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Full Length Article

Exchange rate uncertainty and the connectedness of inflation

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Abstract

In this study, we examine the connectedness of exchange rate uncertainty and inflation. In an economy with a flexible exchange rate, price rigidities can lead importers to carry exchange rate risk and they impose a premium for the risk they face by increasing consumer prices. This pricing behavior provides a channel between exchange rate uncertainty and overall price level. We empirically analyze the impact of exchange rate uncertainty on inflation by using panel data from 149 countries over the period 1980–2017. The estimation results point that the uncertainty of the exchange rate has a significant and positive effect on inflation. We also show that effect of exchange rate uncertainty on inflation is nonlinear. As the exchange rate uncertainty increases, the size of its effect on inflation decreases. Moreover, the degree of exchange rate pass-through and the effect of exchange rate uncertainty on inflation differ among country groups and their effects on inflation have decreased through time.

JEL classification: E31; E52; F41

Keywords: Exchange rate pass-through; Exchange rate uncertainty; Financial stability; Inflation; Pricing power

1. Introduction

Predicting the future is often difficult, particularly when uncertainty is high! As shown by ample evidence, people avoid uncertainty as much as possible, and their behavior changes a great deal in uncertain environments (e.g., Kahneman & Tversky, 1974; Von Neumann & Morgenstern, 1944). Standard economic theory also asserts that individual decision making differs in environments of uncertainty more than in circumstances of certainty. In the global economy, exchange rates are far and away the most volatile variable macroeconomic aggregate. What are consequences of exchange rate uncertainty and fluctuations for economies, specifically at the aggregate price level? Can exchange rate uncertainty increase inflation? In this paper, we study exchange rate uncertainty and attempt to determine the effects of exchange rate uncertainty on the aggregate price level.

Central banks are concerned about exchange rate fluctuations at least for two reasons. First, fluctuations in the exchange rate may reflect their effects at the aggregate price level. This effect, also known as the exchange rate pass-through, refers to the effect of a change (either increase or decrease) in the exchange rate on the overall price level (e.g., Nasir & Vo, 2020). The exchange rate pass-through is a critical element of a country's overall price stability, is important for allocative efficiency and taming deflation. Second, exchange rate fluctuations are important for financial stabilization, which is heavily weighted by central banks, in particular since 2008 global financial crisis (Nasir & Du, 2018).

Exchange rate pass-through is extensively studied in the literature. However, little is known about the impacts of uncertainty in exchange rates on the aggregate price level. In this study, we examine the effect of exchange rate uncertainty on the aggregate price level. First, to guide our empirical strategy, we introduce a stylized model. We show that price rigidity can

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lead importers to carry exchange rate risk and give them incentives for increasing consumer prices when exchange rate uncertainty increases. Next, we empirically examine the effects of exchange rate uncertainty on inflation (hereafter, called exchange rate uncertainty pass-through, or ERUPT). Furthermore, we examine whether the effect of exchange rate uncertainty on inflation is nonlinear and analyze the evolution in ERUPT over time and differences among some groups of country.

In a simple theoretical framework, we consider a small open economy with a flexible exchange rate and with an imported final goods sector that is monopolistically competitive. The first component of our framework is price rigidity. The price of goods is set at the beginning of each period before the exchange rate is known. Second, following Calvo and Reinheart (2000), we assume that forward markets are nonexistent or illiquid, so importers face difficulty in hedging and are averse to bearing the risk of possible exchange rate depreciation. In the model economy, the exchange rate is assumed to be an exogenous random variable.

Our stylized model formalizes the idea that, as prices are sticky, importers cannot reflect changes in exchange rate fluctuations to consumer prices simultaneously, so they face a risk of exchange rate depreciation. This creates a motive for them to increase their prices in advance. In a sense, importers add an exchange rate risk premium to consumer prices, and they raise the "risk premium" on consumer prices when uncertainty in exchange rate movement increases. This price behavior creates a channel through which exchange rate uncertainty affects consumer prices. Moreover, as exchange rate uncertainty has a direct effect on price levels, it decreases exchange rate pass-through (ERPT). For example, when the exchange rate depreciates, consumer prices rise more than the expected exchange rate depreciation due to a premium imposed on consumer prices.

In the empirical analysis, we use annual data from 149 countries over the period 1980 to 2017. We employ an open market Phillips curve specification and measure the inflation rate as the first difference of the logarithm of the consumer price index (CPI). To measure exchange rate uncertainty, we use observed volatility, which is measured by the standard deviation, and conditional volatility, which is estimated by a GARCH model. We use the following control variables as proxies for demand and supply shocks: the output gap, the lagged inflation term, and the crude oil price. Then, we employ fixed-effects specifications in the analysis. Moreover, to account for possible endogeneity problems, we employ the system GMM, and, to account for cross-sectional dependence, we estimate panel-corrected standard errors.

Our empirical results demonstrate that exchange rate uncertainty significantly increases inflation. In addition, we establish that the size of the effect diminishes as exchange rate uncertainty increases. When we estimate the open market Phillips curve specification with real exchange rate and real exchange rate uncertainty, we again find a positive and significant effect of real exchange rate uncertainty on inflation.

We also analyze differences in the relation between exchange rate uncertainty and inflation among groups of countries based on income levels and its evolution over time. The existing literature shows that ERPT declines over time. In line with the existing literature, we find that uncertainty pass-through declines over time. The estimated coefficients of uncertainty pass-through also differ among countries in different income groups. Overall, changes in the uncertainty of the exchange rate lead to a significant change in inflation in all groups of countries by income except low-income countries.

Our paper is related to three strands of the literature. The first is the literature on exchange rate disconnection, which focuses on how and why exchange rate movements are disconnected from other macroeconomic aggregates, especially real ones. Among the many papers in this stream, highlight Krugman (1988), Obstfeld and Rogoff (2000), Duarte and Stockman (2002), and Amiti, Itskhoki, and Konings (2014). Krugman (1988) argues that imperfect integration of the global economy is one reason for the disconnection of exchange rates and that, because the exchange rate is so volatile and uncertain, it is disconnected from fundamentals, which leads to greater volatility. According to Obstfeld and Rogoff (2000), the reasons for this disconnection are price rigidity, international trade costs, and the pricing power of firms. Duarte and Stockman (2002) investigate the role of noise traders in leading volatile exchange rates and their disconnection from fundamentals. Amiti et al. (2014) explain this "disconnection" as a mixture of market share, markup, and the presence of large importers in international trade. However, Bleaney (1996), Cushman (1986), Sharma and Pal (2019) present the relation between exchange rate uncertainty and international trade volume as an exception to "disconnection." They argue that exchange rate uncertainty has a significant impact on export and import volumes. In this literature, our paper is closest to Obstfeld and Rogoff (2000) because we share them the notion that price rigidity plays a key role in the disconnection of exchange rate movements from fundamentals, but we show that price rigidity can also lead to exchange rate uncertainty and has a significant effect on the aggregate price level.

Second, our paper is related to literature on ERPT, which examines the effects of exchange rate movements on the aggregate price level. The extensive literature in this stream has achieved a consensus that ERPT has a positive but incomplete effect (see Burstein & Gopinath, 2014; Pham, Nguyen, Nasir, Huynh, & Steinherr, 2020). Among the important factors determining the degree of ERPT are demand shocks (Mann, 1986), price rigidity (Choudhri & Hakura, 2006; Taylor, 2000), trade costs, tariffs, oil shocks (Nasir, Huynh,& Yarovaya, 2020; Nasir, Lorente, & Huynh, 2020), long-term inflation (Frankel, Parsley, & Wei, 2012; Nasir, Huyn, & Vo, 2020), and exchange rate uncertainty (Frankel et al., 2012; Ozkan & Erden, 2015). Nasir (2020) shows that when uncertainty in an economy is high, the central bank's inflation forecast is misleading and can be improved simply by allocating some weight to the effects of sharp depreciation. We contribute to this literature by providing evidence that, like the

ERPT, the pass-through of exchange rate uncertainty is an important determinant of inflation.

Moreover, Calvo and Reinhart (2000), Ca'Zorzi, Hahn, and Sanchez (2007), and Brun-Aguerre, Fuertes, and Phylaktis (2012) show that the ERPT is different for a developed economy than for emerging market economies. However, the studies present mixed results on whether the elasticity is larger or smaller in developed economies. We contribute to the literature by showing that the elasticity of ERPT differs among country groups. More importantly, this is the first paper to show that ERUPT also differs among country groups.

Some studies focus on the evolution of ERPT over time (e.g., Bonadio, Fischer, & Saur'e, 2020; Choudhri & Hakura, 2006; Sekine, 2006). Most of the studies in this stream show that ERPT has declined over time. However, Nasir and Vo (2020) indicate that ERPT has increased over time in a sample of countries including New Zealand, Canada, and the UK. Among the possible reasons for the decline in ERPT are the increase in central bank credibility, the low-inflation environment, and the floating exchange rate regimes adopted by most countries. We add to this literature by providing evidence that ERUPT, like ERPT, has declined over time.

A relatively small stream of literature investigates the relation between exchange rate uncertainty and commodity prices. Anderton and Skudelny (2001) discover mostly insignificant price effects of exchange rate volatility on imports for euro-area countries. Blagov (2019) tests the effects of exchange rate uncertainty on consumer prices in the euro area and finds that an increase in exchange rate uncertainty leads to a fall in consumer prices on average. Blagov (2019) concludes that exchange rate uncertainty could be an important channel for inflation. Anderton and Skudelny (2001) and Blagov (2019) both examine the relation only for euro-area countries and only for a limited set of prices, rather than aggregate price level. Unlike those studies, we examine the effect of exchange rate uncertainty on the aggregate price level using data from 149 countries over the period 1980–2017. This is the first paper to show the positive and significant effect of exchange rate uncertainty on inflation, defining ERUPT and analyzing variations among country groups and evolution in the relation over time.

The rest of the paper is organized as follows. In Section 2, we develop a stylized model to obtain the empirical findings of the paper. Section 3 summarizes our empirical methodology and data, and Section 4 presents estimation results. Section 5 concludes.

2. Theoretical model and analysis

We present a highly stylized model to better crystallize our points and obtain empirical findings. The model focuses exclusively on the relation between exchange rate uncertainty and inflation dynamics, and it follows Bacchetta and Van Wincoop (2003) and Amiti et al. (2014). We consider a small open economy with a flexible exchange rate.

The economy consists of two sectors: a competitive nontradable domestic final goods sector and a monopolistic competitive sector with the continuum of imported final goods (to keep the model simple, we model only final goods sectors, but it is easy to extend the framework to incorporate intermediate goods sectors). The sales price of both domestic final goods and imported goods is denominated in the domestic currency.

2.1. Consumers

Consumers derive utility from both nontradable final goods and imported final goods. Consumers have a CES-type instantaneous utility function, specified as:

$$U_t = \left(n c_{N,t}{}^{(\lambda-1)/\lambda} + (1-n) c_{T,t}{}^{(\lambda-1)/\lambda} \right)^{\lambda/(\lambda-1)} \tag{1}$$

where c_N and c_T represent nontradable final goods and imported final goods, respectively; λ is the elasticity of substitution between these two types of goods, and $0 < n < 1$ shows the size of nontradable goods and of imported final goods sectors in consumption, respectively. Moreover, the imported final goods sector (c_T) is composed of a unit measure of differentiated goods, c_i, in which elasticity among differentiated goods is given by λ_F, where $\lambda_F > 1$.

$$c_T = \left(\int_0^1 c_i{}^{(\lambda_F-1)/\lambda_F} \right)^{\lambda_F/(\lambda_F-1)} \tag{2}$$

Imported final goods c_i and c_i are perfect substitutes, as λ_F goes to infinity, and perfect complements, as λ_F goes to zero.

2.2. Final goods sector

We make a simplifying assumption that the nontradable domestic final goods sector is perfectly competitive. Firms in that sector produce homogeneous goods c_N at a constant marginal cost m^* and sell these nontradable final goods at price p_N.

The imported final goods sector is monopolistically competitive. A continuum of merchants import final goods from abroad and sell them to domestic consumers. Individual importers have no cost other than the constant border price of imported goods $p^*_{i,t}$ in terms of foreign currency, multiplied by the nominal exchange rate, S_t. Each differentiated imported product $c_{i,t}$ is sold to consumers at price $p_{i,t}$ denominated in domestic currency. Consumer prices for both domestic final goods and imported goods are sticky. Goods prices are set at the beginning of each period t, before the exchange rate is known.[1] Devereux and Engel (2002) argue that an assumption of sticky prices is the best way to determine consumer price data. The profit of importer merchant i at any date t is given by

$$\pi_{i,t} = c_{i,t}\left(p_{i,t} - S_t\, p^*_{i,t}\right) \tag{3}$$

[1] The qualitative results of the paper remain the same in a sticky-price model, such that firms are not allowed to change their prices unless they receive a random "price-change signal" (Calvo, 1983). Under the assumption of such a "price-change signal," our analysis can be interpreted as focusing on the price decision by firms that received the signal.

We assume that merchants are risk averse, following Froot and Stein (1993), Asplund (2002), and Banal-Estanol and Ottaviani (2006). Some reasons for risk-averse behavior are concentrated ownership, limited hedging, limited debt capacity, liquidity constraints, and managerial control.[2] A merchant maximizes his expected lifetime utility, $\sum_{t=0} -\beta^t e^{-\theta_i \pi_{i,t}}$, where $\beta > 0$ discount factor, θ_i denotes his absolute risk aversion coefficient, and $\pi_{i,t}$ is profit.[3]

Last, the price index of imported final goods is denoted $p_{T,t}$ and the consumer price index (CPI) is denoted p_T , in which CPI is defined as

$$P_t = \left(np_{N,t}{}^{(1-\lambda)} + (1-n)p_{T,t}{}^{(1-\lambda)}\right)^{1/(1-\lambda)} \tag{4}$$

2.3. Exchange rate

The nominal exchange rate (units of domestic currency per unit of foreign currency) is a random variable and is given exogenously. S_t is normally distributed with an expected value $E[S_t] = S^*$ and variance $Var[S_t] = \sigma^2$.

Utility maximization results in the following demand for c_i:

$$c_{i,t} = \frac{1-n}{n}\left(p_{i,t}/p_{T,t}\right)^{-\lambda_F}\left(p_{T,t}/P,t\right)^{-\lambda} \tag{5}$$

The exchange rate S_t and the subsequent profit function $\pi_{i,t}$ are normally distributed. Therefore, the solution of the maximization problem can be derived as the solution of a mean-variance maximization problem. Moreover, the maximization problem of the merchant is chronologically homogeneous, so outcomes can be derived by focusing on a single date t.

$$max_{p_{i,t}}\left\{E\left[\frac{1-n}{n}\left(p_{i,t}/p_{T,t}\right)^{-\lambda_F}\left(p_{T,t}/P,t\right)^{-\lambda}\left(p_{i,t}-S_t\,p^*_{i,t}\right)\right] - \frac{\theta_i}{2}var\left[\frac{1-n}{n}\left(p_{i,t}/p_{T,t}\right)^{-\lambda_F}\left(p_{T,t}/P,t\right)^{-\lambda}\left(p_{i,t}-S_t\,p^*_{i,t}\right)\right]\right\} \tag{7}$$

After $E[S_t]$ and $Var[S_t]$ are substituted into Equation (7), the maximization problem can be restated as follows:

$$max_{p_{i,t}}\left\{E\left[\frac{1-n}{n}\left(p_{i,t}/p_{T,t}\right)^{-\lambda_F}\left(p_{T,t}/P,t\right)^{-\lambda}\left(p_{i,t}-S_t p^*_{i,t}\right)\right] - \frac{\theta_i}{2}var\left[\frac{1-n}{n}\left(p_{i,t}/p_{T,t}\right)^{-\lambda_F}\left(p_{T,t}/P,t\right)^{-\lambda}\left(p_{i,t}-S_t p^*_{i,t}\right)\right]\right\} \tag{8}$$

We now derive the first-order condition (FOC) to characterize pricing decisions by the merchant. Deriving FOC with respect to $p_{i,t}$ yields:

$$\frac{\frac{1-n}{n}\left(p_{T,t}\right)^{\lambda_F}\left(p_{T,t}/P,t\right)^{-\lambda} p^*_{i,t}\left(\lambda_F\left(S^*+(S_0-S^*)e^{-\varphi(t-t_0)}\right)+\frac{(1-n)\theta_i}{n2\varphi}\left(p_{T,t}\right)^{\lambda_F}\left(p_{T,t}/P,t\right)^{-\lambda} p^*_{i,t}\left(1-e^{-2\varphi(t-t_0)}\right)\lambda_F\sigma^2 p_{i,t}{}^{-\lambda_F} - p_{i,t}(\lambda_F-1)\right)}{p_{i,t}{}^{(1+\lambda_F)}} = 0$$

Given demand c_i, the exchange rate S_t and marginal cost $p^*_{i,t}$, a merchant maximizes his expected lifetime utility $E\left[\sum_{t=0} -\beta^t e^{-\theta_i \pi_{i,t}}\right]$.

After substituting Equations (3) and (5) into the expected utility, a merchant's maximization problem boils down to the following equation:

$$max_{p_{i,t}}\left\{E\left[\sum_{0}^{\infty} -\beta^t e^{-\theta_i\left(\frac{1-n}{n}\left(p_{i,t}/p_{T,t}\right)^{-\lambda_F}\left(p_{T,t}/P_{,t}\right)^{-\lambda}\left(p_{i,t}-S_t\,p^*_{i,t}\right)\right)}\right]\right\} \tag{6}$$

FOC implies that $p_{i,t}$ is greater than the expected exchange rate, $E[S_t]$, for all parameter values. First, we determine the pricing behavior of the importer.

Lemma 1 The price of imported goods, $p_{i,t}$, is a positive function of both the expected nominal exchange rate and exchange rate uncertainty.

The proof is in the Appendix A. Lemma 1 shows that, in addition to the expected nominal exchange rate, exchange rate uncertainty has a positive impact on the price of the imported goods. The reason for this result is simple: as merchants cannot react to changes in exchange rate fluctuations simultaneously, they face the risk of a rise in the exchange rate after setting their prices. When exchange rate movements are more volatile, the risk of a rise after price setting increases. Risk-averse merchants demand compensation for this risk by increasing prices for their goods in advance. In a sense, merchants add an exchange rate “risk premium” to their prices. Just as the risk premium of an asset increases as its price becomes more volatile, merchants increase this “risk premium” on goods prices when exchange rates are more volatile.

Now, we analyze the ERPT dynamics and define pass-through elasticity, Ψ, as the log change in CPI relative to the expected nominal exchange rate:

[2] Microfoundations that lead to managerial risk-averse behavior are well known (see Gibbons & Murphy, 1992). Kalemli-Ozcan, Sorenson, and Volosovych (2014) provide evidence that firm owners are not risk neutral, and a firm's willingness to take on risk highly depends on asset diversification by its owners.

[3] Constant absolute risk aversion (CARA) preferences are not necessary for obtaining our results. As long as merchants have time-separable expected utility preferences and exchange rate background risk follows a diffusion process, the optimization problem of an agent takes a mean-variance utility maximization form (Ingersoll, 1987; Simsek, 2013), and the qualitative results of the analysis remain the same.

$$\Psi = \mathrm{E}\left[\frac{d\log P}{d\log S}\right]$$

The next result summarizes the effects of merchants' pricing behavior on CPI, P_t, and the ERPT dynamics.

Proposition 1

a. The exchange rate pass-through is positive but incomplete. Moreover, the elasticity of the exchange rate pass-through is a negative function of exchange rate uncertainty.
b. The rise in exchange rate uncertainty, $\mathrm{Var}(S_t)$, increases the CPI.
c. The effect of exchange rate uncertainty on the CPI is nonlinear. As exchange rate uncertainty grows, the size of its effect on the CPI decreases.

Exchange rate uncertainty itself has a direct effect on the CPI. When exchange rate volatility grows, it accelerates change in the CPI. One implication of this effect is that exchange rate uncertainty decreases the elasticity of ERPT. Therefore, exchange rate uncertainty is a factor in incomplete ERPT. It is also noteworthy that importers take into account the expected value of exchange rates when setting consumer prices. Therefore, although importers set consumer prices before the exchange rate is determined, (incomplete) ERPT into consumer prices is still occurs.

3. Data and empirical model

To investigate the effect of exchange rate uncertainty on inflation, following the literature (e.g., Bailliu & Fuji, 2004; Caselli & Roitman, 2016; Jimborean, 2013; Takhtamanova, 2010), we employ an open market Phillips curve specification:

$$\pi_{it} = \beta_0 + \beta_1\pi_{it-1} + \beta_2\Delta S_{it} + \beta_3 vol_{it} + \lambda Z_{it} + \alpha_i + u_{it} \tag{1}$$

where π_{it} is inflation, ΔS_{it} is the percentage change in the exchange rate, vol_{it} is the volatility of the exchange rate, which aims to measure exchange rate uncertainty, Z_{it} is a vector of control variables, and α_i is fixed effects, which capture country-specific characteristics and enable individual heterogeneity in the levels of variables. The inflation rate is the first difference of the logarithm of the CPI. For the exchange rate, we use the nominal exchange rate, which is measured by the domestic currency per US dollar exchange rate. Hence, a positive change in an exchange rate suggests depreciation in the local currency, and vice versa. We use annual data from 149 countries over the period 1980–2017. Because not all data points are available for all countries over the period considered, the panel data are unbalanced.

The related literature uses two main approaches to measure exchange rate uncertainty. The first considers the observed volatility, which is measured by the standard deviation (e.g., Anderson et al., 2001; Koray & Lastrapes, 1989; Mumtaz & Theodoridis, 2015), and the second considers the conditional volatility, which is estimated by ARCH/GARCH models (e.g., Anderson et al., 2001). To check the robustness of our results, we use both approaches in our empirical analyses. We calculate the standard deviation of the monthly logarithmic change in the exchange rate over a year. For conditional volatility, we estimate a GARCH (1,1) model using monthly logarithmic changes in the exchange rate and calculate annual volatility by taking the square root of the averages of estimated volatility over a year. For control variables, we use proxies for demand and supply shocks. The output gap is used to capture the demand effect. We employ Hamilton's regression filter for the output gap. Hamilton (2018) argues that the popular HP filter produces spurious dynamic relations and suffers from end-of-sample bias. He introduces an alternative measure that employs a regression of the variable at date $t + h$ on the lagged values of the variables.[4] We use the logarithmic change in the crude oil price to account for supply shocks. All the data are retrieved from the World Bank and the International Monetary Fund's International Financial Statistics.

In the model, the lagged inflation term captures the inflation inertia. Nickell bias emerges if a lagged dependent variable is used as an independent variable in a fixed-effects specification. However, the bias diminishes as the time dimension of the panel increases, and the fixed-effects estimators become consistent in the case of large T. Because our data do not have a small time dimension, the bias arising from the fixed-effects estimation is negligible. To account for the endogeneity problem, we estimate Equation (1) by employing the system-GMM developed by Arellano and Bond (1991), Arellano and Bover (1995), and Blundell and Bond (1998). Moreover, to account for cross-sectional dependence, we estimate panel-corrected standard errors (PCSE).[5]

4. Estimation results

We report the estimation results of Equation (1) in Table 1. The column shows the fixed-effects estimation results. The second and third column show the system-GMM and PCSE estimation results, respectively. We also control for the year-fixed effects and report the estimation results in Table 2.

The results are quite robust to the estimation methods. The findings indicate that an increase in the exchange rate has a positive effect on inflation. Similarly, a rise in exchange rate uncertainty leads to an increase in inflation. On average, the ERPT to inflation is found to be around 33–35 percent (columns 2 and 4). When we use the standard deviation, the pass-through coefficients turn out to be around 25 percent. Moreover, an increase in the uncertainty of the exchange rate gives rise to a significant increase in inflation. Whereas a one-percentage-point increase in conditional volatility leads to a 0.2-percentage-point rise in inflation, a one-percentage-point increase in the standard deviation of the exchange rate leads to a 0.60-percentage-point increase in the inflation rate. In summary, all estimation results show

[4] The use of the HP filter does not change the results.

[5] PCSE assumes that the errors are heteroskedastic and contemporaneously correlated across panels.

Table 1
Panel estimation results with country-fixed effects.

	FE		System GMM		PCSE	
	(I)	(II)	(III)	(IV)	(V)	(VI)
Lagged inflation	0.462***	0.414***	0.461***	0.402***	0.469***	0.409***
	(0.0575)	(0.0539)	(0.0493)	(0.0435)	(0.0241)	(0.0229)
Change in nominal exchange rate	0.243***	0.337***	0.238***	0.331***	0.241***	0.342***
	(0.0586)	(0.0547)	(0.0707)	(0.0753)	(0.0148)	(0.0172)
Standard deviation	0.592**		0.610**		0.612***	
	(0.253)		(0.245)		(0.0538)	
GARCH		0.206***		0.208***		0.216***
		(0.0299)		(0.0403)		(0.0131)
Output gap	−2.639	−1.207	−4.527	−2.175	−1.907	−1.482
	(3.575)	(3.540)	(3.256)	(3.250)	(2.272)	(2.722)
Change in oil price	0.0438***	0.0460***	0.0461***	0.0469***	0.0452***	0.0486***
	(0.00693)	(0.00729)	(0.00829)	(0.00916)	(0.0101)	(0.0124)
Constant	1.583***	1.792***	1.572***	1.948***	1.530***	1.722***
	(0.561)	(0.462)	(0.570)	(0.471)	(0.355)	(0.415)
Observations	4569	3982	4569	3982	4569	3982
Adjusted R^2	0.762	0.797				
Hansen (p-value)			0.168	0.506		
AR2 (p-value)			0.130	0.056		

Robust standard errors in parentheses.
*p < 0.10, **p < 0.05, ***p < 0.01.

Table 2
Panel estimation results with country and year-fixed effects.

	FE		System GMM	
	(I)	(II)	(III)	(IV)
Lagged inflation	0.447***	0.395***	0.484***	0.369***
	(0.0589)	(0.0546)	(0.0813)	(0.0644)
Change in nominal exchange rate	0.246***	0.345***	0.260***	0.327***
	(0.0617)	(0.0575)	(0.0803)	(0.0834)
Standard deviation	0.593**		0.606*	
	(0.264)		(0.311)	
GARCH		0.213***		0.207***
		(0.0314)		(0.0463)
Output gap	−4.042	−2.962	−13.83	−6.395
	(3.637)	(3.591)	(9.496)	(9.321)
Constant	2.049	1.960	16.79	−22.63
	(1.251)	(1.259)	(22.15)	(21.97)
Observations	4569	3982	4569	3982
Adjusted R^2	0.769	0.808		
Hansen (p-value)			0.124	0.084
AR2 (p-value)			0.472	0.080

Robust standard errors in parentheses.
*p < 0.10, **p < 0.05, ***p < 0.01.

that an increase in exchange rate uncertainty has a positive and significant effect on inflation. In the next section, we provide a more detailed analysis of ERUPT for different groups of countries.

4.1. Exchange rate uncertainty pass-through in different country groups

Our results in Tables 1 and 2 demonstrate the significant effect of exchange rate uncertainty on inflation. Does this effect vary across different groups of countries? In this section, we investigate the effect of exchange rate uncertainty on inflation for different countries, divided into groups by income. Following the standards by the World Bank, the groups are for those with high, upper-middle, lower-middle, and low income. We combine the upper-middle- and lower-middle-income groups into a middle-income group. Table 3 reports the fixed-effects estimation results when the standard deviation is used as a measure for volatility, and Table 4 reports the estimation results using conditional volatility.[6]

Our results suggest that ERPT is larger in high-income countries than in other countries. In the earlier literature, the results are mixed at best. Calvo and Reinhart (2000) argue that ERPT is higher in developing countries, whereas the results by Ca'Zorzi, Hahn, and Sanchez (2007) and Brun-Aguerre et al. (2012) suggest the opposite. Our findings are in line with the latter. More important, we report the results for ERUPT for different country groups. The results using the standard deviation indicate that the coefficient of the volatility of the exchange rate is significant for high-, upper-middle-, and middle-income countries at 10 percent (with a p-value of 0.056), 1 percent, and 5 percent, respectively. When we use the conditional volatility measure, the results show that an increase in exchange rate uncertainty leads to an increase in inflation in all income groups of countries except low-income countries. The estimated coefficients show that the effects of exchange rate changes and uncertainty on inflation differ across country income groups.

[6] We also check the robustness of the results for the potential effect of outliers and employ the quantile regression method, which is more robust to nonnormal error and outliers. The results for the quantile regression method are in Appendix C.

Table 3
Fixed-effects estimation results for countries grouped by income (standard deviation).

	Income Groups				
	High	Upper-Middle	Middle	Lower-Middle	Low
Lagged Inflation	0.360***	0.433***	0.470***	0.358***	0.439***
	(0.0772)	(0.0708)	(0.0679)	(0.0511)	(0.0434)
Change in Nominal	0.458***	0.295***	0.227***	0.0999**	0.303***
Exchange Rate	(0.0635)	(0.0663)	(0.0622)	(0.0431)	(0.0653)
Standard Dev. of	0.722*	0.872***	0.582**	0.0195	0.308
Exchange Rate	(0.379)	(0.258)	(0.248)	(0.212)	(0.216)
Output Gap	8.629***	−6.409	−6.255	−4.134	−1.554
	(2.986)	(7.100)	(5.394)	(2.803)	(4.283)
Change in Oil Price	0.0465***	0.0703***	0.0482***	0.0110	0.0345***
	(0.009)	(0.013)	(0.010)	(0.009)	(0.010)
Adjusted R^2	0.824	0.822	0.761	0.550	0.678

Robust standard errors in parentheses.
*p < 0.10, **p < 0.05, ***p < 0.01.

Table 4
Fixed-effects estimation results for countries grouped by income (conditional volatility).

	Income Groups				
	High	Upper-Middle	Middle	Lower-Middle	Low
Lagged Inflation	0.356***	0.378***	0.420***	0.346***	0.430***
	(0.0771)	(0.0696)	(0.0661)	(0.0463)	(0.0432)
Change in Nominal	0.460***	0.415***	0.323***	0.0913	0.329***
Exchange Rate	(0.0686)	(0.0655)	(0.0639)	(0.0556)	(0.0496)
GARCH	0.602**	0.240***	0.199***	0.471***	0.215
	(0.305)	(0.0384)	(0.0342)	(0.181)	(0.150)
Output Gap	15.41***	−7.309	−5.753	−1.998	−1.010
	(3.304)	(6.578)	(5.460)	(4.355)	(4.460)
Change in Oil Price	0.0494***	0.0753***	0.0497***	0.0112	0.0336***
	(0.010)	(0.014)	(0.010)	(0.009)	(0.011)
Adjusted R^2	0.828	0.861	0.801	0.563	0.675

Robust standard errors in parentheses.
*p < 0.10, **p < 0.05, ***p < 0.01.

4.2. Real exchange rate uncertainty pass-through

In addition to looking at the nominal exchange rate, we examine the effects of real exchange rate movements (percentage change and volatility) on inflation.[7] We report the estimation results of Equation (1), using the real exchange rate, in Table 5. When we use one-lagged inflation as a regressor in the system-GMM estimations, the results suffer from second-degree autocorrelation. To overcome this problem, we add a second lag of inflation to the model and report the AR (3) test results. The fixed-effects and system-GMM estimation results show that changes in the real exchange rate have no significant effect on inflation. However, when cross-sectional dependence is considered, the corresponding coefficient becomes significant. The size of the estimated real ERPT coefficient is found to be around 5 percent in all estimations. Moreover, the results show that an increase in the

Table 5
Estimation results using the real exchange rate.

	Fixed	GMM	PCSE
Lagged inflation	0.584***	0.791***	0.581***
	(0.0724)	(0.0858)	(0.0341)
2nd lag of inflation		−0.138** (0.0565)	
Change in real	0.0538	0.0468	0.0547***
real exchange rate	(0.0423)	(0.0427)	(0.0133)
Standard deviation	0.506***	0.471***	0.489***
	(0.152)	(0.147)	(0.0567)
Output gap	−6.904	−4.471	−4.852*
	(4.882)	(3.961)	(2.945)
Change in oil price	0.0286***	0.0329***	0.0299***
	(0.00717)	(0.00829)	(0.0104)
Constant	1.985***	1.477***	1.982***
	(0.664)	(0.448)	(0.441)
Observations	4241	4122	4241
Adjusted R^2	0.647		
Hansen (p-value)		0.296	
AR (3) (p-value)		0.504	

Robust standard errors in parentheses.
*p < 0.10, **p < 0.05, ***p < 0.01.

[7] The real exchange is calculated as the nominal exchange rate × P_{US}/P, where P_{US} is the price level in the US, and P is the price level in the home country. Because of data availability, we did not include the real effective exchange rate in the analyses.

Table 6
PCSE estimation results for countries grouped by income (real exchange rate).

	Income Groups				
	High	Upper-Middle	Middle	Lower-Middle	Low
Lagged inflation	0.507***	0.628***	0.582***	0.321***	0.584***
	(0.0463)	(0.0401)	(0.0371)	(0.0244)	(0.0931)
Change in real exchange rate	0.113***	0.136***	0.0479***	−0.0851***	−0.0117
	(0.0367)	(0.0249)	(0.0139)	(0.0174)	(0.0616)
Standard deviation	1.236***	0.714***	0.432***	0.422***	1.449***
	(0.291)	(0.0998)	(0.0586)	(0.0587)	(0.307)
Output gap	4.827**	−13.63*	−7.934*	−2.911	−2.349
	(2.391)	(8.065)	(4.404)	(3.096)	(6.102)
Change in oil price	0.0291***	0.0571***	0.0328**	0.00486	0.0203
	(0.00941)	(0.0171)	(0.0137)	(0.0128)	(0.0152)
Constant	0.0678	2.190***	2.750***	4.636***	−1.194
	(0.452)	(0.777)	(0.558)	(0.469)	(0.968)
Observations	1184	1227	2367	1140	690

Robust standard errors in parentheses.
*p < 0.10, **p < 0.05, ***p < 0.01.

uncertainty of the real exchange rate leads to a significant rise in inflation. The size of the uncertainty coefficients suggests that real exchange rate volatility has a greater effect on inflation than real exchange rate changes. These findings reveal that uncertainty in the real exchange rate plays an important role in inflation dynamics.

Table 6 reports the PCSE estimation results for countries by income group using the real exchange rate.[8] We find significant real ERPT for all country groups except the low-income group. The results also suggest that real ERPT is negative for lower-middle-income countries. Additionally, uncertainty in the real exchange rate has a positive and statistically significant effect on inflation in all groups of countries. The findings show that the inflationary effects of uncertainty in the real exchange rate are more notable than change in the real exchange rate.

4.3. Nonlinearity of exchange rate uncertainty pass-through

According to the results of the theoretical model, when uncertainty grows, the size of its effect on inflation declines. To empirically test this prediction, we determine the periods when volatility is high. To do so, we calculate the two-year moving average of the standard deviation ($ma2sd_t$) and define a period of high volatility as a period in which the standard deviation is higher than the two-year moving average. Based on this definition we generate a dummy variable, D_t^{high}, as follows:

$$D_t^{high} = \begin{cases} 1, if\, sd_t > ma2sd_t \\ 0, otherwise \end{cases}$$

in which sd_t is the standard deviation. After we obtain this measure, we add an interaction term, $D_t^{high} xsd_t$ to Equation (1) and estimate it as 1 if $sd_t \leq ma2s_t$ and 0 otherwise and the re-estimate it including both interaction terms.[9] We find that the coefficient of $D_t^{high} xsd_t$ is significantly smaller than the coefficient of $D_t^{low} xsd_t$. The results are reported in Table 7. When all countries are considered, the coefficient of high volatility is estimated as −0.88, which is significant at the 1 percent level. This result suggests that, as the exchange rate uncertainty (volatility) increases, the size of its effect on inflation declines, which is in line with the predictions of the theoretical model. We obtain similar results for middle- and lower-income countries.

4.4. Exchange rate uncertainty pass-through over time

The existing literature documents that ERPT is time varying. Many studies show that ERPT has declined over time (Bouakez & Rebei, 2008; Choudhri & Hakura, 2006; Goldberg & Campa, 2010; Sekine, 2006). Taylor (2000) argues that the low inflationary environment and credible monetary policy in many countries may have contributed to the decline in ERPT. Although the time-varying characteristics of ERPT are well documented, little evidence has emerged on the effect of exchange rate uncertainty on inflation over time. To investigate evolution in the effect of exchange rate uncertainty on inflation over time, we estimate Equation (1) employing a fixed-effect estimation and the rolling-window procedure.

We use 20-year sample windows. The first estimation period is 1981–2000. Rolling the 20-year sample period over time, we end up with the estimation period 1998–2017. All the estimation results are reported in Appendix B. Fig. 1 shows the ERPT coefficient, and Fig. 2 shows the coefficient of ERUPT over time. In both figures, the vertical axis shows the estimated coefficients, and the horizontal axis shows the sample period.

Consistent with the existing literature, the findings clearly suggest that ERPT decreases over time. Moreover, we establish that ERUPT decreases over time, too. The decrease in both pass-through coefficients is more pronounced after 1995. We believe that these findings should provide motivation for future researchers to investigate the reasons for the decline in ERUPT over time. The findings also raise the interesting question of the extent to which the reasons for the declines in ERPT and ERUPT over time are similar or different.

5. Conclusion

Janet Yellen, the fifteenth chair of the Federal Reserve, stated an interview with *Time* (Foroohar, 2016):

> "We necessarily operate in an environment in which there's a great deal of uncertainty. … In such an environment, it makes sense to use a risk-management approach to identify and avoid the big mistakes. That's one reason I favor a cautious approach."

[8] Because the coefficient of the real ERPT is found to be significant using PCSE but insignificant with other estimation methods, we report the PCSE results in Table 6.

[9] Similarly, we calculate a dummy variable, D_t^{low}.

Table 7
Fixed-effects estimation results for nonlinearity.

	Income Groups					
	All	High	Upper-Middle	Middle	Lower-Middle	Low
Lagged inflation	0.441***	0.360***	0.413***	0.441***	0.359***	0.419***
	(0.0555)	(0.0775)	(0.0681)	(0.0653)	(0.0522)	(0.0452)
Change in nominal exchange rate	0.234***	0.457***	0.284***	0.215***	0.100**	0.280***
	(0.0586)	(0.0627)	(0.0676)	(0.0620)	(0.0432)	(0.0462)
Standard deviation	1.447***	0.647	1.582***	1.592***	−0.0562	1.438***
	(0.324)	(0.551)	(0.445)	(0.397)	(0.493)	(0.449)
D^{high}xStandard dev.	−0.886***	0.0870	−0.755	−1.048**	0.0746	−1.029**
	(0.336)	(0.374)	(0.522)	(0.433)	(0.427)	(0.430)
Output gap	−1.563	8.483***	−5.579	−5.067	−4.208	−0.659
	(3.330)	(2.882)	(6.880)	(4.981)	(2.871)	(4.387)
Change in oil price	0.0413***	0.0466***	0.0670***	0.0447***	0.0110	0.0335***
	(0.00721)	(0.00814)	(0.0140)	(0.0103)	(0.00855)	(0.00973)
Adjusted R^2	0.768	0.824	0.826	0.770	0.549	0.687

Robust standard errors in parentheses.
*p < 0.10, **p < 0.05, ***p < 0.01.

How do importers use risk management, and what are consequences of risk management for overall price stability? In the presence of price rigidity, importers face the risk of large exchange rate movements after setting prices. As hedging opportunities in international financial markets are limited, importers have an incentive to increase consumer prices, in a sense, by demanding compensation for this risk. In this study, we show that this pricing behavior creates a link between exchange rate uncertainty and the aggregate price level. The risk premium on an asset increases as its price becomes more volatile. This leads the exchange rate uncertainty to have a direct effect on the aggregate price level. Our empirical estimates indicate that exchange rate uncertainty has a significant effect on the aggregate price level. Moreover, this relation is nonlinear: as exchange rate uncertainty increases, the size of its effect on inflation decreases.

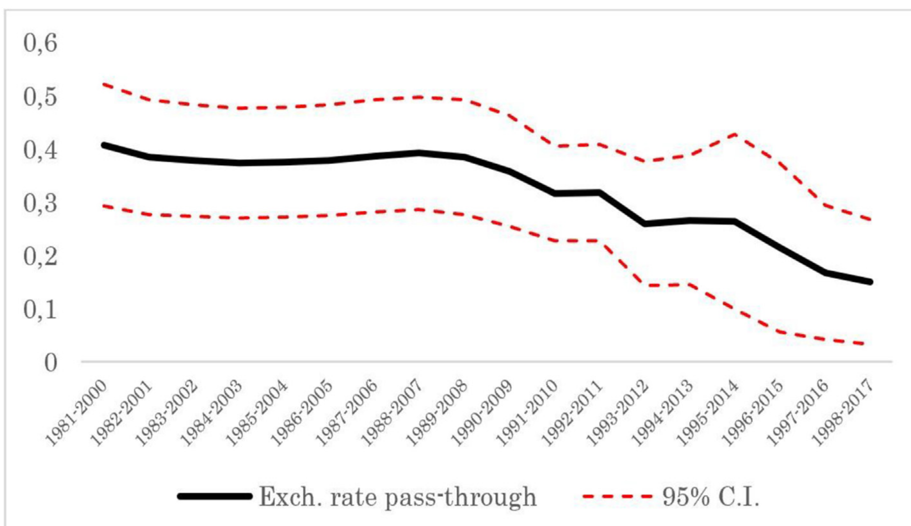

Fig. 1. Exchange rate pass-through over time.

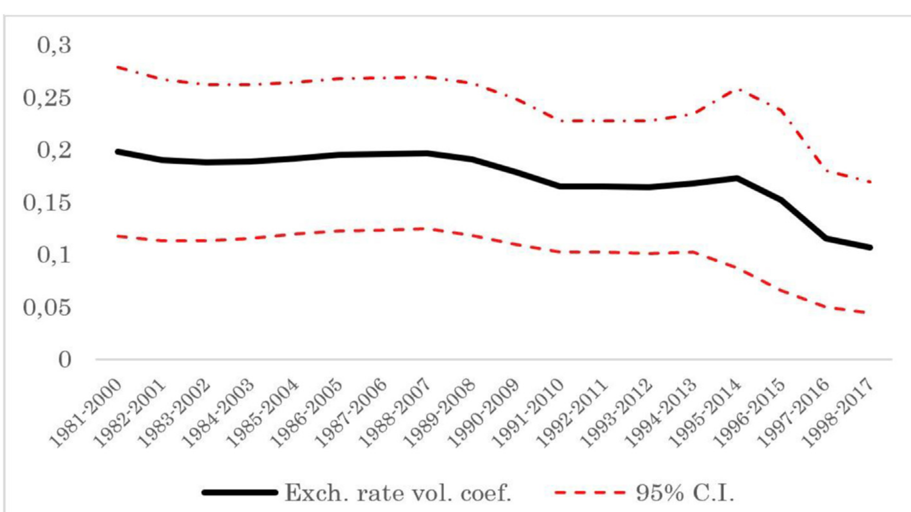

Fig. 2. Exchange rate uncertainty pass-through over time.

The 2008 global financial crisis led to important changes in policymaking. One of the changes at central banks was a rise in concern about financial stability in the economy, mainly exchange rate stability. The question with regard to central banks' concern about exchange rate stability is whether there is a trade-off between exchange rate stability and inflation targeting and whether central banks can adequately balance these two different objectives with a limited set of tools. Our results imply that there might not be much trade-off between exchange rate stability and inflation targeting. Thus implementing policies aimed at reducing exchange rate uncertainty should be on the policy agenda in order to fight inflation.

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Declaration of competing interest:

None.

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Appendix A.

Proof of Lemma 1

We implicitly differentiate the domestic price of imported goods ($p_{i,t}$) with respect to the expected nominal exchange rate, $E[S_t]$, which yields the following equation:

$$\frac{n p_{i,t} p^*_{i,t}}{(1-n)(\lambda_F+1/2)\theta_i\sigma^2\left(p^*_{i,t}\right)^2\left(p_{i,t}/p_{T,t}\right)^{-\lambda_F}\left(p_{T,t}/P,t\right)^{-\lambda}+n\left((\lambda_F+1)E[S_t]p^*_{i,t}-(\lambda_F-1)p_{i,t}{}^{(\lambda_F)}\right)}$$

The equation is positive for all parameter values, implying that the expected exchange rate has a positive effect on $p_{i,t}$.

Next, we implicitly differentiate the domestic price of imported goods ($p_{i,t}$) with respect to the expected nominal exchange rate, $Var(S_t)$.

$$\frac{\frac{(1-n)\theta_i}{n}\left(p_{T,t}\right)^{\lambda_F}\left(p_{T,t}/P,t\right)^{-\lambda}\left(p^*_{i,t}\right)^2}{\frac{2(2\lambda_F+1)(1-n)\theta_i}{n}\left(p_{T,t}\right)^{\lambda_F}\left(p_{T,t}/P,t\right)^{-\lambda}\sigma^2\left(p^*_{i,t}\right)^2+E[S_t]p^*_{i,t}(\lambda_F+1)p_{i,t}{}^{(\lambda_F-1)}-(\lambda_F-1)p_{i,t}{}^{(\lambda_F)}}$$

The derivative is positive, showing that $p_{i,t}$ is a positive function of $Var(S_t)$.

Proof of Proposition 1

1. FOC of the representative merchant's maximization problem shows that $p_{i,t}$ is greater than the expected exchange rate, $E[S_t]$, for all parameter values. Recall that imported goods are imperfect substitutes, and the overall price level for imported goods is. $p_{T,t} = \left(\int_0^1 p_{i,t}^{(\lambda_F-1)/\lambda_F}\right)^{\lambda_F/(\lambda_F-1)}$. CPI is $P_t = \left(np_{N,t}^{(1-\lambda)}+(1-n)p_{T,t}^{(1-\lambda)}\right)^{1/(1-\lambda)}$.

So, the result that $p_{i,t}$ is greater than the expected exchange rate, $E[S_t]$, for all parameter values and $\lambda_F > 1$ guarantees that the ERPT is incomplete.

2. Lemma 1 shows that merchants increase consumer prices whenever exchange rate volatility increases. Then, the fact that the consumer price level is defined as $P_t = \left(n^{(1_{N,t}-\lambda)}+(1-n)p^{(1_{T,t}-\lambda)}\right)^{1/(1-\lambda)}$ implies that CPI is an increasing function of exchange rate volatility. This also implies that the elasticity of the pass-through is a negative function of exchange rate uncertainty.
3. We take the second-order derivative of the expected exchange rate on the domestic price of imported goods with respect to exchange rate variance. The derivative, presented in the following equation, is always negative.

$$\frac{-n p_{i,t} p^{*\,3}_{i,t}(1-n)(2\lambda_F+1)\theta_i\left(p_{i,t}/p_{T,t}\right)^{-\lambda_F}\left(p_{T,t}/P,t\right)^{-\lambda}}{\left((1-n)(\lambda_F+1/2)\theta_i\sigma^2\left(p^*_{i,t}\right)^2\left(p_{i,t}/p_{T,t}\right)^{-\lambda_F}\left(p_{T,t}/P,t\right)^{-\lambda}+n\left((\lambda_F+1)E[S_t]p^*_{i,t}-(\lambda_F-1)p_{i,t}{}^{(\lambda_F)}\right)\right)^2}$$

Therefore, as exchange rate volatility grows, the effect of exchange rate volatility on CPI decreases, which completes the proof.

Appendix B.

Rolling-Window Estimation Results (Fixed Effects).

	model1981	model1982	model1983	model1984	model1985	model1986	model1987	model1988	model1989
Lagged inflation	0.329***	0.333***	0.336***	0.338***	0.340***	0.333***	0.366***	0.369***	0.375***
	(0.0552)	(0.0544)	(0.0545)	(0.0543)	(0.0531)	(0.0493)	(0.0519)	(0.0529)	(0.0533)
Change in nominal	0.346***	0.347***	0.346***	0.344***	0.338***	0.310***	0.315***	0.318***	0.317***
exchange rate	(0.0650)	(0.0631)	(0.0627)	(0.0626)	(0.0631)	(0.0601)	(0.0614)	(0.0616)	(0.0636)
Standard deviation	1.001***	1.009***	1.010***	1.021***	1.009***	0.930***	0.942***	0.958***	0.948***
	(0.265)	(0.257)	(0.257)	(0.262)	(0.258)	(0.240)	(0.248)	(0.251)	(0.257)
Output gap	−6.938	−5.557	−4.596	−3.809	−3.461	−5.263	−3.250	−1.264	−0.636
	−6.231	−5.824	−6.006	−6.181	−6.319	−5.886	−5.570	−5.682	−5.945
Change in oil price	1.545	1.737	1.648	1.916*	1.911*	1.810	2.211*	2.150	4.141***
	−1.240	−1.193	−1.188	−1.160	−1.123	−1.116	−1.297	−1.312	−1.301
Constant	1.897*	1.727*	1.659*	1.673*	1.758**	2.352***	1.838**	1.814**	1.663**
	−1.090	−1.035	(0.979)	(0.925)	(0.896)	(0.815)	(0.804)	(0.771)	(0.790)
Observations	1805	1922	1962	2012	2056	2097	2141	2187	2231
Adjusted R^2	0.828	0.827	0.825	0.823	0.823	0.812	0.819	0.821	0.817

Standard errors in parentheses * p < 0.10, **p < 0.05, ***p < 0.01.

Appendix Table B1
Rolling Window Estimation Results (Standard Deviation)

	model1990	model1991	model1992	model1993	model1994	model1995	model1996	model1997	model1998
Lagged inflation	0.372***	0.351***	0.366***	0.419***	0.414***	0.417***	0.406***	0.384***	0.424***
	(0.0508)	(0.0426)	(0.0490)	(0.0633)	(0.0633)	(0.0723)	(0.105)	(0.0923)	(0.101)
Change in nominal	0.297***	0.269***	0.269***	0.197***	0.191***	0.198**	0.166*	0.132	0.0883
exchange rate	(0.0598)	(0.0548)	(0.0551)	(0.0630)	(0.0617)	(0.0973)	(0.0930)	(0.0827)	(0.0612)
Standard deviation	0.938***	0.881***	0.884***	0.606**	0.617***	0.643*	0.577	0.473	0.346
	(0.236)	(0.210)	(0.210)	(0.242)	(0.234)	(0.387)	(0.352)	(0.310)	(0.227)
Output gap	1.776	1.768	2.897	−0.594	3.700	6.049	7.012	1.996	3.801
	−5.798	−5.789	−6.170	−7.294	−6.069	−4.670	−4.422	−3.113	−2.410
Change in oil price	5.615***	3.997***	4.473***	4.358***	4.747***	5.079***	4.482***	4.227***	3.889***
	(0.903)	(0.775)	(0.770)	(0.812)	(0.788)	(0.807)	(0.960)	(0.857)	(0.705)
Constant	1.450*	1.793***	1.557**	1.841***	1.573**	1.305	1.517	2.049**	2.073***
	(0.740)	(0.630)	(0.633)	(0.688)	(0.651)	(0.888)	−1.052	(0.880)	(0.703)
Observations	2278	2322	2365	2404	2442	2474	2500	2517	2500
Adjusted R^2	0.823	0.811	0.808	0.751	0.753	0.708	0.636	0.575	0.616

	model1981	model1982	model1983	model1984	model1985	model1986	model1987	model1988	model1989
Lagged inflation	0.367***	0.371***	0.378***	0.382***	0.385***	0.388***	0.392***	0.394***	0.402***
	(0.0697)	(0.0696)	(0.0694)	(0.0692)	(0.0691)	(0.0686)	(0.0690)	(0.0687)	(0.0684)
Change in nominal	0.310***	0.306***	0.303***	0.303***	0.308***	0.312***	0.315***	0.318***	0.307***
exchange rate	(0.0743)	(0.0715)	(0.0692)	(0.0685)	(0.0682)	(0.0688)	(0.0690)	(0.0690)	(0.0692)
Standard deviation	0.198***	0.190***	0.188***	0.189***	0.192***	0.195***	0.196***	0.197***	0.191***
	(0.0411)	(0.0393)	(0.0380)	(0.0374)	(0.0370)	(0.0371)	(0.0370)	(0.0369)	(0.0370)
Output gap	−9.407	−8.720	−9.084	−9.395	−9.372	−9.703	−9.307	−8.712	−8.844
	−6.867	−6.529	−6.574	−6.720	−6.777	−6.785	−6.795	−7.086	−7.463
Change in oil price	0.0320***	0.0350***	0.0344***	0.0344***	0.0333***	0.0322***	0.0354***	0.0343***	0.0395***
	(0.0119)	(0.0116)	(0.0114)	(0.0116)	(0.0120)	(0.0122)	(0.0130)	(0.0130)	(0.0132)
Constant	3.383***	3.330***	3.195***	3.106***	2.990***	2.873***	2.722***	2.652***	2.624***
	−1.084	−1.070	−1.042	−1.004	(0.960)	(0.920)	(0.890)	(0.860)	(0.861)
Observations	1646	1676	1688	1701	1713	1725	1737	1748	1762
Adjusted R^2	0.817	0.811	0.808	0.807	0.805	0.803	0.802	0.802	0.802

Standard errors in parentheses * p < 0.10, **p < 0.05, ***p < 0.01.
Standard errors in parentheses * p < 0.10, **p < 0.05, ***p < 0.01.

Appendix Table B2
Rolling Window Estimation Results (Conditional Volatility)

	model1990	model1991	model1992	model1993	model1994	model1995	model1996	model1997	model1998
Lagged inflation	0.400***	0.369***	0.394***	0.405***	0.398***	0.399***	0.382***	0.362***	0.410***
	(0.0664)	(0.0526)	(0.0598)	(0.0620)	(0.0613)	(0.0643)	(0.0730)	(0.0520)	(0.0632)
Change in nominal	0.286***	0.255***	0.255***	0.253***	0.260***	0.268***	0.230***	0.166***	0.152**
exchange rate	(0.0665)	(0.0596)	(0.0596)	(0.0601)	(0.0630)	(0.0817)	(0.0814)	(0.0624)	(0.0594)
Standard deviation	0.179***	0.165***	0.165***	0.164***	0.168***	0.173***	0.152***	0.115***	0.107***
	(0.0353)	(0.0321)	(0.0321)	(0.0323)	(0.0336)	(0.0437)	(0.0439)	(0.0332)	(0.0319)
Output gap	−5.555	−5.074	−4.559	−2.973	4.239	3.777	3.576	−1.167	0.429
	−7.325	−7.727	−7.815	−7.915	−5.470	−4.623	−4.479	−2.624	−2.600
Change in oil price	0.0420***	0.0313***	0.0328***	0.0342***	0.0368***	0.0395***	0.0404***	0.0345***	0.0334***
	(0.0114)	(0.00957)	(0.00951)	(0.00941)	(0.00944)	(0.0104)	(0.0104)	(0.00906)	(0.00865)
Constant	2.717***	3.331***	3.024***	2.792***	2.572***	2.392***	2.769***	3.561***	3.172***
	(0.864)	(0.644)	(0.676)	(0.676)	(0.662)	(0.739)	(0.902)	(0.514)	(0.539)
Observations	1776	1788	1802	1813	1823	1833	1839	1843	1843
Adjusted R^2	0.804	0.795	0.791	0.786	0.797	0.770	0.719	0.669	0.669

Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Rolling Window Estimation Results (Conditional Volatility) (Continued).

Appendix C.

Median Regression Results

We also check the robustness of the results for the potential effect of outliers. To account for the potential effect of an outlier on the relationship, we employ the quantile regression method, which is more robust to nonnormal error and outliers. With the help of the quantile regression method, we estimate the median of the dependent variable conditional on the independent variables and report the results in Appendix Table C1. The findings from the median regression show that exchange rate uncertainty significantly affects inflation. An increase in changes in both the exchange rate and exchange rate uncertainty leads to an increase in inflation. The results also indicate that the relationship holds for all country income groups. In addition, when the conditional median is considered, the coefficient of the output gap is found to be positive and significant.

Appendix Table C1
Median Regression Results

	Income Groups					
	All	High	Upper-Middle	Middle	Lower-Middle	Low
Lagged inflation	0.539***	0.724***	0.562***	0.524***	0.409***	0.451***
	(0.00468)	(0.00712)	(0.00982)	(0.00600)	(0.0110)	(0.0221)
Change in real	0.151***	0.0668***	0.231***	0.168***	0.113***	0.159***
exchange rate	(0.00339)	(0.00810)	(0.00691)	(0.00421)	(0.00961)	(0.0155)
Standard deviation	0.551***	0.331***	0.736***	0.571***	0.398***	0.608***
	(0.0136)	(0.0686)	(0.0270)	(0.0163)	(0.0354)	(0.0788)
Output gap	4.315***	5.752***	4.882*	4.905***	2.018	−3.491
	(1.083)	(1.145)	(2.840)	(1.573)	(2.024)	(3.021)
Change in oil price	0.0311***	0.0224***	0.0480***	0.0365***	0.0256***	0.0240***
	(0.00330)	(0.00326)	(0.0103)	(0.00508)	(0.00567)	(0.00816)
Constant	0.0829	−0.132	−0.802	−0.381	2.179*	2.026
	(1.856)	(0.950)	(1.813)	(1.275)	(1.131)	(1.572)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4569	1293	1267	2575	1308	701

Robust standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

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