Colak, Yasemin; Erden, Lutfi

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Exchange rate pass-through: An analysis of a panel quantile regression

Yasemin Colak[*] • Lutfi Erden

Hacettepe University, Department of Economics, Ankara, Turkey

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Abstract

The purpose of this study is to examine the degree of exchange rate pass-through (ERPT) with the focus on Taylor (2000)'s hypothesis that asserts ERPT tends to be high (low) in high (low) inflation states. To this end, a panel quantile regression is applied to the data from 37 countries over the period of 1996-2018. The panel quantile regression allows us to capture the distributional heterogeneity in the ERPT coefficient and thus to directly address the question of whether the ERPT degree depends on the inflationary environment. The results indicate that ERPT is low (high) at low (high) quantiles of the inflation rate, supporting Taylor's hypothesis.

Keywords: exchange rate pass-through; Taylor's hypothesis; panel quantile regression
JEL Classification Codes: C13, E31, F31

1. Introduction

The transmission of the change in the exchange rate to domestic prices is a phenomenon known as exchange rate pass-through (ERPT). The degree of ERPT is essential for policy implementations of central banks. The degree of pass-through plays a crucial role in price stability and optimal exchange rate regimes. A low degree of ERPT allows maintaining an independent monetary policy and successfully implementing inflation targeting strategy.

A novel study by Taylor (2000) predicts that the exchange rate pass-through to domestic price will be higher in a high inflation environment where price fluctuations are likely to be perceived as permanent. Adopting a staggered price-setting model in a monopolistic competitive environment with rational expectations, Taylor (2000) indicates that any transfer to prices as a result of, for example, exchange rate movements depends on the pricing power of firms. In this model, firms make their pricing decisions four periods in advance. Thus, price decisions will depend on expectations. In case of a rise in marginal costs, firms pass through to prices based on other firms' anticipation of whether the increase is permanent or not. Therefore, in anticipation of permanent increase, we expect to observe greater pass through. Especially in a high inflation environment, these changes tend to be more persistent, leading to higher pass through.

[*] Corresponding author. E-mail: yasemin.colak@hacettepe.edu.tr.

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In the empirical literature, although there has been a growing body of studies investigating the ERPT phenomenon, there are limited number of studies empirically focusing on Taylor's hypothesis. The studies on single country experiences adopt nonlinear time series techniques such as Smooth Transition Autoregressive and Markov-Switching models using the inflation rate as a transitioning (regime shifting) variable (Baharumshah et al., 2017; Herzberg et al., 2003; Holmes, 2009; Junttila and Korhonen, 2012; Shintani et al., 2013). These studies find the ERPT coefficient is higher in high inflation regimes, providing evidence in favor of the Taylor's hypothesis. The studies on multi county experiences employ two step methodology to examine the Taylor's hypothesis. After obtaining time-varying ERPT coefficients for each country in the first step by applying split sample (Choudhri and Hakura, 2006), rolling regression (Brun-Aguerre et al., 2012), DCC-GARCH method (Ozkan and Erden, 2015) and quantile regression (Chou, 2019), these studies relate the ERPT with the average inflation rate among other variables in a panel regression in the second step. The results from the second stage regressions indicate that the ERPT degree responds positively to the average inflation rate, supporting the Taylor's hypothesis. However, the two-step approach is subject to serious econometric problems. The previous panel studies obtain ERPT coefficients of each country in the first step by assuming the degrees of ERPT of each country are identically and independently distributed. In the second step, they regress these estimated ERPT degrees on a set of explanatory variables along with the average inflation attempting to see the response of estimated ERPT degrees to average inflation. However, as most of the global shocks are transmitted through exchange rate fluctuations across countries, the assumption of independent ERPT degrees across countries is overly simplifying and contradictory, and thus may affect the second step analysis, resulting in efficiency losses. Given these considerations, the present study revisits the Taylor's hypothesis employing panel quantile regression to estimate the ERPT degrees and thus the impact of inflation states on ERPT degrees in a single step.

To this end, we use panel data from a sample of 37 countries over the quarterly periods of 1996:1-2018:4. The panel quantile regression serves as a convenient way to test the Taylor's hypothesis by allowing us to capture any heterogeneity in the ERPT coefficient at the conditional distribution of inflation rate. Therefore, we are able to directly address the question of whether the ERPT coefficient differs with respect to the quantiles of inflation rate. Another advantage of panel quantile regression is that heterogenous (nonlinear) ERPT parameter can be evaluated in a linear modeling framework by fitting not on conditional mean as in traditional regressions but on conditional quantiles of price fluctuations, yielding more precise estimates (Chou, 2019; Zhu et al., 2016).

2. Methodology

Following Koenker (2004), one can define a dynamic panel quantile regression as

$$Q_{y_{it}}\left(\tau|x_{it}, y_{it-1,}\eta_i\right) = \eta_i + \alpha(\tau)y_{it-1,} + x_{it}^T\beta(\tau) + u_{it} \quad (1)$$

where η_{i_i} represents the fixed effects, and *u* is the disturbance term. y_{it-1} is the lagged dependent variable. This specification is an extension of the general representation of quantile regression introduced by Koenker and Bassett (1978). For a panelized version of the panel quantile regression with fixed effects taking into account of unobserved heterogeneity across cross section units, the loss function can be written as the following (Koenker, 2004);

$$min_{\alpha,\beta} \sum_{k=1}^{K} \sum_{t=1}^{T} \sum_{i=1}^{N} w_k \rho_{\tau_k}\left(y_{it} - \eta_i - \alpha(\tau)y_{it-1,} - x_{it}^T\beta(\tau_k)\right) + \lambda \sum_{i}^{N} \left|\eta_{i_i}\right| \quad (2)$$

where i is country index, *k* is quantile index, T is the total number of observations per countries, τ represents the τ th quantile and ρ_{τ_k} represents loss function. w_k is the weights for panel quantiles. The weights are used as equal for all quantiles summing to 1.

After laying out the generic panel quantile regression, we consider an open economy Philips curve[1] to analyze the ERPT degree where inflation rate responds to demand and supply shocks as well as exchange rate fluctuations (See for example Takhtamanova, 2010). This serves as a suitable empirical framework as it accounts for supply and demand pressures as well as the effects of domestic and global shocks on inflation. Because of inflation inertia, we consider dynamic panel model including the lagged dependent variable as an explanatory variable. Accordingly, the model can be specified as follows:

$$Q_{y_{it}}\left(\tau | x_{it,}\eta_{i_i}, y_{it-1}, \varepsilon_{it}\right) = \eta_i + \beta_{1\tau} y_{it-1} + \beta_{2\tau}\Delta EXCHANGE\ RATE_{\ it} + \beta_{3\tau} GAP_{it} + \beta_{4\tau}\Delta OIL_{it} + \varepsilon_{it} \quad (3)$$

i represents country index, and t is the time and y_{it} denotes the inflation rate measured as the log difference of consumer price index (CPI). Δ is the (logarithmic) first difference operator and ε_{it} is the disturbance term. Exchange rate is bilateral rate quoted with US dollar as base currency.GAP is the output gap measured as the deviation of real GDP from its HP trend (Hodrick & Prescott, 1997). OIL denotes oil prices taken to represent supply shocks. $\beta_{2\tau}$is a measure of the ERPT degree that might be heterogenous at conditional distribution of inflation rate.

3. Data

The data used for panel quantile regression analysis are obtained from various sources. The inflation rate (quarterly percentage change in CPI) and the exchange rates (domestic currency per US dollar) are taken from the International Financial Statistics (IFS) of IMF. Global prices of WTI crude oil (OIL) are obtained from the Federal Reserve Bank of St. Louis. The data on real GDP are gathered from OECD statistics to obtain the output gap, which is the deviation of real GDP from its HP trend. Based on the data availability at quarterly frequencies, our unbalanced panel data set covers 37 countries[2] over the quarterly periods of 1996:Q1- 2018:Q4.

Table 1 shows descriptive statistics of data. Our data set covers developed and developing countries. In order to see the extent of variation in the inflation rates across the countries, we average the inflation rate over time for each country and identify the quantiles with respect to the average inflation into which each country falls. The developing countries (Colombia, Costa Rica, Russia and Turkey) have the highest mean inflation rate which fall top %10 quantile. Not surprisingly, countries display the lowest mean inflation rate are advanced countries (Switzerland, France, Japan and Sweden). On the other hand, there are 17 euro adopter countries out of our sample. The average inflation rates of Euro adopters over the sample period fall below 0.4 quantile. except for the average inflation of late Euro adopters such as Estonia, Latvia, Slovenia, Slovakia.

Table 1. Descriptive statistics.

Variable	Mean	Std. dev.	Min.	25 %	Median	75 %	Max.
Inflation	0.918	1.836	-3.025	0.149	0.578	1.200	39.840
Exchange rate	0.496	5.128	-16.650	-2.620	0.133	2.986	64.471
Oil	1.196	15.380	-71.067	-5.001	3.010	10.876	32.873
Gap	-0.003	0.693	-7.460	-0.263	0.003	0.262	8.375

[1] In the empirical ERPT literature, the studies use some form of Phillips curve or purchaing power parity relation derived mainly from the framework of new open economy macroeconomics models as empirical models (Choudhri and Hakura, 2006; Ghosh and Rajan, 2009).

[2] Austria, Australia, Belgium, Brazil, Canada, Czech Republic ,Chile, Colombia, Costa Rica, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Latvia, Luxembourg, Netherland, New Zealand, Norway, Poland, Portugal, Russia, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, United Kingdom, Turkey.

4. Empirical results

As is well known, estimating dynamic panel regression such as (3) with fixed effects results in an endogeneity bias (called Nickell bias). However, when T is large relative to N as is the case in this study (T=92), it is shown that the bias is negligible (Judson and Owen, 1999). Further, according to the study by Galvao and Montes-Rojas (2010), one of the advantages of the shrinkage models such as the penalized dynamic panel quantile regression (3) is that it can reduce dynamic bias by shrinking the FE. Thus they suggest the use of the panelized dynamic quantile model estimation to overcome the problem of dynamic bias resulting from endogeneity and/or weak instruments in instrumental variable (IV) estimation technique. Following the lead of the study by Galvo and Montes-Rojas (2010), we estimate the regression (3) by using a panelized version of the loss function, setting the penalty parameter λ to 1that shrinks the FE coefficients towards zero[3]. We choose k to be 9 ($\tau = 0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9$) in order to clearly see if there exists any distiributional heterogeneity in ERPT degrees.

The results are presented in Table 2. The columns gives the results from quantile (0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9 respectively) estimation. As seen, all coefficients have the expected signs. The coefficients on the control variables representing demand and supply shocks are positive and significant at different quantiles. We observe a slight increasing pattern of the effects of oil price changes along with the quantiles. The positive coefficients of output gap in all quantiles indicate the impact on inflation rates of the demand pressure of overcapacity. It is also interesting to note that the coefficients of gap decline along with quantiles, getting almost 3 times as large at 0.1 quantile as it is at the 0.9 quantile. One explanation for this could be that the global shocks due to exchange rate fluctuations come to play more dominant role in affecting inflation than domestics demand pressures at high inflation states, and vice versa.The coefficients of the lagged inflation are insignificant at low quantiles while they become significant and are increasing starting from 0.4 quantile. This shows that inflation is not persistent when it is low but becomes rather persistent when it is high.

In order to focus on the ERPT coefficients, we depict them at different quantiles in Figure 1. As seen, they are all positive and significant across the quantiles. The distributional heterogeneity in the ERPT seems to be present. More specifically, the results show the ERPT coefficient increases along with the quantiles ranging from 0.015 at the 10^{th} quantile to 0.053 at the 90^{th} quantile[4]. ERPT coefficients are low at the low quantiles and get larger along with the higher quantiles of inflation.These results clearly lend support for the Taylor's hypothesis.

The magnitude of ERPT degrees is quite close to those of previous panel data studies (Ozkan and Erden, 2015; Jimborean, 2013).

Since there are 17 Euro members out of 37 countries in our sample that adopted Euro at different dates during the sample periods of 1996-2018, it would be interesting to see if the ERPT degrees for Euro adopters differ. To this end, we define a dichotomous (dummy) variable that takes a value of zero for noneuro countries and a value of one for euro members, and include the interaction of dummy with exchange rate into the model. The results from this experiment

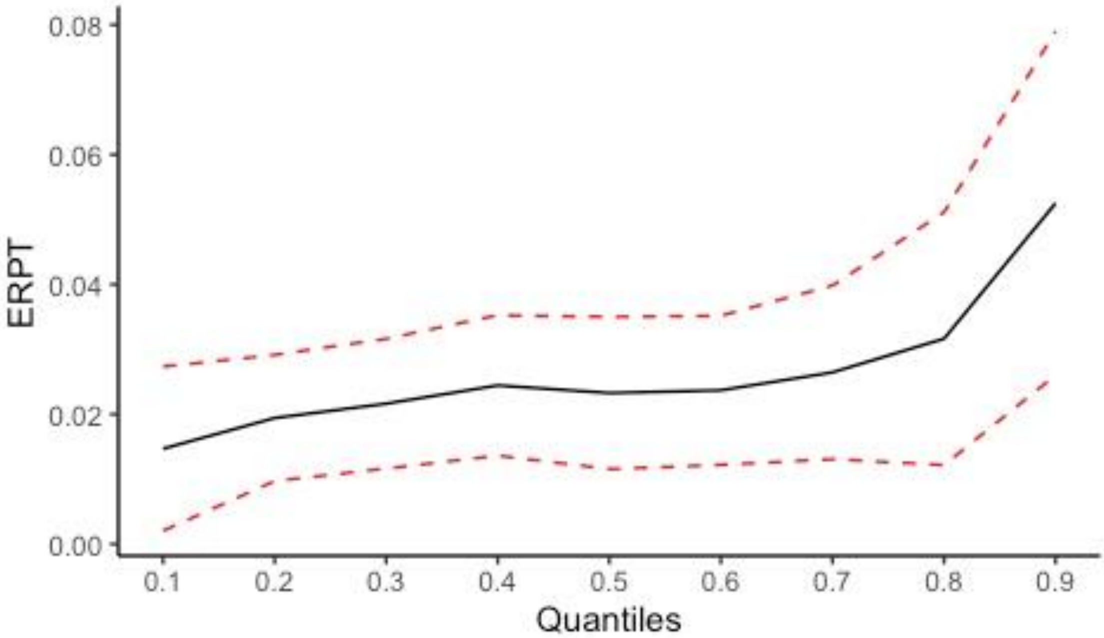
[3] We experiment with λ=0 and 0.5. However, the main results remain the same.

[4] Since our objective is to see if ERPT degrees get higher along with the quantiles of inflation, it would be sufficient to check for homogeneity of the ERPT degrees between low (0.1 quantile), medium (0.5 quantile) and high (0.9 quantile) of inflation rates. One way to see if there are significant differences in the ERPT degrees is to estimate interquantile regressions. We estimate 0.9-0.1, 0.9-0.5 and 0.5-0.1 interquantile regressions and find there exist distributional heterogeneity for the impacts of all variables. Especially, the presence of the significant differences in the ERPT degrees from low (0.1) to medium (0.5) and medium (0.5) to high (0.9) inflation states supports Taylor's hypothesis.

show that the degree of ERPT ranges from 0.029 at 0.1 percentile to 0.062 at 0.9 percentile for noneuro countries while it ranges from 0.0 to 0.009 for euro adopters[5]. In fact, the degrees of ERPT for euro adopters are very small and seem to be homogenous over the quantiles. This result is not surprising because most Euro adopters have the lowest inflation rates in our full sample, resulting in the lowest ERPT degrees for Euro members. This finding supports our previous results on Taylor's hypothesis that predict low ERPT degrees in low inflation environments. One of the reasons for Euro countries to experience such low inflation rates and thus low ERPT could be monetary stability due to independent monetary policy for Euro adopters.

Further, to take into consideration the possibility of the delayed responses of inflation to exchange rate movements, and thus to analyze the long run ERPT degrees, we estimate the panel quantile regression with distributed lags (4 lags because of quarterly data). Table 3 presents the results with the bold row showing the long run ERPT degrees. As seen, the short run pass through follows a similar pattern as before, increasing along with the quantiles although a little smaller in magnitude. The long run ERPT degrees are higher in magnitude as expected. Although the long run ERPT degrees seem to be homogenous around 0.05 up until 0.7 quantile, they start to rise up dramatically to 0.075 at 0.8 and to 0.115 at 0.9 quantile. This means that Taylor's hypothesis still holds in the long run but we observe higher long run pass through only at the extreme (tail) rates of inflation.

Figure 1. Estimated degrees of ERPT.



Notes: The black line shows the ERPT coefficients from dynamic panel quantile estimation. The dashed lines represent 95% confidence interval.

5. Concluding remarks

As most countries across the world have became more integrated and open along with the globalization waves, exchange rate fluctuations have come to play a pivotal role in transmitting external shocks to domestic economies. When the countries aiming to maintain price stability experienced difficulty because of high degrees of ERPT, policy makers started questioning the policy of the adaptation of floating exchange rate regime along with openness to international

[5] These results are available upon request.

Table 2. Panel Quantile Regression Results.

	Quantiles								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
y_{t-1}	-0.023 (0.099)	0.075 (0.105)	0.120 (0.101)	0.173* (0.105)	0.232** (0.113)	0.299*** (0.111)	0.352*** (0.122)	0.411*** (0.133)	0.557*** (0.127)
EXCHANGE RATE	0.015 ** (0.006)	0.019*** (0.005)	0.022*** (0.005)	0.024*** (0.006)	0.023*** (0.006)	0.024*** (0.006)	0.026*** (0.007)	0.032*** (0.010)	0.053*** (0.014)
GAP	0.102 *** (0.020)	0.078*** (0.017)	0.079*** (0.013)	0.077*** (0.013)	0.074*** (0.012)	0.064*** (0.014)	0.061*** (0.014)	0.054*** (0.016)	0.036* (0.020)
OIL	0.017*** (0.002)	0.014*** (0.001)	0.0141** (0.001)	0.015*** (0.001)	0.015*** (0.001)	0.015*** (0.001)	0.016*** (0.001)	0.017*** (0.002)	0.020*** (0.002)

Notes: *,**,*** denote the significance level %10,%5, %1 respectively. The standard errors are in parenthesis.

Table 3. Panel Quantile Regression Results with lagged variables.

	Quantiles								
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
$inflation_{-1}$	-0.110 (0.102)	-0.035 (0.102)	0.053 (0.095)	0.095 (0.091)	0.140 (0.091)	0.195** (0.096)	0.247** (0.103)	0.312*** (0.121)	0.433*** (0.131)
Exchange rate	0.009* (0.005)	0.010** (0.005)	0.014*** (0.005)	0.015*** (0.005)	0.019*** (0.006)	0.018*** (0.006)	0.019*** (0.006)	0.026*** (0.009)	0.040*** (0.012)
$Exchange\ rate_{-1}$	0.012** (0.005)	0.007 (0.004)	0.010** (0.004)	0.007 (0.005)	0.009 (0.006)	0.009 (0.006)	0.010 (0.006)	0.013* (0.007)	0.015 (0.011)
$Exchange\ rate_{-2}$	0.006 (0.008)	0.008* (0.005)	0.006* (0.003)	0.006** (0.003)	0.003 (0.003)	0.004 (0.004)	0.006 (0.005)	0.009 (0.007)	0.030*** (0.010)
$Exchange\ rate_{-3}$	0.011** (0.004)	0.011*** (0.004)	0.009** (0.003)	0.012*** (0.003)	0.011*** (0.004)	0.010*** (0.003)	0.007** (0.003)	0.010** (0.005)	0.009 (0.007)
$Exchange\ rate_{-4}$	0.013*** (0.004)	0.010*** (0.003)	0.005* (0.003)	0.008** (0.003)	0.013*** (0.003)	0.012*** (0.004)	0.014*** (0.004)	0.018*** (0.005)	0.020*** (0.008)
$\sum_{j=0}^{4} Exchange\ rate_{it-j}$	**0.051*** (0.014)**	**0.046*** **(0.012)	**0.045*** **(0.012)	**0.047*** (0.013)**	0.056*** (0.015)	**0.052*** (0.014)**	**0.056*** (0.017)**	0.075*** (0.021)	0.115*** **(0.029)**

Table 3 (cont.) Panel Quantile Regression Results with lagged variables.

	Quantiles								
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
gap	0.058**	0.038*	0.034*	0.017	0.012	0.032**	0.032*	0.002	-0.034**
	(0.028)	(0.022)	(0.020)	(0.016)	(0.013)	(0.014)	(0.018)	(0.017)	(0.021)
gap_{-1}	0.041**	0.039**	0.038**	0.062***	0.048***	0.024	0.012	0.027	0.052
	(0.021)	(0.017)	(0.018)	(0.020)	(0.017)	(0.017)	(0.020)	(0.025)	(0.037)
gap_{-2}	0.012	0.007	-0.003	-0.012	0.018	0.024	0.021	0.032	0.038
	(0.030)	(0.020)	(0.018)	(0.020)	(0.021)	(0.020)	(0.021)	(0.022)	(0.031)
gap_{-3}	-0.036	0.012	0.019	0.017	0.010	0.010	0.015	0.005	-0.004
	(0.025)	(0.016)	(0.014)	(0.015)	(0.018)	(0.020)	(0.018)	(0.025)	(0.038)
gap_{-4}	0.030	-0.010	-0.004	-0.000	-0.000	0.001	0.006	0.027	0.018
	(0.021)	(0.018)	(0.015)	(0.013)	(0.012)	(0.012)	(0.012)	(0.017)	(0.028)
oil	0.016***	0.014***	0.015***	0.016***	0.017***	0.016***	0.018***	0.020***	0.021***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.003)
oil_{-1}	0.006**	0.004***	0.004***	0.002	0.002	0.001	-0.000	0.001	0.002
	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.004)
oil_{-2}	0.006***	0.003*	0.001	0.001	0.001	0.002	0.003**	0.004**	0.004
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
oil_{-3}	0.005***	0.006***	0.006***	0.006***	0.006***	0.007***	0.007***	0.009***	0.010***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
oil_{-4}	0.007***	0.005***	0.003***	0.003***	0.004***	0.003**	0.003**	0.003**	0.000
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)

Notes: *,**,*** denote the significance level %10,%5, %1 respectively. The standard errors are in parenthesis.

capital mobility. However, a novel study by Taylor (2000) raised an argument that the extent of ERPT mainly depends on the monetary stance of a domestic economy, predicting that the ERPT degree is higher in a high inflation environment where monetary shocks are likely to be perceived as permanent. Accordingly, there is no need for "fear of floating" with regard to the ERPT degree as long as monetary policy is credible in maintaining monetary stability and thus low inflation regime. The previous empirical studies provide supporting evidence for the Taylor's hypothesis. The present study reexamines the issue by employing a panel quantile regression that serves as a suitable empirical strategy to directly test the Taylor's hypothesis. Using data from a panel of 37 countries we estimate various panel quantile regressions and find that the degree of ERPT is low at the low quantiles and getting larger along with the higher quantiles of inflation rates. These results clearly support the Taylor's hypothesis, reinforcing the previous findings. Instable monetary condition seems to be the major factor magnifying the extent of ERPT and resulting in an inflationary vicious circle. The policy implication of this finding is obvious. To stabilize prices, monetary policies must be geared towards achieving low inflation regime to mitigate the impact on domestic prices of exchange rate shocks. In so doing, policy makers should establish stronger institutional infrastructures to back up the credibility of monetary policy. This might in turn reduce the expected impact of exchange rate movements on future costs and domestic prices, leading to lower ERPT degree and lower inflation rate. Of course, the different pass-through coefficients might also be due to the nominal exchange rate regimes, the different currency of denomination, and also differences in product introductions, all of which might produce a correlation between the inflation rate and the pass-through above and beyond monetary stability.

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