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Abstract

The main objective of this paper is to examine the efficiency of the foreign exchange (FX) markets before and during the turbulent periods surrounding the COVID-19 pandemic. Our efficiency tests are based on the Unbiasedness Forward Rate Hypothesis (UFRH). We use a pooled sample that contains 26 developed and emerging market currencies spanning the pre-COVID period (from November 30, 2018 to November 29, 2019), as well as the COVID period (from December 2, 2019 to November 30, 2020) as the key event which represents the time of tension. Our central finding in this paper is that FX market efficiency fails to hold during the COVID period, suggesting that the pandemic is a destabilizing event for the currency markets.

Highlights

- This paper investigates the efficiency of the foreign exchange (FX) markets before and during the turbulent periods surrounding the COVID-19 pandemic.
- We use a pooled sample that contains 26 developed and emerging market currencies
- Our sample period spans the pre-Covid period (from November 30, 2018 to November 29, 2019), as well as the Covid period (from December 2, 2019 to November 30, 2020)
- Our central finding is that FX market efficiency fails to hold during the Covid period, suggesting that the pandemic is a destabilizing event for the currency markets.

1. Introduction

The coronavirus COVID-19 pandemic is considered one of the most devastating events in modern history. Since the beginning of the COVID-19 outbreak, it has become clear that the pandemic has repercussions beyond the world healthcare system and has the potential to disrupt the world economy and the financial markets (Fang et al., 2023; Hu and Zhang, 2021; Lu et al., 2023; Uddin et al., 2022; Zhang et al., 2023; Zheng and Zhang, 2021).

In the current research, we examine the impact of COVID-19 on the FX market efficiency. Our motivation for such analysis is that the pandemic has severely impaired the functioning of the FX markets. As the pandemic continues, the FX market volatility has reached unprecedented levels (Aloui, 2021; Devpura, 2021; Feng *et al.*, 2021; Gunay, 2021; Iyke, 2020; Lu et al., 2023; Narayan et al., 2020; Umar and Gubareva, 2020; Wei *et al.*, 2020) making it more difficult for policymakers to formulate an appropriate policy response. Most central banks scrabbled to adjust the monetary frameworks to address the feedback loop between FX rate movements and capital outflows in a bid to weather the financial setbacks from the pandemic outburst. As a result, the FX markets have been closely monitored by international portfolio investors and policy makers alike.

Our efficiency analysis is cast within the general framework of the UFRH which is considered the traditional framework for examining FX market efficiency in the literature (Bai and Mollick, 2010; Baillie and Bollerslev, 1989 and 2000; Bandopadhyaya, 1991; Bilson, 1981; Dell Corte et al., 2011; Erdem and Geyikci, 2021; Fama, 1984; Frankel and Poonawala, 2010, Froot and Thaler, 1990; Gregory and McCurdy, 1986; Kellard and Sarantis, 2008; McFarland et al., 1994; Norrbin and Reffett, 1996; Phillips and McFarland, 1997; Snaith et al., 2013; Yangru and Zhang, 1997). In order for the FX market to be efficient, according to the UFRH, the forward exchange rate for delivery at a specified future date should be an unbiased predictor of the future spot exchange rate and, therefore, there should not be any arbitrage opportunities arising from the forward premium.

Nevertheless, there has been a widespread empirical rejection of the UFRH in the literature (Fama, 1983), resulting in the so called forward premium puzzle (i.e., the forward rate does not appear to be an unbiased predictor for the future spot rate). One potential explanation for the forward premium puzzle is the existence of a time-variant risk premium component in forward rates (Abankwa and Blenman, 2021; Frankel and Chinn, 1993; Hodrick and Srivastava, 1986; Kumar, 2020; Verdelhan, 2010). This explanation has resulted in a flurry of research on the time-varying performance of the FX markets across tranquil and turbulent periods (Ahmad et al., 2012; Flood and Rose, 2002; Grossmann et al., 2014; Lothian and Wu, 2011; Shehadeh et al. 2021; Zhou and Kutan, 2005). A related line of research has proposed crash risk as an alternative explanation to the forward premium puzzle (Atanasov and Nitschka, 2014; Brunnermeier et al. (2009), Daniel et al. (2017), Farhi and Gabaix (2008 and 2016), and Jurek (2014).

These explanations for the forward premium puzzle motivate our work. Within this framework, we examine the response of FX market efficiency to COVID-19 using two empirical tests – Fama (1983) regression (i.e., regressing spot rate changes on forward premium) as a standard efficiency test in the literature, and Pilbeam and Olmo (2011) regression to avoid the potential bias associated with the Fama (1984) regression given that the volatility of spot exchange rate changes is higher than the forward premium. Our analysis is based on comparing the significance and/or direction of the forward premium coefficients during the periods before and during COVID-19. The two sub-periods are pre-COVID period (from November 30, 2018 to November 29, 2019), and COVID period (from December 2, 2019 to November 30, 2020) that represents the time of tension. We use a sample of 10 developed currencies and 16 emerging currencies, given the evidence in prior research that underscores the importance of differentiating between developed and emerging countries when examining FX market efficiency (Bansal and Dahlquist, 2000; Frankel and Poonawala, 2010; Lee, 2013; Miah and Altiti, 2020; Poti et al., 2020; Shehadeh et al. 2021).

Our main finding in this paper is that the pandemic is a destabilizing event to the FX markets, in the sense that currency markets were generally efficient before the pandemic whereas market efficiency fails to hold during COVID period. More specifically, our Fama regression estimates reveal a significant positive relation between spot rate changes and forward premium in the pre-COVID period, a finding which in line with the predictions of the UFRH which predicts that currencies with higher than average forward premium tend to depreciate to eliminate any arbitrage opportunities. Conversely, our estimates turn to be insignificant once we move onto examining the COVID period. Interestingly, we also find that many of our forward premium coefficients are insignificant in the pre-COVID period, but they turn to be significantly negative (i.e., the wrong sign) in the pandemic period. The negative forward premium coefficients are interpreted as an inefficiency signal because they suggest that currencies with higher than average forward premium tend to appreciate. The Pilbeam and Olmo (2011) regression results confirm the Fama regression results, suggesting that the FX markets are mostly inefficient during the COVID period.

This paper contributes to the existing literature in two important respects. First, we add to the extant exchange rate literature on market efficiency. To the best of our knowledge, this article is the first early attempt to examine the impact of COVID-19 pandemic on FX market efficiency. A critical review of the FX market efficiency literature reveals that there has been an academic research on the response of the FX market efficiency to the 1997–1998 Asian crisis (Ahmad et al., 2012; Aroskar *et al.*, 2004; Jeon and Seo, 2003; Kan and Andreosso-O'Callaghan, 2007) and the 2007–2008 financial crisis (Baba and Packer, 2009; Beckmann and Czudaj, 2017; Berg and Mark, 2018; Brunnermeier *et al.*, 2008; Doukas and Zhang, 2013; Dupuy, 2015; Farhi *et al.*, 2009; Farhi and Gabaix, 2008; Fatum and Yamamoto, 2016; Fratzscher, 2009), but no such exploration has been undertaken in the wake of the COVID pandemic. Therefore, our study complements this literature by examining the pandemic impact on the FX market efficiency.

Second, we contribute to the fast growing literature that examines the pandemic-impact on financial markets. The escalation of COVID-19 pandemic has stimulated finance research to examine the influence of the pandemic on various financial instruments such as stocks (Al-Awadhi et al., 2020; Ashraf, 2020; Zaremba et al., 2020; Zhang et al., 2020); Bitcoin (Goodell and Goutte, 2021); gold and cryptocurrencies (Corbet et al., 2020); oil (Okorie and Lin, 2021; Salisu et al., 2020; Sharif et al., 2020); investment funds (Mirza et al., 2020), and currencies (Aloui, 2021; Devpura, 2021; Feng et al., 2021; Gunay, 2021; Iyke, 2020; Lu et al., 2023; Narayan et al., 2020; Umar and Gubareva, 2020; Wei et al., 2020). A common thread in this literature is that they focus predominantly on the influence of the pandemic, and we complement this literature by showing that COVID-19 pandemic is associated with deteriorating FX market efficiency.

The remainder of the article is organized as follows. Section 2 summarizes the literature review. Section 3 outlines the methodological procedures. Section 4 describes data. Empirical results are presented in section 5. Section 6 offers some concluding remarks.

2. Literature Review

Generally speaking, the efficient market hypothesis (EMH) asserts that financial markets are 'informationally efficient', in the sense that all new information is quickly understood by market participants and becomes immediately incorporated into market prices which in turn provide signals for portfolio allocation under the assumption of rationality of market expectations (Fama, 1970). Accordingly, one cannot consistently earn abnormal returns in excess of market returns on a risk-adjusted basis, given the publicly available information at the time the investment is made.

Separately, there has been an extensive literature on FX market efficiency in tranquil periods on one hand, and in turbulent periods on the other hand. In this section, we draw insights from these two separate strands of the literature.

2.1 FX market efficiency – tranquil periods

Since the seminal contribution of Fama (1970), the FX market efficiency has always attracted the academic community within the framework of the UFRH which is considered the traditional framework for examining FX market efficiency in the literature (Chiang et al., 2010; Gârleanu and Panageas, 2021; Kallianiotis, 2018; Kočenda and Poghosyan, 2009; Morley and Pentecost, 1998; Nucci, 2003; Potì and Siddique, 2013; Potì et al., 2020; Verdelhan, 2010).[1] The UFRH is based on the classical formulations of Fama's (1970) EMH. In a semi-strong-form efficient market, asset prices should reflect all publicly available information (Fama, 1970), and thus the current forward price of an asset for delivery at a specified future date should be an unbiased predictor of the future spot rate. Under the joint assumptions of rational expectations and risk neutrality, the UFRH states that the forward exchange rate for delivery at a specified future date should be an unbiased predictor of the future spot exchange rate in an efficient market. Accordingly, exchange rate changes will eliminate any arbitrage opportunities arising from interest rate differentials between countries because we should expect a depreciation of the high interest rate currency against the low interest rate currency by the same amount as the interest rate differential (Fama, 1984).

One of the most puzzling anomalies in the international finance literature is the forward premium puzzle. There has been an overwhelming empirical evidence on the empirical failure of the UFRH, suggesting that the low (high) interest rate currency tend to depreciate (appreciate) (Baillie and Bollerslev, 1989 and 2000; Bansal and Dahlquist, 2000; Barkoulas et al., 2003; Bilson, 1981; Coudert and Mignon, 2013; Dutt, 1994; Frankel and Poonawala, 2010; Froot and Thaler, 1990; Hochradl and Wagner, 2010; Kumar, 2020; Lagoarde-Segot and Lucey, 2008; Li and Miller, 2015; Londono and Zhou, 2017; Sarno et al., 2012; Tucker, 1987). The direct consequence of the failure of the UFRH is the emergence of the popular carry trade strategy, defined as borrowing in a low interest rate currency and lending in a higher interest rate currency betting that the foreign exchange rate will not change so as to offset the profits made on the interest rate differential. Consequently, such profitable strategies give rise to the forward premium puzzle.

[1] Prior research has also examined the market efficiency for other assets such as stocks (Al Janabi et al., 2010; Alexeev and Tapon, 2011; Lo, 2004); bonds (Hotchkiss and Ronen, 2002), and cryptocurrencies (Tran and Leirvik, 2020).

Several explanations have been put forward to explain the failure of the UFRH, such as the adverse selection problem by traders (Burnside et al., 2009); improper modeling of forward and spot rates volatility (Pilbeam and Olmo, 2011); perpetual learning by agents (Barkoulas et al., 2003); different orders of integration of the variables in the conventional Fama regression (Baillie and Bollerslev, 2000); volatility regimes (Clarida et al., 2009); more easily identifiable trends of depreciation of emerging market currencies (Frankel and Poonawala, 2010).

2.2 FX market efficiency – turbulent periods

It has also been argued that forward premium puzzle is driven from the time-varying performance of FX markets across tranquil and turbulent periods (Ahmad et al., 2012; Flood and Rose, 2002; Grossmann et al., 2014; Levich et al., 2019; Lothian and Wu, 2011; Shehadeh et al. 2021; Zhou and Kutan, 2005) due to the existence of a time-variant risk premium component in forward rates (Abankwa and Blenman, 2021; Frankel and Chinn, 1993; Hodrick and Srivastava, 1986; Kumar, 2020; Verdelhan, 2010). A related line of research has proposed a crash risk based explanation to the forward premium puzzle, such as Atanasov and Nitschka (2014), Brunnermeier et al. (2009), Daniel et al. (2017), Farhi and Gabaix (2008 and 2016), and Jurek (2014).

Motivated by these predictions, there has been numerous studies that have suggested that FX market efficiency changes over time, using data from several financial crises – the 1992 European financial market crisis, the 1997-1998 Asian financial crisis, and the 2007-2008 global financial crisis. For example, Aroskar *et al.* (2004) investigate the impact of the 1992 European financial crisis on FX markets efficiency, and they conclude that FX efficiency is not stable during the pre-crisis and the post-crisis periods as a result of market inefficiency, risk premium, and/or common policy guidelines for the European monetary system members. Along the same lines, several studies have documented that the 1997-1998 Asian crisis had severe impact on the efficiency of Asian FX markets (Ahmad et al., 2012; Al-Khazali et al., 2012; Bauer and Herz, 2009; Benson and Faff, 2004; Jeon and Seo, 2003; Kan and Andreosso-O'Callaghan, 2007; Mishra and Sharma, 2010; Shamsuddin and Kim, 2003; Soon and Baharumshah, 2021; Tse and Yip, 2003).

Similarly, prior research has found that the 2007-2008 financial crisis has caused a time variation in the performance of FX markets (Baba and Packer, 2009; Ball, 2009; Beckmann and Czudaj, 2017; Berg and Mark, 2018; Brunnermeier *et al.*, 2008; Bush and Stephens, 2016; Doukas and Zhang, 2013; Dupuy, 2015; Farhi *et al.*, 2009; Farhi and Gabaix, 2008; Fatum and Yamamoto, 2016; Fratzscher, 2009; Kinateder et al., 2021; Matvos and Seru, 2014; Yamani, 2021).

Recently, few studies have examined the FX markets during the pandemic (Feng *et al.*, 2021; Iyke, 2020; Narayan et al., 2020). Narayan et al. (2020) find that the depreciation of the Yen vis-à-vis the US dollar leads to gains in Japanese stock returns by 71% during the COVID-19 period. They claim that this relationship was stronger during COVID-19 period compared to the pre-pandemic period. Furthermore, Feng *et al.* (2021) show that an increase in confirmed cases has significantly increased exchange rate volatility. Lastly, Iyke (2020) has found that COVID-19 outbreak has better predictive power over volatility than over returns for a one-day ahead forecast horizon. A common thread in such literature is that they all predominantly concentrated on FX volatility impacts of the pandemic without examining market efficiency. Hence, we complement this literature by showing that COVID-19 is associated with deteriorating FX market efficiency.

3. Methodology

Our analysis is cast within the UFRH which is the conventional framework for examining FX market efficiency in the literature (Bai and Mollick, 2010; Baillie and Bollerslev, 1989 and 2000; Bandopadhyaya, 1991; Bansal and Dahlquist, 2000; Bilson, 1981; Dell Corte et al., 2011; Erdem and Geyikci, 2021; Fama, 1984; Frankel and Poonawala, 2010; Froot and Thaler, 1990; Gregory and McCurdy, 1986; Kellard and Sarantis, 2008; McFarland et al., 1994; Norrbin and Reffett, 1996; Phillips and McFarland, 1997; Snaith et al., 2013; Yangru and Zhang, 1997).

To empirically examine the UFRH, we employ two approaches: Fama (1984) and Pilbeam and Olmo (2011) regression models. Fama regression is considered the conventional test for examining the unbiasedness of forward rates as predictor of future spot rates.[2] We follow the existing literature on Fama regression (see Ahmad *et al.*, 2012; Bansal and Dahlquist, 2000; Baillie and Bollerslev, 1989, 2000; Fama, 1984; Frankel and Poonawala, 2010; Froot and Thaler, 1990), and regress the log monthly spot exchange rate changes Δs_{t+1} on forward premium $(f_t - s_t)$, as follows

$$\Delta s_{t+1} = \beta_0 + \beta_1(f_t - s_t) + \varepsilon_{t+1}, \qquad (1)$$

where s_t and f_t refers to the logarithm of the nominal spot rate and the one-month forward rates, respectively, expressed as the number of foreign currency units per one US Dollar. If the FX market is efficient, we should expect to find that β_0 is insignificant and β_1 equals one.

[2] We note that FX market efficiency has been measured by alternative methods such as pairwise co-integration tests (Layton and Tan, 1992), linear unit root tests (Giannellis and Papadopoulos, 2009), correlation functions (Podobnik et al., 2002), network analysis (Jeong *et al.*, 2000), Pedroni's panel co-integration method (Makovskỳ, 2014), the multifractal detrended fluctuation analysis (Ning et al., 2018), and vector autoregressions (Rösch et al., 2017).

For robustness, we use the following econometric regression model proposed by Pilbeam and Olmo (2011) to further examine the unbiasedness of forward rates as predictor of future spot rates

$$[(\frac{S_{t+1}}{F_t}) - 1] = \alpha + \rho \frac{1}{F_t} + \varepsilon_{t+1}, \tag{2}$$

where S and F denote spot and forward exchange rates in levels, respectively, and $1/F_t$ is a proxy for risk premium. The rationale for using Pilbeam and Olmo (2011) regression, as defined in Equation 2, is to avoid the potential bias of Fama regression, as defined in Equation 1, that regresses log spot exchange rate changes on the forward premium while the volatility of spot exchange rate changes is usually known to be higher than the forward premium. Pilbeam and Olmo (2011) regression is another way of testing FX market efficiency. More specifically, Equation 2 examines a market efficiency property that implies that $\alpha = \rho = 0$, suggesting that exchange rate changes will eliminate any arbitrage opportunities arising from forward premium.

4. Data and sample periods

Our dataset contains daily observations for spot and one-month forward exchange rates for 10 developed and 16 emerging market currencies. Our sample of developed countries includes Australia, Canada, Denmark, Germany/Euro[3], Japan, New Zealand, Norway, Sweden, Switzerland, and United Kingdom. The emerging countries includes Czech, Hungary, India, Indonesia, Kuwait, Malaysia, Mexico, Philippine, Poland, Saudi Arabia, Singapore, South Africa, South Korea, Taiwan, Thailand, Turkey. All exchange rate data are obtained from DataStream.

To examine the impact of the pandemic on market efficiency, we examine two separate sub-periods around the pandemic: the pre-COVID period, covering the period from November 30, 2018 to November 29, 2019; and the COVID period spanning from December 2, 2019 to November 30, 2020. Our choice of December 2, 2019 as the starting date of the COVID period is inspired by Corbet et al. (2020). According to Wuhan Municipal Health, the cases of pneumonia detected in Wuhan, China occur between December 12, and December 29, but they are first reported to the WHO on December 31, 2019. Further, our choice of November 30, 2020 as the onset of the recovery period is motivated by the announcement of a COVID vaccine candidate by Pfizer Inc. and BionNtech SE on November 9, 2020.

[3] Before the introduction of the euro in January 1999, we splice the Deutsche mark with the Euro.

5. Results

5.1 Preliminary results

To set the stage, Table 1 reports the descriptive statistics of our study variables. Table 1 decomposes average currency excess returns into two components: average forward premium and average spot exchange rate changes. Panel A presents the statistics for the three portfolios, while Panels B and C report the results for developed and developing/emerging market currencies, respectively. Panel A of Table 1 shows that the developed portfolio yields negative excess returns of -0.28% (-0.17% from the forward premium and 0.11% from the spot rate changes) during the pre-COVID period, compared to positive excess returns of 0.45% (-0.06% from the forward premium and -0.51% from the spot rate changes) during the COVID period. A similar pattern is observed for almost all developed market currencies in Panel B of Table 1.

We start our efficiency analysis by examining the randomness of FX return series over time in order to examine a market efficiency property which implies that FX markets are efficient if FX series are stationary (i.e., mean reverting). To this end, we conduct a unit root test which is an autocorrelation test of independence that measures the significance of correlation in FX return series over time. To this end, Table 2 reports the results of two popular unit root tests -Augmented Dickey-Fuller (ADF) test and Phillip-Perron (PP) test, in order to examine the presence of a stochastic trend in spot and forward rate series over time. The null hypothesis in both tests states that the series is nonstationary, suggesting the existence of autocorrelation.

Panel B of Table 2 shows that both statistics for spot and forward rates are significant for 4 out of 10 developed countries (Australia, Canada, Denmark, and Europe) in the pre-COVID period, implying that both series are stationary (i.e., mean reverting) in the sense that past values cannot predict future values. Nevertheless, these statistics turn to be insignificant during the COVID period, implying that the current spot and forward rates may depend on their corresponding historical rates, an indication of market inefficiency. A contrasting pattern is observed for Japan. The inclusion of the sub-periods makes almost no difference for the remaining developed countries. Panel C of Table 2 shows that 7 out of 15 emerging countries (Czech, Hungary, Indonesia, Kuwait, Poland, Saudi Arabia, and South Africa) report significant (insignificant) statistics before (during) the COVID period, while the remaining emerging countries report insignificant results before and during the COVID period.

The state of efficiency in currency markets is also determined by the variance ratio test. A market is considered efficient if the volatility of security prices of a q-period difference should equal to q-times the variance of the one-period returns where q is the lag or the holding period. The variance ratio test statistics examine the null hypothesis that spot exchange rates follow a random walk behavior. Table 3 summarizes the Lo and MacKinlay (1988) overlapping variance ratio test statistics preformed on log spot exchange rates s_t for lags 2, 5, 10, and 30. In Panel B, we find that none of the variance ratio statistics are significant (at the 5% level) for all lags and all developed countries in the pre-COVID period. Conversely, it is interesting to note that there is an evidence to reject the null hypothesis (at the 10% level) for five (four) developed countries for lags two (five) in the COVID period. A similar pattern is observed in Panel C, but the evidence seems to be weaker when using emerging currencies. More specifically, our results reveal that the statistics for lag 2 are insignificant (at the 5% level) for 4 countries (Hungary, Indonesia, South Korea, and Thailand) in the before-COVID period, but they turn to be significant (at least at the 5% level) in the COVID-period. A similar result is found for the statistics for lag 5 in 6 countries.

5.2 Fama regression results

Table 4 reports the intercept β_0 and the slope coefficient β_1 estimates of Fama regression, as defined in Equation 1. We are primarily interested in comparing the significance and the sign of the forward premium coefficients in pre-COVID period vis-à-vis COVID period. The UFRH predicts that the forward premium should render positive beta coefficient indicating that currencies with higher than average forward premium tend to depreciate. If markets are efficient, therefore, we should expect to observe that the slope coefficient estimates render positive betas. We also report the Wald F-test statistics that examines the joint null hypothesis that $\beta_0 = 0$ and $\beta_1 = 1$. Our rationale for reporting the Wald F-test statistics is that, according to the Fama regression, currency markets are efficient if β_0 is insignificantly different from zero, while β_1 equal one. Therefore, we should expect to observe insignificant Wald F-test statistics if markets are efficient.

Our central finding in Table 4 is that the significance and/or direction of the forward premium coefficients are reversed once we move on to the COVID period from the pre-COVID period. Throughout Table 4, we generally find that the forward puzzle is more prominent during the COVID period as compared to the pre-COVID period, as attested by two main observations. First, we observe that many of the forward premium coefficients report the wrong sign (i.e., negative betas) when switching from the pre-COVID period to the COVID period. For example, Panel A reveals that the coefficient estimates for 5 countries (Australia, Denmark, Europe, New Zealand, and Switzerland) are insignificant in the pre-COVID period, but they turn to be significantly negative (i.e., the wrong sign) in the COVID period. The same finding is observed for Hungary and South Korea in Panel B. Second, we find that many of our forward premium coefficients flip sign when switching from the pre-COVID period to the COVID period. More specifically, it is notable that the beta coefficients for Japan and Turkey are significantly positive in the pre-COVID period but turns to be negative, albeit insignificant, in the COVID-period. We also find a stronger evidence on such sign-flip in the results of Kuwait, Saudi Arabia, and Thailand which all report significantly positive (negative) estimates in pre-COVID (COVID) period.

Our evidence, that the pandemic is a destabilizing event for FX markets, is in line with prior research on the time-varying performance of the FX markets in turbulent periods, such as the 1992 European financial crisis (Aroskar *et al.*, 2004), the 1997-1998 Asian financial crisis (Al-Khazali et al., 2012; Jeon and Seo, 2003; Kan and Andreosso-O'Callaghan, 2007), and the 2007-2008 global financial crisis (Ahmad et al., 2012; Baba and Packer, 2009; Beckmann and Czudaj, 2017; Dupuy, 2015; Farhi *et al.*, 2009; Farhi and Gabaix, 2008; Fratzscher, 2009; Yamani, 2021). Our results also in line with recent research suggesting that COVID-19 has increased global uncertainty in financial markets (Ali et al. 2020; Altig et al. 2020; Bai et al. 2021; Baker et al., 2020).

Our results can thus be understood in the context of the existing evidence in the literature on the relation between uncertainty and exchange rate volatility (Berg and Mark, 2018; Husted et al., 2018; Kinateder et al., 2021; Krol, 2014; Liu, 2021), suggesting that an increase in financial and economic uncertainty leads to an increase in FX market volatility. For example, Krol (2014) finds that economic policy uncertainty has significantly positive effect on volatility of FX markets during adverse economic times. Similarly, Gkillas et al. (2018) find that uncertainty causes volatility jumps in currency returns. In support, Liu (2021) shows that there is a nonlinear dynamic relationship between financial and macroeconomic uncertainty and the stability of FX market, using monthly data from August 2005 to December 2017 from China.

5.3 The Pilbeam and Olmo (2011) Regression Results

To provide a further investigation on the FX market efficiency, Table 5 presents the results of Pilbeam and Olmo (2011) regression that avoids the potential bias that may arise in Fama regression results given that the volatility of spot exchange rate changes are usually higher than the forward premium. The null hypothesis in Pilbeam and Olmo (2011) test states that α and ρ

should equal zero (i.e., the market is efficient). As such, we report the Wald F-test statistics which examine the joint null hypothesis that $\alpha = 0$ and $\rho = 0$ under Equation 2. Our overall results in Table 5 show that both subperiods provide consistent results, suggesting that the null hypothesis is rejected across both subperiods as most of the statistics are significant at least 10% level.

In a nutshell, the overall results in Tables 4 and 5 reject the null hypothesis that FX market is efficient and, therefore, lend credence to the previous research that documents a widespread empirical rejection of the UFRH in the literature (Bai and Mollick, 2010; Bandopadhyaya, 1991; Dell Corte et al., 2011; Erdem and Geyikci, 2021; Fama, 1984; Gregory and McCurdy, 1986; Phillips and McFarland, 1997; Yangru and Zhang, 1997). Nevertheless, Tables 4 and 5 provide somehow different evidence on the time-varying performance of FX market across pre-COVID and COVID periods. While Fama regression results show that the forward puzzle is more prominent during the COVID period as compared to the pre-COVID period, Pilbeam and Olmo (2011) regression results show that the inclusion of the two sub-periods makes almost no difference. This latter finding is consistent with Ahmad et al. (2012) who find that FX markets are generally efficient within-country when tested using the Pilbeam and Olmo (2011) regression, but market efficiency fails to hold when tested using Fama (1984) conventional regression.

6. Conclusion

In this article, we examine the impact of COVID-19 pandemic on FX market efficiency using data from 26 developed and emerging market currencies. Our sample period covers the pre-COVID period from November 30, 2018 to November 29, 2019 and the COVID period spanning from December 2, 2019 to November 30, 2020. Our efficiency tests are cast within the conventional UFRH framework by employing Fama (1984) and Pilbeam and Olmo (2011) regression models for examining the unbiasedness of forward rates as predictor of future spot rates.

A general finding from Fama regression analysis reveals that the pandemic is a destabilizing event for global currency markets, as attested by our finding that the forward puzzle is more prominent during the COVID period as compared to the pre-COVID period. More specifically, we find that the significance and/or direction of the forward premium coefficients are reversed once we focus our analysis on the COVID period as compared to the pre-COVID period, suggesting that currency markets are generally efficient before the pandemic whereas market efficiency fails to hold during the COVID period. The overall findings from Pilbeam and Olmo (2011) regression show that the inclusion of the two sub-periods makes almost no difference.

Our evidence, on the time-varying performance in currency markets during the pandemic, provides insights to the practice of currency trading and to the academic literature. From a currency trader perspective, it is important for practitioners to be aware of the evidence that turbulent periods increase uncertainty and deviations from market efficiency which in turn cause asymmetric time-varying shifting trends in currency markets. From an academic perspective, we contribute to several important strands in the finance literature, including (1) the literature on the time-varying performance of FX markets during times of financial turmoil (Ahmad et al., 2012; Al-Khazali et al., 2012; Beckmann and Czudaj, 2017; Yamani, 2021); (2) the literature on the empirical failure of the UFRH (Bai and Mollick, 2010; Dell Corte et al., 2011; Erdem and Geyikci, 2021; Fama, 1984; Yangru and Zhang, 1997); and (3) the recent literature on the influence of COVID 19 pandemic on financial markets (Fang et al., 2023; Hu and Zhang, 2021; Lu et al., 2023; Uddin et al., 2022; Zhang et al., 2023; Zheng and Zhang, 2021).

We acknowledge that the limitation of our empirical work is that we are restricted to models which are cast within the general framework of UFRH. While the UFRH is considered the conventional test for examining FX market efficiency in the literature, the UFRH focuses only on examining the implications of macroeconomic fundamentals (such as spot and forward exchange rates) for FX market efficiency. Nevertheless, FX market efficiency can also be examined within the technical trading analysis framework (such as moving average, momentum, relative strength index) using historical currency data. Several academic researchers have interpreted significant profits generated from FX technical trading rules as an inefficiency signal (Fama 1984; Katusiime et al., 2015; Neely and Weller, 2013; Zarrabi et al., 2017; Yamani, 2021). We leave it to future researchers to use technical trading rules to examine FX market efficiency during the turmoil period associated with the. COVID-19 pandemic.

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Table 1: Descriptive statistics

The table reports the monthly currency excess returns measured as the log forward rate minus the expected log spot rate: $r_{t+1} = (f_t - s_t) - \Delta s_{t+1} = f_t - s_{t+1}$, where r_{t+1} denotes the monthly currency excess returns. We present all statistics across the whole sample period, and two subsample periods: pre-COVID and COVID periods. N is the number of observations. Panel A presents the results for the equally weighted portfolios, Panel B presents the results for the developed currencies, and Panel C reports the results for the emerging currencies.

Panel A. Pooled Samples

	Whole Sample				Pre-COVID Period				COVID Period			
Portfolio	N	Excess Return	Forward Premium	Spot Change	N	Excess Return	Forward Premium	Spot Change	N	Excess Return	Forward Premium	Spot Change
Developed	5340	0.0007	-0.0012	-0.0019	2600	-0.0028	-0.0017	0.0011	2740	0.0045	-0.0006	-0.0051
Emerging	8010	0.0012	0.0017	0.0004	3900	0.0017	0.0018	0.0001	4110	0.00091	0.00171	0.0008
Global	13350	0.0011	0.0006	-0.0005	6500	-0.0001	0.0004	0.0005	6850	0.0023	0.00077	-0.0016

Panel B. Developed Countries

Country	N	Excess Return	Forward Premium	Spot Change	N	Excess Return	Forward Premium	Spot Change	N	Excess Return	Forward Premium	Spot Change
Australia	534	0.0008	-0.0005	-0.00132	260	-0.0042	-0.0008	0.0034	274	0.0060	-0.0003	-0.00629
Canada	534	0.013	-0.004	-0.016	260	0.0008	-0.0006	-0.0014	274	0.0017	-0.00012	-0.00182
Denmark	534	0.0004	-0.019	-0.024	260	-0.0047	-0.0027	0.0021	274	0.0057	-0.0012	-0.0069
Europe	534	0.0004	-0.0018	-0.0023	260	-0.0045	-0.0025	0.0020	274	0.0055	-0.0011	-0.00662
Japan	534	0.014	-0.0016	-0.003	260	-0.0001	-0.0024	-0.0022	274	0.0030	-0.0009	-0.0039
New Zealand	534	0.0009	-0.0003	-0.0012	260	-0.0036	-0.0006	0.0029	274	0.0054	-0.0000	-0.0054
Norway	534	-0.016	-0.0005	0.0009	260	-0.0048	-0.0010	0.0038	274	0.0017	-0.0002	-0.0019
Sweden	534	0.0010	-0.0015	-0.0025	260	-0.0058	-0.0023	0.0035	274	0.0081	-0.0007	-0.0087
Switzerland	534	0.0020	-0.0021	-0.0041	260	-0.0022	-0.0028	-0.0006	274	0.0062	-0.0013	-0.0076
United Kingdom	534	0.0012	-0.0009	-0.0021	260	0.0012	-0.0015	-0.0026	274	0.00121	-0.0005	-0.0017

Table 1: Descriptive statistics (continued)

Panel C. Developing and Emerging Countries												
	Whole Sample				Pre-COVID Period				COVID Period			
Country	N	Excess Return	Forward Premium	Spot Change	N	Excess Return	Forward Premium	Spot Change	N	Excess Return	Forward Premium	Spot Change
Czech	534	0.0010	-0.0005	-0.0015	260	-0.0017	-0.0007	0.0009	274	0.0038	-0.0003	-0.0040
Hungary	534	-0.0032	-0.0012	0.0020	260	-0.0062	-0.0021	0.0041	274	-0.0002	-0.0003	-0.0000
India	534	0.0016	0.0034	0.0018	260	0.0030	0.0036	0.00055	274	0.0002	0.0032	0.0030
Indonesia	534	0.0044	0.0033	-0.0011	260	0.0063	0.0036	-0.0027	274	0.0025	0.0031	0.0006
Kuwait	534	0.0003	0.0004	0.0001	260	0.0003	0.0002	-0.0001	274	0.0003	0.0007	0.0004
Mexico	534	0.0048	0.0046	-0.0002	260	0.0090	0.0050	-0.0040	274	0.0006	0.0042	0.0037
Philippines	534	0.0055	0.0016	-0.0038	260	0.0051	0.0020	-0.0031	274	0.0059	0.0013	-0.0045
Poland	534	0.0003	-0.0004	-0.0006	260	-0.0024	-0.0007	0.00170	274	0.0030	-0.0001	-0.0030
Saudi Arabia	534	0.0000	0.0000	-0.0001	260	0.00002	-0.0000	-0.0000	274	0.0000	0.00003	0.0000
Singapore	534	0.0007	-0.0003	-0.0009	260	0.0003	-0.0005	-0.0007	274	0.0011	-0.00011	-0.0012
South Africa	534	0.0011	0.0038	0.0027	260	0.0027	0.0038	0.0012	274	-0.0004	0.00383	0.0042
South Korea	534	0.0002	-0.0007	-0.0009	260	-0.0047	-0.0009	0.0038	274	0.0053	-0.0004	-0.0056
Taiwan	534	0.0021	-0.0013	-0.0034	260	-0.0006	-0.0019	-0.0013	274	0.0048	-0.0006	-0.0055
Thailand	534	0.0029	-0.0004	-0.0032	260	0.0057	-0.0007	-0.0064	274	-0.0000	-0.0001	-0.0001
Turkey	534	-0.022	0.0135	0.0158	260	0.0084	0.0161	0.0077	274	-0.0131	0.0111	0.0241

Table 2: Unit root test results on spot and forward exchange rates

The table displays the results of the Augmented Dickey–Fuller (ADF) test and Phillip-Perron (PP) test for both spot and forward exchange rate series. The null hypothesis in both tests states that the exchange rate series is a unit root. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

Panel A. Pooled Samples												
	Spot Rates						Forward Rates					
	Whole Sample		Pre COVID		COVID Period		Whole Sample		Pre COVID		COVID Period	
Portfolio	*ADF*	*PP*	*ADF*	*PP*	*ADF*	*PP*	*ADF*	*PP*	*ADF*	*PP*	*ADF*	*PP*
Developed	-2.36	-2.37	-2.48	-2.48	-2.43	-2.44	-2.36	-2.36	-2.48	-2.48	-2.43	-2.43
Emerging	**-2.83***	**-2.87****	-2.99	-3.01	-2.91	-2.93	-2.83*	-2.87**	-2.99	-3.01	-2.91	-2.93
Global	**-3.60*****	**-3.65*****	**-3.68****	**-3.73****	**-3.58****	**-3.62****	**-3.60*****	**-3.65*****	**-3.68****	**-3.73****	**-3.58****	**-3.62****
Panel B. Developed Countries												
Country	*ADF*	*PP*	*ADF*	*PP*	*ADF*	*PP*	*ADF*	*PP*	*ADF*	*PP*	*ADF*	*PP*
Australia	-1.35	-1.36	**-3.70****	**-3.64****	-1.76	-1.65	-1.35	-1.45	**-3.71****	**-3.65****	-1.76	-1.64
Canada	-2.00	-1.92	**-3.64****	**-3.32***	-1.46	-1.46	-1.98	-1.90	**-3.64****	**-3.32***	-1.45	-1.45
Denmark	-0.68	-1.23	**-4.56*****	**-4.26*****	-2.35	-2.24	-0.66	-1.22	**-4.57*****	**-4.27*****	-2.32	-2.21
Europe	-0.72	-1.28	**-4.53*****	**-4.22*****	-2.33	-2.23	-0.70	-1.26	**-4.55*****	**-4.24*****	-2.30	-2.19
Japan	**-4.54*****	**-4.28*****	-2.16	-2.22	**-5.73*****	**-4.94*****	**-4.49*****	**-4.13*****	-2.18	-2.24	**-5.74*****	**-4.90*****
New Zealand	-1.03	-1.27	-2.61	-2.82	-1.36	-1.50	-1.03	-1.26	-2.62	-2.83	-1.36	-1.49
Norway	-2.27	-2.00	-2.65	-2.75	-2.11	-1.85	-2.26	-1.95	-2.64	-2.74	-2.11	-1.85
Sweden	-1.21	-1.30	-2.53	-2.62	-1.83	-1.97	-1.20	-1.28	-2.51	-2.61	-1.81	-1.95
Switzerland	-2.77	-2.49	-2.64	-2.58	-3.28*	-2.88	-2.76	-2.47	-2.64	-2.59	-3.22*	-3.00
United Kingdom	-1.90	-2.60	-1.68	-1.62	-2.23	-2.11	-1.88	-2.58	-1.67	-1.62	-2.19	-2.09

Table 2: Unit root test results on spot and forward exchange rates (continued)

Panel C. Emerging Countries												
	Spot Rates						Forward Rates					
	Whole Sample		Pre COVID		COVID Period		Whole Sample		Pre COVID		COVID Period	
Country	*ADF*	*PP*	*ADF*	*PP*	*ADF*	*PP*	*ADF*	*PP*	*ADF*	*PP*	*ADF*	*PP*
Czech	-1.70	-1.94	**-3.23***	**-3.39***	-1.48	-1.74	-1.67	-1.95	**-3.18***	**-3.33***	-1.47	-1.75
Hungary	-1.96	-2.33	**-3.60****	**-3.38***	-1.88	-2.17	-1.93	-2.31	**-3.62****	**-3.39***	-1.84	-2.14
India	-1.92	-1.93	-2.02	-2.10	-1.21	-1.13	-1.92	-1.96	-2.05	-2.17	-1.22	-1.17
Indonesia	-3.61**	-2.63	-3.49**	-2.99	-2.60	-1.77	-3.61**	-2.62	-3.47**	-2.96	-2.60	-1.76
Kuwait	-1.84	-2.03	**-3.91****	**-3.64****	-1.36	-1.62	-1.74	-1.90	**-3.82****	**-3.65****	-1.44	-1.52
Mexico	-2.47	-1.93	-3.13	-3.07	-1.24	-1.17	-2.47	-1.90	-3.15*	-3.09	-1.23	-1.16
Philippines	**-3.13***	**-3.14***	-2.94	-2.91	-2.81	-2.70	**-3.31***	**-3.18***	-2.94	-2.95	-2.81	-2.76
Poland	-1.95	-2.02	-3.15*	-2.92	-1.63	-1.81	-1.94	-1.99	-3.15*	-2.92	-1.62	-1.79
Saudi Arabia	-2.77	-4.56***	**-3.18***	**-3.64****	-1.88	-3.51**	-2.41	-3.95**	**-3.70****	**-4.05*****	-1.93	-2.72
Singapore	-1.25	-1.45	-2.29	-2.50	-1.06	-1.41	-1.25	-1.47	-2.30	-2.51	-1.06	-1.41
South Africa	-1.03	-1.10	-4.28***	-2.99	-0.63	-0.63	-1.04	-1.10	-4.28***	-2.99	-0.65	-0.64
South Korea	-0.27	-0.91	-1.66	-1.72	-0.96	-1.37	-1.13	-1.00	-1.67	-1.73	-0.90	-1.25
Taiwan	-1.66	-1.54	-1.51	-1.09	-1.95	-1.71	-1.66	-1.51	-1.51	-1.10	-1.84	-1.58
Thailand	-1.92	-1.98	-2.37	-2.45	-1.44	-1.29	-1.91	-1.96	-2.37	-2.45	-1.43	-1.27
Turkey	-1.74	-2.04	-1.68	-2.00	-1.94	-2.68	-1.96	-2.04	-1.61	-2.02	-3.05	-2.72

Table 3: Variance ratio test results

The table reports the variance ratio estimates preformed on log spot rates for lags equal 2, 5, 10, and 30 days. The null hypothesis states that log spot exchange rate follow a random walk behavior. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

Panel A. Pooled Samples												
	Lag 2			Lag 5			Lag 10			Lag 30		
Portfolio	Whole Sample	Pre-COVID Period	COVID Period	Whole Sample	Pre-COVID Period	COVID Period	Whole Sample	Pre-COVID Period	COVID Period	Whole Sample	Pre-COVID Period	COVID Period
Developed	1.001	1.001	1.001	1.002	1.000	1.004	1.001	0.999	1.004	0.993	0.995	1.003
Emerging	0.999	0.999	1.000	0.999	1.000	0.999	0.999	1.000	0.999	0.998	0.999	0.997
All	0.999	0.999	1.000	0.999	1.000	1.000	0.999	1.000	1.000	0.997	1.000	0.997

Panel B. Developed Countries												
	Lag 2			Lag 5			Lag 10			Lag 30		
Country	Whole Sample	Pre-COVID Period	COVID Period	Whole Sample	Pre-COVID Period	COVID Period	Whole Sample	Pre-COVID Period	COVID Period	Whole Sample	Pre-COVID Period	COVID Period
Australia	1.098**	1.056	1.105*	1.351***	1.099	1.405***	1.265*	1.010	1.308	1.133	0.483	1.272
Canada	1.076*	1.102*	1.066	1.128	1.199	1.100	1.125	1.008	1.166	0.947	0.560	1.106
Denmark	1.131***	1.054	1.152**	1.207**	1.109	1.219*	0.994	0.895	1.046	0.729	0.472*	0.757
Europe	1.132***	1.061	1.151**	1.206**	1.121	1.215	0.995	0.710	1.049	0.725	0.350*	0.757
Japan	1.076*	1.011	1.105*	1.129	1.073	1.154	0.935	0.964	0.922	0.389**	0.713	0.242**
New Zealand	0.989	1.048	0.965	1.062	1.050	1.052	0.934	0.831	0.939	0.952	0.669	0.976
Norway	1.086**	1.022	1.096	1.301***	0.993	1.354***	1.276*	0.832	1.349*	1.066	0.573	1.142
Sweden	1.031	1.025	1.027	1.115	0.971	1.155	1.026	0.818	1.067	0.972	0.674	0.945
Switzerland	1.104**	1.097	1.103*	1.138	1.193	1.095	0.880	0.829	0.869	0.555*	0.572	0.472
United Kingdom	1.026	0.953	1.065	1.179	0.910	1.322**	1.039	0.867	1.130	0.702	0.744	0.680

Table 3: Variance ratio test results (continued)

Panel C. Emerging Countries												
	Lag 2			Lag 5			Lag 10			Lag 30		
Country	Whole Sample	Pre-COVID Period	COVID Period	Whole Sample	Pre-COVID Period	COVID Period	Whole Sample	Pre-COVID Period	COVID Period	Whole Sample	Pre-COVID Period	COVID Period
Czech	1.092**	1.108*	1.088	1.429***	1.217	1.465***	1.323**	0.949	1.384*	1.207	0.656	1.295
Hungary	1.161***	1.080	1.185***	1.382***	1.190	1.438***	1.260*	1.021	1.326	0.874	0.577	0.960
India	0.998	1.054	0.934	0.951	1.001	0.893	0.926	0.936	0.916	1.008	0.837	1.204
Indonesia	1.137***	1.103*	1.144**	1.567***	1.096	1.669***	1.941***	1.118	2.119***	2.432***	0.723	2.799***
Kuwait	1.047	0.926	1.066	1.124	0.938	1.153	1.257*	0.714	1.340*	1.189	0.341*	1.317
Mexico	1.005	0.945	1.018	1.101	0.885	1.146	1.245*	0.813	1.335	1.526**	0.598	1.715*
Philippines	0.925*	0.928	0.918	0.832*	0.851	0.797	0.742*	0.819	0.602*	0.544*	0.596	0.448
Poland	1.090**	1.067	1.094	1.332***	1.174	1.369***	1.267*	0.987	1.333	1.043	0.744	1.120
Saudi Arabia	0.817***	0.706***	0.824***	0.566***	0.600***	0.564***	0.322***	0.371***	0.318***	0.318**	0.192**	0.325*
Singapore	1.065	0.991	1.093	1.325***	1.066	1.424***	1.327**	1.100	1.414**	1.181	1.021	1.245
South Africa	1.006	1.022	0.996	0.995	0.936	1.031	1.096	1.081	1.105	1.293	0.659	1.692*
South Korea	0.857***	0.988	0.796***	0.954	0.983	0.927	0.857	1.001	0.766	0.785	0.963	0.650
Taiwan	1.036	1.105	0.970	1.105	1.128	1.051	1.060	1.185	0.886	1.035	1.270	0.684
Thailand	1.103**	0.996	1.162***	1.370***	1.014	1.563***	1.485***	1.010	1.726***	1.763***	1.052	2.051***
Turkey	0.968	0.895*	1.043	0.925	0.719**	1.130	0.919	0.704	1.108	0.805	0.632	0.859

Table 4: Fama regression results

The table reports the coefficient estimates, from the conventional Fama regression ($\Delta s_{t+1} = \beta_0 + \beta_1(f_t - s_t) + \varepsilon_{t+1}$). The t-statistics are reported in parentheses below the coefficient estimates. We also the Wald F-test statistics. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

Panel A. Pooled Samples									
	Whole Period			Pre-COVID Period			COVID Period		
Sample	β_0	β_1	Wald	β_0	β_1	Wald	β_0	β_1	Wald
Developed	0.001	2.31	0.04	0.050	31.26	3.30**	0.006	15.86	0.60
	(0.08)	(0.43)		(2.18)	(2.65)		(0.43)	(1.10)	
Emerging	-0.006	1.59	0.18	-0.013	2.93	0.27	-0.012	4.14	0.27
	(-0.60)	(0.74)		(-0.67)	(0.78)		(-0.66)	(0.79)	
Global	0.002	0.62	0.10	-0.001	-1.87	0.62	0.003	-5.75	1.81
	(0.42)	(0.38)		(-0.06)	(-0.72)		(0.26)	(-1.61)	

Panel B. Developed Countries									
Currency	β_0	β_1	Wald	β_0	β_1	Wald	β_0	β_1	Wald
Australia	-0.017***	-29.99***	34.30***	0.005	1.85	8.63***	-0.026***	-75.17***	41.25***
	(-7.15)	(-7.99)		(1.39)	(0.42)		(-7.94)	(-8.59)	
Canada	0.0004	5.65**	2.54*	0.003	7.29**	2.45*	0.003	43.11***	8.10***
	(0.32)	(2.09)		(1.43)	(2.26)		(1.45)	(3.96)	
Denmark	-0.015***	-6.69***	64.58***	0.004	0.61	37.16***	-0.018***	-9.44***	35.30***
	(-10.48)	(-9.87)		(0.74)	(0.33)		(-8.39)	(-6.16)	
Europe	-0.016***	-7.40***	61.99***	0.001	-0.21	33.12***	-0.020***	-11.42***	35.94***
	(-10.35)	(-9.79)		(0.31)	(-0.11)		(-8.46)	(-6.46)	
Japan	-0.001	1.06	2.33*	0.047***	20.73***	47.36***	-0.004***	-0.32	6.31***
	(-0.98)	(1.55)		(9.62)	(10.22)		(-3.10)	(-0.30)	
New Zealand	-0.010***	-23.95***	27.84***	-0.003	-9.21	4.29**	-0.008***	-54.18***	29.36***
	(-5.65)	(-7.13)		(-0.45)	(-0.89)		(-3.81)	(-7.06)	
Norway	0.000	-1.45	0.65	0.003	-0.98	9.53***	0.006	55.31***	4.39**
	(0.06)	(-0.43)		(0.96)	(-0.36)		(1.42)	(2.97)	
Sweden	-0.020***	-11.31***	57.88***	-0.023***	-11.33***	19.41***	-0.025***	-21.86***	44.94***
	(-9.67)	(-9.85)		(-2.97)	(-3.48)		(-9.35)	(-7.89)	
Switzerland	-0.012***	-3.85***	29.42***	-0.001	-0.27	4.14**	-0.011***	-2.67*	23.04***
	(-7.67)	(-5.56)		(-0.22)	(-0.12)		(-5.11)	(-1.86)	
United Kingdom	-0.007***	-5.12***	6.12***	-0.045***	-29.25***	21.54***	-0.008***	-13.15***	5.51***
	(-3.38)	(-2.79)		(-6.56)	(-6.28)		(-2.84)	(-3.02)	

Table 4: Fama regression results (continued)

Panel C. Emerging Countries									
	Whole Period			Pre-COVID Period			COVID Period		
Currency	β_0	β_1	Wald	β_0	β_1	Wald	β_0	β_1	Wald
Czech	0.002	6.82***	4.94***	0.004***	3.50***	4.19**	0.0002	19.75***	10.14***
	(1.13)	(3.58)		(2.89)	(2.96)		(0.08)	(4.47)	
Hungary	-0.004**	-5.37***	17.58***	0.006	1.10	14.46***	-0.004	-13.96***	14.59***
	(-2.27)	(-4.54)		(1.08)	(0.39)		(-1.68)	(-5.04)	
India	-0.001	0.83	2.57*	0.0003	0.08	4.70***	-0.0041	2.20	0.37
	(-0.28)	(0.77)		(0.04)	(0.04)		-0.86	1.54	
Indonesia	0.049***	-15.04***	15.95***	0.0182**	-5.82**	31.22***	0.0756***	-24.11***	8.19***
	(4.48)	(-4.63)		(2.16)	(-2.50)		(3.79)	(-3.81)	
Kuwait	0.00007	0.19	2.00	-0.0002**	0.75**	4.00**	0.0023**	-2.79*	2.96*
	(0.23)	(0.36)		(-2.17)	(2.45)		(2.00)	(-1.73)	
Mexico	-0.036	7.62**	3.55**	-0.0673***	12.77***	27.26***	-0.0677**	16.60**	2.28
	(-1.95)	(1.96)		(-3.76)	(3.54)		(-2.13)	(2.27)	
Philippines	-0.004***	-0.15	90.36***	-0.002	-0.54	26.79***	-0.004***	-0.49	112.53***
	(-3.83)	(-0.31)		(-1.10)	(-0.62)		(-4.55)	(-0.91)	
Poland	-0.004**	-8.77***	5.33***	-0.010***	-16.18***	13.56***	-0.003	-5.31	1.01
	(-2.38)	(-2.93)		(-3.48)	(-4.35)		(-1.39)	(-0.48)	
Saudi Arabia	-0.00001	-0.59***	204.42***	-0.00002**	0.38***	18.76***	0.00002	-0.66***	111.70***
	(-0.28)	(-7.47)		(-2.08)	(3.62)		(0.49)	(-5.95)	
Singapore	-0.003***	-6.57***	5.29***	-0.008***	-14.75***	6.96***	-0.004***	-22.77***	4.77***
	(-3.16)	(-2.61)		(-3.70)	(-3.46)		(-2.84)	(-2.74)	
South Africa	-0.163***	43.25***	41.49***	0.165***	-42.67***	15.60***	-0.245***	65.28***	71.54***
	(-9.10)	(9.31)		(5.36)	(-5.33)		(-11.81)	(12.15)	
South Korea	-0.008***	-10.11***	24.80***	0.004	-0.20	9.12***	-0.009***	-8.65***	21.18***
	(-5.71)	(-6.40)		(0.81)	(-0.04)		(-6.32)	(-4.38)	
Taiwan	-0.008***	-3.21***	63.74***	-0.013***	-5.90***	14.60***	-0.007***	-1.80***	65.01***
	(-11.29)	(-7.38)		(-4.95)	(-4.54)		(-10.28)	(-2.56)	
Thailand	-0.007***	-8.34***	18.82***	0.001	10.80***	32.71***	-0.005***	-38.99***	93.72***
	(-6.09)	(-4.31)		(0.32)	(2.90)		(-4.45)	(-13.35)	
Turkey	0.022***	-0.47*	15.31***	-0.004	0.71**	9.17***	0.032***	-0.72	20.74***
	(5.47)	(-1.72)		(-0.65)	(2.07)		(5.06)	(-1.34)	

Table 5: The Pilbeam and Olmo (2011) regression results

The table presents the coefficient estimates, with t-statistics in parentheses below, from the so called Pilbeam and Olmo (2011) Panel A shows the results for pooled regressions using the three baskets of currencies, while Panels B and C report the results for developed and emerging market currencies, respectively. Acronyms for sample currencies are described in Table 1. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

Panel A. Pooled Samples									
	Whole Period			Pre-COVID Period			COVID Period		
Sample	β_0	β_1	Wald	β_0	β_1	Wald	β_0	β_1	Wald
Developed	0.154	-0.10	22.50***	0.306	-0.21	23.91***	0.289	-0.18	22.37***
	(5.91)	(-2.79)		(6.19)	(-3.08)		(5.84)	(-2.66)	
Emerging	0.772	0.45	31.47***	1.645	0.90	30.91***	1.497	0.82	31.95***
	(5.73)	(2.91)		(5.75)	(2.78)		(5.88)	(2.81)	
Global	0.500	0.30	38.79***	1.162	0.61	41.62***	1.080	0.57	44.61***
	(5.61)	(2.80)		(6.06)	(2.61)		(6.26)	(2.73)	

Panel B. Developed Countries									
Currency	β_0	β_1	Wald	β_0	β_1	Wald	β_0	β_1	Wald
Australia	-0.243	0.35	26.11***	-0.345	0.50	46.07***	-0.209	0.30	10.15***
	(-7.23)	(7.22)		(-8.21)	(8.31)		(-4.15)	(4.05)	
Canada	-0.376	0.50	48.77***	-0.912	1.21	121.77***	-0.339	0.45	19.37***
	(-9.81)	(9.79)		(-15.56)	(15.55)		(-6.18)	(6.15)	
Denmark	-0.048	0.32	1.58	-0.281	1.90	71.04***	-0.053	0.31	10.51***
	(-1.74)	(1.73)		(-7.06)	(7.19)		(-1.45)	(1.30)	
Europe	-0.062	0.05	2.46*	-0.291	0.26	67.75***	-0.062	0.05	9.98***
	(-2.19)	(2.18)		(-7.27)	(7.39)		(-1.63)	(1.49)	
Japan	-0.285	30.62	39.66***	-0.527	57.52	66.76***	-0.270	28.60	19.24***
	(-8.68)	(8.65)		(-11.55)	(11.55)		(-5.26)	(5.20)	
New Zealand	-0.243	0.37	27.73***	-0.300	0.46	33.70***	-0.196	0.30	8.89***
	(-7.45)	(7.44)		(-7.46)	(7.55)		(-3.70)	(3.61)	
Norway	-0.253	2.32	35.43***	-0.207	1.86	24.39***	-0.430	4.05	27.69***
	(-8.21)	(8.30)		(-5.09)	(5.21)		(-7.43)	(7.44)	
Sweden	-0.109	1.02	7.25***	-0.343	3.28	58.17***	-0.069	0.57	8.90***
	(-3.79)	(3.77)		(-8.99)	(9.15)		(-1.76)	(1.57)	
Switzerland	0.018	-0.02	4.42**	-0.687	0.68	68.30***	-0.102	0.09	23.18***
	(0.87)	(-0.96)		(-11.10)	(11.13)		(-3.01)	(2.84)	
United Kingdom	-0.403	0.31	53.17***	-0.306	0.24	19.91***	-0.484	0.38	32.23***
	(-10.30)	(10.28)		(-6.28)	(6.26)		(-8.03)	(8.02)	

Table 5: The Pilbeam and Olmo (2011) regression results (continued)

Panel C. Emerging Countries									
	Whole Period			Pre-COVID Period			COVID Period		
Currency	β_0	β_1	Wald	β_0	β_1	Wald	β_0	β_1	Wald
Czech	-0.395	9.11	51.58***	-0.498	11.44	50.16***	-0.396	9.16	23.67***
	(-10.16)	(10.15)		(-9.68)	(9.72)		(-6.82)	(6.77)	
Hungary	-0.258	77.85	48.73***	-0.189	56.28	29.83***	-0.642	197.95	58.06***
	(-9.27)	(9.41)		(-4.94)	(5.11)		(-10.74)	(10.76)	
India	-0.134	9.55	19.51***	-0.628	44.15	61.83***	-0.339	25.09	42.09***
	(-5.93)	(5.87)		(-10.62)	(10.57)		(-9.17)	(9.17)	
Indonesia	-0.600	8581.18	97.70***	-1.001	14162.41	261.64***	-0.679	9868.88	58.67***
	(-13.82)	(13.74)		(-19.99)	(19.87)		(-10.83)	(10.82)	
Kuwait	-0.238	0.07	40.60***	-0.833	0.25	101.88***	-0.394	0.12	37.27***
	(-8.93)	(8.92)		(-13.83)	(13.82)		(-8.62)	(8.61)	
Mexico	-0.238	4.77	29.44***	-0.941	18.10	237.72***	-0.412	8.85	35.02***
	(-7.63)	(7.55)		(-19.58)	(19.41)		(-8.28)	(8.35)	
Philippines	-0.038	1.64	88.13***	-0.444	22.84	68.92***	0.006	-0.61	105.62***
	(-2.44)	(2.09)		(-8.78)	(8.68)		(0.32)	(-0.62)	
Poland	-0.389	1.51	55.97***	-0.514	1.98	54.16***	-0.387	1.50	24.29***
	(-10.57)	(10.58)		(-9.95)	(10.00)		(-6.92)	(6.88)	
Saudi Arabia	-0.550	2.06	110.20***	-0.819	3.07	144.36***	-0.664	2.49	70.30***
	(-14.82)	(14.82)		(-16.85)	(16.85)		(-11.85)	(11.85)	
Singapore	-0.260	0.36	31.18***	-0.654	0.89	62.45***	-0.233	0.32	12.11***
	(-7.83)	(7.81)		(-11.17)	(11.16)		(-4.83)	(4.81)	
South Africa	-0.174	2.68	24.32***	-0.721	10.41	75.41***	-0.319	5.26	29.50***
	(-6.94)	(6.97)		(-12.26)	(12.24)		(-7.57)	(7.65)	
South Korea	-0.165	193.14	16.39***	-0.267	315.26	37.85***	0.053	-69.13	8.50***
	(-5.72)	(5.73)		(-7.12)	(7.25)		(1.10)	(-1.21)	
Taiwan	0.089	-2.76	33.16***	-0.306	9.47	13.65***	0.088	-2.76	63.00***
	(5.94)	(-6.08)		(-5.10)	(5.11)		(3.50)	(-3.69)	
Thailand	-0.320	9.91	62.25***	-0.244	7.45	69.72***	-0.411	12.89	32.10***
	(-10.56)	(10.48)		(-8.46)	(8.27)		(-8.00)	(8.01)	
Turkey	0.011	-0.05	1.72	-0.354	1.98	41.93***	-0.098	0.76	31.06***
	(0.76)	(-0.56)		(-8.19)	(8.01)		(-4.38)	(5.03)	