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Climate Physical Risk and Asian Stock Market Returns

Abstract

This study provides new evidence on the impact of climate physical risk (as measured by the Global Climate Risk Index (CRI) from Germanwatch) on stock market returns. Specifically, a panel model with fixed effects is estimated using annual data from 2007 to 2021 for a set of 65 countries as well as for a subset of 18 Asian ones, which are also divided in two clusters on the basis of their degree of market capitalisation. The results suggest a negative impact of climate physical risk on stock markets; this effect is more pronounced in Asian countries with lower market capitalisation, which are perceived as riskier.

JEL-Codes: C330, G120, G180.

Keywords: climate change, physical risk, Global Climate Risk Index, stock markets, Asia, panel data, fixed effects.

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1. Introduction

Climate change is a global phenomenon which represents one of the foremost challenges of the 21st century. The Intergovernmental Panel on Climate Change (IPCC) reports that rising global temperatures increase the likelihood of exceeding critical climate thresholds. Once these tipping points have been reached, they can trigger self-reinforcing feedback loops that exacerbate global warming, such as permafrost thawing or widespread forest dieback.

Over the past decade, concern with the consequences of global warming has spawned a large literature examining the associated risks, typically arising from a combination of exposure and vulnerability, and their impact on the economy. The latter is particularly significant in regions lacking resilience, coping mechanisms, or adaptive capacities, which makes them more susceptible to extreme natural events or adverse climate change effects (World Risk Report, 2023).

Climate-related risks are often categorised into physical and transition risks. The former refer to the direct impact of extreme weather events, such as floods, typhoons, droughts, and heat waves, which threaten infrastructure, food security, and human health, and lead to financial losses or increased expenses from chronic and acute physical events (Bua et al., 2022). On the other hand, the latter emerge from the shift to a low-carbon economy, influenced by regulatory changes, technological advancements, and changes in social and market attitudes (Ardia et al., 2023).

Physical risk can be further divided into acute and chronic risks. The first category refers to sudden, episodic occurrences capable of causing substantial harm, such as wildfires, floods, and tropical storms. By contrast, the second category includes risks persisting over extended periods, such as sea level rises and increases in global mean temperature, which manifest themselves as ongoing processes rather than single events (Buhr et al., 2022). In fact extreme weather events are ranked by the World Economic Forum's Global Risks Report 2018 as the top global risk in terms of likelihood, and the second most significant in terms of impact, following weapons of mass destruction.

Climate risk affects all sectors of the economy, including the financial one. One of the earliest studies on its impact on financial markets is due to Worthington and Valadkhani (2004), who analysed the consequence of natural disasters for the Australian equity market by estimating an ARMA model for daily data from 31 December 1982 to 1 January 2002. They found that the impact varies depending on the type of natural disaster, with cyclones and bushfires having the most significant effects. Worthington (2008) used instead a GARCH model to obtain evidence for different regions and sectors, and found that the insurance sector is particularly affected as a result of claims from disaster-hit areas.

Subsequent research investigated the repercussions of climate change for other markets and economic variables. For instance, Lanfear et al. (2019) studied the impact of US hurricanes on stock returns from 1990 to 2017, and detected short-term sensitivity but long-term insensitivity. U-Din et al. (2022) reported a negative, widespread effect of weather catastrophes on stock market returns and volatility in Canada the day after their occurrence, the IT and financial services sectors being the most affected. Keerthiratne et al. (2017) examined the effects of natural disasters on private credit using data for a cluster of 147 countries, and found a significant positive impact which, however, decreases with higher income levels. Finally, Chang et al. (2020) showed that disaster-related deaths have a negative effect on foreign debt, debt service, exchange rate stability, current account, and international liquidity.

As pointed out by Arndt et al. (2020), climate change represents a significant challenge for policy makers, especially in the emerging economies, which are particularly vulnerable owing to the size of weather-sensitive sectors such as agriculture and food processing. The World Bank estimates that more than 100 million people living in International Development Association (IDA) countries will be pushed into extreme poverty as a result of climate change by 2030. The World Risk Index (2023) identifies geographical location as a factor contributing to the risk of being affected by natural disasters, but gas emissions due to human activity are an equally important factor requiring decisive policy actions. In the case of a region such as Asia, where the issue of climate change has only recently been addressed, a supranational policy framework is yet to be adopted, and thus common policies are still lacking (Lim et al., 2024, Aggarwal et al., 2023), and carbon emissions have been trending upwards and having widespread effects. The UN ESCAP (Economic and Social Commission for Asia and the Pacific) report (2018) concluded that variations in temperature and rainfall have negatively influenced the economic growth of the Asian countries.

Since the 2015 Paris Agreement, climate business activities in sectors such as renewable energy, green buildings, and energy efficiency have surged, driven by governmental commitments to combat global warming (IFC, 2017). Chien et al. (2022) showed that in the Asian countries renewable energy (RE) reduces greenhouse gas (GHG) emissions, while urbanisation poses significant environmental challenges. Amran et al. (2014) found that Asian companies are improving their climate change reporting system practices and disclosure, whilst Ozdemir (2022) reported that climate change is affecting agricultural productivity in Asia, where growing crops and raising livestock are becoming more challenging.

The latest Global Risks Report, issued in 2024, highlights the fact that climate change poses significant risks to Asia, since it affects various aspects of this region's environment, economy, and society. Asia is particularly vulnerable to extreme weather events, which can disrupt agricultural production, lead to food insecurity, and threaten coastal cities. Limited financial resources, insufficient technological capabilities, and inadequate policy frameworks pose substantial challenges for countries in the region to adapt effectively and build resilience. For instance, the collapse of coral reef systems, which protect coastlines from storm surges, could leave coastal communities highly vulnerable. Alano et al. (2016) showed that in Asia the economic and financial effects of extreme temperatures and severe weather events can substantially hinder the region's growth potential and exacerbate inequality.

Only a few studies have analysed the impact of climate change on the Asian stock markets. As pointed out by Oloko et al. (2022), these have adjusted over time to accommodate climate change-related investments; however, his results from the estimation of a GARCH-MIDAS model reveal that the long-term stock return volatility of about 40% of Asian stock markets is unaffected by climate change. Chowdhury (2023) used instead a fixed effect model to study the influence of weather on South-Asia stock market returns with yearly data from 1995 to 2021, and found that temperature and economic growth have a positive effect on stock prices, while interest rates affect them negatively. Beirne et al. (2021) showed that in Southeast Asia higher climate vulnerability significantly increases sovereign bond yields, while greater climate resilience reduces them. Global factors, such as US bond yields and financial market volatility (VIX), also appear to influence ASEAN bond yields.

The present study aims to contribute to this area of the literature by providing new, more extensive evidence on the effects of climate change on the Asian stock markets. For this purpose we use, for the first time in this context, the Global Climate Risk (CRI) Index (Huang et al., 2018, Cavlak et al., 2021, Samimi et al., 2011, Garschagen et al., 2021), provided by Germanwatch. It focuses on weather-related events such as storms, floods, temperature extremes, and mass movements. Geological events, such as earthquakes, are excluded as they are not directly related to climate change. The index score is based for each country on its average ranking in all four weather-related events, with specific weightings given to each class of events.

Our empirical analysis is conducted using an unbalanced panel. To highlight the possible differences between Asia and other regions of the world the model is first estimated using annual data for a wider set of 65 countries and then for a subgroup including only 18 Asian countries, in both cases over the period from 2007 to 2021. A robustness check is also carried out for Asia by creating two clusters of countries on the basis of their market capitalisation expressed in US dollars.

The layout of the paper is the following: Section 2 describes the data and the model; Section 3 discusses the empirical results; Section 4 offers some concluding remarks.

2. Data and Empirical Framework

We use annual data on value-weighted stock market indices obtained from Bloomberg. Stock returns are then calculated as the first difference of the logarithm of the stock price indices. The analysis is carried out for the full panel (65 countries) first and then for the Asian markets only (18 countries), over the period 2007-2021, for a total of 947 and 270 observations, respectively. The list of countries with their stock market indices is reported in Table 1. Both the selection of these series and the choice of the time span are driven by the availability of CRI data. We opted to drop countries with two or more CRI missing observations and to shorten the sample by one year in the case of countries with only one CRI missing observation. As a result our panel is unbalanced.

Please insert Table 1 about here

As a measure of climate change we use the Global Climate Risk (CRI) Index, which assesses the degree to which countries have experienced the repercussions of weather-induced loss events, including storms, floods, heatwaves, and more. The data source is Germanwatch (https://www.germanwatch.org/en/cri). This index can be broken down into four main categories: i) Number of deaths, which is the total count of fatalities resulting from weather-related events such as storms, floods, temperature extremes, and mass movements (heat and cold waves, etc.); ii) Number of deaths per 100,000 inhabitants, which is a measure used to standardize the death toll across different countries with varying population sizes; iii) Sum of losses in US$ in purchasing power parity (PPP), and finally iv) Losses per unit of Gross Domestic Product (GDP), which is a measure used to assess the economic impact of weather-related events relative to the size of a country's economy.

We also control for global stock market uncertainty by including in the model the Chicago Board Options Exchange volatility index (VIX), for which the data source is againBloomberg. Recent studies, such as Bouri et al. (2023), have highlighted the significance of VIX changes as a global factor affecting stock markets worldwide.

As stated before, the aim of the empirical analysis is to investigate the effects of climate risk on stock market returns. For this purpose, we estimate the following panel data model with fixed effects (and cross-section weights to correct for heteroscedasticity): [1]

$$x_{i,t} = \alpha_i + \beta_1 CRI_{i,t} + \beta_2 VIX_t + \varepsilon_{i,t} \tag{1}$$

where $x_{i,t}$, stands for stock market returns, α_i is the intercept, β_1 is the coefficient on the CRI, β_2 is the coefficient on the VIX_t, and $\varepsilon_{i,t}$ is the error term.

3. Empirical Results

Table 2 reports descriptive statistics and unit root tests for the variables used for the analysis. The average stock return is 7.60 for the full sample and 10.17 for Asia, whilst the corresponding mean CRI score are 62.25 and 55.66 respectively, which indicates that the Asian countries face lower climate risk compared to the full set of countries. This could reflect better adaptation measures, less exposure to severe climate events, or other regional characteristics that reduce climate risk. Note that a higher value of the CRI Index indicates lower climate risk, and thus a positive coefficient on this variable implies a negative effect of climate risk on stock market returns. Finally, the Levin–Lin–Chu (LLC), Levin et al. (2002), and Pesaran (2007) unit root test statistics suggest that all stock returns and CRI series are stationary or I(0) (integrated of order 1). In all cases the null hypothesis is that the series contains a unit root, and the alternative is that it is stationary.

[1] The null hypothesis of random effects was rejected by the Hausman test.

Table 3 shows the results for the full set of countries as well as the Asian subgroup. Note that a fixed effect (rather than a random one) specification has been estimated on the basis of the results of the Hausman test. Further, cross-sectional weights have been used to correct for potential cross-sectional dependence.

Please insert Tables 2 and 3 about here

The coefficient on CRI is positive and significant both for the full sample (0.09) and for the Asian subgroup (0.20); as noted before, a positive value implies a negative impact on stock returns, which is consistent with the findings of Le Tran et al. (2023), who highlight the increasing significance of physical climate risk for investors. In addition, the much larger size of this coefficient in the case of Asia confirms earlier evidence suggesting that this region is more affected by climate change (see Pagnottoni et al., 2022). Finally, the effect of the VIX is always negative and significant as expected.

As a robustness check, we create two clusters, each of them including 9 Asian stock markets, on the basis of their (High/Low) market capitalisation, expressed in US dollars (Tan et al., 2012). Table 4 reports descriptive statistics and unit root tests for these two groups of countries. It can be seen that both the mean and volatility of returns in markets with Low capitalisation are higher than those of markets with High capitalisation (11.31 as opposed to 9.01 for the former, and 32.11 compared to 29.76 for the latter). The CRI scores range from a minimum of 2.50 to a maximum of 126.17, with a mean value of 55.07 and a standard deviation of 31.53 for the Asian countries with High market capitalisation, the corresponding values for those with Low market capitalisation being slightly higher, more precisely 56.24 and 33.02, respectively. Again, all variables appear to be stationary, I(0), as implied by the Levin–Lin–Chu (LLC), Levin et al. (2002), and Pesaran (2007) test statistics. Figures 1a and 2a display the Asian stock market returns, whereas Figures 1b and 2b show the corresponding CRI scores. Visual inspection suggests that there are no significant differences between the two sets of countries in terms of the behaviour of either series.

Please insert Tables 4 and 5 and Figures from 1a to 2b about here

Table 5 reports the estimation results for the two clusters. The Hausman test again suggests that a fixed effect specification is appropriate (for both clusters). We find a larger and significant impact of the CRI on financial markets in the cluster labelled as Low (0.32) compared to the one named High (0.13). This is consistent with the generally held view that, since investment in large-cap stocks concerns well established companies, it poses less of a risk (though it has a lower growth potential) – our evidence suggests that indeed climate risk is also perceived differently depending on a company's stage in its business development. However, whether climate risk is sufficiently reflected in stock prices remains an open question, most financial experts believing that it is at least partially mispriced (see Bauer et al., 2024). Finally, the effect of the VIX is again negative and significant as expected.

Please insert Table 5 about here

4. Conclusions

This study investigates the impact of climate physical risk on stock market returns. Specifically, a panel model with fixed effects is estimated using annual data from 2007 to 2021 for a set of 65 countries and then also for a subset of 18 Asian ones, so as to identify possible distinguishing features of the latter. This focus is motivated by the fact that, as argued by Gaspar et al (2021), the Asia-Pacific region is pivotal in the global climate fight due to its large population, significant carbon emissions, and vulnerability to extreme weather. It also holds the world's biggest population, two of the top three carbon dioxide emitters, and is a leader in green technology. Further, it is increasingly integrating climate change-related investments into financial markets (Aggarwal et al., 2023). As a measure of climate risk we use, for the first time in this context, the Global Climate Risk Index (CRI) from Germanwatch, which includes extensive information concerning the impact of extreme weather events.

Our results indicate a significant and negative effect of climate risk on stock market returns. This is particularly large in the case of the Asian markets with low capitalisation, which are generally perceived as riskier; however, mispricing of climate risk is likely to occur in all cases. Financial institutions, investors and policy makers should take into account the fact that the effects of climate risk can vary substantially across countries, markets capitalisation being one of the factors playing a role. However, regardless of any cross-market differences there is a clear need for effective climate policies that reduce emissions, enhance resilience, and support sustainable economic growth and financial markets stability (Lim et al., 2024).

It should be noted that the present study focuses exclusively on the impact of climate risk on stock markets at the aggregate level (with special attention being paid to the Asian case). Future work could shed further light on the issues of interest by using firm level data concerning firm characteristics such as size, environmental awareness, debt and geographical location.

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Table 1: List of Countries and Stock Market Indices

Argentina	MERVAL	Malawi	MASI
Australia	S&P/ASX200	Malta	MSE INDEX
Austria	ATX	Mexico	MEXBOL
Belgium	BEL 20	Netherlands	AEX
Brazil	BOVESPA	New Zealand	NZX 50
Bulgaria	SOFIX	Nigeria	NSE ALL-SHARE*
Canada	S&P/TSX	Norway	OBX INDEX
Colombia	COLCAP	Panama	BVPSI
Costa Rica	CRSMBI	Peru	S&P/BVL
Croatia	CROBEX	Poland	WIG20
Czech Republic	PX INDEX	Portugal	PSI-20
Denmark	OMXC20	Romania	BET
Ecuador	BVQ INDEX*	Slovak Republic	SAX
Finland	OMXH25	Slovenia	SBI TOP
France	CAC 40	South Africa	JSE ALL SHARE
Germany	DAX	Spain	IBEX 35
Greece	ATHEX	Sweden	OMXS30
Hungary	BUX	Switzerland	SMI
Ireland	ISEQ OVERALL	Uganda	ALSI
Italy	FTSE MIB	United Kingdom	FTSE 100
Jamaica	JSE MARKET	United States	S&P 500
Kenya	NSE 30	Uruguay	BVMBG*
Latvia	OMX RIGA	Venezuela	IBC*
Lithuania	OMX VILNIUS		

Asian Countries and Stock Market Indices

High Market Capitalisation		**Low Market Capitalisation**	
China	CSI 300	Georgia	GSE INDEX
India	SENSEX	Israel	TA-32*
Indonesia	IDX COMPOSITE	Kazakhstan	KASE
Japan	NIKKEI 225	Pakistan	KSE 100
Malaysia	FTSE KLCI	Philippines	PSEi
Saudi Arabia	TASI	Russia	MOEX
South Korea	KOSPI	Sri Lanka	CSE ALL SHARE
Singapore	STI	Turkey	BIST 100
Thailand	SET INDEX	Vietnam	VN-INDEX*

Notes: The selection of countries is based on the availability of the CRI index. The panel is unbalanced and it includes 65 countries and 947 observations. The Asian market panel consists of 18 countries and 266 observations. Asian countries have been clustered by market capitalisation in US dollars (Tan et al., 2021). Indices calculated by Bloomberg are denoted by an asterisk.

Table 2: Descriptive statistics and Unit Root Tests

	Full Panel				Asia			
Variables	**Mean**	**S.D.**	**Min**	**Max**	**Mean**	**S.D.**	**Min**	**Max**
Stock Returns	7.60	27.54	-79.71	135.15	10.17	30.93	-67.20	134.40
VIX	19.85	6.49	11.09	32.69	19.88	6.45	11.09	32.69
Climate Risk Indicator								
CRI	62.25	28.56	2.17	126.17	55.66	32.23	2.17	126.17

Panel Unit Root Tests

	LLC		**Pesaran**		**LLC**		**Pesaran**	
	T. Stat.	p-value	T. Stat.	p-value	T. Stat.	p-value	T. Stat.	p-value
Stock Returns	-25.12	0.00	-21.45	0.00	-11.93	0.00	-10.40	0.00
CRI	-7.92	0.00	-8.06	0.00	-4.49	0.00	-3.11	0.00
	ADF				**ADF**			
VIX	-27.45	0.00			-27.45	0.000		

Notes: The sample size covers the period 2007-2021. S.D. stands for standard deviation. LLC and Pesaran refer to Levin et al. (2002) and Pesaran (2007) unit root tests, respectively. In the LLC (Pesaran) tests the null hypothesis is that the series contains a common (individual) unit root process, and the alternative that it is stationary. The VIX does not have a longitudinal dimension; therefore stationarity is tested by means of the Augmented Dickey Fuller (ADF) test.

Table 3: Panel estimation results

	Full Sample	Asian Markets
Intercept	19.56	7.67
	(0.00)	(0.27)
CRI	0.09	0.20
	(0.01)	(0.00)
VIX	-0.87	-0.44
	(0.00)	(0.07)
Hausman Test	8.30	6.00
	(0.01)	(0.04)
Countries	65	18
Obs.	947	266
F-Statistics	1.88	0.96
	(0.00)	(0.04)

Notes: The full panel is unbalanced and includes 65 countries and 947 observations; the Asian subgroup is again an unbalanced panel and comprises 18 countries and 266 observations. P-values are reported in round brackets. The Hausman test comparing fixed effect and random effect estimates is also included.

Table 4: Descriptive statistics and Unit Root Test - Asian markets

	High Market Capitalisation				Low Market Capitalisation			
Variables	**Mean**	**S.D.**	**Min**	**Max**	**Mean**	**S.D.**	**Min**	**Max**
Stock Returns	9.01	29.76	-64.88	134.40	11.31	32.11	-67.20	125.24
VIX	19.85	6.44	11.09	32.69	19.91	6.47	11.09	32.69
				Climate Risk Indicator				
CRI	55.07	31.53	2.50	126.17	56.24	33.02	2.17	122.33

Panel Unit Root Tests

	LLC		Pesaran		LLC		Pesaran	
	T. Stat.	p-value	T. Stat.	p-value	T. Stat.	p-value	T. Stat.	p-value
Stock Returns	-6.92	0.00	-7.16	0.00	-10.01	0.00	-7.55	0.00
CRI	-2.84	0.00	-1.77	0.03	-3.58	0.00	-2.65	0.00
	ADF				**ADF**			
VIX	-27.45	0.00			-27.45	0.00		

Notes: see the notes to Table 2.

Table 5: Panel estimation results – Asian markets clustered by market capitalisation

	High Market Capitalisation	Low Market Capitalisation
Intercept	9.65	5.00
	(0.03)	(0.02)
CRI	0.13	0.32
	(0.01)	(0.01)
VIX	-0.40	-0.58
	(0.02)	(0.01)
Hausman Test	3.25	5.92
	(0.09)	(0.05)
Countries	9	9
Obs.	132	134
F-Statistics	0.76	1.19
	(0.03)	(0.01)

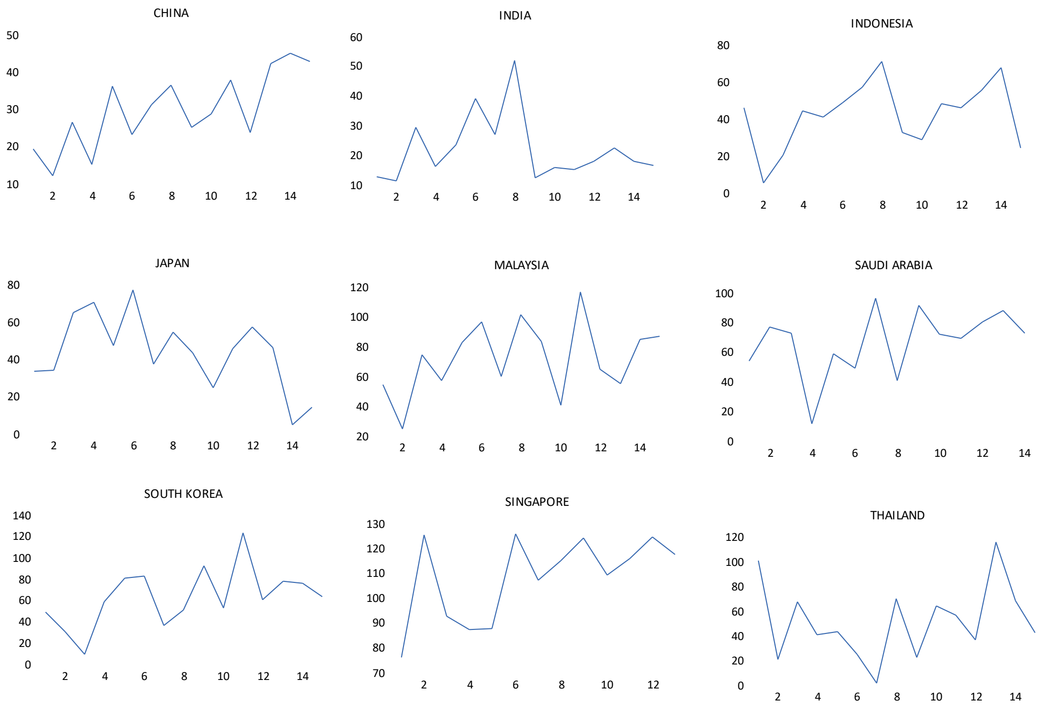
Notes: see the notes to Table 3. Asian countries have been clustered by market capitalisation in US dollars (Tan et al., 2021).

Figure 1a: Stock Market Returns - Asian Markets with High Market Capitalisation

Notes: This figure displays stock market returns for the 9 Asian countries with high market capitalisation as specified in Table 1.

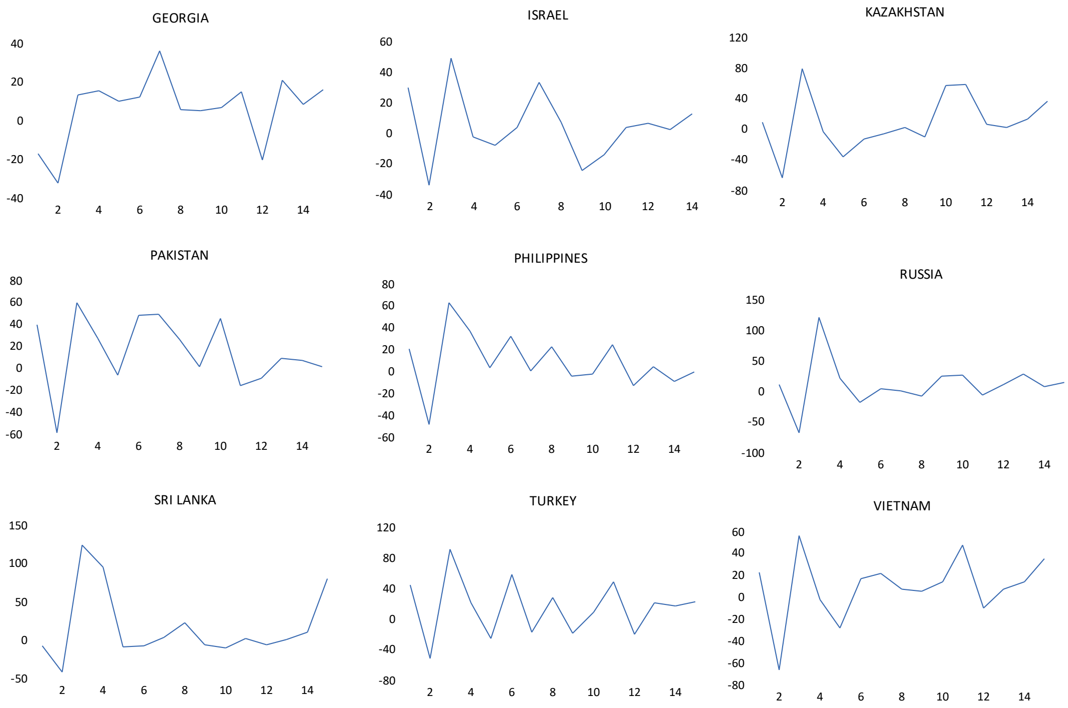
Figure 1b: Global Climate Risk Index (CRI) –

Asian Markets with High Market Capitalisation



Notes: This figure displays the CRI for the 9 Asian countries with high market capitalisation as specified in Table 1.

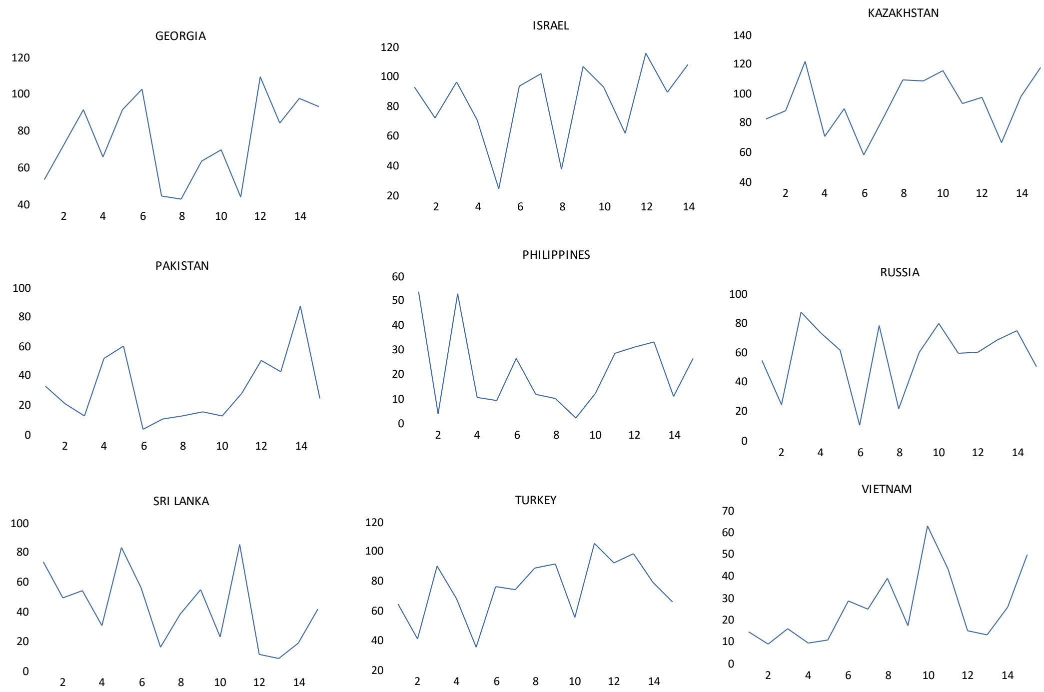
Figure 2a: Stock Market Returns – Asian Markets with Low Market Capitalisation



Notes: This figure displays stock market returns for the 9 Asian countries with low market capitalisation as specified in Table 1.

Figure 2b: Global Climate Risk Index (CRI) –

Asian Markets with Low Market Capitalisation



Notes: This figure displays the CRI for the 9 Asian countries with low market capitalisation as specified in Table 1.