Is Climate Transition Risk Priced in FX Markets?

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Abstract

This study examines how climate transition risks influence foreign exchange (FX) markets through their effect on equity market risk premia. We document that higher climate transition risks generate higher stock risk premia, which are subsequently transmitted to FX returns via the portfolio rebalancing behaviour of international equity investors. Our empirical findings indicate that this transmission mechanism is evident exclusively in emerging markets and becomes significantly more pronounced following the Paris Agreement. In these settings, climate transition risks will generate negative FX returns, while the corresponding positive equity market performance more than offsets these losses, resulting in deviations from the Uncovered Equity Parity (UEP) condition.

***Keywords*:** Climate transition risk; Foreign exchange markets; UEP

JEL classifications:

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1 Introduction

The Paris COP21 accord in December 2015 marked a significant global milestone, committing nearly 200 nations to achieving carbon neutrality by the mid-21st century. This growing urgency to address climate change has accelerated the transition of countries from environmentally harmful fossil fuels to renewable energy sources. Consequently, investors in financial markets are increasingly factoring the potential impact of climate transition risks into asset prices. Climate transition risks include challenges arising from shifts in economic, geopolitical, market structural, and regulatory landscapes, extending beyond the domain of climate factors. For instance, Acemoglu and Robinson (2001) highlight the societal consequences of political transition risks, emphasizing how unequal wealth distribution can lead to regime changes and heightened uncertainty surrounding fiscal policies. Similarly, other forms of transition risks, such as geopolitical tensions and technological revolutions, can exert significant influence on asset prices and market stability. A key characteristic of transition risks is the inherent uncertainty regarding the speed and scope of these transformations, which can affect various sectors and investors' valuations for the financial impacts.

For climate transition, the Network for Greening the Financial System (NGFS)[1] categorizes climate-related risks into physical risks and transition risks, where climate physical risks arise from acute events like extreme weather and chronic changes such as sea-level rise, and climate transition risks stem from shifts in policies, technologies, or market dynamics associated with the transition to a low-carbon economy. According to the NGFS, countries face varying levels of transition risk depending on their economic structures, policy frameworks, and vulnerability towards climate change. Some nations may encounter significant challenges, such as costly regulatory adjustments or stranded assets, while others may experience a smoother adaptation process. In financial markets, investor perceptions of climate risks are dynamic, and variations of investors' beliefs will impact the holdings of climate transition risk portfolios since the retail investors recently demand ESG (Environmental, Social, and Governance) investment with respect to climate transition risks (Giglio et al., 2025). Over time, these perceptions evolve as countries implement (or delay) climate policies, creating dynamic feedback loops between national transition efforts and financial market reactions.

[1] To support the goals of the 2015 Paris Agreement, the NGFS defines the climate-related risks into physical and transition risks, as outlined in its May 2020 Guide for Supervisors on integrating these risks into prudential supervision (ngfs_guide_for_supervisors.pdf)

As climate transition risk receives increasing attention from international investors, the behaviours of investors are expected to affect capital allocation through global portfolio rebalancing (Camanho et al., 2022). A central question to ask is how climate transition risks influence investment returns and, consequently, international capital flows. These effects are mediated by the performance of both stock and foreign exchange (FX) markets, given that foreign equity returns are inherently sensitive to the fluctuations in both currency and equity values. This relationship holds particular importance for policymakers, as shifts in equity market investment flows can significantly impact a country's Balance of Payments (BoP). In this paper, we provide new insights into the interplay between stock markets and exchange rates in the context of climate transition risks, and we examine whether these risks are reflected in FX market returns.

Our paper aims to address three key questions: (1) Does climate transition risk affect FX market and how? (2) Are there different patterns for emerging markets and developed markets[2]? (3) Does the strength of this effect increase after the Paris Agreement?

Our contributions are threefold. First, we extend the climate transition risk literature that traditionally focused on firm-level equity, real estate and bond markets to FX markets (De Jong and Nguyen, 2016; Engle et al., 2020; Giglio et al., 2021; Bolton and Kacperczyk, 2023). Second, by examining climate transition risk at the country level, we integrate the Uncovered Equity Parity (UEP) framework in our investigation of how climate-driven equity returns influence FX dynamics via investors' portfolio-rebalancing, or return-chasing behaviours (Hau and Rey, 2006; Fuertes et al., 2019). This approach allows us to distinguish between the patterns observed in emerging and developed markets, and extends the concept of the climate transition risk premium from the firm level to the country level. Third, we analyse post-Paris Agreement (COP21) data to assess how the global climate accord reshaped risk pricing across financial markets. By examining climate transition risks at the country level, participants in the FX market can gain a deeper understanding of how the global shift towards a low-carbon economy will shape currency dynamics along with stock markets. FX market participants can identify which currencies are more exposed to climate transition shocks. For instance, countries slow to transition may face higher borrowing costs or reduced investor confidence in FX markets, and economies with large carbon footprints and weak

[2] Emerging Markets (EMs) and Developed Markets (DMs) are also commonly referred to in the literature as Emerging Market and Developing Economies (EMDEs) and Advanced Economies (AEs), respectively.

adaptation plans, equivalent to higher transition risks, may be subject to long-term depreciation trends in currencies.

Based on a sample of 35 countries, including 15 developed and 20 emerging countries and using monthly data over the period from January 2000 to September 2024, our main empirical results can be summarised as follows. Climate transition risk factors are increasingly integrated into the pricing of foreign exchange (FX) returns through portfolio rebalancing behaviours. While climate transition risks exert a negative impact on nominal exchange rate[3] returns, positive stock market performance associated with these risks helps offset these losses. Notable differences exist between developed and emerging markets, particularly after the COP21, indicating investors' growing recognition of climate transition risks in asset pricing. In the post-COP21 period, climate risks have played a more important role, with higher-risk portfolios generating significant excess returns, particularly in emerging markets.

Our paper builds on the literature of climate transition risks, which emphasizes on the shift toward net-zero policy, regulatory, and technological changes that can disrupt the established market dynamics. In general, the transition risk often indicates uncertainty about the implementations of these changes and how they can affect economic activities. Laitner and Stolyarov (2003) provide a theoretical framework for the relationship between technical change and economic growth and stock markets. Transition towards new technologies can cause a stock market decline in the short term which is subsequently reversed. Extant empirical evidence suggests that climate transition factors are incorporated into asset pricing kernels for stocks, and bonds market (see e.g., De Jong and Nguyen 2016; Bolton and Kacperczyk, 2023, 2024). However, the implications of climate transition risks for foreign exchange markets remain relatively underexplored, with most existing research focusing on the impact of climate physical risks on the real exchange rate. For example, Lee et al. (2022) document significant heterogeneity in FX responses to temperature shocks across countries and time horizons. Hale (2024) finds that climate disasters have limited impact on real exchange rates, while Cheema-Fox et al. (2022) reveal that non-G10 currencies, particularly in climate-vulnerable countries, are more affected by climate vulnerability risks. Arteaga-Garavito et al. (2024) analyse the impact of climate news shock impact on currencies, international trade flows and equity returns. Our study is different from their work in two key aspects: (1) we incorporate the impact of climate transition risks on the nominal foreign exchange rate, thus complementing the existing literature that predominantly focuses on climate physical risks; (2) we

[3] Nominal FX (nominal exchange rate) is the rate at which one currency can be exchanged for another. In our case, nominal FX is the amount United States Dollar per Unit of other currencies.

emphasize the interconnected dynamics and portfolio rebalancing behaviours between international stock markets and currency markets, offering a more comprehensive perspective of the impact of climate transition risk on global financial interactions.

Adopting the country-level perspective, our paper fills a gap in the literature by examining whether aggregate climate transition risk, contributes to the climate transition risk premium. Such impact starts from the global stock carbon premia that internationally, stocks with higher exposure to emission transition risk are expected to generate higher returns (e.g., Bolton and Kacperczyk, 2023). Bolton and Kacperczyk (2023) specify that the underlying channels for the impact of carbon transition risk on the stock returns are related to cash flow and the discount rates, generated from the uncertainty over the potential capital expenditures to curb the amount of greenhouse gas and from investors' expectation towards the target of net zero emission. Moreover, Karydas and Xepapadeas (2022) apply dynamic CAPM model, documenting the increasing risk premia for not only carbon and but also the temperature risks to show the time-varying characteristics. For the cashflow channel, one of the possible explanations of how transition risk affects a firm's value via capital flows is that multinational firms with higher levels of exposure to climate risk reduce foreign direct investment (FDI) into countries with high physical climate risk, and that will influence the firm's capital inflows negatively (Gu and Hale, 2023). Regarding the discount rate channel, carbon pricing or green investment can be viewed as a restriction for investors' effective investment decisions in the form of higher required returns (Pastor et al., 2021), and therefore international investors will require compensations for bearing the climate transition risks. Thus, different levels of exposure to cashflow and discount rate channels will be likely to generate varying climate transition risk premia. Accordingly, investors may adjust their portfolios in response to changes in climate transition risk perceptions by reallocating investment across international markets which, in turn, can influence exchange rates. The investors' green preference is studied in a survey conducted by Giglio et al. (2025) documenting that 24% of the respondents consider ESG investment as a hedge to climate risks, where 52% of overall respondents are considering ESG investment. As green investing gains traction, firm-level carbon premiums may aggregate to country-level market effects, underscoring the need to explore how transition risks propagate through stock and FX channels.

To obtain better understanding of the market dynamics, this research also investigates the interplay between stock markets and FX rates, focusing on the portfolio-rebalancing and return-chasing hypotheses under the uncovered equity parity theory. The portfolio-rebalancing hypothesis (Hau and Rey, 2004, 2006; Cappiello and De Santis, 2007; Camanho et al., 2022) suggests that investors reduce FX risk by

repatriating wealth from foreign markets during surges in foreign equity returns, leading to local currency depreciation. Conversely, the return-chasing hypothesis (Fuertes et al., 2019) posits that investors increase foreign equity holdings in high-performing markets, appreciating the local currency. Empirical evidence on the relationship between equity flows and FX rates is mixed, with studies supporting both return-chasing and alternative investment styles. For instance, while Kim (2011) highlights the role of return-chasing behaviours, Curcuru et al. (2014) and Fuertes et al. (2019) document positive correlations between equity returns and FX returns that suggest deviations from the Uncovered Equity Parity (UEP) condition. Our research extends this literature by examining how climate transition risks interact with these dynamics and influence FX movements driven by capital flows due to equity return differentials generated by the differential impact of climate transition risk on countries. In conclusion, firstly, the climate transition risk affects the equity valuation via its influence on expected cash flows and the discount rate (Bolton and Kacperczyk, 2023). Secondly, under the UEP relationship, the international equity valuations will be transmitted to the foreign exchange rate, with the direction of the impact depending on whether investors follow return chasing, or portfolio rebalancing strategies. (Hau and Rey, 2006; Fuertes et al., 2019). A schematic representation of the transmission mechanism can be found in the Appendix Figure A1.

We explore the research questions separately for two panels of developed and emerging markets, respectively. Emerging markets differ from their developed counterparts in key aspects, such as liquidity, volatility, and market efficiency, as indicated by that one stylized fact for emerging market is that currencies from emerging markets offers higher returns than currencies from developed markets, but with lower volatility (see e.g. Gilmore and Hayashi, 2011). Additionally, stocks in emerging markets, can provide more returns but are also more volatile (Bekaert and Harvey, 1997), and the liquidity of emerging stock markets will be affected by the local political and legal institutions (Lesmond, 2005). All the factors may shape the relationship between stock and FX returns because of the international capital flows, and Ftiti et al. (2024) point out that BRICS countries are more likely to receive capital inflows, unlike European countries that are mainly associated with the capital outflows. Emerging and developed market also differ for climate transition risk premium as Zhang (2024) points out that developed market has lower carbon returns compared to the emerging market. Therefore, based on heterogeneity for market dynamics between emerging and developed markets, our research aims to capture the potentially different pattern of impact from climate transition risks on the two market groups.

The remainder of this paper is structured as follows: Section 2 introduces the theoretical framework, focusing on Uncovered Equity Parity (UEP) which is the basis of our research. Section 3 describes the data and methodology employed in the empirical analysis. Section 4 presents the main empirical findings, Section 5 presents robustness tests and Section 6 provides additionally analysis; Finally, Section 7 concludes with a summary of the key findings.

2 Theoretical Background

In this section, we describe the relationship between climate transition risk and FX returns within a standard no-arbitrage framework following Hau and Rey (2006) for UEP and Cochrane (2009) for asset pricing. The UEP theory relies on the first assumption that local investors[4] are risk-averse and will allocate their portfolios across domestic and foreign equities and riskless bonds, to maximize the investment returns. For example, an US (local) investor can invest in the UK (foreign) stock market in GPB by converting from USD into GBP, and thus the returns will be from both stock prices and nominal exchange rate changes. The second assumption is that FX market has a less than perfect elastic supply of foreign exchanges, indicating that any supply and demand imbalances will result in movement of exchange rate until the market clears. The direction of the currency movement depends on the type of net order flow in the market. The third assumption is that investors cannot perfectly hedge their FX exposure in the market, which is also why risk-averse investors tend to rebalance their portfolio when the risk exposure increases. Under the basic model setting, for an investor who can invest in international portfolios, the maximization problem is:

$$\max_{\{K_t^h, K_t^l\}} \mathbb{E}_t \int_{s=t}^{\infty} e^{-r(s-t)} \left[d\Pi_s - \frac{1}{2} \rho \, d\Pi_s^2 \right]$$

Where $d\Pi_t = K_t dR_t$. $d\Pi_t$ is the excess investment profits, and K_t^h, K_t^l[5] are the domestic and foreign equity holdings and dR_t is the excess equity returns. In the maximization equation, r is the riskless return from bond. The risk-averse investors have the level of risk aversion ρ. Let's assume that the foreign equity holdings obtain higher returns, and the risk-averse investors will sell part of the foreign holdings and exchange to decrease the risk exposure. The action of portfolio rebalancing will generate net order flow in FX market that exists not perfectly elastic supply of foreign exchange. Such impact will induce a negative return on FX market with the realizations of positive stock market returns as shown by the following equation:

[4] In our paper, local investors are assumed to be US investors, so that the US market and currency are also the local stock market and currency, while other markets (stock and FX) are the foreign markets.

[5] For K_t^h, the home investment returns are $d\Pi_t^h = K_t^h dR_t^h$; For K_t^l, the foreign investment returns are $d\Pi_t^l = K_t^l dR_t^l$

$$\mathbb{E}_t\left(-\frac{dE_t dR_t^f}{\bar{P}}\right)dt = \mathbb{E}_t\left(\frac{dE_t dR_t^h}{\bar{P}}\right)dt < 0$$

Under the imperfect FX market, the foreign exchange returns dE_t are negatively correlated with the foreign equity returns $\frac{dR_t^f}{\bar{P}}$. Furthermore, as shown by Hau and Rey (2006), the correlation between excess equity returns and nominal foreign exchange returns are minus unity:

$$\text{Corr}\left[-dE_t, \frac{\left(dR_t^f - dR_t^h\right)}{\bar{P}}\right] = -1$$

Therefore, the UEP theory implies that local investors will rebalance the portfolios so that global stock returns are cancelled out by the foreign exchange returns, which the foreign equity excess is equal to 0. Based on the above induction, the UEP condition can be written as:

$$1 + r_t^h = \left(1 + r_t^j\right) * \frac{S_{t+1}}{S_t}$$

Where r_t^h and r_t^j represent the domestic and foreign stock returns, respectively, and s_t and s_{t+1} denote the current and future spot exchange rates. By taking the logarithm of the UEP condition, the excess foreign equity returns can be expressed as:

$$r_t^j - r_t^h + \Delta s_{t+1} \tag{1}$$

The theory implies that the excess foreign equity returns are equal to 0 because of portfolio rebalancing, while many empirical works document the violation of such parity (Chabot et al., 2014; Cenedese et al., 2016; Fuertes et al., 2019) that either stock market differentials are independent of FX returns, or investors are driven by the return chasing behaviours that stock and FX returns are positively correlated. For return-chasing behaviours, the typical investors will increase the level of holdings for assets with better performance so that the foreign equity returns, and foreign exchange returns are positively correlated. Therefore, the theory may not be informative for the transmission of climate transition risk due to the mixed evidence, so that our primary goal in this paper is to investigate the market dynamics between stock and foreign exchange under the UEP framework and climate transition risk.

What's more, from asset pricing perspective, our research examines if climate transition risk factor can be incorporated into the pricing kernel of UEP portfolios. Without arbitrage opportunities, the excess returns can be expressed as the following Euler equation:

$$\mathbb{E}_t\left(m_{t+1}R_{i,t+1}\right) = 0$$

where m_{t+1} is the stochastic discount factor (SDF), and $R_{i,t+1}$ represents the return on asset i at time t. Combining the Euler equation and the natural logarithm of the UEP equation, we derive the Euler equation for domestic and foreign investors holding foreign currency assets:

$$E_t\left[m_{t+1}\left(r_t^j - r_t^h + \Delta s_{t+1}\right)\right] = 0 \quad (2)$$

Next, assume a vector of risk factors, v_{t+1}, with factor means μ_v, and risk factors δ_{t+1} following Menkhoff et al., (2012a) notation for volatility innovation. Then, we define the stochastic discount factor as a linear function:

$$m_{t+1} = 1 - q_1^T(v_{t+1} - \mu_v) - q_2 * \delta_{t+1} \quad (3)$$

Where the vector q is the SDF loading on individual risk factors. Substituting equation (3) into the Euler equation (2) yields the conventional beta representation for excess foreign exchange returns:

$$E\left(r_t^j - r_t^h + \Delta s_{t+1}\right) = \lambda' * \beta_i \quad (4)$$

Where β_i contains the betas estimation for all assets and λ[6] is the vector of the factor risk premium. The impact of climate transition risks on excess foreign equity returns from UEP are captured via Equation (4). This shows that foreign equity excess returns are a linear combination of factor loadings and risk premia. This equation allows us to evaluate whether climate transition risk affects FX markets through international stock markets, as investors adjust risk exposures via portfolio rebalancing.

3 Data & Methodology

3.1 Data Description

Our research applies monthly data over the period from January 2000 to September 2024. Our dataset includes the climate transition risks index at country level and the corresponding stock market indices and FX rates. Climate transition risk indicators are available at a quarterly frequency and are assigned to each month within the corresponding quarter to reflect the gradual incorporation of transition risk-related information by investors (Bolton and Kacperczyk, 2023). Firstly, for climate transition risk indices, the data from all countries are obtained from London Stock Exchange Group (LSEG) Sovereign Sustainability Solutions via DataStream. These indices assess climate transition risks along two dimensions: Greenhouse Gas-to-GDP (GHG-to-GDP) performance and the NDC (Nationally Determined Contributions) implied temperature rise. The GHG-to-GDP index measures the gap between current greenhouse gas emissions and the levels required to

[6] $\lambda = \sum * q$, $\sum$ is the covariance matrix of the SDF loadings, and q is the SDF loadings. Both covariance matrix and q are obtained from GMM estimation.

achieve carbon neutrality, while the NDC implied temperature rise evaluates the extent to which national emission targets are aligned with the 1.5°C goal[7]. We interpret the GHG-to-GDP performance as an indicator of the efficiency with which a country manages its overall carbon emissions, and the NDC implied temperature rise as a measure of a country's commitment to achieving carbon neutrality. The two components can be combined to construct a climate transition risk index because they provide complementary perspectives on a country's climate performance, addressing both current alignment and future trajectory with global climate goals. In this context, higher efficiency and stronger commitment are associated with lower levels of climate transition risk. Originally, the index ranges from 0 to 100, with higher values indicating lower climate transition risks. To provide better intuition, we transform the index by subtracting its value from 100, so that a higher index value corresponds to a greater level of climate transition risk. For instance, if a country exhibits elevated risks related to greenhouse gas emissions and temperature changes, its climate transition risk index will also be high. One of the benefits of using the transition risks index from LSEG is to avoid the forward-looking bias. Following Zhang (2024), our study also applies the point-in-time data to match the realization of stock and FX market returns. Additionally, the proportion of each component to form the final index is not disclosed by LSEG, and Appendix Table A2 shows the name and code for individual country climate transition index.

The equity market returns for each country are measured using the equity index data taken from both DataStream and WM Reuters. The dataset includes price indices in countries' own local currencies. However, the availability of equity indices for countries varies over time. Monthly price indices are converted into monthly stock returns by applying the natural logarithm. Stock return differentials are constructed as the difference between US stock market returns (S&P 500) and other foreign stock index returns. The individual foreign exchange spot and forward rates are obtained from DataStream and WM Reuters, which can be expressed as the amount foreign currency per unit of USD. Therefore, the excess foreign equity returns, as indicated by Equation (1) that $r_t^j - r_t^h + \Delta s_{t+1}$, can be further written as $r_t^j - r_t^h + \Delta s_{t+1} \approx f_t - s_{t+1}$, as suggested by Menkhoff et al., (2012a)[8], where f_t is forward exchange rate. The dataset includes exchange rate indices in local currencies spanning January 2000 to September 2024, while the data availability varies for different currencies. FX rates are obtained

[7] For more detailed explanation of the climate transition risk index see: https://www.lseg.com/content/dam/ftse-russell/en_us/documents/policy-documents/sustainable-sovereign-risk-methodology.pdf

[8] Please kindly see page 688 equation (3) for Menkhoff et al. (2012a), and the definition of each variable is given in the section on the theoretical background.

as units of local currency per US$ (see Appendix Table A3 for more details on the data) and are converted into units of US$ per local currency for convenience. Additionally, if a country has more than one equity indices, we specify in Appendix Table A4 which one we have used, together with its specific code. Following Nucera et al. (2024) the data is obtained for the last trading day within each month for both stock indices and FX rates.

Our sample of countries includes 35 countries, with 15 classified as developed markets and 20 as emerging markets. Selection criteria are based on the currency transaction volume in 2022 from Bank of International Settlement[9] and The division of countries the into advanced and emerging economies is based according to the IMF definition.[10] The 15 developed markets comprising Australia, Austria, Canada, Denmark, Finland, France, Germany, Hong Kong, Japan, Norway, Singapore, South Korea, Sweden, Switzerland, and the United Kingdom. The 20 emerging markets are Argentina, Brazil, Bulgaria, Chile, China (Mainland), Colombia, Czech Republic, Hungary, India, Indonesia, Malaysia, Mexico, Peru, Philippines, Poland, Russia[11], Romania, South Africa, Thailand, and Turkey.

3.2 Methodology

3.2.1 Methodology: Portfolio Approach

This research applies portfolio approach for UEP theory that for every month, the foreign exchange and international stock market are jointly sorted into five quintile portfolios in terms of the climate transition risks, and the holding period for each quintile is one month. The countries that have the lowest climate transition risk index are assigned into the first portfolio (P1), while the others are allocated into quintile portfolios from P2 to P5 according to the level of climate transition risks. After sorting the asset returns, we form a long-short portfolio strategy, obtained by longing P5 and shorting P1. Furthermore, our research relies on UEP theory to show the behaviour patterns of international equity investors, and therefore we decompose the quintile and long-short portfolios

[9] For more details, please refer to BIS website for the transaction volume in 2022: Triennial Survey publication table: BIS,DER_D11_3,1.0

[10] For more details, please refer to IMF website for the list of country: World Economic Outlook Database - Groups and Aggregates

[11] Stock data (MOEX Russia Index) after June 2024 for Russia are obtained via Moscow Exchange: https://www.moex.com/en/index/IMOEX/archive?from=2024-12-27&till=2025-01-27&sort=TRADEDATE&order=desc

into stock differentials between US and other countries' stock indices, and spot foreign exchange rate changes, as we have shown in Equation (1). Additionally, our research divides also the underlying dataset into developed market and emerging market group, to test the potential heterogeneity for investors' risk-return profile with respect to climate transition.

As suggested by Bolton and Kacperczyk (2023), higher stock returns are associated with higher level of climate transition risk. After the construction of quintile portfolios by the level of transition risks, the quintile portfolio with higher climate transition risks will likely yield higher returns. Additionally, the UEP theory argues that stock returns differentials are negatively correlated with FX spot returns, which further implies negative FX spot returns for countries with higher value of climate transition risk premia. However, if stock return differentials and exchange rate movements are positively correlated, UEP is violated, suggesting that FX markets are influenced by return-chasing behaviours. Conversely, if stock return differentials are fully offset by FX returns, UEP holds, indicating that investors rebalance foreign equity exposures as part of risk management. However, if stock and FX returns are only partially reconciled, the resulting negative correlation may still indicate portfolio rebalancing. While this represents a deviation from UEP, it does not necessarily contradict the theory, as portfolio rebalancing is a fundamental mechanism underlying UEP. More precisely, portfolio rebalancing is the necessary condition for UEP, since portfolio rebalancing only requires correlation between returns to be negatively, instead of being minus unity. The proposed decomposition of UEP excess returns into stock differentials and FX returns aims to provide empirical evidence either supporting portfolio rebalancing or validating the presence of return-chasing behaviour in international financial markets.

To show that our work is not merely theoretical sensible, the returns net of FX transaction costs is incorporated into the analysis, and the transaction costs are controlled by bid-ask spreads. The net returns on a long position or short position are calculated as follows:

$$r_{long,net} = s_{t+1,b} - f_{t,a}$$

$$r_{short,net} = f_{t,b} - s_{t+1,a}$$

Where $r_{long,net}$ and $r_{short,net}$ are the long, short position returns net of transaction costs, s and f are the natural logarithm of spot and forward FX prices, and b and a denote the bid and ask prices. The quintile portfolio (P1) returns are replaced by $r_{short,net}$, and the net returns of portfolios from P2 to P5 are replaced by $r_{long,net}$, following Menkhoff et al. (2012a), and Colacito et al. (2020).

3.2.2 Methodology: Asset Pricing Approach

As discussed in the theoretical framework, the pricing kernel for foreign exchange and equity excess returns can be expressed as:

$$r_{i,t+1} = \alpha + \beta_{it} * factor_premium_t + \epsilon_t \quad (5)$$

where the specific factors are detailed below. To evaluate whether climate transition risk is a priced factor, risk premia are estimated using the Generalized Method of Moments (GMM) introduced by Hansen (1982). Our research reports the J-statistics to show if the pricing errors are equal to zero, and the standard errors are based on Newey and West (1987) to account for serial correlation in error terms. Additionally, the traditional two-step Fama-MacBeth (FMB) methodology (Fama and MacBeth, 1973) is employed to validate the results obtained from the GMM estimation.

For UEP, the Fama-French-Carhart model (Fama and French, 2012; Carhart, 1997) is extended to include the climate transition risk and Dollar factors, following the empirical structure used by Cenedese et al. (2016). International CAPM factors that Market Risk (Mrk-RF), Size (SMB), Value (HML) and Momentum (MOM) for both developed and emerging stock markets are obtained from the Fama-French Data Library[12]. The Dollar factor is chosen for the control variable for FX analysis, since the empirical evidence that dollar factor can explain the majority of cross-sectional FX returns (Nucera et al., 2024).

Based on the methods outlined by Cenedese et al. (2016) and Menkhoff et al. (2012a), our study develops measures for global stock volatility and global FX volatility as additional control variables. These measures are calculated monthly. The calculation involves first computing the average of the absolute values of returns for each cross-section and then aggregating the daily averages to derive the monthly volatility proxy. The calculation is represented by the following formula:

$$\mathrm{Vol}_t^{\mathrm{FX}} = \frac{1}{T_t} \sum_{\tau \in T_t} \left[\sum_{k \in K_\tau} \left(\frac{\left| r_{fx,\tau}^k \right|}{K_\tau} \right) \right]$$

[12] For more details, please refer to the Fama-French Data Library: https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

$$\mathrm{Vol}_t^{\mathrm{ST}} = \frac{1}{T_t}\sum_{\tau \in T_t}\left[\sum_{k \in K_\tau}\left(\frac{\left|r_{s,\tau}^{k}\right|}{K_\tau}\right)\right]$$

Where $|r_\tau^k|$ is the absolute daily log return for either currency pair or stock markets k on each day τ, and T_t represents the number of days for each month in our sample. Finally, our research collects the volatility innovations that the estimation residuals from the AR (1) process for each global volatility proxy.

For UEP, the model is expressed as:

$$E(r_{i,t+1}) = \beta_0 R_t^{CTR} + \beta_1 \mathrm{Vol}_t^{\mathrm{ST}} + \beta_2 \mathrm{Vol}_t^{\mathrm{FX}} + \beta_3 DOLLAR_t + \beta_4 (Mrk - RF)_t + \beta_5 SMB_t + \beta_6 HML_t + \beta_7 MOM_t^{ST} \quad (6)$$

where $r_{i,t+1}$ represents foreign equity excess returns for country i at time $t+1$, R^{CTR} are the risk premium for climate transition risks, and $Vol^{ST}, Vol^{FX}, DOLLAR, Mrk - RF, SMB, HML, MOM^{ST}$ are the risk premia for control variables, β_s denote the factor loadings, and α_0 and ϵ_t represent the abnormal return and error term, respectively.

3.3 Research Strategy

To address the research questions, we outline the following steps in our analysis. We start by conducting a preliminary analysis to explore the time-series trends and statistical properties, such as skewness, kurtosis, and trends of development of climate risk indices, stock returns, and FX returns. This step provides an initial understanding of how climate transition risks can potentially be correlated with FX and stock markets and highlights the different patterns between developed and emerging markets. We subsequently construct quintile portfolios and implement a long-short portfolio strategy based on climate transition risks. This allows us to evaluate the profitability of the long-short strategy for climate transition risks and its implications for international equity investors. Additionally, from asset pricing perspective, we assess whether climate transition risks can be integrated into the pricing kernel of foreign equity returns using GMM estimation. To capture temporal pattern of climate transition risk premia, we divide the sample into two periods that pre-COP21 and post-COP21, regarding to Paris Agreement. This approach provides better understanding of the impact of the Paris Agreement over the climate transition risks in financial markets. What's more, we study the simultaneous correlation between stock differentials and FX returns in the fixed-effect model to understand how stock differentials can affect FX returns with

the interaction of climate transition risks. Throughout the analysis we present results for developed and emerging markets separately to capture the heterogeneity of the two market groups.

4 Empirical Analysis

4.1 Preliminary Analysis

Figure 1 presents the trends in climate transition risks for developed and emerging market groups. In general, emerging markets exhibit higher level of climate transition risks than developed markets, with the risk index no less than 42.5 on average. Before the Paris COP21 agreement, climate risks in emerging markets increased slightly, as indicated by an increasing index, while risks in developed markets and the overall sample period decreased. Following the COP21 agreement, all countries saw a substantial decline in the level of risks, with a continuing downward trend. This pattern suggests a major shift in market dynamics, likely reflecting heightened global attention to sustainability and climate initiatives, especially for emerging markets. However, emerging markets appear to exhibit persistently higher level of climate transition risks, since the average level of risk is higher for emerging markets than the developed markets. In contrast, developed markets retain the better performance in sustainability reforms, establishing themselves as frontrunners in the transition toward more environmentally conscious economies. The heterogeneity may also encourage investors to take different risk-return profile regarding to climate transition risks.

Table 1 and Table 2, together with Figures 2 and 3, provide a comprehensive overview of stock and FX market performance across developed and emerging markets. Stock markets in developed economies exhibit lower mean returns, smaller standard deviations, and minimal skewness and kurtosis, indicative of predictable and stable performance. In contrast, emerging markets, such as Argentina and Turkey, show higher mean returns accompanied by markedly larger standard deviations and significant kurtosis, reflecting a pronounced risk-reward trade-off and occasional sharp price fluctuations. Cumulative stock returns generally trend upward over time for both market groups, with significant declines during global events like the early 2000s recession, the Global Financial Crisis, and the COVID-19 pandemic. Conversely, FX markets display distinct characteristics that developed market currencies tend to experience slightly positive returns with lower volatility, while emerging market currencies are characterized by lower negative average returns but significantly larger standard deviations, along with substantial skewness and kurtosis.

Cumulative FX returns reveal that, over the period from 2000 to 2024, developed markets experience inconsistent movements around a horizontal trend with cumulative log returns near 2%, whereas emerging markets consistently record negative returns. Moreover, a pronounced decline in FX returns for both markets following COP21 agreement can possibly indicate the sensitivity of currency markets to climate transition risks.

The interaction between stock and FX markets further shows the underlying dynamics of international investment flows and investor behaviours. Although the UEP theory argues that differences in expected stock returns should be offset by corresponding movements in exchange rates, the empirical evidence intuitively suggests a divergence from the parity. Specifically, the observation that positive stock returns generally exceed negative FX returns suggests that investors may have hedged a portion of their FX exposure in advance, or that FX markets have sufficient liquidity to absorb some of the net order flow resulting from shifts in international investment. Consequently, these dynamics contribute to a deviation from the predictions of the UEP theory. This discrepancy is particularly evident in emerging markets, where the persistent negative FX performance, with positive stock returns, indicates portfolio rebalancing. The observed patterns not only highlight the contrasting return-volatility profiles between developed and emerging markets but also suggest that global policy shifts play a crucial role in shaping currency valuations.

4.2 Emerging V.S. Developed Markets

This section examines the impacts of climate transition risks on excess foreign equity returns in developed and emerging markets, focusing on the different periods before and after the Paris COP21 agreement. Both the portfolio approach and asset pricing approach are employed to analyse each market. Additionally, the relationship between stock differentials and FX returns are analysed in the fixed-effect model.

4.2.1 Climate Transition Risk

We first present the portfolio analysis for developed markets, which is reported in Table 3. Sorting quintile portfolios by climate transition risks reveals no clear monotonic relationship between the risk levels and excess foreign equity returns, while we would have expected that the excess foreign equity returns for each portfolio are increasing with the level of climate transition risks. We find that UEP returns reveal Sharpe Ratios (SR) ranging from -0.50 to 0.12. For UEP excess returns,

P1 (lowest transition risk) delivers the highest annual return of 0.18% with an SR of 0.03, while P5 (highest transition risk) yields -1.40% annually with an SR of -0.22. There is no evidence of compensation for climate transition risks in stock differentials component, as both returns and SRs remain negative with only exceptions for P4, whereas FX components generate positive returns and SRs across all quintiles. The long-short strategy, buying P5 and selling P1, fails to yield significant excess returns over the full sample period, with the NW t-stats of -1.08. Similarly, the decomposition of the long-short strategy returns for stock differential and FX components is statistically insignificant, with t-values of -1.37 and -0.06, respectively. Overall, climate transition risks show no meaningful impact on UEP portfolios and the sub-components on developed markets.

As indicated by the Figure 1., the emerging and developed market groups exhibit different patterns in the development of climate transition risks. In contrast, the analysis of emerging markets, presented in Table 4, provides evidence of compensations for exposure to such climate transition risks. For UEP excess returns, P5, representing the highest level of transition risks, achieves 4.65% annual returns with an SR of 0.73, compared to 3.12% annually and an SR of 0.43 for P1. Stock and FX quintile portfolios in emerging markets display a different return structure, where P5 for the FX components consistently yielding the lowest returns and SR and P1 offer the highest ones. A long-short portfolio strategy in emerging markets, buying P5 and selling P1, produces 1.53% excess foreign equity returns with statistical significance. The stock and FX components contribute 3.72% and -2.19%, respectively, to the total returns, indicating a clear deviation of the UEP theory. The negative correlation between returns in these two markets suggests that investors are engaging in portfolio-rebalancing rather than return-chasing behaviour.

Following the portfolio sorting analysis, which shows the impact of climate transition risks on UEP excess returns in emerging markets, our research further employs the GMM to assess the explanatory power of climate transition risks on foreign excess equity returns. Table 5 presents the GMM estimations risk premia R^{CTR} from equation (6). Traditional factors, including Dollar, SMB, MOM, and volatility innovations for both stock and FX markets, show varying significant explanatory power over excess foreign equity returns. With control variables, the risk premia estimate for R^{CTR} is approximately 0.57% per month from GMM. These findings reinforce the empirical evidence in Table 4, highlighting the significant influence of climate transition risks on excess foreign equity returns in emerging markets. Additionally, the GMM estimations are also

applied to the developed markets as in Table 6. The estimations of R_t^{CTR} are insignificant, implying no sign of climate transition risks pricing in the UEP excess returns for developed markets. Therefore, results from GMM show again the findings from portfolio approach that climate transition risks are more significant for emerging markets, compared to developed markets. What's more, GMM estimations report low adjusted R^2 values, suggesting that the overall explanatory power of the climate transition risks with other controls for excess foreign equity returns across the full sample period is limited in developed markets.

4.2.2 Paris Agreement (COP21)

The Paris Agreement represents a crucial milestone, highlighting the significant impact of global sustainability initiatives on financial market dynamics. The climate transition risks presented in Figure 1. show that starting from 2016, the declining trends of climate transition indices may indicate positive impact of Paris Agreement on climate issues, while such indices for emerging markets completely change the trajectories of climate transition risks compared to those of developed markets. Based on these observed facts, we conduct research on the effect of climate transition on foreign equity returns before and after the Paris Agreement. The sample period is thus split into two sub-periods regarding to the Paris Agreement. The pre-COP21 period is from January 2000 to December 2015, and the post-COP21 period is from January 2016 to September 2024.

Table 7 compares quintile portfolios for developed markets before and after the Paris Agreement. It evaluates the impact of climate transition risk on excess foreign equity returns, stock differentials, and FX components. Before the agreement, quintile portfolios displayed no monotonicity in returns, and insignificant estimation of long-short portfolio returns with NW t-stats of 0.44, which is consistent with the whole sample period analysis. Similar performance applies to stock and FX components that no evidence has been found to support the effect of climate transition risk on stock and FX markets. Additionally, post-period results highlight a dramatic shift, with negative UEP returns (-3.80%) driven by declining stock performance (-3.21%) with limited impact from FX component (-0.59%), while the UEP returns are also insignificant estimation with NW t-stats of -1.32. This suggests that climate transition risks have shown limited impact in developed markets, while the results show the disparity that numerically equity markets are affected more than FX markets.

Table 8 repeats the analysis for emerging markets and reveals distinct patterns compared to that of the developed markets. As we have seen in Figure 1, the climate indices decrease only after the Paris COP21 agreement for the emerging market group, and thus, it is reasonable to conjecture that climate transition risk factor will not affect the excess foreign equity returns for emerging markets during the pre-COP 21 period but deliver such impact over the post-COP21 period. The empirical evidence confirms the above hypothesis that pre-period long-short portfolio exhibited no significant excess foreign equity returns, as seen in Quintile (5 - 1), where UEP returns were 0.73%, driven by contributions from stock (0.80%) and FX (-0.37%), which are both insignificant estimates. Post-period performance demonstrates a divergent trend that Quintile 5 excess returns decreased substantially to -0.80%, while other quintiles (e.g., Quintile 1, 2 and 4) showed marked larger underperformance, reflecting the different level of impact from transition risks for different quintile portfolios. From long-short portfolios, in post-period, investors can expect an annual return of 3.96% with NW t-stats of 3.35. The further decomposition of UEP deviations shows that stock and FX market jointly contribute to the overall returns, where 10.08% (NW t-stats = 2.68) and -6.12% (NW t-stats = -2.82) are from stock market and FX market respectively. The positive stock differential returns show that under the emerging markets during post-period, stronger stock market risk premia are associated with higher climate transition risks, and further transmitted to FX markets with negative returns. Therefore, negative relationship between stock differentials and FX returns shows that investors tend to engage in portfolio rebalancing in emerging markets following COP21. Additionally, the positive returns from stocks outperform the negative FX returns, indicating the violation of UEP theory.

Based on the performance of emerging markets after the Paris Agreement, our analysis further examines the factor risk premium from GMM of climate transition risk to confirm that impact of climate transition risk is larger for emerging market at post-period. From Table 9 to Table 10, our research re-estimates R_t^{CTR} obtained through equation (6). Under GMM estimation, the risk premia for climate transition risks are consistently positive and statistically significant across different model specifications. This equities from emerging markets offer compensation for exposure to climate transition risks after controlling for Dollar and other common international equity factors. Overall, the results from GMM support the findings from portfolio approach since the estimated risk premia are both positive and significant.

There are two possible explanations for why climate transition risks appear to affect emerging markets only after COP21. First, the Paris Agreement may have accelerated the integration of climate transition risks as a systematic risk within financial markets, because of the increasing awareness from investors. Following COP21, these risks likely gained greater financial relevance, particularly in emerging markets, where the markets are essentially more volatile and thus investors may have larger reaction toward climate transition risks for emerging markets. Therefore, to have a better understanding of the time-varying characteristic for R_t^{CTR}, we employ a one-year rolling window GMM estimation for Equation (6) to capture impact of Paris Agreement on risk premia in emerging markets. The resulting estimates from Figure 4. reinforce our previous findings for emerging markets by demonstrating that climate transition risks are associated with a positive risk premium only after the Paris Agreement, with the premium consistently stabilizing around 0.8% at the 95% confidence level. In contrast, there is no empirical evidence prior to the Paris Agreement indicating that climate transition risks were priced as a systematic risk in the international equity markets, since the risk premia are not significantly different from 0.

Second, the different patterns of impact between developed and emerging markets could be attributed to the inherently lower levels of climate transition risk in developed markets. This can be possibly explained by the higher maturity in developed markets for climate-related financial regulations, such as carbon taxes and Emission Trading Systems (ETS). According to World Bank data[13], prior to COP21, developed markets exhibited a coverage ratio of approximately 80% compared to 15% in emerging markets. More recently, these figures have increased to 93% for developed markets and 45% for emerging markets. These findings suggest that, in developed markets, the implementation of regulatory mechanisms may have mitigated the impact of climate transition risks on asset prices.

4.2.3 Stock Differentials and FX Returns

Table 11 shows the simultaneous correlation between stock differentials and FX returns. Column (1) and (4) are consistent with the finding of Cenedese et al., (2016) that FX returns are independent of stock return differentials, with the insignificant estimation of -0.0112 (t = -0.59) and 0.0155 (t = 1.14). From Column (2), after considering the climate transition risk, stock and FX components are negatively correlated with the estimation of -0.0589 for the interaction term

[13] World Bank website: Price | Carbon Pricing Dashboard. The coverage ratio is based on our sample countries and calculations.

($\Delta S * CTR$), implying the portfolio rebalancing behaviours from investors in emerging markets. Column (3) reinforces our findings from portfolio sorting analysis that the impact of climate transition risk will be much stronger for EMs after COP21, since the risk premia for the whole period are mainly driven by the period after COP21, and we have the estimation of -0.0244 for $\Delta S * CTR * COP21$ with t = -3.60. Additionally, from Column (2) to Column (3), the estimation of βs for ΔS are significantly positive, showing that without the impact of climate transition risks, investors in EMs are doing portfolio chasing as suggested by Fuertes et al., (2019). In contrast, for developed markets, the estimations from Column (4) to Column (6) show that the FX returns are unrelated to the stock market return differentials, even after considering the interactions with climate transition risks and the event of COP21. Therefore, the fixed-effect model shows again the channel that higher climate transition risks will generate negative FX returns via the stock markets, and such impact are more pronounced for EMs after COP21.

5 Robustness Tests

To guarantee the reliability of our findings, we performed comprehensive robustness checks to confirm the stability of the estimated relationships between climate transition risks and excess returns in foreign exchange and equity. These robustness checks involved varying background conditions: (1) employing alternative proxies for climate transition risks; (2) adjusting the number of portfolios; (3) incorporating the MSCI stock index and additional control variables; (4) changing the rebalancing frequency; (5) varying the sample countries; and (6) Fama-MacBeth (FMB) analysis.

5.1 Alternative Proxy for Climate Transition Risks

Existing studies (Bolton and Kacperczyk, 2023; Aswani et al., 2024; Zhang, 2024) suggest that alternative indicators, such as actual carbon emissions and emission intensity, can serve as effective proxies for climate transition risk. Building on this framework, our study replaces the applied climate transition risk index with actual carbon emission intensity[14] data and tests the robustness of our findings against the different transition risk indicator. Table 12 illustrates that the results in emerging markets follow a pattern similar to our earlier analysis. Specifically, the

[14] Carbon intensity is the ratio for carbon emission over GDP for individual country. It indicates how much carbon a country emits relative to the size of its economy, reflecting the efficiency and sustainability of its energy use and production processes.

long-short strategy applied to emerging markets produces significant and positive excess UEP portfolio returns of 1.84% per annum (NW t-stats = 2.28) after COP21, when actual carbon intensity is used as the proxy. This result indicates that the sensitivity of emerging market stocks and FX rates to climate transition risks is robust when the measure of risk is altered. In contrast, our estimations for developed markets, including excess foreign equity returns, as well as the stock and FX market components, lack statistical significance. Under the UEP framework, neither the original climate transition indices nor the actual carbon emission data provide evidence of a significant impact from climate transition index in developed markets. In summary, our findings suggest that emerging markets after COP21 are more significant to climate transition risks than developed markets. This robustness check not only validates the use of actual carbon emission intensity as a climate transition risk indicator but also reinforces the overall impact of climate transition risks on emerging market for investors' portfolio rebalancing behaviours.

5.2 Reallocation of Portfolios

Initially, excess foreign equity returns were allocated into five quintile portfolios based on climate transition risks. In this section, following Cenedese et al. (2016), we extend the analysis by varying the number of portfolios from three to six depending on the level of climate transition risk, compared with our portfolio approach applied above that countries with excess foreign equity returns are sorted into only five quintile portfolios, to test the validity of our previous findings for both emerging and developed markets. The sample period is divided in December 2015 to account for the impact of the Paris Agreement. As shown in Table 13, the long-short strategy returns in developed markets reveal no significant excess foreign equity returns across all portfolio variations and remain consistent before or after the Pairs Agreement. Similarly, the stock and FX components do not exhibit any significant returns related to climate transition risks, so no clear correlations are captured. In contrast, the results for emerging markets align with our earlier findings, demonstrating that long-short strategies yield substantial positive returns post-COP21. Also, prior to COP21, the same strategies fail to provide compensation for the same level of climate transition risks in emerging markets. The long-short portfolio returns are consistent in sign, with variations in magnitude, indicating that different portfolio allocations do not alter the qualitative conclusion that emerging markets compensate investors for climate transition risk exposure starting from the COP21.

5.3 MSCI Stock Index and Additional Control Variables

In this section, our research substitutes local stock market indices with MSCI stock market indices due to the latter's better liquidity and practical applicability. For investors who are unable to directly access certain stock markets, an alternative approach is to invest in funds or other financial instruments that track the country-specific MSCI stock indices, which makes the investment more feasible. The fact that countries are likely to set entrance and exit barriers for the foreign investors, subsequentially generating the liquidity risks for foreign investors. Hence, we apply the MSCI stock index data, since the MSCI data is the underlying or linked with mutual funds and ETFs that are tradeable and more liquid. Another adjustment is that Russia is excluded from the sample countries due to the data availability, so that 34 countries are analysed, with 15 from developed markets and 19 from the emerging markets, compared to the original sample, which was 35 countries in total. Additionally, to have a robust result over the estimation of the climate transition risk factor, several other control variables are included: Momentum (MOM^{FX}), Carry (CARRY), and Long-Term Yield (LT) (Lustig et al., 2011; Asness et al., 2013; Ang and Chen, 2010; Menkhoff et al., 2012b). The forward premium ($f_t - s_t$) is used to form the carry factor. Momentum factor (1-month) is constructed by the lagged 1-month performance of the FX returns. The Long-Term Yield factor is calculated as the difference between long-term government bond yields in the US and other foreign countries, with yield data sourced from DataStream and WM Reuters.

The robustness of our main findings is being tested following the above new stock data and control variables settings. The results are reported from Table 14 to Table 15. From Table 14, the quintile portfolio and long-short strategy shows the similar results with significantly positive risk premia but a small deduction in numbers. The heterogeneity between emerging markets and developed markets, and the impact of COP21 agreement remain valid after applying the MSCI stock index. Table 15 reports the GMM estimations, with additional control variables, the estimation of R_t^{CTR} is 0.4166 with Newey-West t-stats of 2.63, which agrees with our previous estimation of climate transition risk premia. Furthermore, the risk premia from all model settings are consistently positive and significant, again these results reinforce the findings from portfolio approach that the long-short strategy offers positive risk premia in foreign equity investment returns.

5.4 Rebalancing Frequencies

To assess the sensitivity of our empirical findings to rebalancing frequencies, our study replaces the monthly investment period strategy by quarterly, semi-annual, and annual strategies. Table 16 demonstrates that, for emerging markets post-COP21, a holding period of up to six months yields significant excess returns. The observed negative correlation between stock and FX components further confirms the portfolio rebalancing behaviour for international equity investors. However, under an annual holding period strategy, the long-short portfolio does not generate statistically significant excess returns, indicating the limits of arbitrage profits based on climate transition risk. Additionally, the empirical results for developed markets remain robust across different periods, with climate transition risks showing no impact on stock and FX returns. Overall, this analysis provides further insight into the climate transition risk premium and its effectiveness across various time horizons.

5.5 Time-varying Climate Transition Risk Premia

To address potential concerns regarding the influence of specific emerging market countries on our findings, we perform one complementary robustness exercise using Equation (6) for GMM estimation. As shown in Figure 6., where one country is dropped at a time to maintain a consistent sample of 19 countries per iteration, both the estimated risk premia (R_t^{CTR}, ranging from 0.76% to 0.86%) and the NW t-stats (fluctuating narrowly between 3.22 and 3.32) demonstrate limited variation. These findings suggest that the qualitative impact of climate transition risks on international equity markets is robust and are not likely to be driven by specific countries from emerging markets, as the estimations are consistently significant within each dropping iteration.

5.6 Fama-MacBeth Analysis

In addition to using the GMM, our research employs Fama–MacBeth (FMB) analysis to re-estimate equation (6) and assess the impact of climate transition risks in both developed and emerging markets. This approach allows us to obtain the cross-sectional average of risk premia estimates for UEP excess returns at country-level. We perform the FMB estimation for the entire sample period across both markets, and also separately for emerging markets before and after the Paris Agreement. The results, presented in Tables 17 through 20, indicate that climate transition risks are priced only in emerging markets. Moreover, the impact of these risks appears to be more pronounced after the Paris Agreement. Specifically, the estimated risk premium for climate

transition risks is 0.3161 (NW t-stats = 2.24) for the full sample of emerging markets, while the estimates are 1.5105 (NW t-stats = 1.18) before and 0.4789 (NW t-stats = 2.96) after the Paris Agreement.

5.7 Summary of Robustness Checks

Our robustness checks involve several key steps to ensure the validity of our findings. First, we replace the climate transition risk index with carbon emission intensity as a proxy for transition uncertainty. The results indicate similar patterns in emerging markets compared to our initial analysis, with long-short portfolios continuing to generate positive returns for carbon emission intensity. Developed markets show no compensation for climate transition risk indices neither before nor after COP21. Next, we reallocate excess foreign equity returns into varying quintile portfolios to perform the same heterogenous exercises across different market types and Paris Agreement. The findings reveal no significant excess returns in developed markets, and emerging markets show substantial positive returns post-COP21. Then, we replace local stock index with MSCI stock index which has better liquidity in the financial market and include additional control variables. The results remain consistent, reinforcing our previous conclusions. Additionally, our study analyses the impact of different rebalancing frequencies, and the results show that arbitrage returns from UEP portfolios are more pronounced when the rebalancing is more frequent. Then, we provide evidence for that climate transition risk premia in international equity markets are not likely to be driven by specific countries. Finally, we re-estimate the climate transition risk premia using FMB, and the results show that our findings for emerging markets after Paris Agreement are not challenged.

6 Additional Analysis

6.1 Climate Physical Risk

Arteaga-Garavito et al. (2024) demonstrate that a positive climate news shock, including both transition and physical risks, is associated with an increase in the real exchange rate for countries with greater exposure. To confirm that our results are not driven by climate physical risks, we perform a portfolio sorting analysis using the climate vulnerability index from the Notre Dame Global Adaptation Initiative (ND-GAIN) [15] following Cheema-Fox et al. (2022). The

[15] Link for ND-GAIN climate vulnerability index: Country Index // Notre Dame Global Adaptation Initiative // University of Notre Dame

vulnerability index measures a country's propensity to adverse impacts from climate-related disruptions and disasters, such as wildfire, flood etc. As shown in Table 21, the analysis for emerging markets reveals distinct patterns relative to our previous findings. Although long-short portfolios generate positive returns, no statistically significant investment returns are observed when isolating climate physical risks. Moreover, our results for developed markets remain unchanged, indicating that these markets do not provide compensation for physical climate risks. Consequently, under the UEP theory, there is no evidence that either physical or transition risks are priced in developed markets. The event of COP21 shows no impact over market dynamics between international stock and FX markets, under climate physical risks. Overall, our findings suggest that the impact of climate transition risks on emerging market stocks and FX rates operates independently of the effects of climate physical risks.

6.2 Reaction to Climate Transition Risk with Delay

Hong et al., (2019) and Pastor et al., (2022) argue that stock may react to climate risks with delay, which indicates that lagged proxies for climate transition risks can potentially continue to have an impact on stock returns. Building on their findings, our study employs various lags of the climate transition index to assess whether portfolio rebalancing behaviour is similarly influenced by these lagged measures. Table 22 indicates that an index with lags up to three months generates statistically significant excess UEP returns with positive stock market differentials and negative FX returns, and thus the portfolio rebalancing behaviour observed in emerging markets post-COP21 remains robust, while no impact has been identified for developed markets. In contrast, for lags exceeding three months, the magnitude of excess UEP returns remains high, yet these returns become statistically insignificant. Specifically, a six-month lag yields excess returns of 2.01% (NW-t = 1.55) and a twelve-month lag yields excess returns of 1.13% (NW-t = 1.60). This pattern may be attributed to investors' tendency to update their expectations based on more recent information, thereby basing their investment decisions on the most current data available.

7 Conclusion

This study investigates the impact of climate transition risk on FX returns, focusing on portfolio rebalancing channel through international stock markets. Firstly, our findings reveal that climate risk factors can have an impact on FX returns under UEP framework. The climate transition risks can be used to explain the excess foreign equity returns, and for the decomposition of excess returns,

the stock and foreign exchange components indicate the portfolio rebalancing behaviours and the violation of UEP theory among global investors. While the nominal exchange rate returns negatively contribute to UEP deviation with higher climate transition risks, the stock market components yield the value of positive returns that outweigh the negative returns from FX market.

Secondly, our analysis also addresses significantly different patterns between developed and emerging markets, with little evidence supporting climate transition risks being priced in developed markets. The analysis encompasses the periods before and after the COP21. Prior to COP21, climate transition risks had a limited impact on asset pricing for both groups of market. Quintile portfolios exhibited non-monotonic trends, and long-short portfolio strategies yielded negligible returns, suggesting no evidence for investor to take climate transition risks into account. Conversely, following COP21, the correlation between climate risks and excess returns markedly intensified. Portfolios with higher climate risks yield more excess returns, exhibiting statistically significant long-short returns. While the impact of climate transition risk is silent for developed market after COP21, emerging markets exhibit robust dynamics between stock and foreign exchange markets, suggesting deeper financial integration in these markets in the context of climate transition risks and also the country-level heterogeneity of financial integration (Aftab and Phylaktis, 2022). These results also highlight the increasing acknowledgement by investors of climate transition risks and their incorporation into pricing strategies to hedge climate risks considering global climate policies, as suggested by Giglio et al. (2025). Therefore, investors should exploit the excess returns and adjust rebalancing strategies as climate policies evolve. Additionally, policy makers need to design climate policies that are market-sensitive to mitigate the risk of investment flows. Together, these insights advance our understanding of how climate factors influence international financial markets and emphasize the need for continued exploration of their economic and policy implications towards the climate transition risks.

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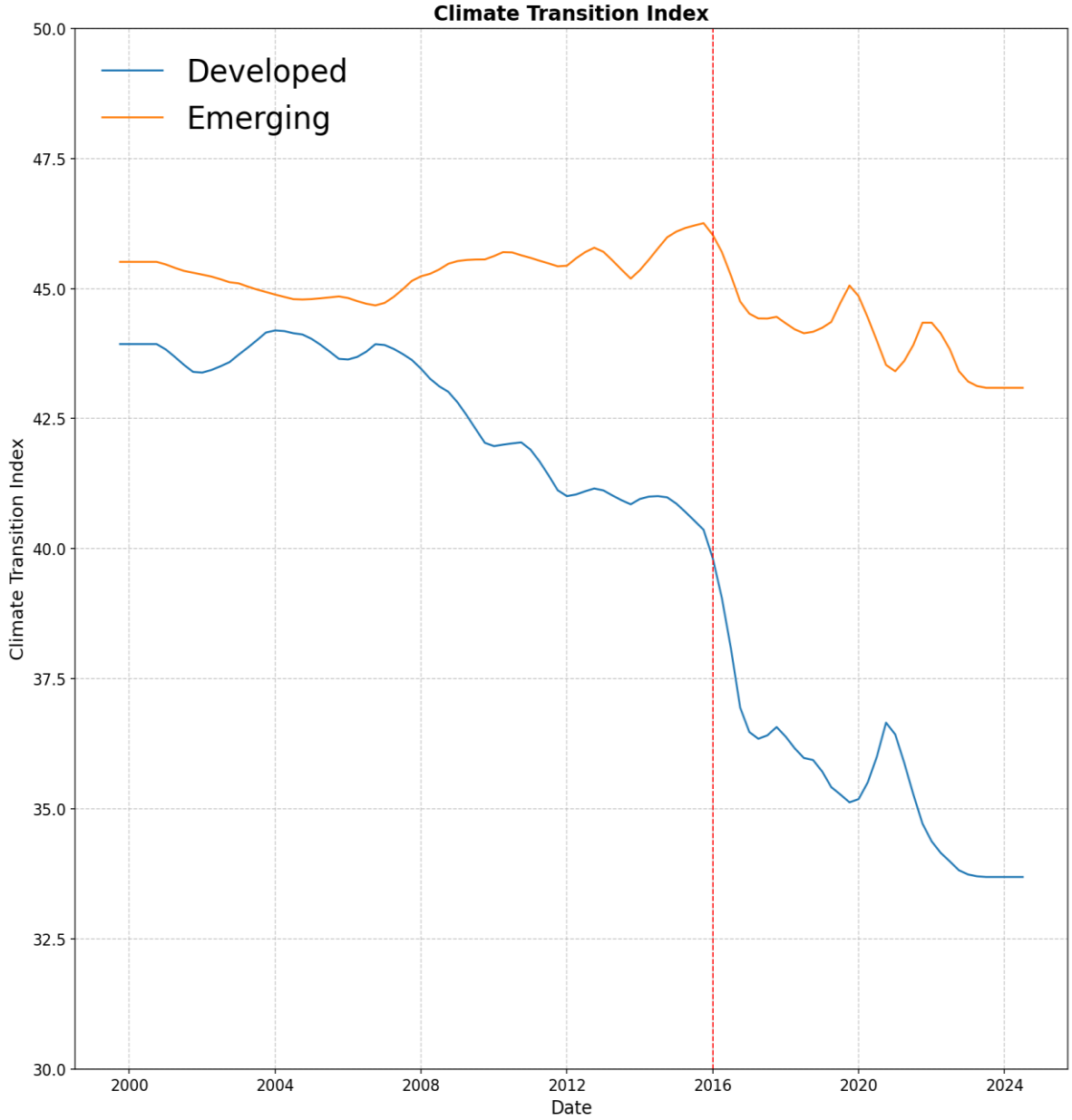
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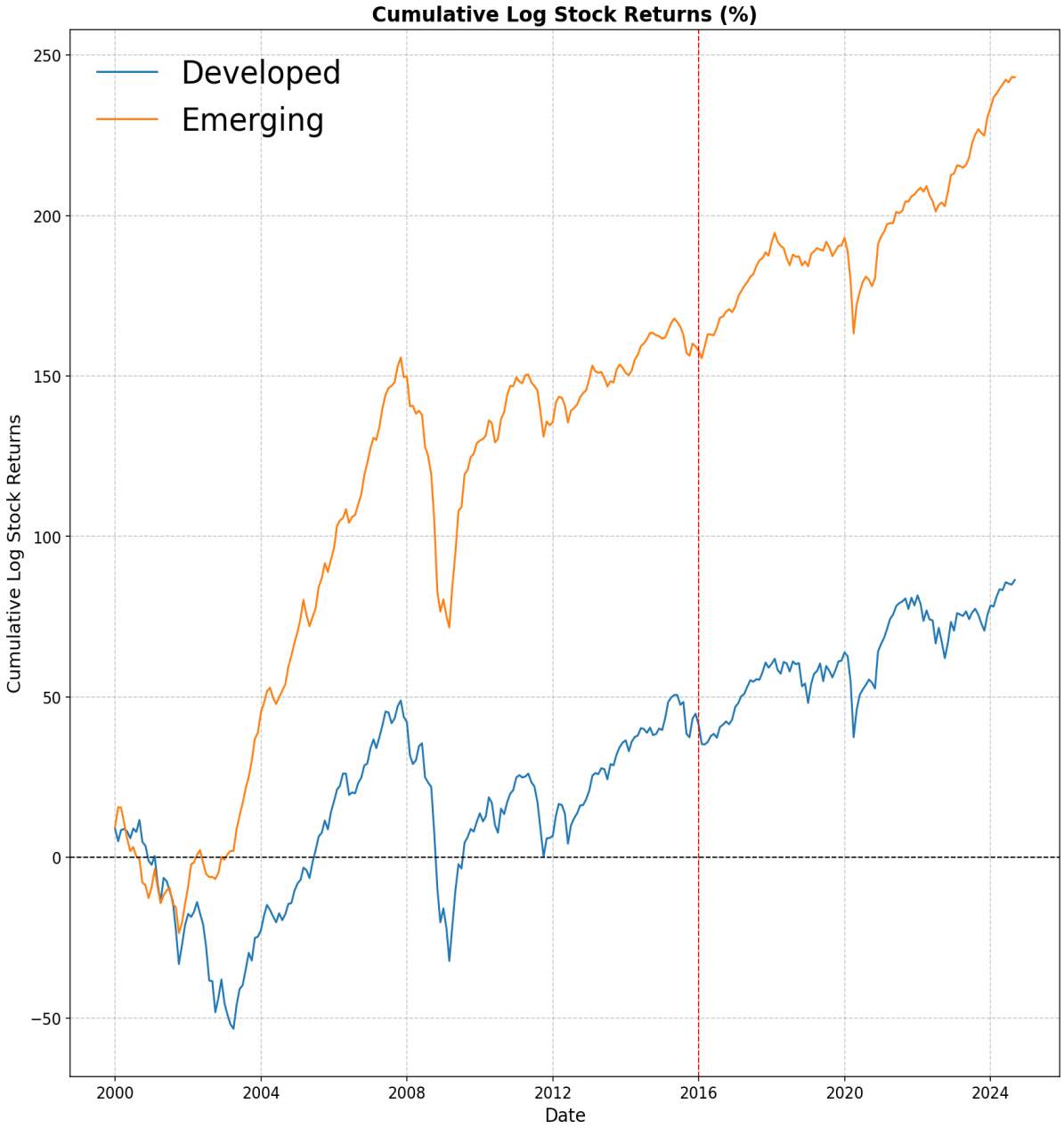
Figures and Tables

Figure 1: Climate Transition Index



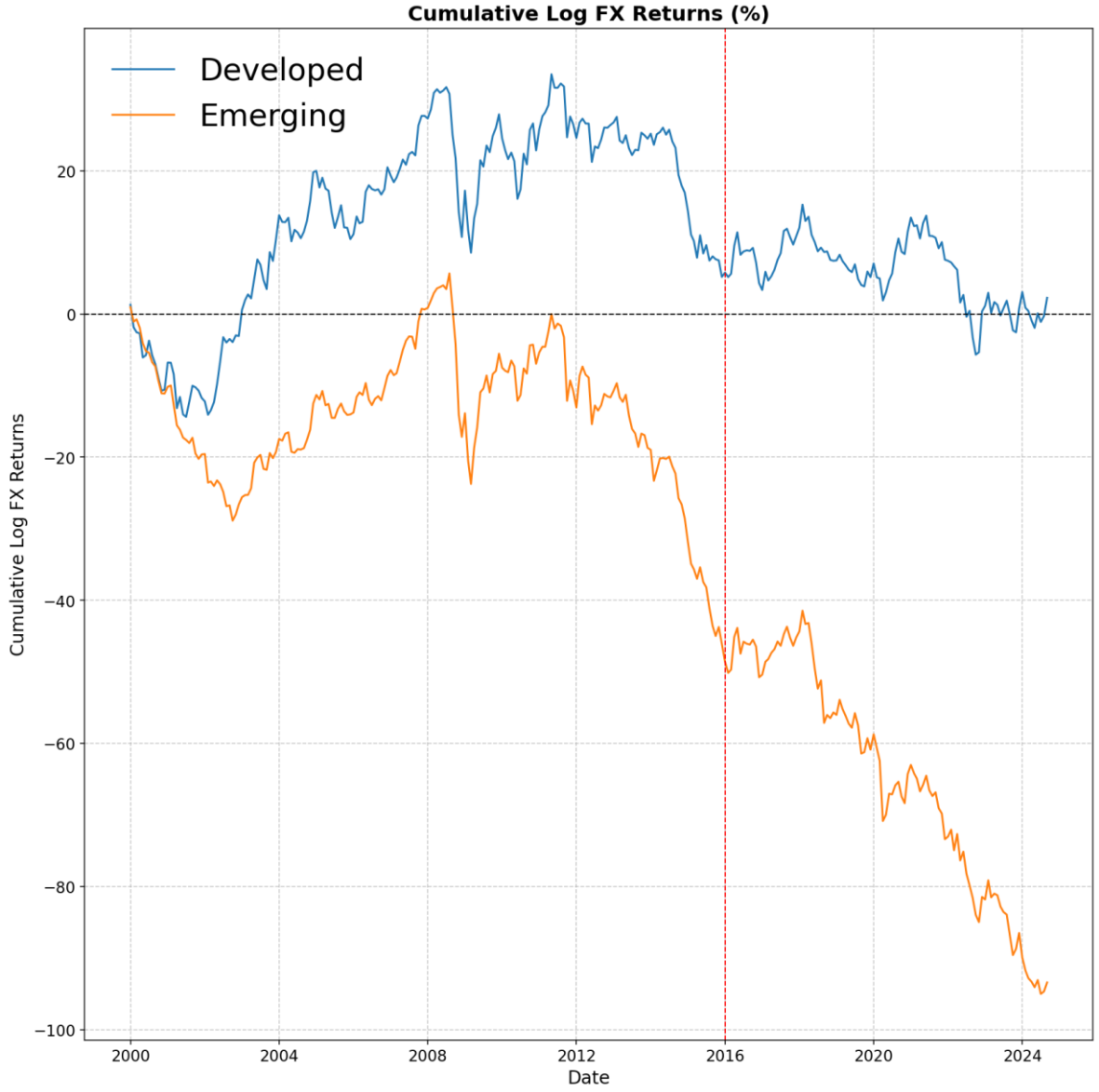
Description: This graph plots the quarterly Climate Transition Risk Index for both developed (blue line) and emerging (yellow line) market groups from Q1 2000 through Q3 2024. The red line marks the event of the Paris Agreement, which divides the sample into two sub-periods. For better interpretability, the risk index is obtained by subtracting 100 from the original values so that higher values now correspond to higher levels of transition risk. The obtained values for each market group represent the average index calculated across its individual constituents.

Figure 2: Cumulative Log Stock Returns



Description: This graph plots the cumulative log stock returns for both developed market group (blue line) and emerging market group (yellow line), from January 2000 to September 2024, with 297 observations each. The red line represents the Paris Agreement that separates our sample into two sub-periods.

Figure 3: Cumulative Log FX Returns



Description: This graph plots the cumulative log FX returns for both developed market group (blue line) and emerging market group (yellow line), from January 2000 to September 2024, with 297 observations. The red line represents the Paris Agreement that separates our sample into two sub-periods.

Table 1: Summary Statistics for Stock Index

	count	mean	std	min	25%	50%	75%	max	skewness	kurtosis
Panel A. Developed Market										
Australia	297	0.3375	4.0223	-19.5104	-2.1642	1.0997	2.9655	10.3716	-0.8549	-2.2734
Austria	297	0.4011	6.5260	-35.6102	-1.8595	1.3673	3.8622	22.3355	-1.4035	-5.6686
Canada	297	0.381	4.4734	-22.7229	-1.506	0.9824	2.8232	16.3916	-1.1247	-4.3450
Denmark	297	0.7573	4.8266	-18.7619	-1.5427	1.1367	4.1400	14.5276	-0.8818	-1.9187
Finland	297	-0.0327	7.0176	-29.105	-3.2472	0.5035	3.7999	30.3438	-0.3034	-3.3403
France	297	0.1183	5.3444	-23.7205	-2.5390	0.6894	3.5050	17.3807	-0.724	-1.7240
Germany	297	0.3906	6.0673	-23.0896	-2.4942	0.8854	4.127	18.2938	-0.7816	-1.7967
Hong Kong	297	0.0462	6.1349	-22.7914	-3.4826	0.5650	3.704	19.6365	-0.2721	-0.9316
Japan	297	0.2486	5.7036	-28.1743	-2.7322	0.7413	3.8989	13.9678	-0.6933	-1.7075
Norway	297	0.6919	5.1015	-35.337	-1.3455	1.3676	3.8705	16.5417	-2.0268	-10.2098
Singapore	297	0.1428	5.3247	-22.4935	-2.3930	0.7506	3.0905	21.4659	-0.5785	-3.0391
South Korea	297	0.3323	6.2595	-24.3011	-2.7308	0.6897	3.7755	19.3417	-0.3640	-1.2665
Sweden	297	0.3017	5.5058	-16.8661	-2.4273	0.7908	3.7576	14.8978	-0.4837	-0.7852
Switzerland	297	0.1717	4.0232	-16.0873	-1.7172	0.6811	2.6356	12.2149	-0.7292	-1.3979
United Kingdom	297	0.0774	4.1347	-19.8898	-2.0917	0.6581	2.5582	12.1374	-0.8772	-2.4687
Developed	297	0.2910	4.3132	-17.4894	-1.7317	0.8632	3.0340	11.5121	-0.8985	-2.0218
Panel B. Emerging Market										
Argentina	297	2.7205	11.7027	-45.7962	-3.9658	2.1653	10.0799	40.9598	-0.2133	-1.8513
Brazil	297	0.6878	7.0554	-35.5309	-3.4903	0.8014	5.8745	16.4841	-0.7397	-2.4796
Bulgaria	286	0.7148	7.5376	-50.9278	-1.9327	0.2826	3.7345	28.5905	-1.2777	-10.3136
Chile	297	0.6339	4.5533	-22.2994	-2.4831	0.4421	3.7900	16.421	-0.0646	-2.3358
China	297	0.2188	7.5494	-28.7696	-3.7499	0.6536	4.2117	24.2502	-0.6051	-2.5185
Colombia	200	0.1665	5.3983	-32.1243	-2.8282	0.5641	3.4994	13.3654	-1.4698	-6.9856
Czech Republic	297	0.4109	6.0233	-31.5231	-2.3247	0.7860	3.8256	19.5673	-0.9068	-4.0521
Hungary	297	0.7665	6.6759	-30.8179	-2.4793	0.9434	4.5803	18.9982	-0.8225	-3.4487
India	297	1.0507	7.4096	-30.5585	-1.9959	1.5688	5.1080	31.6443	-0.6029	-3.0439
Indonesia	297	0.8604	5.8010	-30.3571	-1.7186	1.1168	4.0709	16.8247	-0.7209	-3.1366
Malaysia	297	0.2790	3.9340	-13.042	-1.6341	0.5099	2.3122	12.9133	-0.1921	-1.3762
Mexico	297	0.7192	5.5404	-22.4387	-2.3439	0.9731	4.0978	17.6871	-0.3134	-1.7089
Peru	297	0.9262	7.5744	-36.9487	-3.2493	0.6985	5.3217	36.7134	0.0516	-4.6125
Philippines	297	0.4210	5.7285	-23.7914	-2.8627	1.2000	4.258	17.1284	-0.5104	-1.6436
Poland	297	0.5149	6.0434	-27.4511	-2.8460	0.5977	4.3576	18.838	-0.3487	-1.5429
Romania	297	1.2019	8.0239	-37.7969	-1.5894	1.5096	4.7720	36.2282	-0.4316	-4.5942
Russia	297	0.8778	7.9291	-35.6993	-2.9786	1.5178	5.3771	28.5172	-0.8108	-3.1300
South Africa	297	0.8130	4.8142	-17.0074	-2.3174	1.2549	3.6080	14.3261	-0.1321	-0.8152
Thailand	297	0.3916	6.2855	-28.0191	-2.7067	0.6036	3.7315	20.5068	-0.5728	-3.2225
Turkey	297	1.5982	10.6690	-56.7997	-5.0553	1.7703	7.5274	67.2831	0.3743	-7.4642
Emerging	297	0.8184	3.9238	-22.3063	-0.9193	1.1296	2.9317	13.1839	-1.0958	-5.7663

Description: This table summarizes the monthly log return statistics for stock indices across 35 sample countries from January 2000 to September 2024. The statistics presented include the count, the mean, or average monthly return of the stock indices, and the standard deviation (std), capturing the variability or volatility in the returns. The table includes the minimum and maximum monthly returns, along with the percentiles (25%, 50%, and 75%) that describe the distribution of returns across quartiles. Skewness is reported to show the asymmetry of the return distribution, and kurtosis is also provided.

Table 2: Summary Statistics for FX

	count	mean	std	min	25%	50%	75%	max	skewness	kurtosis
Panel A. Developed Markets										
ATS/USD	297	0.03158	2.70028	-9.29633	-1.50350	0.14885	1.65418	9.85865	-0.10773	1.07435
AUD/USD	297	0.02244	3.52185	-15.20549	-1.90476	-0.03051	2.54715	10.66199	-0.33343	1.28521
CAD/USD	297	0.02979	2.44596	-11.56626	-1.31895	0.03944	1.67063	9.26633	-0.36084	2.26794
CHF/USD	297	0.21023	2.88433	-13.99340	-1.55225	0.17986	1.91603	12.85866	0.03964	2.90769
DEM/USD	297	0.03158	2.70025	-9.29775	-1.50383	0.14800	1.65636	9.85644	-0.10787	1.07387
DKK/USD	297	0.03068	2.69398	-9.07751	-1.49729	0.12836	1.63680	9.93486	-0.09202	1.06317
FIM/USD	297	0.03158	2.70027	-9.29545	-1.50310	0.15039	1.65321	9.85808	-0.10769	1.07430
FRF/USD	297	0.03158	2.70033	-9.29664	-1.50369	0.14854	1.65439	9.85917	-0.10775	1.07455
GBP/USD	297	-0.06544	2.61949	-11.07689	-1.64877	-0.10937	1.73275	10.05801	-0.27956	1.64985
HKD/USD	297	-0.00118	0.15310	-0.65986	-0.05545	-0.00129	0.03677	0.90539	1.12342	8.16421
JPY/USD	297	-0.12227	2.78101	-8.99359	-1.82323	-0.03220	1.55075	8.58490	-0.13385	0.56992
KRW/USD	297	-0.04893	3.01650	-13.15004	-1.46444	0.09074	1.38351	13.41273	-0.24397	4.58433
NOK/USD	297	-0.09104	3.37286	-11.90898	-2.12204	-0.13111	2.02187	8.48384	-0.18144	0.33296
SEK/USD	297	-0.06116	3.29469	-10.58309	-2.01524	-0.05442	1.90631	11.03705	0.05078	0.42324
SGD/USD	297	0.08473	1.59044	-8.56889	-0.81084	0.07164	1.04482	6.08553	-0.52461	3.29328
Developed	297	0.00761	2.14019	-7.51453	-1.20429	-0.03777	1.19018	6.48171	-0.09731	0.90552
Panel B. Emerging Market										
ARS/USD	297	-2.3096	7.7232	-80.6535	-2.2875	-0.8818	0.0342	10.1288	-6.5758	55.5926
BGN/USD	297	0.0296	2.7266	-10.2656	-1.5066	0.1289	1.6044	10.2700	-0.1882	1.3998
BRL/USD	297	-0.3631	4.5786	-16.0802	-2.7319	-0.0545	2.2312	12.7545	-0.4358	1.2244
CLP/USD	297	-0.1750	3.5054	-16.4252	-2.1177	-0.1504	2.2773	7.5519	-0.6406	1.8086
CNY/USD	297	0.0681	0.9821	-3.8852	-0.0760	0.0000	0.3896	5.1300	-0.1579	5.1948
COP/USD	297	-0.2600	3.8947	-16.5965	-2.3333	-0.1451	2.1816	11.0171	-0.4337	1.0783
CZK/USD	297	0.1554	3.4847	-13.6734	-1.9302	0.2243	2.3189	9.5282	-0.3623	1.1723
HUF/USD	297	-0.1177	4.0473	-19.8664	-2.1684	0.2774	2.3218	10.2808	-0.8887	3.3555
IDR/USD	297	-0.2552	3.0955	-14.9443	-1.5461	-0.1171	1.0056	16.2207	-0.0010	6.2241
INR/USD	297	-0.2222	1.9999	-8.6013	-0.9804	-0.0417	0.6350	8.1357	-0.2795	3.0959
MXN/USD	297	-0.2480	3.3239	-22.2474	-1.9047	0.1348	1.4630	10.9213	-1.3553	8.3250
MYR/USD	297	-0.0459	1.8933	-7.8224	-0.7025	0.0000	1.0000	7.2664	-0.3629	3.1879
PEN/USD	297	-0.0262	1.5330	-5.1788	-0.9492	0.0176	0.6525	5.4482	0.1613	1.5270
PHP/USD	297	-0.1091	1.7287	-10.0701	-1.1023	-0.0270	0.8386	5.3303	-0.6715	3.3920
PLN/USD	297	0.0333	3.8385	-16.7602	-2.3386	0.0331	2.5186	10.8660	-0.6937	2.2689
RON/USD	297	-0.3103	2.9998	-16.0748	-1.9839	-0.1825	1.2243	10.5595	-0.4029	3.3207
RUB/USD	297	-0.4085	5.0371	-34.4827	-1.6468	-0.0904	1.5477	23.5715	-1.1827	10.9536
THB/USD	297	0.0433	2.0396	-7.8263	-1.1200	0.1463	1.1293	8.1368	-0.0354	1.3147
TRY/USD	297	-1.4075	5.4437	-40.6302	-3.3950	-0.9179	1.2873	11.1172	-2.5890	14.5575
ZAR/USD	297	-0.3583	4.7172	-19.5795	-3.2471	-0.1340	2.6689	11.4878	-0.5024	1.3229
Emerging	297	-0.3143	2.1214	-9.8165	-1.6176	-0.1295	1.0008	5.0633	-0.7804	2.4583

Description: This table presents a summary of monthly log return statistics for foreign exchange (FX) rates against the US Dollar (local currency). The data spans from January 2000 to September 2024, covering 297 observations for each currency pair. The table includes: the count, the mean, the standard deviation (std), the minimum and maximum monthly returns observed during the period, and the percentiles (25%, 50%, and 75%) that show the distribution of monthly returns across quartiles. Additionally, the table reports skewness, which reflects the asymmetry of the return distribution, and kurtosis is also included.

Table 3: Climate Transition Risk Quintile Portfolio Under UEP (Developed)

UEP	Climate Transition Risk		
Quintile	UEP	ΔStock	FX
1			
retx	0.18	-0.52	0.69
sigma	5.76	6.06	3.16
SR	0.03	-0.08	0.22
2			
retx	-3.67	-4.04	0.37
sigma	7.39	7.79	2.98
SR	-0.50	-0.52	0.12
3			
retx	0.15	-0.19	0.35
sigma	7.27	7.42	2.71
SR	0.02	-0.03	0.13
4			
retx	0.90	0.22	0.68
sigma	7.44	7.84	2.80
SR	0.12	0.03	0.24
5			
retx	-1.40	-1.52	0.12
sigma	6.35	7.10	2.54
SR	-0.22	-0.21	0.05
5-1	-1.58	-1.01	-0.57
NW t-stats	-1.08	-1.37	-0.06

Description: This table reports the performance of quintile portfolios for developed market group sorted by Climate Transition Risk index (CTR) under Uncovered Equity Parity (UEP) from January 2000 to September 2024. The lowest CTR countries are grouped into Quintile 1, while the highest are in Quintile 5, where 5-1 means the excess returns for the long-short strategy. The table shows excess returns (*retx*), standard deviation (*sigma*), and Sharpe ratio (*SR*) for each quintile. Statistical significance is shown by using Newey-West t- statistics (NW t-stats).

Table 4: Climate Transition Risk Quintile Portfolio Under UEP (Emerging)

UEP	Climate Transition Risk		
Quintile	UEP	ΔStock	FX
1			
retx	3.12	3.66	-0.54
sigma	7.31	7.59	4.10
SR	0.43	0.48	-0.13
2			
retx	3.52	4.27	-0.75
sigma	7.74	8.00	3.18
SR	0.45	0.53	-0.23
3			
retx	2.38	4.43	-2.05
sigma	7.35	7.27	3.57
SR	0.32	0.61	-0.58
4			
retx	2.57	3.39	-0.82
sigma	8.12	8.34	2.18
SR	0.32	0.41	-0.38
5			
retx	4.65	7.38	-2.73
sigma	6.33	6.55	2.08
SR	0.73	1.13	-1.31
5-1	1.53	3.72	-2.19
NW t-stats	2.47	1.97	-1.88

Description: This table reports the performance of quintile portfolios for emerging market group sorted by Climate Transition Risk index (CTR) under Uncovered Equity Parity (UEP) from January 2000 to September 2024. The lowest CTR countries are grouped into Quintile 1, while the highest are in Quintile 5. The table shows excess returns (*retx*), standard deviation (*sigma*), and Sharpe ratio (*SR*) for each quintile. Statistical significance is shown by using Newey-West t- statistics (NW t-stats).

Table 5: GMM for Emerging Markets

	Risk premia								
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CTR	2.0568	1.8779	1.8662	2.1041	1.9377	1.7363	2.0013	1.9564	0.5730
	(3.54)	(3.48)	(1.64)	(3.88)	(5.11)	(3.33)	(2.64)	(2.59)	(2.81)
DOLLAR	0.5874								1.2691
	(3.45)								(0.69)
Mkt-RF		0.8746							-0.5260
		(3.16)							(-0.15)
SMB			0.4363						2.0403
			(0.31)						(1.47)
HML				1.1037					0.1342
				(2.33)					(-0.06)
MOM					-1.1356				-5.1318
					(-1.09)				(-0.32)
Vol_t^{ST}						-0.8489			-0.7102
						(-1.55)			(-0.22)
Vol_t^{FX}							-0.5969		-0.2490
							(-1.23)		(-0.17)
Adj R^2	0.3286	0.3347	0.0782	0.0808	0.0918	0.1706	0.0897	0.0642	0.4063
J-value	5.4014	170.5941	32.8572	10.1659	16.8435	62.0579	25.6138	9.5164	12.9842
P-value	0.14	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.16

Description: This table presents the results of Generalized Method of Moments (GMM) for excess foreign equity returns of emerging market group for all sample period, with the control variables including climate transition risk (CTR), momentum (MOM), market risk (Mkt-RF), the US dollar (DOLLAR) and so on. The regression coefficients, Newey-West t-statistics, J-statistics, P-value and $Adj\ R^2$ are provided for each regression model. Each column, from 1 to 9, represents one regression model.

Table 6: GMM for Developed Markets

	Risk premia								
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CTR	0.3308	0.3172	-0.2669	-0.3472	-0.1746	0.4473	0.1250	-0.2375	1.3927
	(0.38)	(0.34)	(-0.43)	(-0.58)	(-0.28)	(0.42)	(0.15)	(-0.34)	(0.90)
DOLLAR	0.3394								0.1784
	(1.31)								(2.41)
Mkt-RF		0.4436							0.0439
		(1.27)							(0.03)
SMB			0.4397						0.3275
			(0.95)						(0.45)
HML				0.2453					-0.3550
				(0.32)					(-0.36)
MOM					-0.3240				2.4993
					(-0.48)				(1.02)
Vol_t^{ST}						-0.2936			-0.6013
						(-1.02)			(-1.03)
Vol_t^{FX}							-0.1094		-0.1201
							(-0.73)		(-0.42)
Adj R^2	-0.0847	-0.0318	-0.0815	-0.0947	-0.0886	-0.0385	-0.0637	-0.0914	-0.0138
J-value	14.7494	64.7196	29.4906	16.8313	19.4708	25.4999	18.2671	14.2436	50.9861
P-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Description: This table presents the results of Generalized Method of Moments (GMM) regression estimates for excess foreign equity returns of developed market group for all sample period with additional control variables. The regression coefficients, Newey-West t-statistics, J-statistics, P-value and $Adj\ R^2$ are provided for each regression model.

Table 7: Climate Transition Risk Quintile Portfolio Under UEP for Developed Markets

UEP	Before COP21			Post COP21		
Quintile	UEP	ΔStock	FX	UEP	ΔStock	FX
1						
retx	3.01	1.83	1.18	-5.42	-4.95	-0.47
sigma	5.97	3.34	3.34	9.00	6.01	2.80
SR	0.51	0.55	0.35	-0.60	-0.82	-0.17
2						
retx	-1.49	-2.88	1.39	-6.57	-6.27	-0.30
sigma	7.72	3.30	3.30	8.94	7.34	2.30
SR	-0.19	-0.87	0.42	-0.74	-0.85	-0.13
3						
retx	3.81	3.11	0.70	-4.99	-5.25	0.26
sigma	7.27	2.98	2.98	8.39	7.57	2.14
SR	0.52	1.05	0.23	-0.59	-0.69	0.12
4						
retx	3.09	1.52	1.57	-9.22	-8.16	-1.06
sigma	7.28	3.17	3.17	8.51	8.14	1.93
SR	0.42	0.48	0.50	-1.08	-1.00	-0.55
5						
retx	3.09	1.52	1.57	-9.22	-8.16	-1.06
sigma	6.23	2.65	2.65	7.72	7.53	2.31
SR	0.50	0.57	0.59	-1.19	-1.08	-0.46
5-1	0.08	-0.31	0.39	-3.80	-3.21	-0.59
NW t-stats	0.44	-0.09	0.09	-1.32	-1.19	-0.06

Description: This table reports the performance of quintile portfolios for developed market group sorted by Climate Transition Risk index (CTR) under Uncovered Equity Parity (UEP) for pre- and post- the Paris COP21 agreement. The lowest CTR currencies are grouped into Quintile 1, while the highest are in Quintile 5. The table shows excess returns (retx), standard deviation (sigma), and Sharpe ratio (SR) for each quintile. Statistical significance is presented by Newey-West t-statistics (NW t-stats).

Table 8: Climate Transition Risk Quintile Portfolio Under UEP for Emerging Markets

UEP	Before COP21			Post COP21		
Quintile	UEP	ΔStock	FX	UEP	ΔStock	FX
1						
retx	7.06	7.94	-0.88	-4.76	-4.42	-0.34
sigma	23.52	7.70	1.07	7.02	7.37	0.98
SR	0.30	1.03	-0.82	-0.68	-0.60	-0.34
2						
retx	7.88	8.28	-0.40	-4.80	-4.31	-0.49
sigma	24.75	8.01	1.10	7.57	7.96	1.07
SR	0.32	1.03	-0.36	-0.63	-0.54	-0.46
3						
retx	2.35	4.42	-2.07	-1.05	-4.24	3.18
sigma	25.38	7.91	1.96	5.91	5.90	1.39
SR	0.09	0.56	-1.05	-0.18	-0.72	2.30
4						
retx	7.55	8.92	-1.36	-6.62	-5.91	-0.71
sigma	29.28	9.48	1.67	5.31	5.56	1.44
SR	0.26	0.94	-0.82	-1.25	-1.06	-0.49
5						
retx	7.79	8.75	-0.96	-0.80	5.66	-6.46
sigma	19.68	6.32	2.03	6.54	7.00	2.06
SR	0.40	1.38	-0.47	-0.12	0.81	-3.14
5-1	0.73	0.80	-0.07	3.96	10.08	-6.12
NW t-stats	0.16	0.31	-0.37	3.35	2.68	-2.82

Description: This table reports the performance of quintile portfolios for emerging market group sorted by climate Transition Risk index (CTR) under Uncovered Equity Parity (UEP) for pre- and post- the Paris COP21 agreement. The lowest CTR currencies are grouped into Quintile 1, while the highest are in Quintile 5. The table shows excess returns (retx), standard deviation (sigma), and Sharpe ratio (SR) for each quintile. Statistical significance is presented by Newey-West t-statistics (NW t-stats).

Table 9: GMM for Emerging Markets Before Paris COP21

	Risk premia								
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CTR	0.0685	-0.0482	0.0370	0.2329	0.0319	0.0799	0.6150	0.0483	0.3119
	(0.17)	(-0.12)	(0.09)	(0.39)	(0.09)	(2.16)	(3.10)	(1.12)	(1.56)
DOLLAR	0.0118								0.3173
	(0.05)								(0.66)
Mkt-RF		-0.4744							0.6107
		(-0.81)							(0.55)
SMB			0.8100						1.0746
			(1.81)						(1.85)
HML				0.1840					0.3415
				(0.71)					(-0.84)
MOM					0.9684				0.3829
					(1.49)				(-0.49)
Vol_t^{ST}						-0.7836			-1.4246
						(-1.18)			(-2.34)
Vol_t^{FX}							-0.5328		-0.3681
							(-1.76)		(-1.35)
Adj R^2	-0.5688	-0.0618	-0.6426	-0.1837	-0.7651	-0.1757	-0.1902	-0.8554	-0.0304
J-value	6.0764	37.4991	15.1592	8.0574	6.0064	6.4568	11.2193	10.0097	29.195
P-value	0.11	0.00	0.00	0.04	0.11	0.09	0.01	0.01	0.00

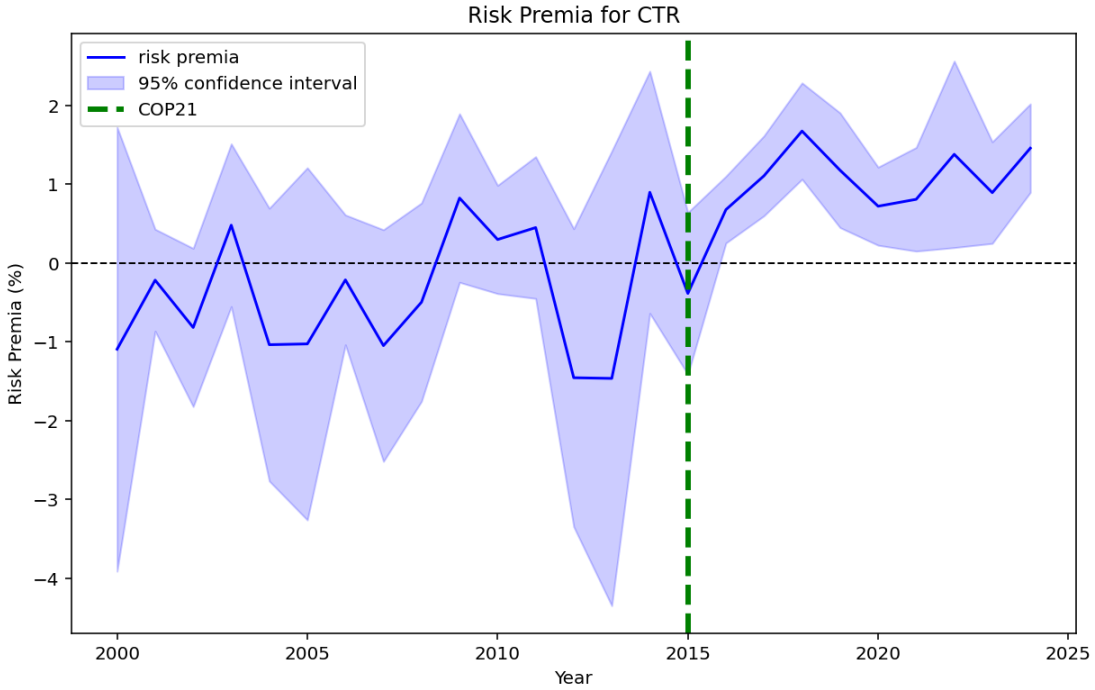
Description: This table presents the results of Generalized Method of Moments (GMM) estimates for excess foreign equity returns of emerging market group before COP21. The regression coefficients, Newey-West t-statistics, J-statistics, P-value and $Adj\ R^2$ are provided for each regression model.

Table 10: GMM for Emerging Markets After Paris COP21

Panel B. Risk premia									
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CTR	2.3940	2.1762	2.3113	2.3866	1.8441	2.0202	2.3270	2.3131	0.8602
	(3.19)	(5.13)	(2.80)	(3.33)	(3.05)	(3.41)	(3.43)	(3.79)	(3.49)
DOLLAR	0.4795								1.3908
	(1.11)								(0.78)
Mkt-RF		1.1961							2.0376
		(4.24)							(0.85)
SMB			-0.1070						-1.0114
			(-0.04)						(-0.51)
HML				0.6900					-2.7541
				(0.80)					(-1.75)
MOM					-2.0182				-5.0487
					(-1.22)				(-0.90)
Vol_t^{ST}						-0.9533			-2.1707
						(-1.48)			(-2.66)
Vol_t^{FX}							0.0689		-0.8220
							(0.07)		(-2.48)
Adj R^2	0.2280	0.2130	0.2381	0.2311	0.2301	0.2125	0.2323	0.2344	0.2109
J-value	7.5358	11.7921	6.7052	7.0947	13.5186	8.5205	9.9986	6.6071	11.4535
P-value	0.16	0.01	0.08	0.07	0.00	0.04	0.02	0.04	0.25

Description: This table presents the results of Generalized Method of Moments (GMM) estimates for excess foreign equity returns of emerging market group after COP21. The regression coefficients, Newey-West t-statistics, J-statistics, P-value and $Adj\ R^2$ are provided for each regression model.

Figure 4: Rolling Window Estimation of R_t^{CTR}



Description: This plot repeats the estimations of Equation (6) with every 12 months for the whole sample periods of EMs. The risk premia for CTR, R_t^{CTR}, and confidence interval at 95% are reported, and the green dashed line represents the event of COP21, which separates the sample and provides the trends of how R_t^{CTR} develop overtime

Table 11: Stock Differentials and FX Returns

Variable	EMs			DMs		
	(1)	(2)	(3)	(4)	(5)	(6)
ΔS	-0.0112	0.2109	0.2081	0.0155	0.0193	0.0220
	(-0.59)	(2.78)	(2.68)	(1.14)	(0.45)	(0.59)
CTR		0.3431	0.3106		0.0820	-0.0108
		(0.53)	(0.50)		(0.79)	(0.08)
$\Delta S * CTR$		-0.0589	-0.0502		-0.0011	-0.0029
		(-2.97)	(-2.41)		(-0.08)	(-0.19)
$CTR * COP21$			-0.2053			0.0481
			(-0.56)			(1.41)
$\Delta S * CTR * COP21$			-0.0244			0.0041
			(-3.60)			(0.70)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
N	4572	4570	4467	3560	3558	3555
$Adj\ R^2$	-0.0692	-0.0649	-0.0583	-0.0869	-0.0874	-0.0876

Description: The table reports the relationship between stock differentials (ΔS_{it}) and FX returns for both EMs (Column 1 to Column 3) and DMs (Column 4 to Column 6). The analysis employs a Fixed-Effects model, represented as follows: $\mathrm{FX_{it}} = \beta_1 \Delta S_{it} + \beta_2 CTR_{it} + \beta_3 \Delta S_{it} + \beta_4 \Delta S_{it} * CTR_{it} + \beta_5 CTR * COP21 + \beta_5 \Delta S_{it} * CTR_{it} * COP21 + \alpha_i + \alpha_t + \epsilon_{it}$, where i and t represent country and time. ΔS_{it} and FX_{it} are instantaneous returns, and CTR_{it} is the value of climate transition risk index. The variable $COP21$ is a dummy that equals 1 for periods after December 2015 and 0 otherwise. The model incorporates country-fixed effects (α_i), time-fixed effects (α_t), and an error term (ϵ_{it}). The table presents estimates for β coefficients along with their t-statistics (in parentheses). Additionally, the table includes the number of observations (N) and the adjusted R^2.

Table 12: Carbon Emission Intensity Long-Short Strategy

Long-Short Strategy	Emerging Market						Developed Market					
	Before COP21			Post COP21			Before COP21			Post COP21		
	UEP	Stock	FX	UEP	Stock	FX	UEP	Stock	FX	UEP	Stock	FX
5-1	-2.11	-2.11	0.00	1.84	4.51	-2.66	-0.79	-0.05	-0.74	-2.70	-2.17	-0.53
NW t-stats	-0.51	-0.54	0.00	2.28	1.88	-1.98	-0.32	-0.02	-0.44	-0.68	-0.58	-0.35

Description: This tables report the long-short (5-1) strategy returns for climate transition risk using the carbon emission intensity data, and the Newey-West t-statistic is also included. Results for both emerging market and developed markets are presented, and to further show the robustness over the effect from COP21 agreement, the sample period again is divided into the pre- and post-COP21.

Table 13: Alternative Number of UEP Portfolios

Long-Short Strategy	Emerging Markets						Developed Markets					
	Before COP21			Post COP21			Before COP21			Post COP21		
	UEP	Stock	FX	UEP	Stock	FX	UEP	Stock	FX	UEP	Stock	FX
3-1	0.34	1.58	-1.24	3.38	7.60	-4.23	1.29	1.27	0.02	-1.53	-1.52	0.00
NW t-stats	1.24	0.79	-1.27	2.40	1.84	-2.57	0.30	0.45	0.04	-0.67	-0.78	0.01
4-1	0.27	1.79	-1.52	4.23	8.21	-3.98	1.24	1.25	-0.01	-3.49	-2.27	-1.22
NW t-stats	0.43	0.20	-0.52	3.41	2.75	-2.88	0.10	0.12	-0.03	-0.88	-1.28	-0.31
6-1	1.49	2.93	-1.44	5.12	8.96	-3.84	-0.49	0.44	-0.93	-2.31	-2.62	-0.31
NW t-stats	0.11	0.14	-0.38	2.27	2.19	-1.89	-0.40	0.41	-0.16	-1.23	-1.95	-0.92

Description: This tables report the long-short strategy returns for climate transition risk portfolios with 3, 4, 6 number of portfolios, and the Newey-West t-statistic is also included. Results for both emerging market and developed markets are presented, and the sample period again is divided into the pre- and post-COP21.

Table 14: Long-Short Strategies Under MSCI Stock Index

Long-Short Strategy	Emerging Market						Developed Market					
	Before COP21			Post COP21			Before COP21			Post COP21		
	UEP	Stock	FX	UEP	Stock	FX	UEP	Stock	FX	UEP	Stock	FX
5-1	0.53	0.19	0.34	3.46	8.72	-5.26	0.08	-0.79	0.87	-4.30	-3.88	-0.42
NW t-stats	0.32	0.31	0.05	3.08	2.68	-3.57	0.03	-0.37	0.09	-0.56	-1.59	-0.06

Description: This tables report the long-short (5-1) strategy returns for climate transition risk quintile portfolios by using MSCI country stock index, and the Newey-West t-statistic is also included. Results for both emerging market and developed markets are presented, and to further show the robustness over the effect from COP21 agreement, the sample period again is divided into the pre- and post-COP21.

Table 15: GMM for Emerging Markets After Paris COP21 (MSCI)

	Risk Premia											
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
CTR	1.3946	1.3052	1.3198	0.9863	1.1615	1.2269	1.1653	1.2233	1.0308	1.2886	1.2706	0.4166
	(2.51)	(2.50)	(2.80)	(1.89)	(1.99)	(2.89)	(2.50)	(2.57)	(2.13)	(3.61)	(2.98)	(2.63)
DOLLAR	0.1408											-0.8533
	(0.43)											(-2.70)
CARRY		-0.2694										-1.2471
		(-0.28)										(-0.46)
LT			-0.4499									-1.6092
			(-0.65)									(-0.65)
MOM^{FX}				-0.7234								-1.6560
				(-0.71)								(-0.62)
Mkt-RF					1.0684							-5.4272
					(1.12)							(-1.24)
SMB						0.6327						1.1722
						(1.10)						(0.54)
HML							0.2182					3.2039
							(0.34)					(0.84)
MOM^{ST}								-0.1062				-0.8809
								(-0.16)				(-0.26)
Vol_t^{ST}									-1.2127			-2.0528
									(-1.82)			(-1.91)
Vol_t^{FX}										0.1125		0.1669
										(0.28)		(0.14)
Adj R^2	-0.0500	-0.1665	-0.2020	-0.2032	-0.0018	-0.2061	-0.1152	-0.2550	-0.1697	-0.2510	-0.2480	0.1005
J-value	6.0531	7.5948	5.6071	21.9053	9.003	5.188	24.4544	5.3928	27.2454	6.6348	4.9044	17.0498
P-value	0.11	0.06	0.13	0.00	0.03	0.16	0.00	0.15	0.00	0.08	0.09	0.15

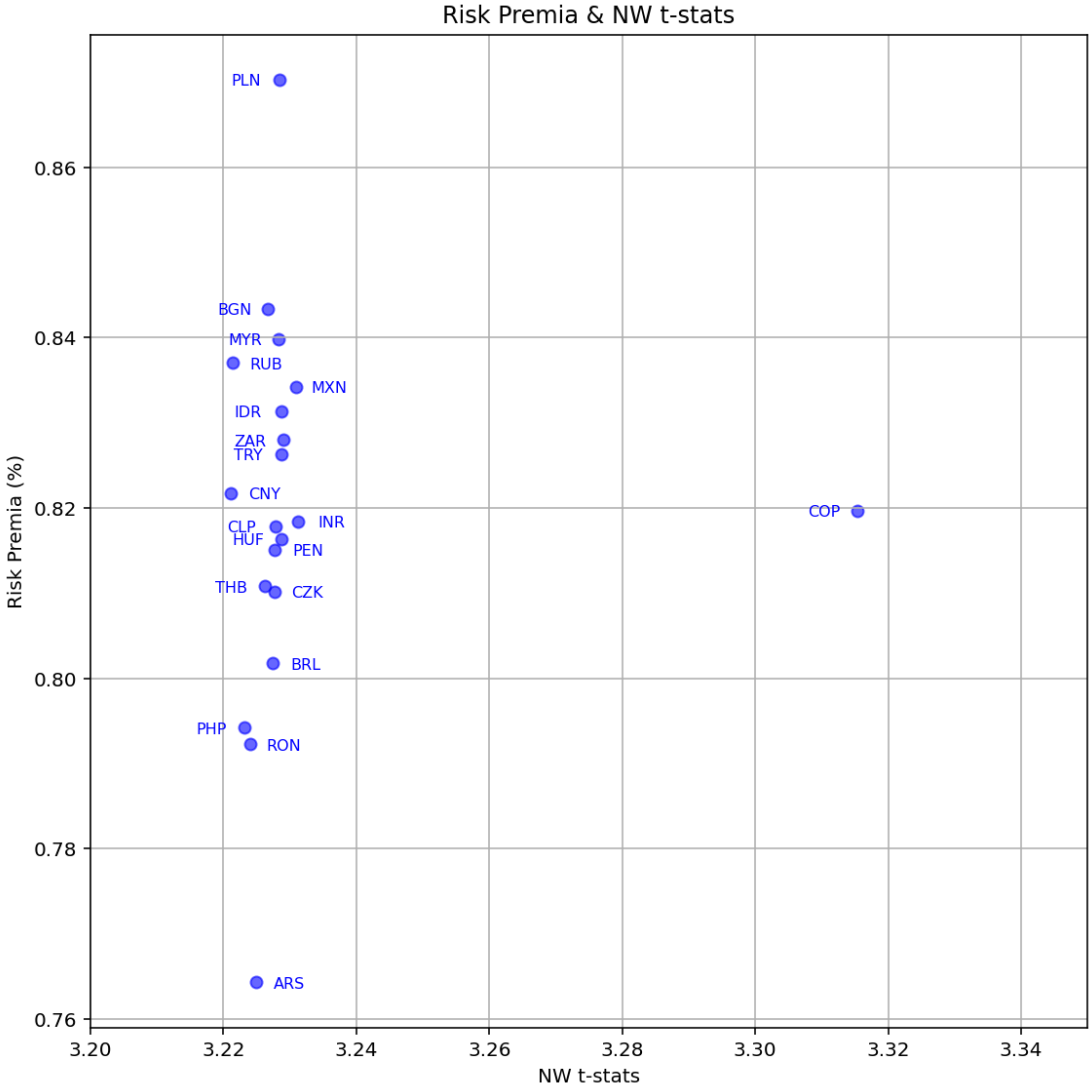
Description: This table presents the results of Generalized Method of Moments (GMM) estimates for excess foreign equity returns via MSCI stock index of emerging market group after COP21. The regression coefficients, Newey-West t-statistics, J-statistics, P-value and Adj R^2 are provided for each regression model.

Table 16: Rebalancing Frequency

Long-Short Strategy	Emerging Markets						Developed Markets					
	Before COP21			Post COP21			Before COP21			Post COP21		
	UEP	Stock	FX	UEP	Stock	FX	UEP	Stock	FX	UEP	Stock	FX
3M	-0.17	0.13	-0.29	4.99	8.05	-3.06	-0.66	-0.62	-0.04	-1.13	-1.15	0.02
NW t-stats	0.05	0.04	-0.57	2.53	3.14	-2.82	-0.36	-0.32	-0.09	-1.12	-0.98	0.04
6M	-0.29	-0.14	-0.15	4.92	7.69	-2.76	-0.52	-0.50	-0.02	-1.28	-1.29	0.01
NW t-stats	-0.11	-0.05	-0.37	3.71	3.88	-1.85	-0.32	-0.30	-0.09	-1.06	-1.36	0.06
12M	0.04	0.11	-0.07	5.22	7.74	-2.53	-0.34	-0.33	-0.01	-0.73	-0.74	0.01
NW t-stats	0.02	0.06	-0.33	1.49	5.50	-1.46	-0.24	-0.24	-0.09	-1.11	-1.14	0.06

Description: This tables report the long-short strategy returns for different rebalancing frequencies (3-month, 6-month and 12-month), and the Newey-West t-statistic is also included. Results for both emerging market and developed markets are presented, and the sample period again is divided into the pre- and post-COP21.

Figure 5: R_t^{CTR} with One-by-One Dropping



Description: This plot shows the risk premia for climate transition risks and the NW t-stats with one-by-one dropping of the sample countries, for EMs after COP21. Each estimation contains 19 countries with only one dropped country from the original sample. For example, ARS means that Argentina is being omitted for the estimation. The estimation is conducted via Equation (6).

Table 17: FMB for Emerging Markets

	Risk premia								
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CTR	0.5936	1.9562	0.0567	0.4024	1.6217	0.8867	3.7352	1.0429	0.3161
	(2.07)	(4.36)	(1.95)	(5.38)	(5.04)	(2.21)	(2.81)	(1.96)	(2.24)
DOLLAR	2.3838								0.3524
	(2.75)								(1.05)
Mkt-RF		0.5646							-2.0693
		(4.59)							(-0.31)
SMB			-0.2081						2.4208
			(-0.70)						(1.95)
HML				0.1904					-0.5894
				(1.96)					(-1.44)
MOM					-2.7216				-3.5110
					(-0.41)				(-0.22)
Vol_t^{ST}						-2.0428			-0.5104
						(-0.28)			(-0.04)
Vol_t^{FX}							-0.7975		-1.3023
							(-1.82)		(-0.13)
Adj R^2	0.0187	0.0016	0.0106	0.0169	0.0115	0.0135	0.0022	0.0201	0.0075

Description: This table presents the results of Fama-MacBeth (FMB) for excess foreign equity returns of emerging market group for all sample period, assessed against various factors, including climate transition risk (CTR), momentum (MOM), market risk (Mkt-RF), and the effect of the US dollar (DOLLAR) etc. The regression coefficients, Newey-West t-statistics and $Adj\ R^2$ are provided for each regression model. Each column represents one regression model.

Table 18: FMB for Developed Markets

	Risk premia								
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CTR	0.3308	0.3172	-0.2669	-0.3472	-0.1746	0.4473	0.1250	-0.2375	-0.3927
	(0.38)	(0.34)	(-0.43)	(-0.58)	(-0.28)	(0.42)	(0.15)	(-0.34)	(-0.90)
DOLLAR	0.3394								0.1784
	(1.31)								(2.41)
Mkt-RF		0.4436							0.0439
		(1.27)							(0.03)
SMB			0.4397						0.3275
			(0.95)						(0.45)
HML				0.2453					-0.3550
				(0.32)					(-0.36)
MOM					-0.3240				2.4993
					(-0.48)				(1.02)
Vol_t^{ST}						-0.2936			-0.6013
						(-1.02)			(-1.03)
Vol_t^{FX}							-0.1094		-0.1201
							(-0.73)		(-0.42)
Adj R^2	-0.0847	-0.0318	-0.0815	-0.0947	-0.0886	-0.0385	-0.0637	-0.0914	-0.0138

Description: This table presents the results of Fama-MacBeth (FMB) regression estimates for excess foreign equity returns of developed market group for all sample period, assessed against various factors, including climate transition risk (CTR), momentum (MOM), market risk (Mkt-RF), and the effect of the US dollar (DOLLAR) etc. The regression coefficients, Newey-West t-statistics and Adj R^2 are provided for each regression model. Each column represents one regression model.

Table 19: FMB for Emerging Markets Before Paris COP21

	Risk Premia								
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CTR	1.2371	-1.3857	1.5712	1.8161	-1.0438	0.5814	0.1347	0.9832	1.5105
	(-0.32)	(-0.69)	(0.58)	(0.90)	(-0.64)	(2.96)	(2.70)	(0.44)	(1.18)
DOLLAR	1.8352								2.1346
	(1.34)								(2.08)
Mkt-RF		-1.6085							-0.2206
		(-0.90)							(-0.07)
SMB			1.0147						3.0195
			(1.95)						(0.53)
HML				1.9044					1.5665
				(0.30)					(0.96)
MOM					1.1717				1.4406
					(1.34)				(0.21)
Vol_t^{ST}						-2.0543			-3.3832
						(-0.54)			(-2.21)
Vol_t^{FX}							-1.3897		-1.5202
							(-1.43)		(-0.83)
Adj R^2	-0.0059	-0.0201	-0.0117	-0.0119	-0.0142	-0.0121	-0.0168	-0.0028	-0.0137

Description: This table presents the results of Fama-MacBeth (FMB) estimates for excess foreign equity returns of emerging market group before COP21, assessed against various factors, including climate transition risk (CTR), momentum (MOM), market risk (Mkt-RF), and the effect of the US dollar (DOLLAR) etc. The regression coefficients, Newey-West t-statistics, J-statistics, P-value, and Adj R^2 are provided for each regression model. Each column represents one regression model.

Table 20: FMB for Emerging Markets After Paris COP21

	Risk premia								
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CTR	0.8608	2.0189	4.017	2.5870	2.3289	3.1656	1.2727	0.5394	0.4789
	(4.52)	(4.18)	(1.96)	(2.77)	(3.84)	(3.52)	(3.83)	(3.67)	(2.24)
DOLLAR	1.9407								3.0015
	(1.81)								(0.04)
Mkt-RF		2.6524							-0.2572
		(4.25)							(-0.27)
SMB			-1.4757						-2.3821
			(-1.20)						(0.21)
HML				-1.9361					-3.5681
				(-0.27)					(-1.95)
MOM					-1.6978				-3.3479
					(-0.25)				(-1.63)
Vol_t^{ST}						-2.7541			-0.2085
						(-1.35)			(-3.64)
Vol_t^{FX}							1.4311		-1.6991
							(0.33)		(-2.49)
Adj R^2	0.0061	0.0154	0.0150	0.0071	0.0091	0.0201	0.0179	0.0206	0.0046

Description: This table presents the results of Fama-MacBeth (FMB) estimates for excess foreign equity returns of emerging market group after COP21, assessed against various factors, including climate transition risk (CTR), momentum (MOM), market risk (Mkt-RF), and the effect of the US dollar (DOLLAR) etc. The regression coefficients, Newey-West t-statistics, J-statistics, P-value and Adj R^2 are provided for each regression model. Each column represents one regression model.

Table 21: Climate Physical Risk

Long-Short Strategy	Emerging Market						Developed Market					
	Before COP21			Post COP21			Before COP21			Post COP21		
	UEP	Stock	FX	UEP	Stock	FX	UEP	Stock	FX	UEP	Stock	FX
P5-P1	-1.45	-2.10	0.65	-1.19	-1.22	0.03	-1.91	-1.24	-0.67	2.38	1.81	0.57
NW t-stats	-0.33	-0.49	0.55	-0.28	-0.29	0.03	-0.83	-0.57	-0.64	0.69	0.63	0.40

Description: This tables report the long-short (5-1) strategy returns for climate transition risk quintile portfolios by MSCI country stock index, and the Newey-West t-statistic is also included. Results for both emerging market and developed markets are presented, and to further show the robustness over the effect from COP21 agreement, the sample period again is divided into the pre- and post-COP21.

Table 22: Lags of Climate Transition Risk Index

Long-Short Strategy	Emerging Markets						Developed Markets					
	Before COP21			Post COP21			Before COP21			Post COP21		
	UEP	Stock	FX	UEP	Stock	FX	UEP	Stock	FX	UEP	Stock	FX
3M	2.40	2.96	-0.56	2.98	8.46	-5.48	-0.94	-0.81	-0.13	-3.09	-3.07	-0.02
NW t-stats	0.55	0.67	-0.37	2.33	2.61	-2.74	-0.44	-0.37	-0.09	-1.24	-1.44	0.00
6M	-0.86	-0.77	-0.09	2.01	7.35	-5.33	-0.71	-0.56	-0.15	-1.32	-1.77	0.46
NW t-stats	-0.23	-0.22	-0.06	1.55	2.73	-1.61	-0.33	-0.26	-0.10	-0.58	-0.93	0.43
12M	-1.68	-2.15	0.77	1.13	6.25	-5.12	-1.07	-0.76	-0.31	-0.16	-0.65	0.50
NW t-stats	-0.44	-0.60	0.32	1.60	1.65	-1.59	-0.49	-0.34	-0.20	-0.06	-0.32	0.43

Description: This tables report the long-short strategy returns for the lags of climate transition risk index (3-month, 6-month and 12-month), and the Newey-West t-statistic is also included. Results for both emerging market and developed markets are presented, and to further show the robustness over the effect from COP21 agreement, the sample period again is divided into the pre- and post-COP21.

Appendix.

Figure A1: Relationship between climate transition risk and foreign exchange return



Description: This figure shows the transmission mechanism of the impact of climate transition risks to foreign exchange returns via the stock market valuation.

Table A2: Country Climate Transition Index

Country	Climate Transition Risk Index
Australia	AUSOVABAR
Austria	OESOVABAR
Canada	CNSOVABAR
Denmark	DKSOVABAR
Finland	FNSOVABAR
France	FRSOVABAR
Germany	BDSOVABAR
Hongkong	HKSOVABAR
Japan	JPSOVABAR
Norway	NWSOVABAR
Singapore	SPSOVABAR
South Korea	KOSOVABAR
Sweden	SDSOVABAR
Switzerland	SWSOVABAR
United Kingdom	UKSOVABAR
Argentina	AGSOVABAR
Brazil	BRSOVABAR
Bulgaria	BLSOVABAR
Chile	CLSOVABAR
China (Mainland)	CHSOVABAR
Columbia	CBSOVABAR
Czech Republic	CZSOVABAR
Hungary	HNSOVABAR
India	INSOVABAR
Indonesia	IDSOVABAR
Malaysia	MYSOVABAR
Mexico	MXSOVABAR
Peru	PESOVABAR
Philippines	PHSOVABAR
Poland	POSOVABAR
Russia	RSSOVABAR
Romania	RMSOVABAR
South Africa	SASOVABAR
Thailand	THSOVABAR
Turkey	TKSOVABAR

Description: This table presents in the first column the countries analysed in the empirical analysis. The second report DataStream code for Climate Transition risk index.

Table A3: Currency spot and 1-month forward rate

Currency	Spot	Forward
USDBGN	TDBGNSP	USBGN1F
USDTHB	TDTHBSP	USTHB1F
USDARS	TDARSSP	USARS1F
USDBRL	TDBRLSP	USBRL1F
USDCLP	TDCLPSP	USCLP1F
USDCOP	TDCOPSP	USCOP1F
USDCZK	TDCZKSP	USCZK1F
USDHUF	TDHUFSP	USHUF1F
USDINR	TDINRSP	USINR1F
USDIDR	TDIDRSP	USIDR1F
USDKRW	TDRUBSP	USKRW1F
USDMYR	TDMYRSP	MYUSN1M
USDMXN	TDMXNSP	USMXN1F
USDPEN	TDPENSP	USPEN1F
USDPLN	TDPLNSP	USPLN1F
USDPHP	TDPHPSP	USPHP1F
USDRON	TDRONSP	USRON1F
USDZAR	TDZARSP	USZAR1F
USDCNY	TDCNYSP	TDCNY1M
USDTRY	TDTRYSP	USTRY1F
USDAUD	AUSTDOI	BBAUD1F USAUD1F
USDATS	AUSTSC$	USATS1F
USDCAD	CNDOLL$	USCAD1F
USDFIM	FRENFR$	USFIM1F
USDFRF	FINMAR$	USFRF1F
USDDEM	DMARKE$	USDEM1F
USDHKD	HKDOLL$	USHKD1F
USDJPY	JAPAYE$	JE1MUSD
USDDKK	DANISH$	USDKK1F
USDNOK	NORKRO$	USNOK1F TDNOK1M
USDRUB	TDKRWSP	USRUB1F
USDSGD	SINGDO$	USSGD1F
USDSEK	SWEKRO$	TDSEK1M
USDCHF	SWISSF$	USCHF1F
USDGBP	UKDOLLR	UKUSD1F

Description: This table presents in the first column the currencies analysed in the empirical analysis. The second and third column report DataStream codes for spot and 1-month forward exchange rate. The codes provided for each currency can be used to obtain the data from DataStream. Originally, the spot and forward FX rates are expressed as the value of foreign currency per unit of USD. In our research, we further obtain the inverse all the FX rates for computational convenience.

Table A4: Country Stock Index Code

Country	Stock Index Code	MSCI Code
Argentina	ARGMERV	MSARGTL
Australia	ASX200I	MSAUSTL
Austria	ATXINDX	MSASTRL
Brazil	BRSHRPRCF	MSBRAZL
Bulgaria	BSSOFIX	MSBLGNL
Canada	TTOSP60	MSCNDAL
Chile	IGPAGEN	MSCHILL
China	CHSASHR	MSCHINL
Colombia	CBSHRPRCF	MSCOLML
Czech Republic	CZPXIDX	MSCZCHL
Denmark	COSEASH	MSDNMKL
Finland	HEXINDX	MSFIND
France	FRCAC40	MSFRNCL
Germany	DAXINDX	MSGERML
Hong Kong	HNGKNGI	MSHGKGL
Hungary	BUXINDX	MSHUNGL
India	ICRI500	MSINDIL
Indonesia	JAKCOMP	MSINDFL
Japan	JAPDOWA	MSJPANL
Malaysia	FBMKLCI	MSMALFL
Mexico	MXIPC35	MSMEXFL
Norway	NWSHRPRCF	MSNWAYL
Peru	PEGENRL	MSPERU$
Philippines	PSECOMP	MSPHLFL
Poland	POSHRPRCF	MSPLNDL
Russia	RS:MOC	-
Romania	RMBETRL	MSROMNL
Singapore	SNGPORI	MSSINGL
South Africa	JSEOVER	MSSARFL
South Korea	KORCOMP	MSKOREL
Sweden	SWEDOMX	MSSWDNL
Switzerland	SWISSMI	MSSWITL
Thailand	BNGKSET	MSTHAFL
Turkey	TRKIST	MSTURKL
United Kingdom	FTSE100	MSUTDKL

Description: This table presents in the first column the countries analysed in the empirical analysis. The second report DataStream code for stock index. Each of the Stock Index Code and MSCI Code can be used to download unique stock index via DataStream.

Table A5: Risk Factors in GMM and FMB

Risk Factor	
FX market	
DOLLAR	Calculation based on spot, forward exchange rate, and government 10Y bond from WM/Reuters accessed via DataStream.
CARRY	
LT	
MOM^{FX} (1 month)	
Vol^{FX}	Calculation based on the methodology at section 3.2
Stock market	
SMB	Obtained from Fama-French Data Library(Kenneth R. French - Data Library).
HML	
Mkt-RF	
MOM^{ST}	
Vol^{ST}	Calculation based on the methodology at section 3.2

Description: This table presents the risk factors used in GMM and FMB estimation, where contains two groups of risk factors that FX market and Stock market. FX market group are obtained based on the calculation of data from WM/Reuters, and Stock market Data are obtained directly from Fama-French Data Library.