DOES HIGH INFLATION HAVE AN EFFECT ON THE REACTION OF EXCHANGE RATES TO INTEREST AND INFLATION RATES?

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ABSTRACT

Currency exchange rates are one of the most important determinants of international commercial and financial market activity. Inflation rates, a recent problem in many developed countries, and interest rates are commonly accepted theoretical determinants of changes in exchange rates, yet published research contains many puzzles regarding the relation between interest, inflation, and exchange rates. This article evaluates interest, inflation, and exchange rates relations between the U.S. and eight developed economies to determine whether higher-than-expected inflation has an effect on the short-run stability of these relations. This study applies both time-series and panel tests including differences-in-differences estimation and finds that exchange rates react differently in the short-run when inflation rates increase beyond inflation policy targets.

1. INTRODUCTION

The importance of currency exchange rates for international commerce cannot be overstated due to their immediate effects on the relative price of similar goods across international borders. Exchange rates become one of the most important determinants of imports and exports. All else equal, home currency appreciation increases imports because a nation's residents will buy more goods abroad as they become relatively cheaper. Simultaneously, home currency appreciation decreases exports as that nation's goods become more expensive abroad (Arize et al., 2000). Exchange rates have further effects on overall national income (Keynes, 1919), international capital flows (Friedman, 1953), financial asset prices (Lucas, 1978), and wealth (Schumpeter, 1911; Fisher, 1930).

The recent world pandemic shocked policymakers struggling to balance the provision of consumer goods with the protection of consumers. World economies experienced varying levels of idled resources that reduced supply while fiscal and monetary stimuli were employed to stabilize demand. The result of these policies was more money chasing fewer goods, some economists' basic definition of inflation (Friedman & Schwartz, 1982). Inflation is not usually considered a problem until it is high, but high inflation has no official, commonly accepted definition. Economists may substitute higher-than-expected inflation rates when the general price level grows at a rate beyond market expectations or outside of policy targets, usually greater than four percent per year. Inflation rates approaching double digits introduce uncertainty resulting in unexpected goods and labor market instability (Friedman & Schwartz, 1982) as well as higher nominal interest rates (Wicksell, 1907; Fisher, 1930). High inflation has been a recent problem in many developed countries resulting from policymakers' reluctance to retreat from crisis policies for more stable economic policies despite their attempts at dissuading markets from reacting to high inflation even as rates began to increase and persist.

This article evaluates interest, inflation, and exchange rates relations between the U.S. and eight developed economies to determine whether higher-than-expected inflation has an effect on the long-run stability of these relations. The remainder of this article is organized as follows: Section 2 provides a review of relevant literature. Section 3 describes the data and methodologies used. Section 4 presents quantitative results and important findings. Section 5 concludes and suggests further research.

2. REVIEW OF RELEVANT LITERATURE

Common theoretical techniques used to forecast changes in exchange rates rely on relations of interest rates and inflation rates among other known, commonly accepted determinants of exchange rates, which include national income (gross domestic product), government intervention in international commerce (increases and decreases in trade barriers), currency market interventions by speculators and central banks (forward rates), and changes in consumer preferences. Three prevailing financial economic theories attempt to explain fluctuations in exchange rates: purchasing power parity (PPP), interest rate parity (IRP) and international Fisher effect (IFE). PPP relies on relative price fluctuations from economy to economy. IRP relies on relative changes in nominal interest rates. IFE relies on the real interest rate, which combines interest and inflation rates into a single, meaningful measurement (Fisher, 1930). All else equal, each of these three relations is theoretically used to predict the direction and magnitude of changes in exchange rates.

Research evaluating these three theories is full of "puzzles" and "disconnects." Though a long-standing theory, PPP (Cassel, 1918) has little empirical support and has become known as the PPP puzzle (Meese & Rogoff, 1983; Mark, 1990; Backus & Smith, 1993; Rogoff, 1996; Obstfeld & Rogoff, 2000; Engel & West, 2005). Support remains for a long-term, cointegrating relation between prices and inflation with no need to calculate PPP (Kamin & Klau, 2003; Cheung et al., 2019; Papell & Prodan, 2020). Studies on IRP have identified similar puzzles noting little empirical support for IRP (Fama, 1984; McCallum, 1994; Engel & West, 2006; Mark, 2009), demonstrating instead that Taylor rule fundamentals (lagged interest rates, inflation gap, and output gap) provide more accurate forecasting models for exchange-rate fluctuations (Molodtsova & Papell, 2009; Engel et al., 2019). A recent study implied that interest-rate policies consistent with IRP may avoid costly foreign exchange interventions that deviate from capital market arbitrage to achieve independent exchange rates (Amador et al., 2020). IFE studies continue to show puzzles as well. Most studies on the Fisher effect fail to observe any notable relation (Coppock & Poitras, 2000). Two studies on the USD/MXN exchange rate actually find the opposite, namely that over long terms, real interest rates react to exchange rates rather than the opposite relation predicted by IFE (Salas-Ortiz & Gomez-Monge 2015; Capasso et al., 2019), but a high real interest rate may also reduce exchange rate volatility (Benita & Lauterbach, 2007).

3. DATA AND METHODOLOGY

The theoretical relations described in Sections 1 and 2 support a simple specification that assumes exchange rates are a function of interest rates and inflation rates:

exchange rate = *f*(interest rate, inflation rate)

Using data obtained from XE.com (https://www.xe.com/currencytables/), eight historical spot exchange rates (USD/CAD, USD/CNY, EUR/USD, USD/JPY, USD/KRW, USD/MXN, USD/CHF, and GBP/USD) priced in USD were observed monthly from December 2006 to December 2022 providing 193 consecutive observations for each time series (1,544 for the panel). Using OECD data (OECD https://stats.oecd.org/index.aspx?queryid=86#), historical interest rates and inflation rates were observed monthly for nine currencies (Canada, China, European Union (EU), Japan, Korea, Mexico, Switzerland, United Kingdom (UK), and United States (US)) from December 2006 to December 2022 providing 193 consecutive monthly observations for each currency (1,737 for the panel). All exchange rates were restated as the natural log of the spot exchange rate priced in USD. Interest rates and inflation rates were restated as the natural log of the annualized percentage rate. High (higher-than-expected) inflation indicator variables were defined as a value of one if the inflation rate exceeds four percent (beyond common policy targets) and a value of zero otherwise. Higher inflation rate cutoffs were considered, but often resulted in very small sample sizes. Summary statistics of the panel are detailed below in Table 1.

TABLE 1. PANEL SUMMARY STATISTICS

Variable	Obs	Mean	Std. Dev.	Min	Max
exrate	1,544	.6378521	.6291002	.000653	2.075839
intrate	1,544	1.984901	2.306078	-1.15	10.82
infrate	1,544	2.087395	2.016687	-2.5	11.5
hiusinf	1,544	.1139896	.3179016	0	1
hiforinf	1,544	.1450777	.3522933	0	1

The full panel that results from the observed data provides eight panels with commonly observed, long-term cointegrating relations (noted in the literature review) further requiring specific time-series tests to avoid spurious results from panel regression. The first tests applied to each time-series use vector autoregression (VAR) models to identify the number of lags appropriate to test each time series in the panels by minimizing final prediction error (FPE) and information criteria (maximizing the test statistics provided by Akaike [AIC], Hannan & Quinn [HQIC], and Schwarz's Bayesian [SBIC] information criteria).

Next, tests are applied to each time-series and to the entire panel to determine whether each variable's means and variances are stationary over time. Non-stationary variables contain unit roots or are random walks. Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) are tests recommended most often to test each time-series for unit roots and random walks (Dickey & Fuller, 1979; Phillips & Perron, 1988). Additional tests (Levin–Lin–Chu, 2002; Harris–Tzavalis, 1999; Breitung, 2000; Breitung & Das, 2005; Im–Pesaran–Shin, 2003; and Choi, 2001 Fisher-type tests) were applied to the full panel. These tests share a null hypothesis that all panels contain a unit root. The final test (Hadri, 2000 Lagrange multiplier (LM) test) supposes a null hypothesis that all the panels are trend stationary.

Johansen-Juselius (JJ) tests are recommended to determine whether cointegrating relations exist between variables before any results can be obtained from the specification (Johansen & Juselius, 1990). Two separate tests are employed to identify cointegration vectors: a maximum eigenvalue test and a trace test. Both the maximum eigenvalue and trace tests presume a null hypothesis of $r = 0$ cointegrating relations versus an alternative hypothesis of $r + 1$ up to $n - 1$ cointegrating relations (where n equals the number of variables, in this case $n = 3$).

Once detected, cointegrated vectors may be tested using a variety of autoregression models. Among available alternatives, a vector error correction model (VECM) allows multiple cointegrating relations and can estimate both short and long-term effects by measuring how the dependent variable returns to an equilibrium after changes in explanatory variables (Engle & Granger, 1987). These benefits suggest VECM is the correct test to estimate these results.

Estimated results typically limit theoretical relationships to correlations. Whenever one time series' prior values predict another time series' future values, predictive causality (or more accurately, precedence, a temporal relation) can be measured (Granger, 1969). One variable can then be said to "Granger cause" (GC) another. Given this possibility and subject to the results of the cointegration and VECM tests performed herein, GC may be applied to the estimated results to test pairwise theoretical relations between the variables. Two null hypotheses are applied to each relation: 1) that X does not GC Y, and 2) that Y does not GC X. If one of the pair of null hypotheses is rejected, unidirectional GC exists for the other. If both null hypotheses are rejected, bidirectional GC exists. And if neither hypothesis is rejected, no GC exists.

Impulse response functions (IRFs) are modeled using VAR and describe how endogenous variables react over time to exogenous shocks. IRFs may provide additional information for robustness of the results obtained from cointegration tests, VECM estimates, and GC tests (Lütkepohl, 2008).

Finally, subject to stationarity test results, difference-in-differences estimation (DD) allows a natural experiment using historical panel data by analyzing the differences between responses in exchange rates for months with high inflation rates versus those without. DD removes unobservable, time-invariant differences as well as fixed effects between exchange-rates at the first difference but compares exchange-rate changes under high inflation to exchange-rate changes under low inflation at the second difference. This approach is similar to a treatment-control experimental design and a fixed-effects estimator. High inflation months are the treatment group, and low inflation months are the control group. The effects of high and low inflation rates on changes in the exchange rate are then measured and compared.

4. RESULTS

Table 2 shows selected results of lag selection-order criteria. Results are reported based on minimum FPE and AIC (noted by asterisks) for each country in the panel. All other lag selection-order results are omitted for space.

TABLE 2. SELECTED LAG SELECTION-ORDER CRITERIA

Sample: April 2007 - December 2022 Number of observations = 189

	lags	LL	LR	df	p	FPE	AIC	HQIC	SBIC
Canada	2	911.6	87.7*	9	0.000	1.6e-08*	-9.424*	-9.278*	-9.063*
China	3	861.8	24.6*	9	0.003	3.0e-08*	-8.802*	-8.593	-8.287
EU	2	998.0	146.9*	9	0.000	6.5e-09*	-10.338*	-10.192*	-9.978*
Japan	3	801.4	21.4*	9	0.011	5.7e-08*	-8.163*	-7.954	-7.648
Korea	2	970.3	90.4	9	0.000	8.7e-09*	-10.045*	-9.899*	-9.685*
Mexico	2	1137.2	179.7	9	0.000	1.5e-09*	-11.811*	-11.665*	-11.451*
Switz.	3	379.5	31.9*	9	0.000	5.0e-06*	-3.698*	-3.489*	-3.184
UK	2	1034.2	89.7*	9	0.000	4.4e-09*	-10.722*	-10.576*	-10.362*

Endogenous variables: natural log of exchange rate, natural log of interest rate, and natural log of inflation rate; Exogenous variable: constant

As shown in the results, three lags were preferred for China, Japan, and Switzerland and two lags for Canada, E. U., Korea, Mexico, and U.K. Tests for each individual time series used the respective country's preferred lag structure. Tests of the full panel imposed two lags where applicable regardless of the underlying countries' preferred lag structures.

Because of the differing lag structures reported in Table 2, ADF and PP results are presented for each variable by country in Table 3. The null hypothesis for ADF and PP tests is that the variable contains a unit root.

TABLE 3. RESULTS OF UNIT ROOT TESTS

	Exchange Rate Z(t) test statistics			
	Augmented Dickey-Fuller		Phillips-Perron	
Country	Level	First Difference	Level	First Difference
Canada	-1.266	-8.476***	-0.536	-15.682***
China	-2.895***	-5.903***	0.443	-9.461***
EU	-1.641*	-6.467***	-1.640*	-13.096***
Japan	-1.319*	-6.189***	-0.358	-12.615***
Korea	-2.695***	-7.602***	-1.032	-14.577***
Mexico	-1.440*	-7.420***	-1.508*	-12.537***
Switz.	-2.928***	-7.049***	0.502	-15.887***
UK	-2.007**	-6.409***	-1.509	-12.776***

Interest Rate Z(t) test statistics

Country	Augmented Dickey-Fuller Level	Augmented Dickey-Fuller First Difference	Phillips-Perron Level	Phillips-Perron First Difference
Canada	-2.381***	-4.080***	-0.801	-5.915***
China	-2.931***	-8.090***	-0.893	-15.127***
EU	-2.185**	-4.362***	-1.775	-5.161***
Japan	-1.436*	-4.493***	-1.594	-10.955***
Korea	-2.094**	-5.894***	-0.945	-6.650***
Mexico	-1.628*	-2.903***	0.641	-4.006***
Switz.	-2.425***	-6.515***	-2.090**	-14.987***
UK	-2.129**	-4.797***	-1.664*	-7.185***

Inflation Rate Z(t) test statistics

Country	Augmented Dickey-Fuller Level	Augmented Dickey-Fuller First Difference	Phillips-Perron Level	Phillips-Perron First Difference
Canada	-1.444*	-7.390***	-0.165	-12.051***
China	-3.405***	-5.179***	-1.596	-12.585***
EU	-0.438	-5.388***	2.146	-9.101***
Japan	-1.711**	-6.334***	-1.306	-10.807***
Korea	-1.575*	-8.878***	-0.442	-11.468***
Mexico	-1.585*	-8.176***	0.149	-10.027***
Switz.	-2.519***	-5.146***	-1.507	-10.870***
UK	-0.059	-5.188***	1.677*	-10.471***

Z(t) t-distribution

Critical Values

Augmented Dickey-Fuller test N = 190 1%	5%	10%	Phillips-Perron test N = 192 1%	5%	10%
-2.347	-1.653	-1.286	-13.484	-7.961	-5.661
			-2.588	-1.950	-1.616

The results of the ADF tests show that the null hypothesis of the presence of a unit root can be rejected at various critical values for all countries for levels of each variable. The null hypothesis of the presence of a unit root on first differences can be rejected at the one percent critical value for all variables and all countries in the panel.

PP tests correct for autocorrelation and heteroscedasticity offering a more robust check on the presence of a unit root. The results of PP tests corroborate the ADF results and show that the null hypothesis can be rejected at the one percent critical value in all cases for first differences but not for levels. Results of panel stationarity test results corroborated the reported ADF and PP results but are omitted for space. The first differences of the variables are stationary and integrated of order one.

JJ tests require evaluating each rank in succession. If the first (r=0) cannot be rejected, then each successive rank is evaluated until the null is rejected or the last rank fails to reject. The results of JJ tests are presented in Table 4.

TABLE 4. RESULTS OF COINTEGRATION TEST

Country	n	lags	Trace Critical Value r=0 24.31	r=1 12.53	r=2 3.84
Canada	190	2	196.6754	104.4821	27.5623
China	189	3	143.7400	67.6340	32.8542
EU	190	2	134.5930	68.7259	16.4442
Japan	189	3	174.7914	79.6672	32.0252
Korea	190	2	200.4876	105.9559	29.4528
Mexico	190	2	170.8749	84.1957	16.3497
Switz.	189	3	216.8478	90.7228	36.9669
UK	190	2	157.2102	78.5968	25.2593

In this case, the results show that the null hypothesis (at least one variable is not cointegrated with another) cannot be rejected for $r = 2$. Therefore, two cointegrating relations exist over each panel suggesting a long-term relation between exchange, interest, and inflation rates.

The presence of stationary first differences and two long-term cointegrating relations allow VECM estimation. VECM results are presented in Table 5.

TABLE 5. RESULTS OF VECM ESTIMATION

Country	n	coefficients interest rate	inflation rate	constant
Canada	191	-0.7292*	3.1830***	-3.9893
China	190	-0.3342***	0.1638***	2.1558
EU	191	-0.3123***	0.4417***	-0.8871
Japan	190	0.0504	0.8001***	3.8518
Korea	191	-0.2939***	0.3711***	6.8348
Mexico	191	7.3040**	-15.0745***	18.1667
Switz.	190	-3.9513***	6.2530***	-7.3149
UK	191	-1.1172***	1.8788***	-2.5395

VECM results show a direct, significant (1% confidence) relation for a change in the inflation rate to a change in the exchange rate for seven of the eight panels, and an inverse, significant (1% confidence) relation for a change in the interest rate to a change in the exchange rate for five of the eight panels. Mexico results show the opposite effects: an inverse, significant (1% confidence) relation for the inflation rate, and a direct, significant (5% confidence) relation for the interest rate. China's interest rate is significant at the 10% level, and a change in Japan's interest rate has no significant relation to a change in the exchange rate. This study will not opine about central bank policy actions, but different findings regarding both inflation and interest rates can be reasonably expected if central banks use different policy rules or varying levels of discretion in their monetary policy decisions.

Coefficients of log-transformed variables may be interpreted as elasticities, and each exchange rate is priced in USD. These restrictions suggest that USD/CAD will increase 3.183% (the USD price of CAD will increase, and CAD will appreciate against USD) for each 1% increase in CAD inflation rate and will decrease 0.729% (CAD will depreciate against USD) for each 1% increase in CAD interest rate. Each time-series may be interpreted in this manner using the respective coefficients. The signs and economy of each coefficient are consistent with theory because the relative differentials in interest and inflation rates between economies are of interest, not the levels themselves. Currencies are expected to appreciate against currencies with higher relative inflation rates because higher prices decrease imports resulting in a depreciating currency. Currencies are expected to appreciate against currencies with lower relative interest rates because higher interest rates increase financial capital inflows resulting in an appreciating currency. The lengthy results of IRFs, which corroborated VECM results, are omitted for space.

Finding a cointegrating relation is not the same as detecting causality. However, as previously noted, Granger causality testing may show that one time series predicts another providing a measurement of precedence. The null hypotheses applied to each pairwise relation are that *X* does not GC *Y*, and that *Y* does not GC *X*. These tests produce six hypotheses for each of the eight panels; therefore, complete results of Granger causality tests are omitted for space.

Selected results of Granger causality tests are presented in Table 6 and show each time a null hypothesis is rejected (each time one variable can be said to GC another) or that no null hypotheses were rejected for that exchange rate (no GC could be established for any relation).

TABLE 6. SELECTED RESULTS OF GRANGER TESTS

Complete Time Series		
Country	Null hypothesis	Chi^2 statistic
Canada	no null hypothesis was rejected	-
China	no null hypothesis was rejected	-
EU	no null hypothesis was rejected	-
Japan	INF does not GC EXR	15.239***
	EXR does not GC INT	10.267***
Korea	INT does not GC EXR	9.645***
	EXR does not GC INT	10.408***
Mexico	no null hypothesis was rejected	-
Switz.	no null hypothesis was rejected	-
UK	INF does not GC INT	15.239***

Low Inflation in the U.S.

Country	Null hypothesis	Chi^2 statistic
Canada	INT does not GC EXR	11.214***
China	no null hypothesis was rejected	-
EU	no null hypothesis was rejected	-
Japan	INF does not GC EXR	15.639***
Korea	INT does not GC EXR	11.382***
	EXR does not GC INT	11.010***
Mexico	no null hypothesis was rejected	-
Switz.	no null hypothesis was rejected	-
UK	INF does not GC INT	10.531***
	EXR does not GC INT	13.556***

High Inflation in the U.S.

Country	Null hypothesis	Chi^2 statistic
All	no null hypothesis was rejected	-

Low Inflation in the Foreign Currency

Country	Null hypothesis	Chi^2 statistic
Canada	INT does not GC EXR	11.214***
China	INT does not GC INF	9.457***
EU	no null hypothesis was rejected	-
Japan	INF does not GC EXR	15.239***
	EXR does not GC INT	10.267***
Korea	INT does not GC EXR	17.866***
Mexico	no null hypothesis was rejected	-
Switz.	no null hypothesis was rejected	-
UK	INF does not GC INT	11.013***
	EXR does not GC INT	12.513***

High Inflation in the Foreign Currency

Country	Null hypothesis	Chi^2 statistic
All	no null hypothesis was rejected	-

Results are mixed. Different panels show different Granger causality relations with no consistent result. However, this study also questions whether high inflation changes the long-standing cointegrated relations. Under high inflation in either the USD or the other currency forming the exchange rate, no null hypothesis can be rejected (no variable can be said to GC another). No definitive conclusion can be drawn yet. However, any long-standing GC relations between exchange, interest, and inflation rates noted in this study did not persist in the presence of short-run, higher-than-target inflation rates.

Because the first differences were stationary throughout the panel, the final test employs the entire panel to estimate results using DD with robust standard errors (Bertrand et al., 2004). The results are presented in Table 7.

TABLE 7: DD ESTIMATION

High Inflation in the U. S.				
Outcome Variable	Exchange Rate	Standard Error	t score	p value
Baseline				
Control	-1.058			
Treated	-0.953			
Diff (T-C)	0.106	1.801	0.06	0.953
Follow-up				
Control	-1.060			
Treated	-0.954			
Diff (T-C)	0.106	1.799	0.06	0.953
Diff-in-Diff	-0.000	0.003	-0.06	0.955

High Inflation in the Foreign Country				
Outcome Variable	Exchange Rate	Standard Error	t score	p value
Baseline				
Control	0.095			
Treated	-5.721			
Diff (T-C)	-5.816	1.704	-3.41	0.001***
Follow-up				
Control	0.092			
Treated	-5.716			
Diff (T-C)	-5.808	1.701	-3.41	0.001***
Diff-in-Diff	0.008	0.003	3.11	0.002***

Outcome variables (exchange rates) treated with high inflation in the U. S. showed no significant differences from the baseline or the control (inflation within policy targets). However, when the outcome variable was treated with high inflation in the foreign country, the resulting differences from baseline and control are significant. These results suggest that exchange rates do react differently to high inflation rates than they do to inflation rates within policy targets.

5. CONCLUSION AND FUTURE RESEARCH

Currency exchange rates remain important because of their effects on international commercial and financial market activity. The recent problem of higher-than-expected inflation in many developed countries has not been considered by research as a potential explanation to the many puzzles regarding the short-run relations between interest, inflation, and exchange rates noted in relevant literature. This study evaluated interest, inflation, and exchange rates relations between the U.S. and eight developed economies to determine whether higher-than-expected inflation has an effect on the short-run stability of these relations.

This study found that exchange rates do react differently in the short run when inflation rates increase beyond expected inflation. This study contributes to the relation of exchange, interest, and inflation rates in three ways. First, the long-term cointegrating relations found in prior studies also persist in the most recent data confirming theory regarding the reaction of exchange rates to interest and inflation rates. Variables remain stationary, and cointegrating relations are stable. Second, puzzles noted in prior research also persist in more recent data. The mixed results noted in this study's Granger causality tests are one example. Finally, this study applied vector error correction model estimation for each currency and differences-in-differences estimation to the entire panel and found that exchange rates react differently to inflation rates beyond expected inflation.

Additional panel regression over longer time periods may provide more insight into the general stability of long-term relations between inflation and exchange rates. However, future research should attempt to identify structural breakpoints in the long-term relation between inflation rates and exchange rates and consider utilizing long-run structural vector autoregression to estimate the results for each panel.

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