unit root test, and PP is the Phillips-Perron unit root test. ***, **, and * indicate significance at 1%, 5%, and 10%, respectively.*

Oil prices show the highest volatility of all the variables, while import prices are the most volatile of domestic prices. The means of the domestic prices similar, with consumer prices having the lowest value. Finally, the unit root test statistics indicate that all variables are stationary in their annual percentage values at least the 5% significance level.

4.2. Methodology

Single equation models or system methods are usually employed for ERPT analyses. A single equation method uses reduced-form regressions from a partial equilibrium model in which the exchange rate is assumed to be exogenous. System methods are capable of capturing endogenous exchange rate feedback effects. Hence, vector autoregression (VAR) models are the most preferred system method. Unlike single equation approaches, VAR models can determine the causal relationship between the variables (Aron *et al.*, 2014) and reveal the effects of the pricing chain by allowing simultaneous analysis of ERPT to multiple domestic prices (Ito and Sato, 2008).

The state of the business cycle and exchange rate expectations may change ERPT over time (Kara *et al.*, 2017b). Many studies have demonstrated that ERPT behaves nonlinearly or asymmetrically. Noguiera Jr. and León-Ledesma (2011) and Ben Cheikh and Rault (2016) determined that ERPT rises in times of increasing macroeconomic instability. Junttila and Korhonen (2012) demonstrated that ERPT depended on the inflation environment. Balcilar *et al.* (2021) showed that ERPT was affected by the state of the economy. Akdeniz *et al.* (2022) found that ERPT coefficients changed in a time-varying fashion. Anghelescu (2022) reported that ERPT coefficients varied depending on macroeconomic shocks.

There are similar findings regarding the Turkish economy. Kara *et al.* (2007) and Çatık *et al.* (2016) found that ERPT had a time-varying pattern. Çiftçi and Yılmaz (2018) reported that the size of import price shocks affected ERPT. Gayeker *et al.* (2021) demonstrated that ERPT was affected by credibility and exchange rate uncertainty. To capture nonlinearities in ERPT, we therefore employ the TVP-VAR model rather than the linear VAR model.

The TVP-VAR model has some clear advantages over other nonlinear methods. For instance, the behavior of the variables does not depend on the transition variable, unlike in models like threshold-VAR. Therefore, changes in ERPT coefficients can be determined gradually.

Furthermore, the time-varying variance-covariance matrix captures the unanticipated effects of exogenous shocks (Primiceri, 2005; Koop *et al.*, 2009).[10]

This article explores ERPT to domestic prices with time-varying transition coefficients obtained from the TVP-VAR model.[11] The model includes both time-varying coefficients and a variance-covariance matrix of additive innovations. Allowing for these leaves it up to the data to specify whether the time variation of the linear structure produces from changes in the spreading mechanism (response) or changes in the size of the shocks (impulse) (Primiceri, 2005, p.823).

The TVP-VAR model includes one measurement equation and three transition equations. These four state-space equations account for both evaluations of the parameters and the stochastic volatilities (Balli *et al.*, 2021, p.13). Based on Primiceri (2005) and Nakajima (2011), the measurement equation is defined as follows:

$$y_t = c_t + B_{1,t}y_{t-1} + \cdots + B_{k,t}y_{t-k} + u_t, \quad t = 1, \dots, T \quad u_t \sim N(0, \Omega_t) \tag{2}$$

where y_t is the $n \times 1$ vector of endogenous variables. The $n \times 1$ vector of time-varying constant terms is defined by c_t. The $n \times n$ matrices of the time-varying coefficients and unobservable shock are represented by $B_{i,t}$ and u_t, respectively. The error terms are assumed to have a normal distribution with a zero mean. The variance-covariance matrix of the error term is indicated by Ω_t. Triangular reduction of Ω_t can be identified by

$$A_t \Omega_t A_t' = \Sigma_t \Sigma_t' \tag{3}$$

In Equation 3, A_t and Σ_t are the triangular matrix and diagonal matrix, respectively. The triangular matrix reflects the simultaneous relationship of the structural shock by recursive identification, while the diagonal matrix reflects the time-varying idiosyncratic shocks (Primiceri, 2005, p.824):

$$A_t = \begin{bmatrix} 1 & 0 & \cdots & 0 \\ \alpha_{21,t} & 1 & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ \alpha_{n1,t} & \cdots & \alpha_{nn-1,t} & 1 \end{bmatrix} \qquad \Sigma_t = \begin{bmatrix} \sigma_{1,t} & 0 & \cdots & 0 \\ 0 & \sigma_{2,t} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \sigma_{n,t} \end{bmatrix} \tag{4}$$

For all i from 1 to n, σ_i is the standard deviation of the structural shocks while stacking the elements in the rows of B_i is composed by β with $k^2s \times 1$ dimension. Additionally, throughout the Kronecker product, $\otimes$, the endogenous variables and intercept matrix can be identified by $X_t = I_k \otimes ([1, y'_{t-1}, \dots y'_{t-k}])$. Given these definitions, the TVP-VAR model can be written as follows:

$$y_t = X_t \beta_t + A_t^{-1} \sum_t \varepsilon_t, \qquad \varepsilon_t \sim N(0, I) \tag{5}$$

The parameters A_t and Σ_t and the coefficients β_t are time-varying. To implement the time-varying parameters and error variances modelling strategy, assuming that α_t vector of lower-triangular elements in A_t with stacked by rows. In this matrix structure for all $i = 1, \dots, n$ identified $h_t = (h_{1t}, \dots, h_{nt})'$ with $h_{it} = \log \sigma_{it}^2$. (Nakajima *et al.*, 2011, p.227). Following Primiceri (2005) and Nakajima (2011) the state equations are assumed to exhibit the time-varying behavior of the parameters and error variances:

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[10] *It is possible to segment the general optimization problem into simplified local optimization problems without losing significant information, using approaches such as the Gibbs Sampler (Kubinschi and Barnea, 2016).*

[11] *The Hannan-Quinn and Schwarz Information Criteria are employed to determine the lag length in the VAR model. The optimal lag length is determined as two based on these criteria.*

$$\begin{aligned} \beta_{t+1} &= \beta_t + u_{\beta t}, \\ \alpha_{t+1} &= \alpha_t + u_{\alpha t}, \\ h_{t+1} &= h_t + u_{ht}, \end{aligned} \qquad \begin{bmatrix} e_t \\ u_{\beta_t} \\ u_{\alpha_t} \\ u_{h_t} \end{bmatrix} \sim N\left[0, \begin{bmatrix} I & 0 & 0 & 0 \\ 0 & \Sigma_\beta & 0 & 0 \\ 0 & 0 & \Sigma_\alpha & 0 \\ 0 & 0 & 0 & \Sigma_h \end{bmatrix}\right] \tag{6}$$

According to Primiceri (2005) and Nakajima (2011), the time-varying parameters of the measurement equations β_{t+1} and α_{t+1}follow a random walk, whereas the stochastic volatilities h_{t+1} follow an independent geometric (exponential) random walk. Finally, the error terms of the equations in the previous equations are assumed to be independent of one another and follow normal distributions (Toparlı *et al.*, 2019, p.5; Helmi *et al.*, 2023, p.6).

5. Empirical Findings

Before estimating the TVP-VAR models, possible parameter instabilities in the sample were examined by obtaining the recursive residuals from the linear VAR estimations. Recursive residuals outside the confidence bands indicate parameter instability (Çatık, 2020, p.65). As seen in Figure 2, the residuals of the production variable lay outside the confidence bands for most of the sample. The residuals for the exchange rate and domestic prices have increased considerably recently, while the parameter instabilities are more pronounced following the exchange rate shock in August 2018. These findings verify using time-varying models.

TVP-VAR model estimation involving several parameter estimations may lead to an over-parameterization problem. To this end, Bayesian methodology uses the Markov chain Monte Carlo (MCMC) algorithm. Following Nakajima (2011), we employed the multi-move sampling procedure among the many sampling procedures used to estimate Bayesian VARs. We drew 10.000 samples from the posterior distribution, separating the initial 1.000 as the burn-in sample.[12]

We investigated the stability of the selected parameters of the TVP-VAR models. As seen in Table 2, the estimation results indicate that the TVP-VAR model is appropriate for the analysis. First, the estimated parameters' first posterior mean remains within the upper and lower 95 percent, confidence bands. Second, Geweke's (1992) convergence diagnostics (CD) test is not high. Finally, the inefficiency factors are not rejected for all parameters of the TVP-VAR model, which confirms that the null hypothesis of convergence to the posterior distribution is valid (Nakajima *et al.*, 2011).[13]

[12] *In this paper, the priors of Nakajima (2011) were used to calibrate the TVP-VAR model:* $\Sigma_\beta \sim IW(25, 0.01I)$, $(\Sigma_\alpha)_i^{-2} \sim G(5, 0.02)$, $(\Sigma_h)_i^{-2} \sim G(5, 0.02)$. $(\Sigma_\alpha)_i^{-2}$ *and* $(\Sigma_h)_i^{-2}$ *indicate the* i^{th} *diagonal elements of the* Σ_α *and* Σ_h *matrices, respectively. The following flat priors were employed in the MCMC algorithm:* $\mu_{\beta_0} = \mu_{a_0} = \mu_{h_0}$ *and* $\Sigma_{\beta_0} = \Sigma_{a_0} = \Sigma_{h_0}$. *See Nakajima (2011) for a detailed explanation about the estimation steps of the TVP-VAR model.*

[13] *Additional diagnostic test results regarding stability, shown in Appendix Figure A1, also confirm the convergence. Since the autocorrelation functions of the selected parameters quickly converge to zero, their sample paths look steady. Furthermore, the distribution of selected parameters is close to the standard normal.*

Figure 2. Recursive residuals of the linear VAR model

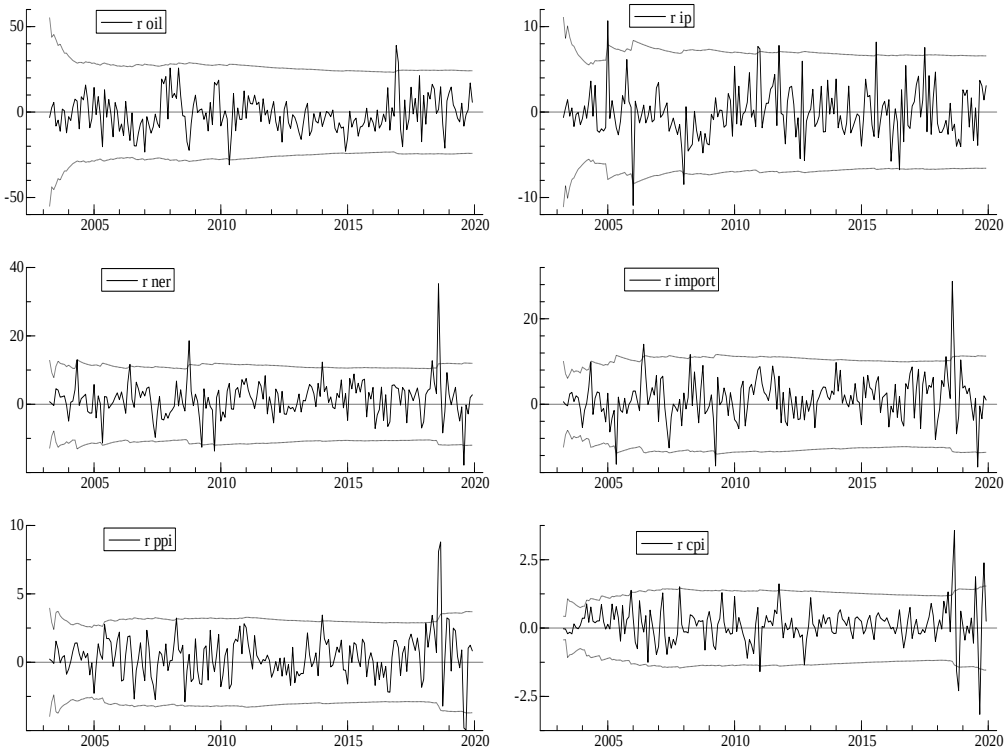


Table 2. Estimation results for selected parameters of the TVP-VAR model

Parameters	Mean	Std. Dev.	95%Lower	95%Upper	CD	Inefficiency
$(\Sigma_\beta)_1$	0.022	0.002	0.018	0.028	0.000	9.84
$(\Sigma_\beta)_2$	0.022	0.002	0.018	0.028	0.539	14.61
$(\Sigma_\alpha)_1$	0.062	0.018	0.037	0.106	0.066	67.28
$(\Sigma_\alpha)_2$	0.064	0.015	0.039	0.099	0.406	46.63
$(\Sigma_h)_1$	0.163	0.035	0.110	0.250	0.653	27.28
$(\Sigma_h)_2$	0.237	0.054	0.148	0.353	0.108	63.10

After the stability tests of the TVP-VAR models, estimation of the time-varying responses based on the time-varying variance-covariance matrix of residuals is presented in Equation 5 as the first step in computing the time-varying ERPT coefficients. We used cumulative responses of domestic

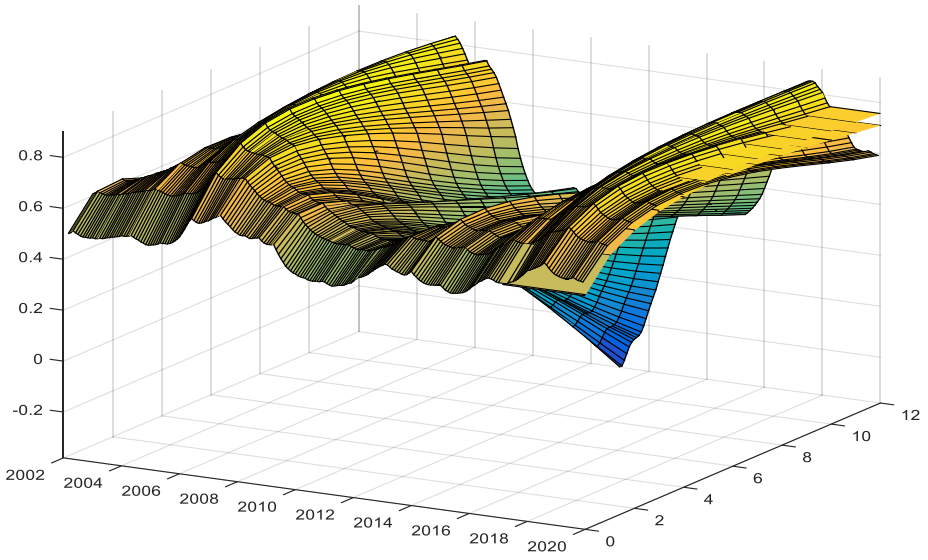
prices to calculate ERPT coefficients.[14] Following Leigh and Rossi (2002) and Kara *et al.* (2007), the time-varying ERPT coefficients are calculated employing the equation below:

$$TV - PT_{t,t+i} = \frac{crp_{t,t+i}}{crs_{t,t+i}} \quad (7)$$

where $TV - PT_{t,t+i}$ indicate the time-varying ERPT coefficients. The cumulative responses of domestic prices to the shock variable after the i-th period is shown by $crp_{t,t+i}$, whereas $crs_{t,t+i}$ represents the cumulative response of the shock variable to its shocks after the i period. Figures 3 to 5 present the time-varying ERPT coefficients calculated based on Equation 7. Panel (a) in Figures 3-5 shows the changes in ERPT coefficients in three-dimensional space, while panel (b) indicates the significance of the pass-through coefficients with standard error bands.

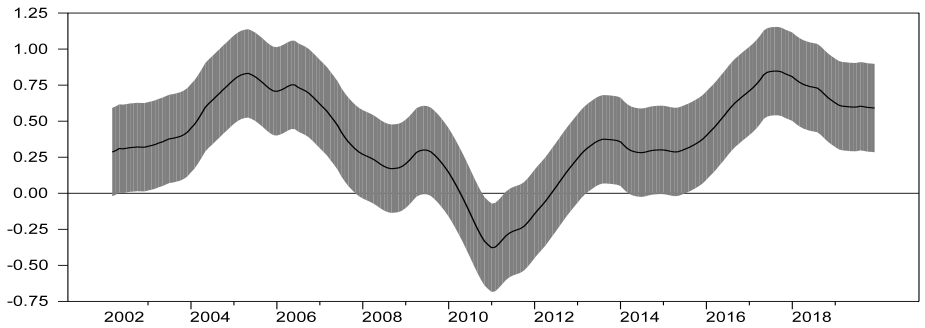
Figure 3. Time-varying exchange rate pass-through to import prices

(a) ERPT coefficients



[14] *Appendix Figures A2, A3, and A4 show time-varying cumulative responses of domestic prices to exchange rate shocks and their confidence intervals at h=12 with* $\pm$ *1 standard error.*

(b) ERPT coefficients at h=12 with ± 1 standard error bands

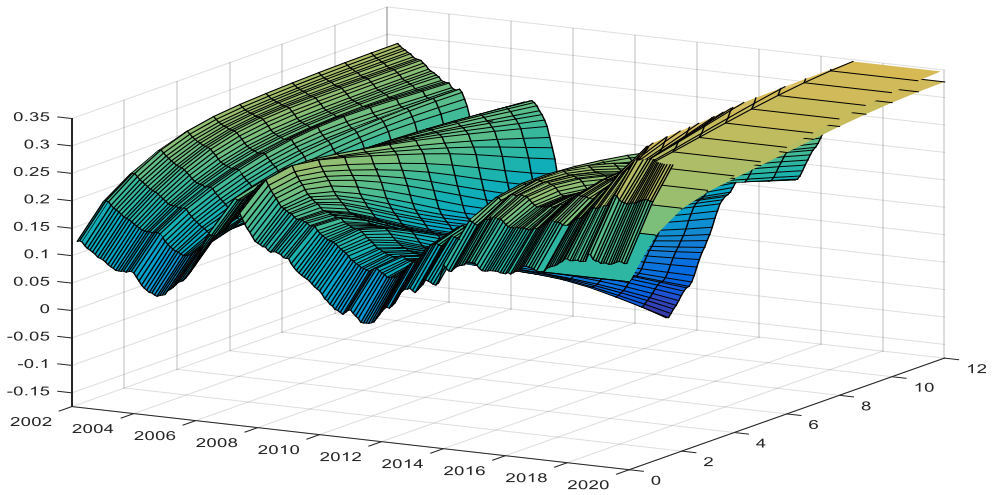


First, we examined ERPT to import prices, the first stage pass-through. The pass-through coefficient was around 80% in times of adapting to inflation targeting, but it decreased after 2006. The confidence bands indicate that ERPT was insignificant between 2008 and 2013 (see Figure 3 (b)). The coefficient, which increased gradually after 2013, exceeded 80% in late 2017.

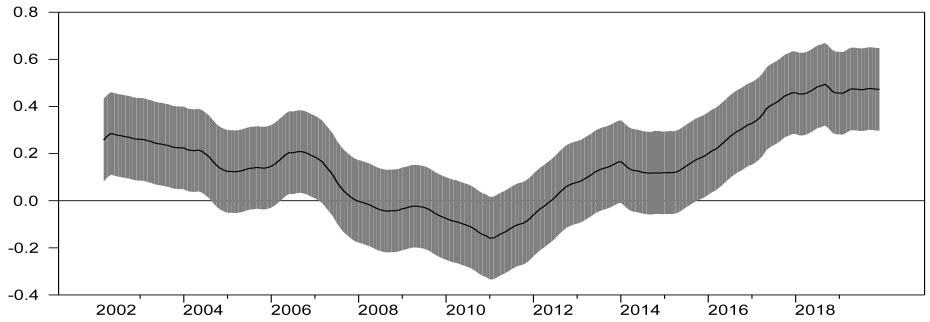
Understanding the relationship between producer and consumer prices is crucial for monetary policy behavior in defining the nature of inflation dynamics. Since producer prices reflect changes in input prices, such as raw materials and intermediate goods, it reveals the role of supply dynamics on consumer inflation. Changes in producer prices have lagged effects on consumer prices depending on the speed of the transmission mechanism. Figure 4 shows ERPT to producer prices in Turkey.

Figure 4. Time-varying exchange rate pass-through to producer prices

(a) ERPT coefficients



(b) ERPT coefficients at h=12 with ± 1 standard error bands



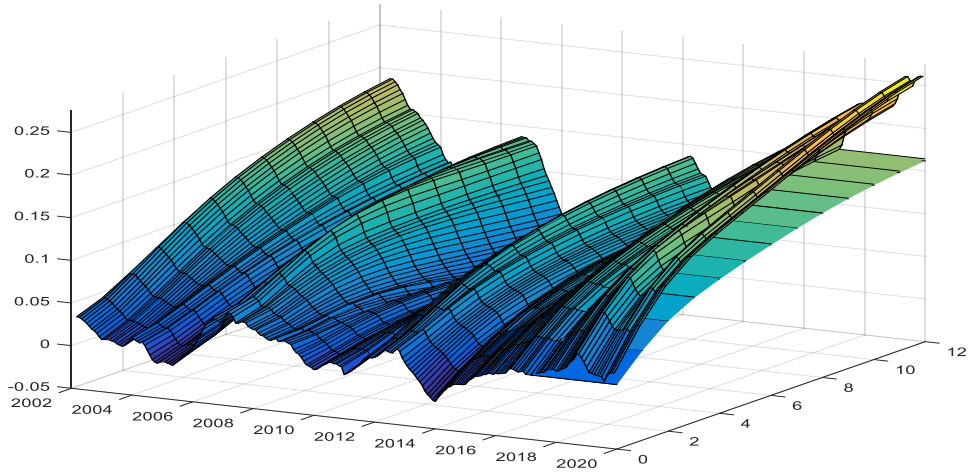
The mean pass-through coefficient was 15.69% over the sample period. More specifically, it was 10.25% between 2002 and 2011 but 21.18% after 2011. It was around 25% during the early periods of inflation targeting. However, it was gradually close to 50% in 2019.

In Turkey, where the share of intermediate goods in the composition of imported goods is over 70%, the imported inputs channel plays a key role in ERPT to producer prices (Ertuğ *et al.*, 2020). Accordingly, upside risks in firm costs are reflected in producer prices in times of TL depreciation. Another risk for ERPT in addition to the dominance of imported inputs in total imports is foreign currency borrowing. High capital inflows in the post-crisis era and macroprudential regulations that facilitated foreign currency borrowing[15] have significantly increased Turkey's private sector's external debt burden. More specifically, the external debt of non-financial corporations rose to 20% of GDP in 2018 from 15% in 2008 (IMF, 2019). Our findings are consistent with Ertuğ *et al.* (2020) and Fendoğlu *et al.* (2020), who reported that growing foreign currency debt increases ERPT in Turkey.

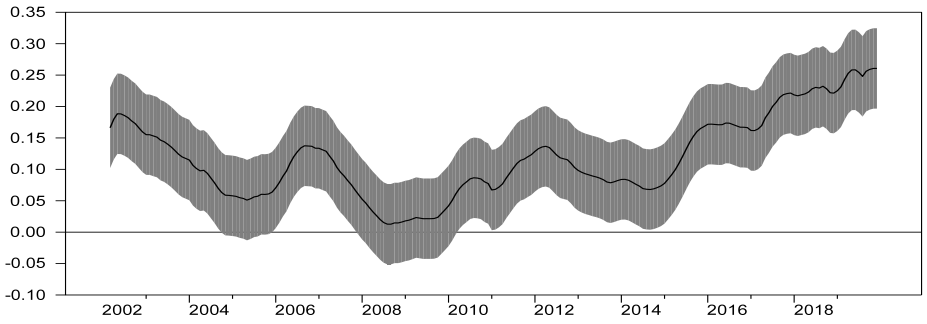
[15] *The regulation introduced in 2009 allowed corporations with no foreign currency income to borrow loans in foreign currency for at least one year with a minimum of 5 million US dollars without any foreign currency commitment (IMF, 2010).*

Figure 5. Time-varying exchange rate pass-through to consumer prices

(a) ERPT coefficients



(b) ERPT coefficients at h=12 with ± 1 standard error bands



As seen in Figure 5, ERPT to consumer prices declined significantly between 2002 and 2005. Low pass-through coefficients indicate that the disinflation policies implemented following the adoption of the inflation targeting regime were successful and show that the CBRT was on the way to achieving price stability. After the exchange rate shock of May 2006, however, the ERPT coefficient rose above 15% when TL depreciated by around 30% (Kara and Orak, 2008). During the GFC, ERPT gradually decreased to become statistically insignificant due to weakening growth performance because of shrinking demand and low inflation caused by a growing output gap.

The exchange rate gradually increased its contribution to consumer inflation after the new policy mix. The taper tantrum (Bernanke, 2013) triggered exchange rate fluctuations in all EMEs. The pass-through coefficient, which increased following both the exchange rate shock in August 2018 and the taper tantrum, peaked at over 25% in 2019.

Over the last decade, rising exchange rate volatility and exchange rate shocks have played a major role in increasing ERPT to consumer prices. Togay and Bulut (2021) reported that the exchange rate had more effect than inflation targets on inflation expectations in Turkey. Gülşen and Kara (2021) demonstrated that the impact of the exchange rate on inflation expectations has been rising in Turkey. Similarly, Koç *et al.* (2021) show that the effect of the exchange rate on inflation expectations increased in 2018. The negative impact of exchange rate fluctuations on inflation expectations is attributed to the change in monetary policy preferences in favor of growth. The effect of expansionary monetary policy to increase long-term interest rates indicates the uncertainty in inflation expectations (Karaman and Yıldırım-Karaman, 2019). Due to poor understanding of the new policy mix, monetary policy uncertainty increased (Cevik and Erduman, 2020). In addition, the credibility of the monetary policy was damaged due both to the CBRT's failure to achieve its inflation targets and also the increasing pressures it faced from the government to increase growth (Çakmaklı and Demiralp, 2020). The malfunctioning transmission mechanisms and a lack of credibility weakened the nominal anchor power of the policy rate and increased expectations of inflation (Gürkaynak *et al.*, 2015; Kara *et al.*, 2017a; IMF, 2018; Karaman and Yıldırım-Karaman, 2019).

A clearer comparison with the literature can be achieved by considering our findings as pre-and post-GFC. On the one hand, the decreasing ERPT coefficients before the GFC confirm the findings of Kara *et al.* (2007), Kara and Öğünç (2008), Çatık and Güçlü (2012) and Çatık *et al.* (2016) while the declining coefficients in the low and stable inflation environment also confirm Taylor's (2000) hypothesis. On the other hand, the statistically significant and increasing ERPT coefficients post-GFC largely confirm Kara *et al.* (2017a) and Gayaker *et al.* (2021). Similar to Kara and Sarıkaya (2021), we found a clear upward trend in ERPT to producer and consumer prices after 2017. Furthermore, increasing ERPT during sharp depreciations, such as May 2006 and August 2018, is also consistent with Kal *et al.* (2015) and Türel and Orhan (2022).

6. Conclusion

This paper analyzed ERPT to domestic prices in Turkey using the TVP-VAR model for the period 2002:01 to 2019:12. The empirical results can be summarized as follows. The ERPT coefficient in all domestic prices was less than 1 when it was statistically significant, which indicates incomplete pass-through. The effect of the distribution chain was confirmed because the highest coefficient was for import prices, whereas the lowest was for consumer prices. As for the pattern of ERPT, the pass-through followed a similar path for all domestic prices. The pass-through coefficients declined with the transition to inflation targeting and became statistically insignificant during the GFC to reach their lowest values. ERPT to domestic prices, which increased gradually after 2011, peaked at the end of the sample period (except for ERPT to import prices).

Our findings re-confirm Taylor's (2000) hypothesis. In the low and stable inflationary environment induced by a successful disinflation process, the ERPT coefficients also remained low. Conversely, ERPT increased dramatically in the last decade. In addition to triggering exogenous factors, such as rising exchange rate volatility and exchange rate shocks, this can be explained by several endogenous factors. The high share of imported inputs in total imports and the increase in corporations' foreign currency debt were reflected in producer prices through rising costs due to domestic currency depreciation. The upward trend in ERPT to consumer prices may be attributed to factors that increased inflation expectations. These expectations became difficult to anchor because the transmission mechanism no longer functioned properly due to the new policy mix. In addition, policy authorities' growth priorities further undermined the credibility of CBRT monetary policy, which was already weakened by its failure to achieve inflation targets.

ERPT to domestic prices has risen in Turkey since 2010. However, this does not mean that the reducing effect on ERPT of inflation targeting has disappeared. Rather, inflation targeting was not

implemented successfully in Turkey due to an unorthodox monetary policy manner that favored financial stability and growth during the relevant period.

Our study has some limitations. First, the sample only focused on the period before the COVID-19 pandemic and recent external shocks. Therefore, current data with proper context may shed light on the impact of recent developments on ERPT. Second, the study only focused on determining time-varying ERPT coefficients. Given the time-varying nature of ERPT, analyzing ERPT by considering the shocks that affect exchange rates or examining ERPT determinants with time-varying methods may contribute to filling the research gap, especially for the Turkish economy. Finally, time-varying panel data models may also contribute to a better understanding of the evolution of ERPT in EMEs.

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