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Climate Risks and Prediction of Sectoral REITs Volatility: International Evidence

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Abstract

This study examines the nexus between climate risks and the return volatility of the real estate investment trusts (REITs) market, a topic of increasing importance for market participants in both emerging and developed economies. Using sectoral REITs from 14 selected countries and alternative measures of climate risks involving both country-specific (climate change vulnerability index, based on climate news) and global (climate policy uncertainty index) measures, reflecting both physical and transition climate risks, we apply a predictive model that accommodates the salient features of the data. Our results indicate that REIT volatility generally increases in response to climate policy uncertainty in most countries. However, the resilience of REITs to the adverse effects of climate change is underscored, providing a sense of confidence in the market's ability to withstand these climate challenges. This outcome transcends the in-sample predictability as the out-of-sample forecast performance validates the predictive content of climate change risks for REITs return volatility. The findings have important practical and policy implications.

Keywords: Climate risks; emerging and developed economies; sectoral REITs; realized volatility; feasible quasi-generalized least squares (FQGLS) method; forecast evaluation

JEL Codes: Q54, R3, C53

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1. Introduction

Climate change physical and transition risks profoundly affect real estate investment trusts (REITs). In terms of physical climate risk, recent extreme weather events, such as heat waves, floods, storms, and wildfires, notably in 2023 and 2024, have driven up operational costs and caused significant property damage, especially for those with assets located in the hardest-hit areas. Rising sea levels are a growing concern for coastal properties, requiring substantial investment in resilience measures to protect these assets. Such physical climate challenges mean higher insurance premiums, increased maintenance costs, and disruption to REIT rental income. However, given the various obstacles that climate change presents to environmental sustainability for REIT investors, it is now proposed that investors knowledgeable about emerging technologies are more likely to overcome these obstacles, especially when it comes to protecting the environment to maximize returns on REIT investments (Salisu et al., 2023a). In terms of transitional climate risk, uncertainty about climate policies represents another concern for the real estate sector and participants in the REIT market. It includes changes in the economy, financial and fiscal regulations, technology, consumer behaviour and responses to climate change. In this regard, climate policy uncertainty is important for carbon dioxide emissions[1], regulation, and the behaviours of environmentally responsible consumers and investors, ultimately affecting the decisions to make or postpone investment in carbon-intensive industries such as the real estate sector. This, in turn, can affect the revenue, operating and capital costs, and capitalization rates[2]. Transition risks, reflected by higher climate policy uncertainty, could reduce the attractiveness of the real estate market, leading to tighter regulations and increased costs. This could result in large fluctuations in REITs returns. For instance, tighter regulations, such as the imposition of a carbon tax on building emissions, could increase the cost of financing properties and mounting public pressure, potentially driving the return volatility of REITs higher[3].

The arbitrage pricing theory (APT) underpins the theoretical link between climate change and REITs. This theory assumes that various macroeconomic variables which account for systematic risk can be used to forecast an asset's expected return and, consequently, its level of volatility.

[1] The real estate sector contributes around 40% of CO2 emissions globally (https://www.unepfi.org/themes/climate-change/climate-risks-in-the-real-estate-sector).
[2] https://www.mckinsey.com/industries/real-estate/our-insights/climate-risk-and-the-opportunity-for-real-estate.
[3] https://www.unepfi.org/themes/climate-change/climate-risks-in-the-real-estate-sector.

Since climate risks impact more than just the environment or the specific sector they originate from, they fall under systemic risks. Thus, in theory, the APT is a good fit to explain how climate change and REITs are related (Salisu et al., 2023a). At the same time, climate risks capture rare disaster events (Battiston, 2021), which are known to be associated with movements in the first and second moments of asset prices (Del Fava et al., 2024). Based on their well-established ability to provide investors with diversification benefits (see, for example, Lee and Stevenson, 2005; Chiang, 2007), real estate companies and REITs make up a significant portion of the portfolios of institutional investors (Andonov et al., 2013; Biasin et al., 2024). As such, they are important players in the process of asset allocation.

The relationship between climate change and REITs has been the subject of various empirical studies. In certain cases, climate risk is observed to have significant effects on real estate prices through the discount channel (Giglio et al., 2021a; Salisu et al., 2024). The literature also sufficiently demonstrates that temperature patterns can affect the economy through various channels. For example, temperature variations have a significant impact on per capita income (see Dell et al., 2009), labour productivity and sales volume (Custodio et al., 2022; Salisu et al., 2023b), manufacturing export (Dell et al., 2012), and the performance of commercial real estate investment (Cvijanovic and Van de Minne, 2021). Furthermore, the construction of climate risk-related factors by some literature is based on mimicking portfolios; examples include climate policies, specifically those on carbon emissions (see Oestreich and Tsiakas, 2015; Baker et al., 2022; Delis et al., 2019; Choi et al., 2020; Bolton and Kacperczyk, 2021), and news about climate change or disasters (Engle et al., 2020; Huynh and Xia, 2021; Wei et al., 2022). However, as noted by Giglio et al. (2021b), substantial news about the realization of various climate risks is not very common in the related literature.

This study builds upon the work of Salisu et al. (2024) on the nexus between climate change and REITs by examining the impact of climate risks on the return volatility of overall and sectoral REITs in both emerging and developed economies. While Salisu et al. (2024) provide valuable insight, it is confined to sectoral REITs in the United States, thereby limiting the wider applications of the findings. The current research addresses this limitation by conducting a more comprehensive analysis that extends beyond a single country through the incorporation of data from multiple

countries across various regions, which enhances the robustness of the findings and enables more meaningful generalization. This broader geographical scope facilitates the identification of patterns and trends outside the US, offering a global perspective on the relationship between climate risk and the return volatility of REITs. This overarching approach ensures that our results are relevant and applicable to wider countries, providing policymakers, researchers, and investors, as well as portfolio managers, with a more complete understanding of the subject.

In addition to enhancing the applicability of earlier results, this study introduces a nuanced analysis of climate risks by considering both country-specific and global climate uncertainty in modelling the country-specific realized volatility of sectoral REITs returns. Unlike Salisu et al. (2024), who focus on a single measure of climate risk, this research incorporates alternative measures such as climate attention (climate change vulnerability (CCV)) and the climate policy uncertainty (CPU) index, which are reflective of both transition and physical climate risks. For instance, CPU shows uncertainty about climate policies, which could capture transition risks as it highlights uncertainty about adaptation to climate change by moving to a green economy, but higher CPU means lower mitigation and likely higher physical risks too. Similarly, climate attention is, in general, attention to climate change, which can arise due to both transition and physical risks as people's searching intensifies depending on certain events taking place in the economy related to climate. This dual consideration of CCV and CPU offers a comprehensive assessment of how climate risks influence the REITs market. This approach not only enriches our analysis compared to Salisu et al. (2024), but also provides a deeper understanding of the complexities and nuances associated with climate risks and the REITs market at both country and global level.

Another contribution consists of using daily frequency data for country-specific sectoral (diversified, healthcare, hedge, hotel and hospitality, industrial, office, residential, retail, specialty, self-storage, and utility) REITs for 14 selected countries. Hoesli and Oikarinen (2012) argue that the overall (i.e. broad) REIT index masks relevant sector-specific information, given that REIT indices are heterogeneous in terms of property types. Different characteristics, demand and supply drivers, and responses to economic factors characterize each REIT sector[4].

[4] Highly cyclical REITs, such as hotels and lodgings, have a short-term lease duration, whereas apartments are less affected by the state of the economy given that their demand base is structurally more stable and more diversified

Our research is comprehensive, covering a wide sample period with varying start and end dates, ranging from January 1, 2013, to October 19, 2022. The REITs data are transformed using a 20-day rolling window annualized realized volatility to measure the uncertainty/risk level associated with REITs. We employ the Westerlund and Narayan (2012, 2015) [WN]-type distributed lag model, a comprehensive approach that accommodates key data features – endogeneity, persistence, and conditional heteroscedasticity – common in economic and financial series with high-frequency data. This allows us to evaluate the relationship between country-specific sectoral REITs realized volatility and country-specific and global climate uncertainty, considering day-of-the-week effects and potential breaks.

In summary, we investigate the relationship between climate change volatility and REITs using a WN-type distributed lag model framework to evaluate the relationship between the realized volatility of country-specific sectoral REITs and country-specific and global climate uncertainty. Our analysis shows that most sectoral REITs tend to experience a positive nexus to heightened climate uncertainty. However, industrial, retail, and self-storage REITs generally show the opposite trend. For these sectors, heightened climate uncertainty tends to reduce REITs volatility, likely because investors become more cautious and trade less.

The rest of the paper is organized as follows. Section 2 describes the dataset and methodology used in the study. Section 3 discusses the empirical results, and section 4 concludes.

2. Datasets and Methodology

We use daily frequency data for country-specific sectoral (diversified, healthcare, hedge, hotel and hospitality, industrial, office, residential, retail, specialty, self-storage, and utility) and overall REITs for selected countries[5], along with daily country-specific and global climate change risk measures, including the climate attention (climate change vulnerability (CCV)) and climate policy uncertainty (CPU) indexes, which reflect two diverse yet complementary aspects of climate risks.

(Anderson et al., 2003). According to Wheaton (1999), "real estate certainly does not behave uniformly as a single sector within the economy". Industrial spaces are usually highly correlated with the state of the economy, whereas retail properties are weakly correlated with the economy.

[5] Australia, Canada, China, France, Germany, Hong Kong, Italy, Japan, Mexico, New Zealand, South Africa, Spain, the United Kingdom and the United States.

Specifically, CCV indexes somewhat reflect both transition and physical aspects of climate risks, whereas CPU indexes reflect transition climate risk.

The Standard & Poor's (S&P) REITs indexes at the overall and sectoral levels are obtained from Refinitiv Datastream, while the publicly-available CCV and CPU indexes are based on the work of Arteaga-Garavito et al. (2023)[6] and Guo et al. (2023)[7], respectively.

Arteaga-Garavito et al. (2023) construct a climate attention index that measures the extent to which climate change is discussed in the news media. This method focuses on newspapers with a significant presence on Twitter across many countries. It allows the authors to compile a large dataset of over 23 million tweets, which they aggregate at the country level across daily, weekly, monthly, quarterly, and yearly frequencies, while we use daily data to match the frequency of our REIT indexes. Arteaga-Garavito et al. (2023) compare the aggregated text to a corpus of authoritative texts on climate change, in line with Engle et al. (2020). The data covers a total of 25 countries that span a wide range of local languages, income levels, and geographical regions. Of these 25, we use 14 CCV indexes corresponding to our country-specific REITs data.

The CPU indexes of Guo et al. (2023) are constructed using approximately 1.7 million news articles sourced from major local newspapers in Canada, China, France, Germany, Japan, the UK, and the US. The data are categorized into national and global (average across the seven countries) indexes with different frequencies, at daily, weekly, and monthly intervals. Understandably, in line with the frequency of the REITs, we use the daily frequency of these CPU indexes.

The datasets have varying start and end dates, with the earliest starting on January 1, 2013, and the latest ending on October 19, 2022. The REITs price data are transformed by calculating a 20-day rolling window annualized realized volatility to measure the uncertainty/risk level associated with REITs.

[6] The data is from: https://sites.google.com/view/internationalclimatenews/download?authuser=0.
[7] The data is from: http://www.cnefn.com/main/data_detail?id=4.

The summary statistics (measures of location, spread and shape), along with preliminary results that highlight some salient data characteristics (conditional heteroscedasticity, first and higher-order autocorrelation and persistence), are presented in Table 1 and sub-grouped by the sectoral REITs and climate change variables. On average, the overall realized volatility of REITs ranges between 4.687 and 32.633, with the lowest observed in China and Hong-Kong's hotel & hospitality sector, and the highest in South Africa's retail sector. However, the widest deviation is noted in South Africa's office space sector, while the narrowest is in China and Hong-Kong. The REITs realized volatility is positively skewed and leptokurtic (except for New Zealand's industrial sector) during the study period, exhibiting kurtosis values above the normal distribution. Most country-specific sectoral REITs show evidence of ARCH effects, except for healthcare (UK), hotel & hospitality (Canada, China, Hong-Kong, and the US), industrial (South Africa), office (Germany, Italy, South Africa, and the UK), retail (UK), self-storage (Australia and the UK), and utility (Spain). First and/or higher-order autocorrelation effects are observed in the majority of REITs sectors, with high persistence characterizing all the REITs realized volatility.

The average climate change vulnerability (CCV) index for the fourteen countries (Australia, Canada, China, France, Germany, Hong-Kong, Italy, Japan, Mexico, New Zealand, South Africa, Spain, the UK, and the US) ranges between 0.083 and 0.157, with deviations ranging between 0.023 and 0.039. Most country-specific CCVs are positively skewed (except for Germany, Mexico, and Spain), leptokurtic (except for Australia, France, Germany, South Africa, and Spain), with evidence of ARCH effects, first and higher-order autocorrelation, and persistence effects. For climate policy uncertainty (CPU), Germany, the UK, and the US averages exceed the global average, with the highest deviation in Japan. The global and country-specific CPUs are positively skewed, leptokurtic, and exhibit ARCH effects (except for Canada and the UK), autocorrelation (except for Japan and the UK), and persistence (except for Canada, Japan, and the UK). The optimal model for assessing the REITs realized volatility - climate-related uncertainty measures (CCV and CPU) nexus would be one that adequately accounts for most, if not all, of these observed salient data features (conditional heteroscedasticity, first and/or higher order autocorrelation and persistence effects). The WN-type predictive model framework, which is based on feasible quasi-generalized least squares (FQGLS), satisfies this condition.

Table 1: Summary and Preliminary Analyses

Country	Mean	Standard Deviation	Skewness	Kurtosis	N	$ARCH(5)$	$ARCH(10)$	$Q(5)$	$Q(10)$	$Q2(5)$	$Q2(10)$	Persistence
DIVERSIFIED REITs												
Australia	22.320	14.365	5.406	41.461	2082	92.22***	50.06***	492.49***	557.58***	681.82***	745.78***	0.993***
Canada	18.851	16.854	4.895	33.252	2082	100.99***	64.02***	391.53***	488.68***	442.85***	485.16***	0.994***
China	13.327	8.313	3.095	17.205	2082	13.68***	8.01***	193.52***	210.47***	78.075***	93.592***	0.992***
France	21.774	14.020	3.426	20.072	2082	2.880**	6.091***	187.75***	334.17***	15.023**	70.528***	0.992***
Germany	18.845	9.389	2.570	14.498	2082	0.60	1.733*	85.853***	168.47***	2.9752	18.086*	0.989***
Hong-Kong	14.497	8.276	2.927	16.059	2082	9.06***	5.38***	174.15***	188.54***	51.333***	61.45***	0.991***
Japan	16.676	13.623	6.805	58.918	2082	62.42***	34.65***	588.37***	683.11***	289.07***	294.1***	0.990***
New Zealand	17.336	9.677	5.357	42.706	2082	31.87***	16.26***	279.47***	350.56***	143.64***	150.66***	0.988***
South Africa	29.583	17.660	3.886	22.741	2082	64.98***	33.25***	241.49***	273.27***	349.26***	357.41***	0.989***
United Kingdom	22.799	14.430	3.369	17.776	2082	2.441**	1.23	127.01***	171.3***	12.294**	12.513	0.988***
United States	19.257	15.435	4.866	32.936	2082	70.89***	39.71***	424.37***	555.12***	309.61***	336.25***	0.994***
HEALTHCARE REITs												
Canada	19.387	14.498	5.953	47.282	2082	180.73***	103.91***	500.55***	676.46***	822.26***	991.42***	0.993***
New Zealand	19.227	9.477	3.949	27.954	2082	11.78***	12.64***	202.41***	305.24***	72.059***	186.02***	0.989***
United Kingdom	19.236	10.796	3.560	18.627	2082	0.90	0.63	118.01***	194.14***	4.6389	6.6499	0.988***
United States	22.310	17.642	5.178	36.526	2082	59.56***	30.10***	351.81***	402.6***	286.88***	289.85***	0.993***
HEDGE												
China	16.211	6.253	2.533	12.973	2082	0.03	1.696*	44.408***	78.786***	0.1479	17.171*	0.979***
HOTEL AND HOSPITALITY REITs												
Canada	27.150	15.639	3.433	15.626	486	0.00	0.00	1.744	2.5755	0.0234	0.0422	0.952***
China	4.687	6.893	1.301	3.764	2082	1.16	1.07	81.264***	118.83***	6.0575	11.248	0.995***
Hong Kong	4.687	6.893	1.301	3.764	2082	1.16	1.07	81.264***	118.83***	6.0575	11.248	0.995***
Japan	22.463	16.426	4.326	28.337	2082	44.92***	25.40***	201.5***	245.04***	239.23***	294.05***	0.992***
Mexico	23.077	20.155	1.651	9.102	2082	14.97***	18.21***	149.07***	206.2***	87.89***	222.3***	0.995***
United States	28.285	22.095	3.463	18.745	2082	0.84	0.42	209.96***	242.56***	4.4793	4.5896	0.992***
INDUSTRIAL REITs												
Australia	24.274	14.108	4.904	36.944	2082	52.87***	28.19***	349.76***	412.21***	387.47***	412.92***	0.991***
Japan	16.749	11.307	6.290	53.702	2082	206.26***	127.88***	425.92***	473.62***	580.71***	584.83***	0.988***
Mexico	24.526	12.659	4.245	27.675	2082	43.14***	25.31***	205.58***	270.17***	273.87***	369.9***	0.989***
New Zealand	6.357	8.885	0.970	2.563	2082	13.40***	7.73***	63.821***	97.65***	73.188***	91.869***	0.996***
South Africa	18.834	17.645	1.186	7.052	2082	0.01	0.01	35.493***	58.493***	0.0331	0.0994	0.993***
United Kingdom	20.765	12.847	3.315	16.466	2082	4.07***	2.48***	194.95***	279.63***	21.849***	27.548***	0.991***
United States	20.055	12.539	4.879	34.946	2082	20.36***	10.68***	259.48***	358.61***	104.83***	119.59***	0.992***
OFFICE REITs												
Australia	21.282	10.494	4.221	29.602	2082	42.56***	23.46***	176.79***	225.29***	250.8***	318.54***	0.991***
Canada	19.266	14.005	5.274	39.886	2082	29.08***	15.68***	300.84***	398.22***	165.63***	205.32***	0.991***
China	15.461	7.342	1.631	6.647	2082	0.19	2.41***	49.562***	64.198***	0.9254	23.953***	0.984***
Germany	22.422	13.705	2.891	15.750	2082	0.75	0.38	84.356***	100.35***	3.8161	3.8674	0.983***
Hong Kong	16.278	7.241	1.559	6.295	2082	0.19	2.065**	48.324***	61.586***	0.9662	20.53**	0.982***
Italy	16.998	15.973	0.809	3.647	2082	0.01	0.01	16.493***	22.17**	0.064	0.1229	0.985***
Japan	17.396	12.323	6.200	50.898	2082	47.76***	25.75***	448.31***	510.21***	278.74***	306.35***	0.990***
South Africa	24.444	24.452	1.013	4.148	2082	0.04	0.02	32.08***	40.328***	0.197	0.2493	0.991***
United Kingdom	24.102	16.601	4.460	28.856	2082	1.63	0.81	142.92***	176.03***	8.2226	8.2564	0.985***
United States	19.370	13.418	4.314	28.541	2082	11.94***	6.58***	350.51***	446.06***	67.954***	79.455***	0.993***
RESIDENTIAL REITs												
Australia	26.637	12.242	2.983	18.272	2082	16.34***	8.94***	85.453***	110.97***	88.079***	98.264***	0.989***
Canada	17.563	10.315	5.005	37.377	2082	47.46***	26.82***	217.34***	258.57***	224.3***	232.71***	0.990***
Japan	17.227	11.960	6.933	60.934	2082	84.28***	43.48***	484.66***	620.19***	425.84***	453.56***	0.990***
United States	18.399	12.824	5.067	36.425	2082	9.32***	4.79***	288.14***	405.56***	48.947***	52.698***	0.993***
RETAIL REITs												
Australia	23.181	13.653	4.172	27.686	2082	75.67***	43.59***	260.2***	325.42***	462.05***	635.6***	0.992***
Canada	16.923	12.519	5.053	36.982	2082	56.16***	29.27***	321.57***	393.83***	301.4***	317.29***	0.992***
China	18.110	6.486	2.262	11.828	2082	0.06	1.763*	37.425***	68.475***	0.2807	17.909*	0.976***
France	30.354	22.956	2.488	10.083	2082	5.44***	3.58***	121.93***	163.08***	30.729***	41.352***	0.992***
Hong Kong	18.110	6.486	2.262	11.828	2082	0.06	1.763*	37.425***	68.475***	0.2807	17.909*	0.976***
Italy	30.931	13.809	1.795	8.271	2082	2.027*	1.06	75.179***	97.474***	10.164*	10.632	0.979***
Japan	18.371	14.744	6.122	49.712	2082	114.30***	62.22***	607.72***	719.75***	540.13***	610.66***	0.992***
South Africa	32.633	18.176	3.486	20.443	2082	51.84***	30.26***	196.16***	219.43***	322.48***	359.68***	0.990***
United Kingdom	26.459	16.457	2.600	11.460	2082	1.32	0.69	76.843***	118.23***	6.7164	7.0472	0.987***
United States	22.587	18.634	4.653	29.473	2082	20.13***	10.18***	284.48***	322.17***	99.261***	101.27***	0.992***
SPECIALTY REITs												
Australia	20.242	11.518	3.944	22.806	2082	8.55***	4.26***	151.84***	169.98***	41.486***	41.505***	0.982***
United States	19.097	11.137	4.926	36.344	2082	15.44***	10.96***	187.78***	312.95***	90.455***	145.02***	0.991***
SELF-STORAGE REITs												
Australia	21.054	17.352	4.687	37.933	2082	1.74	0.87	154.25***	159.49***	9.0771	9.1125	0.988***
United Kingdom	24.525	12.722	3.798	21.901	2082	1.78	0.94	162.15***	202.01***	8.8995	9.597	0.986***

United States	19.133	9.822	3.912	25.430	2082	7.91***	4.86***	88.792***	140.43***	43.095***	57.549***	0.988***
OVERALL REITs												
Australia	20.674	12.612	5.082	38.567	2082	119.90***	63.51***	#REF!	#REF!	#REF!	#REF!	0.993***
Canada	16.079	12.499	5.418	41.285	2082	92.64***	54.48***	415.19***	524.93***	453.11***	487.96***	0.993***
China	16.277	6.265	2.522	12.901	2082	0.03	1.695*	44.525***	78.712***	0.1516	17.167*	0.979***
France	25.023	17.130	2.819	13.600	2082	2.791**	5.393***	139.81***	228.7***	15.176**	57.02***	0.991***
Germany	18.975	11.172	3.549	22.478	2082	1.66	0.84	119.77***	149.33***	8.4182	8.6402	0.985***
Hong Kong	16.524	6.252	2.469	12.636	2082	0.03	1.649*	44.235***	77.834***	0.1594	16.704*	0.979***
Italy	26.652	12.715	2.609	13.369	2082	2.369**	1.23	65.942***	96.95***	11.892**	12.412	0.981***
Japan	15.790	12.233	6.806	58.953	2082	44.27***	23.49***	568.45***	656.22***	250.02***	259.62***	0.990***
Mexico	23.390	13.858	5.244	38.330	2082	31.44***	23.85***	300.1***	400.19***	218.23***	334.24***	0.990***
New Zealand	15.666	9.213	5.554	44.739	2082	6.20***	3.68***	181.86***	263.71***	30.852***	38.471***	0.988***
South Africa	28.618	16.623	3.912	23.320	2082	76.61***	39.58***	243.74***	277.57***	400.89***	410.65***	0.989***
Spain	21.801	12.798	2.361	10.068	2082	0.37	0.26	49.264***	82.402***	1.8542	2.6197	0.987***
United Kingdom	20.960	13.711	3.943	23.288	2082	2.352**	1.19	181.33***	250.5***	11.973**	12.267	0.988***
United States	17.498	12.690	5.114	36.976	2082	11.79***	6.37***	334.62***	457.01***	62.538***	70.761***	0.993***
CCV												
Australia	0.131	0.039	0.348	2.775	2101	6.98***	3.80***	305.83***	400.75***	37.433***	42.53***	0.790***
Canada	0.134	0.023	1.049	7.212	2101	20.10***	10.90***	178.85***	292.59***	125.42***	141.73***	0.580***
China	0.125	0.035	0.467	4.996	2101	44.63***	22.59***	157.69***	236.19***	220.53***	228.83***	0.802***
France	0.139	0.037	0.120	2.377	2101	30.15***	15.23***	218.81***	256.94***	131.21***	132.61***	0.841***
Germany	0.104	0.028	-0.136	1.800	2101	9.26***	4.82***	247.15***	281***	49.655***	50.935***	0.874***
Hong Kong	0.091	0.029	0.175	3.192	2101	20.81***	12.08***	214.93***	330.15***	109.14***	140.79***	0.720***
Italy	0.097	0.028	0.891	3.494	2101	23.85***	12.32***	239.11***	292.35***	133.97***	147.65***	0.818***
Japan	0.112	0.029	0.821	3.500	2101	19.80***	10.62***	237.27***	382.45***	122.58***	148.82***	0.712***
Mexico	0.157	0.026	-0.209	3.179	2101	19.68***	10.13***	122.94***	209.86***	93.435***	100.47***	0.752***
New Zealand	0.083	0.026	1.011	5.848	2101	16.76***	12.02***	164.17***	322.4***	109.84***	187.59***	0.360***
South Africa	0.091	0.028	0.292	2.585	2101	16.66***	8.63***	245.04***	404.67***	79.908***	85.554***	0.674***
Spain	0.150	0.031	-0.115	2.924	2101	7.65***	4.02***	249.4***	299.94***	38.566***	40.853***	0.814***
United Kingdom	0.138	0.032	0.532	4.217	2101	37.07***	20.27***	328.45***	447.78***	218.06***	283.91***	0.707***
United States	0.157	0.029	0.324	4.483	2101	24.30***	12.22***	105.96***	178.27***	155.73***	156.88***	0.760***
CPU												
Global	112.569	98.189	1.610	7.521	2557	4.49***	3.09***	101.15***	216.69***	24.581***	34.919***	0.145***
Canada	111.338	209.486	2.128	8.177	2557	1.77	1.30	7.1187	31.513***	8.9435	14.094	0.020
China	104.983	130.550	1.952	9.563	2557	11.26***	6.88***	90.383***	176.61***	70.245***	97.566***	0.173***
France	112.244	220.939	2.755	18.013	2557	9.03***	6.67***	52.245***	129.29***	44.947***	72.184***	0.062***
Germany	122.975	309.199	2.873	12.618	2557	3.43***	2.79***	6.801	27.795***	17.289***	30.35***	0.063***
Japan	86.845	745.319	9.400	98.104	2557	0.93	1.05***	5.5957	11.81	4.6783	10.14	0.007
United Kingdom	122.816	289.303	3.604	20.861	2557	1.07	0.93	2.7292	9.668	5.4434	9.3875	-0.008
United States	115.928	232.391	2.162	8.093	2557	4.12***	2.87***	17.115***	34.253***	21.895***	35.074***	0.015

Note: The table contains the summaries and preliminary analyses results of inherent salient data features, where $ARCH(\#)$, $Q(\#)$ and $Q^2(\#)$ represent the tests for presence of conditional heteroscedasticity, first and higher-order serial correlations, respectively; and statistical significance implying that the tested feature is present in the series, up to the specified lag #. ***, ** and * denote statistical significance at the 1%, 5% and 10% level, respectively.

As previously noted, we apply the Westerlund and Narayan (2012, 2015) [WN]-type distributed lag model[8], which is based on the feasible quasi-generalized least squares (FQGLS) method. This approach allows for the simultaneous accommodation of key data features – endogeneity, persistence, and conditional heteroscedasticity – common in economic and financial series. Our variables of interest exhibit at least one of these features, making it essential to account for them in the estimation model. The model addresses persistence and/or endogeneity by incorporating a differencing term, while heteroscedasticity is managed by pre-weighting the model variables with the standard deviation of the residuals from a conventional $GARCH(1,1)$ model.

The WN-type model is formulated as:

[8] This methodology has been applied to evaluate the predictability of various asset classes such as the stock market (see, for example, Narayan and Gupta, 2015; Phan et al., 2015), foreign exchange market (see, for example, Salisu et al., 2021a, 2021b) as well as the REITs market (see, for example, Salisu et al., 2024).

$$rv_t = \alpha + \lambda rv_{t-1} + \sum_{i=1}^{5} \beta_i cu_{t-i} + \gamma\left(cu_t - \rho cu_{t-1}\right) + \sum_{i=1}^{5} \delta_i brk_{it} + \varepsilon_t \quad (1)$$

where rv_t is the 20-day rolling window generated REITs realized volatility at time t; cu_{t-i} is the i^{th} time lag of the climate-related uncertainty measure, proxied by climate change vulnerability or climate policy uncertainty; α is the constant; λ is the slope coefficients associated with the lag of the REITs realized volatility; $\sum_{i=1}^{5} \beta_i cu_{t-i}$ is incorporated to account for days of the week effect (see, Zhang et al., 2017; Yaya and Ogbonna, 2019; Salisu and Akanni, 2020; Salisu et al., 2021c; among others), where $\beta_i's$ are the lags of the specified climate-related uncertainty; $\gamma\left(cu_t - \rho cu_{t-1}\right)$ represents the endogeneity/persistence adjustment term for the specified climate-related uncertainty, with ρ - the autoregressive coefficient of the predictor variable, indicating the corresponding degree of persistence; $\sum_{i=1}^{5} \delta_i brk_{it}$ indicates the incorporation of a maximum of 5 break dummies, brk_{it} and the associated coefficients, denoted by δ_i, where the break dates are determined using the Bai and Perron (2003) multiple breakpoint test, which involves regressing each REITs realized volatility on its one period lag of climate-related uncertainty; while ε_t is the residual term that follows a white noise process. The underlying predictability test has the null hypothesis, $\left[H_0 : \sum_{i=1}^{5} \beta_i = 0\right]$ against a mutually exclusive alternative, $\left[H_a : \sum_{i=1}^{5} \beta_i \neq 0\right]$, where a rejection (non-rejection) of the null hypothesis implies predictability (no predictability) of REITs realized volatility based on climate uncertainty.

For the forecast evaluation exercise, we employ the Clark and West [hereafter, CW] (2007) test in a formal pairwise comparison of our WN-type (unrestricted) model and a restricted variant - an $AR(1)$ model that is used as the benchmark model. The statistic is well suited to testing the equality of the forecast precisions of contending nested models. The estimation equation for the CW statistic is:

$$\hat{f}_{t+h} = \left(r_{t+h} - \hat{r}_{1t,t+h}\right)^2 - \left[\left(r_{t+h} - \hat{r}_{2t,t+h}\right)^2 - \left(\hat{r}_{1t,t+h} - \hat{r}_{2t,t+h}\right)^2\right] \quad (2)$$

where h is the forecast period; $\left(r_{t+h} - \hat{r}_{1t,t+h}\right)^2$ and $\left(r_{t+h} - \hat{r}_{2t,t+h}\right)^2$ are the squared residuals associated with the forecasts of the restricted $\left(AR(1)\right)$ and unrestricted (WN-type) models,

respectively; while $\left(\hat{r}_{1t,t+h} - \hat{r}_{2t,t+h}\right)^2$ is the CW test incorporated adjusted squared residual that serves as a corrective measure for the noisy forecasts of the larger model. The term, $\hat{f}_{t+h}$ is defined as $MSE_1 - \left(MSE_2 - adj.\right)$, where $MSE_1 = P^{-1}\sum\left(r_{t+h} - \hat{r}_{1t,t+h}\right)^2$, $MSE_2 = P^{-1}\sum\left(r_{t+h} - \hat{r}_{2t,t+h}\right)^2$, $adj. = P^{-1}\sum\left(\hat{r}_{1t,t+h} - \hat{r}_{2t,t+h}\right)^2$ and P is the number of averaged forecast points. The test is based on the statistical significance (t-statistic) of the estimate of the constant in a regression of $\hat{f}_{t+h}$ on a constant. Positively (negatively) significant coefficients imply outperformance of the unrestricted (restricted) model over the restricted (unrestricted) model; while the non-significance of the estimated constant would imply that the forecast precisions of the paired models are equal.

3. Empirical Results

We apply the WN-type distributed lag model framework to evaluate the relationship between country-specific sectoral REITs realized volatility and country-specific and global climate uncertainty measures, considering day-of-the-week effects and potential breaks. We present both in-sample predictability and forecast evaluation results (for 20-, 60-, and 120-day out-of-sample periods). Our WN-type model includes, separately, country-specific climate change vulnerability (CCV) in Table 2, country-specific climate policy uncertainty (CPU) in Table 3, and global CPU in Table 4 as proxies for climate uncertainty. For all three WN-type model variants, we report the sums of the coefficients corresponding to the five lags of climate uncertainty as the in-sample predictability. The full sample period is used for in-sample predictability, while a 90:10 data split is applied for forecast evaluation. This split is chosen to include all potential breakpoints within the estimation sample, with the out-of-sample forecast evaluation based on the remaining 10% of the data not used for estimating model parameters. The resulting model forecasts are compared using the conventional Clark-West (CW) test. The overall stance for each country REITs realized volatility is reported (see the result in Table 5) in a similitude of the sectoral stance.

3.1.Predictability of REITs Volatility based on Climate Change Vulnerability

In Table 2, where climate change vulnerability is used to proxy climate uncertainty, we find evidence of predictability of country-specific sectoral REITs realized volatility based on CCV. Across the various sectoral REITs (except for country-specific industrial, retail and self-storage

REITs where the nexus is mostly negative), the REITs volatility – climate uncertainty nexus is mostly positive. The negative nexus is indicative of the tendency of heightened climate uncertainty to reduce REITs volatility, through reduced trading activities that may have been occasioned by risk averseness of investors in the said market. However, the positive nexus reflects the tendency for REITs volatility to increase with heightened climate uncertainty. While this may highlight the resilience of the said sectoral REITs to climate change vulnerability, it may also be feasible if the market is dominated by risk loving investors that stake their investments on risky assets, thereby maintaining trading activities within the REIT market. The incorporation of the climate change vulnerability index as a proxy for climate uncertainty improves the forecast precision of the autoregressive model which is the benchmark model. The outperformance transcends the in-sample period to the three specified out-of-sample (20, 60 and 120) periods. This indicates that the climate change vulnerability has predictive potential for sectoral REITs volatility; the stance is not sensitive to the forecast horizon. These results are supported by Salisu et al. (2024), who report that climate concerns amplify the volatility of REITs returns, albeit in the US.

Table 2: Country-Specific REITs and Country-Specific Climate Uncertainty

Country	Predictability	Forecast Evaluation			
	Parameter Estimate	In-Sample	Out-of-Sample		
			$h = 20$	$h = 60$	$h = 120$
Diversified REITs					
Australia	3.80E-01*** [6.69E-02]	2.64E+01*** [2.02E+00]	2.62E+01*** [2.00E+00]	2.58E+01*** [1.96E+00]	2.56E+01*** [1.90E+00]
Canada	1.34E-01* [7.29E-02]	-1.18E+01* [6.93E+00]	3.96E+01*** [2.71E+00]	3.69E+01*** [2.71E+00]	3.36E+01*** [2.67E+00]
China	-1.92E-01** [8.89E-02]	2.56E+01*** [1.01E+00]	2.53E+01*** [1.01E+00]	2.48E+01*** [9.89E-01]	2.40E+01*** [9.64E-01]
France	2.86E+00*** [1.38E-01]	4.74E+01*** [6.02E+00]	4.18E+01*** [6.10E+00]	3.97E+01*** [5.99E+00]	3.57E+01*** [5.84E+00]
Germany	-1.26E+00*** [1.57E-01]	1.42E+01*** [2.28E+00]	1.40E+01*** [2.25E+00]	1.37E+01*** [2.21E+00]	1.32E+01*** [2.15E+00]
Hong Kong	2.48E-01*** [7.80E-02]	1.64E+01*** [7.03E-01]	1.68E+01*** [7.01E-01]	1.66E+01*** [6.90E-01]	1.60E+01*** [6.82E-01]
Japan	-1.98E+00*** [1.44E-01]	2.33E+01*** [2.12E+00]	2.29E+01***[2.09E+00]	2.25E+01*** [2.06E+00]	2.17E+01*** [2.00E+00]
New Zealand	2.14E+00*** [1.01E-01]	-2.69E+13*** [3.65E+12]	-3.76E+13*** [4.51E+12]	-7.17E+13*** [9.55E+12]	-1.24E+14*** [1.66E+13]
South Africa	1.20E+01*** [1.24E-01]	3.68E+01*** [8.23E+00]	3.56E+01*** [8.15E+00]	3.79E+01*** [7.99E+00]	3.94E+01*** [7.77E+00]
United Kingdom	1.30E+00*** [1.88E-01]	-1.11E+01* [6.26E+00]	-9.83E+00 [6.21E+00]	3.52E+01*** [3.57E+00]	3.38E+01*** [3.47E+00]
United States	3.73E-01** [1.48E-01]	5.70E+01*** [3.72E+00]	3.34E+08*** [6.65E+07]	-7.82E+08*** [2.43E+08]	-7.66E+08** [3.41E+08]
Health Care					
Canada	1.11E+00*** [3.64E-02]	1.72E+01*** [1.85E+00]	1.72E+01*** [1.83E+00]	1.59E+01*** [1.81E+00]	1.49E+01*** [1.77E+00]
New Zealand	5.14E+00*** [1.50E-01]	1.85E+01*** [1.95E+00]	1.89E+01*** [1.93E+00]	1.90E+01*** [1.90E+00]	2.07E+01*** [1.86E+00]
United Kingdom	-3.72E+00*** [1.04E-01]	7.52E+00*** [1.58E+00]	7.44E+00*** [1.56E+00]	7.50E+00*** [1.53E+00]	6.53E+00*** [1.49E+00]
United States	3.01E+00*** [1.11E-01]	3.22E+01*** [3.03E+00]	3.23E+01*** [3.00E+00]	2.92E+01*** [3.18E+00]	2.85E+01*** [3.09E+00]
Hedge					
China	-9.16E-01*** [7.35E-02]	2.20E+01*** [1.44E+00]	2.16E+01*** [1.43E+00]	2.14E+01*** [1.40E+00]	2.08E+01*** [1.36E+00]
Hotel and Hospitality REITs					
Canada	-3.65E+01*** [2.50E+00]	2.17E+00 [6.12E+00]	9.12E-01 [5.87E+00]	-1.19E+01* [6.10E+00]	-1.19E+01* [6.10E+00]
China	0.00E+00** [0.00E+00]	1.50E+01*** [2.10E+00]	1.41E+01*** [2.04E+00]	1.34E+01*** [1.93E+00]	1.27E+01*** [1.78E+00]
Japan	9.50E+00*** [1.55E-01]	3.83E+01*** [5.19E+00]	3.79E+01*** [5.14E+00]	3.60E+01*** [5.05E+00]	3.53E+01*** [4.91E+00]
Mexico	2.61E+00*** [2.45E-01]	2.07E+02*** [7.62E+00]	2.65E+02*** [1.54E+01]	2.88E+02*** [1.65E+01]	2.91E+02*** [1.61E+01]
United States	7.38E-01*** [7.92E-02]	-2.69E+02*** [3.31E+01]	-2.65E+02*** [3.28E+01]	-2.57E+02*** [3.21E+01]	-2.45E+02*** [3.12E+01]
Industrial REITs					
Australia	-3.80E+00*** [1.12E-01]	1.58E+01*** [3.09E+00]	1.51E+01*** [3.06E+00]	1.37E+01*** [3.01E+00]	1.20E+01*** [2.93E+00]
Japan	-1.83E+00*** [9.68E-02]	1.43E+01 [8.68E+00]	1.25E+01 [8.60E+00]	1.15E+01 [8.43E+00]	2.02E+01*** [1.42E+00]
Mexico	-2.77E+00*** [2.21E-01]	1.48E+01*** [1.83E+00]	1.42E+01*** [1.87E+00]	1.39E+01*** [1.84E+00]	1.34E+01*** [1.78E+00]

South Africa	-2.86E+01*** [7.55E-01]	4.31E+02*** [1.29E+01]	4.30E+02*** [1.28E+01]	4.24E+02*** [1.26E+01]	4.17E+02*** [1.23E+01]
United Kingdom	-3.56E+00*** [7.30E-02]	2.74E+01*** [4.42E+00]	2.09E+01*** [2.76E+00]	2.27E+01*** [2.73E+00]	2.48E+01*** [2.67E+00]
United States	-5.62E-02 [5.63E-02]	-2.73E+02** [1.21E+02]	-2.91E+02** [1.20E+02]	-6.55E+02*** [1.36E+02]	-1.00E+03*** [1.44E+02]
Office REITs					
Australia	9.69E-01*** [4.25E-02]	3.46E+01*** [1.20E+00]	3.42E+01*** [1.20E+00]	2.82E+01*** [1.18E+00]	2.75E+01*** [1.15E+00]
Canada	1.51E+00*** [1.13E-01]	1.28E+01*** [3.49E+00]	1.25E+01*** [3.46E+00]	1.18E+01*** [3.39E+00]	1.00E+01*** [3.30E+00]
China	4.70E-01*** [7.54E-02]	9.42E+00*** [1.04E+00]	1.71E+01*** [9.42E-01]	1.67E+01*** [9.25E-01]	1.59E+01*** [9.03E-01]
Germany	8.14E-01*** [1.91E-01]	5.09E+01*** [2.77E+00]	4.25E+01*** [3.35E+00]	3.39E+01*** [3.68E+00]	2.33E+01*** [3.92E+00]
Hong-Kong	-1.41E+00*** [7.61E-02]	1.40E+01*** [9.39E-01]	1.37E+01*** [9.33E-01]	1.33E+01*** [9.17E-01]	1.24E+01*** [8.97E-01]
Italy	1.50E+00*** [7.79E-02]	6.92E+01*** [4.17E+00]	7.37E+01*** [4.24E+00]	7.74E+01*** [4.13E+00]	8.19E+01*** [4.05E+00]
Japan	-2.81E+00*** [8.30E-02]	1.93E+01*** [1.62E+00]	1.90E+01*** [1.61E+00]	1.86E+01*** [1.58E+00]	1.81E+01*** [1.53E+00]
South Africa	-2.90E-10 [1.39E-09]	1.78E+02*** [1.54E+01]	1.90E+02*** [1.55E+01]	2.32E+02*** [1.65E+01]	3.41E+02*** [2.26E+01]
United Kingdom	-6.80E+00*** [2.07E-01]	3.63E+01*** [4.77E+00]	3.59E+01*** [4.72E+00]	3.50E+01*** [4.63E+00]	3.25E+01*** [4.51E+00]
United States	3.44E+00*** [1.06E-01]	2.00E+01*** [2.52E+00]	1.98E+01*** [2.49E+00]	1.95E+01*** [2.44E+00]	1.93E+01*** [2.37E+00]
Residential REITs					
Australia	8.99E-01*** [3.96E-02]	5.07E+01*** [2.32E+00]	5.05E+01*** [2.30E+00]	5.05E+01*** [2.27E+00]	5.28E+01*** [2.26E+00]
Canada	2.03E-01*** [4.90E-02]	1.33E+01*** [1.33E+00]	1.31E+01*** [1.32E+00]	1.26E+01*** [1.29E+00]	1.18E+01*** [1.26E+00]
Japan	9.90E-01*** [7.73E-02]	1.35E+01*** [1.67E+00]	1.34E+01*** [1.65E+00]	1.33E+01*** [1.62E+00]	1.27E+01*** [1.58E+00]
United States	1.62E+00*** [1.03E-01]	3.40E+01*** [1.60E+00]	3.36E+01*** [1.59E+00]	3.28E+01*** [1.56E+00]	3.18E+01*** [1.52E+00]
Retail REITs					
Australia	-3.03E-01*** [9.04E-02]	5.97E+01*** [2.04E+00]	5.93E+01*** [2.02E+00]	6.78E+01*** [2.05E+00]	6.61E+01*** [2.01E+00]
Canada	-3.09E-01*** [6.98E-02]	1.24E+01*** [2.79E+00]	1.21E+01*** [2.76E+00]	1.05E+01*** [2.73E+00]	8.25E+00*** [2.67E+00]
China	-7.71E-01*** [9.58E-02]	2.48E+01*** [1.58E+00]	2.43E+01*** [1.56E+00]	2.44E+01*** [1.53E+00]	2.39E+01*** [1.50E+00]
France	-5.89E+00*** [1.43E-01]	5.82E+09*** [1.25E+09]	6.40E+10*** [1.07E+10]	7.60E+10*** [1.23E+10]	1.73E+11*** [1.91E+10]
Hong Kong	2.05E+00*** [4.70E-02]	1.86E+01*** [1.19E+00]	1.81E+01*** [1.19E+00]	1.83E+01*** [1.16E+00]	1.79E+01*** [1.13E+00]
Italy	1.94E+00*** [1.23E-01]	5.75E+01*** [4.14E+00]	5.99E+01*** [4.17E+00]	5.91E+01*** [4.09E+00]	5.80E+01*** [3.98E+00]
Japan	-6.12E-01*** [8.91E-02]	3.39E+01*** [3.40E+00]	3.35E+01*** [3.37E+00]	3.32E+01*** [3.30E+00]	3.23E+01*** [3.21E+00]
South Africa	3.84E+00*** [2.04E-01]	5.46E+01*** [4.90E+00]	5.40E+01*** [4.86E+00]	5.73E+01*** [4.79E+00]	6.05E+01*** [4.67E+00]
United Kingdom	-5.33E+00*** [1.62E-01]	5.68E+01*** [5.46E+00]	5.60E+01*** [5.41E+00]	5.51E+01*** [5.30E+00]	5.30E+01*** [5.16E+00]
United States	7.73E-01*** [1.16E-01]	-1.64E+02*** [1.99E+01]	-1.62E+02*** [1.97E+01]	-1.59E+02*** [1.93E+01]	-1.54E+02*** [1.87E+01]
Specialty REITs					
Australia	2.67E+01*** [5.06E-01]	4.56E+00** [2.10E+00]	4.15E+00** [2.09E+00]	4.61E+00** [2.05E+00]	5.40E+00*** [2.00E+00]
United States	-2.10E+00*** [7.37E-02]	1.44E+01*** [1.26E+00]	1.47E+01*** [1.25E+00]	1.64E+01*** [1.27E+00]	1.79E+01*** [1.25E+00]
Self-Storage REITs					
Australia	5.24E-07*** [1.35E-07]	9.53E+01*** [5.49E+00]	8.53E+01*** [5.24E+00]	7.17E+01*** [2.42E+00]	6.94E+01*** [2.35E+00]
United Kingdom	-9.02E+00*** [2.11E-01]	2.46E+01*** [2.02E+00]	2.52E+01*** [2.01E+00]	2.52E+01*** [1.97E+00]	2.44E+01*** [1.92E+00]
United States	-2.04E+00*** [6.88E-02]	6.51E+00*** [1.12E+00]	6.92E+00*** [1.12E+00]	9.38E=00*** [1.20E+00]	1.18E+01*** [1.28E+00]

Note: The results presented are estimations of the WN-type distributed lag predictive model for country-specific REITs realized volatility using the country-specific climate attention data singly as a predictor, while simultaneously accounting for inherent persistence, endogeneity, conditional heteroscedasticity and structural breaks. Column 2 presents the in-sample predictability of country-specific REITs realized volatility based on the country-specific climate attention; Columns 3 - 6 present the Clark and West (2007) test statistics that entail a pairwise comparison of our predictive model with the benchmark AR(1) model. Each cell in the table contains the estimates and the corresponding standard errors in square brackets; while ***, ** and * indicate statistical significance at the 1%, 5% and 10% level, respectively. Under the Clark and West result columns, our predictive model is judged as preferred when the CW statistic is positive and statistically significant.

3.2.Predictability of Sectoral REITs Volatility based on Alternative Measures of Climate Uncertainty

After establishing the association between sectoral REITs volatility and climate uncertainty, as represented by climate change vulnerability, we further explore two additional proxies for climate policy uncertainty. Our aim is to evaluate the sensitivity of our results to different climate change risk proxies. Specifically, we examine country-specific climate policy uncertainty (see results in Table 3) and global climate policy uncertainty (see results in Table 4). The strong positive relationship between sectoral REITs volatility and climate uncertainty is reaffirmed, indicating that increased climate uncertainty correlates with heightened sectoral REITs volatility. This trend is consistent for both country-specific and global climate policy uncertainty. Notably, both types of

climate policy uncertainty lead to increased sectoral REITs volatility, emphasizing the sector's sensitivity to climate-related policies aimed at promoting environmentally friendly and conservative energy use. Stricter regulations appear to amplify sectoral REITs volatility in most cases, possibly due to ongoing trading and the perceived high returns of such risky assets. Including climate policy uncertainty indexes also enhances the forecast accuracy of the benchmark model. Our WN-type predictive model consistently outperforms the benchmark across both in-sample and out-of-sample periods (20, 60, and 120 days). In conclusion, climate policy uncertainty, whether country-specific or global, has significant predictive power for sectoral REITs volatility, and the robustness of forecast performance remains strong across various forecast horizons.

Table 3: Country-Specific REITs and Country-Specific measure of Climate Policy Uncertainty

Country	Predictability	Forecast Evaluation			
	Parameter Estimate	In-Sample	Out-of-Sample		
			$h = 20$	$h = 60$	$h = 120$
Diversified REITs					
Canada	3.14E-04*** [1.70E-05]	2.68E+01*** [2.38E+00]	2.66E+01*** [2.36E+00]	2.62E+01*** [2.32E+00]	2.56E+01*** [2.26E+00]
China	1.85E-03*** [3.08E-05]	-1.79E-01 [2.12E+00]	-3.15E-01 [2.10E+00]	-1.62E-01 [2.06E+00]	-9.26E-01 [2.02E+00]
France	1.54E-04*** [1.44E-05]	8.85E+00*** [2.27E+00]	8.65E+00*** [2.26E+00]	9.25E+00*** [2.22E+00]	5.53E+00** [2.25E+00]
Germany	-5.04E-05*** [7.19E-06]	1.48E+01*** [1.44E+00]	1.43E+01*** [1.43E+00]	1.43E+01*** [1.41E+00]	1.30E+01*** [1.39E+00]
Japan	7.48E-05*** [6.79E-06]	1.28E+01*** [1.69E+00]	1.20E+01*** [1.69E+00]	1.16E+01*** [1.66E+00]	1.30E+01*** [1.63E+00]
United Kingdom	1.40E-04*** [1.87E-05]	2.83E+01*** [2.04E+00]	2.80E+01*** [2.03E+00]	2.75E+01*** [1.99E+00]	2.68E+01*** [1.95E+00]
United States	3.52E-04*** [1.11E-05]	-5.78E+09*** [1.81E+09]	-5.78E+09*** [1.81E+09]	-3.64E+09 [2.73E+09]	-2.23E+09 [2.94E+09]
Health Care					
Canada	6.09E-04*** [9.08E-06]	1.77E+01*** [1.10E+00]	1.76E+01*** [1.09E+00]	1.73E+01*** [1.07E+00]	1.69E+01*** [1.06E+00]
United Kingdom	1.05E-03*** [2.06E-05]	6.58E+00*** [1.48E+00]	6.62E+00*** [1.47E+00]	7.17E+00*** [1.45E+00]	7.07E+00*** [1.41E+00]
United States	3.62E-04*** [5.84E-06]	1.08E+01*** [3.18E+00]	1.07E+01*** [3.15E+00]	1.05E+01*** [3.10E+00]	1.05E+01*** [3.02E+00]
Hedge					
China	-3.51E-04*** [2.51E-05]	1.33E+01*** [7.76E-01]	1.33E+01*** [7.70E-01]	1.32E+01*** [7.57E-01]	1.30E+01*** [7.42E-01]
Hotel and Hospitality REITs					
Canada	4.12E-03*** [5.25E-05]	7.96E+00*** [1.33E+00]	8.84E+00*** [1.37E+00]	4.40E+01*** [7.85E+00]	3.26E+01*** [7.56E+00]
China	2.29E-12*** [8.57E-13]	2.43E+01*** [1.42E+00]	2.40E+01*** [1.42E+00]	2.36E+01*** [1.39E+00]	2.23E+01*** [1.36E+00]
Japan	-3.87E-06 [9.37E-06]	4.00E+01*** [3.18E+00]	3.99E+01*** [3.15E+00]	3.89E+01*** [3.10E+00]	3.79E+01*** [3.03E+00]
United States	-5.00E-04*** [0.00E+00]	-3.51E+01*** [8.34E+00]	-3.49E+01*** [8.27E+00]	-4.00E+01*** [8.18E+00]	-4.46E+01*** [8.00E+00]
Industrial REITs					
Japan	4.66E-05*** [6.99E-06]	1.35E+01*** [1.10E+00]	1.28E+01*** [1.10E+00]	1.35E+01*** [1.10E+00]	1.59E+01*** [1.14E+00]
United Kingdom	3.72E-04*** [1.50E-05]	1.74E+01*** [1.23E+00]	1.72E+01*** [1.22E+00]	1.69E+01*** [1.20E+00]	1.64E+01*** [1.17E+00]
United States	3.34E-04*** [9.73E-06]	3.50E+01*** [7.43E+00]	3.40E+01*** [7.37E+00]	3.33E+01*** [7.25E+00]	3.43E+01*** [7.07E+00]
Office REITs					
Canada	2.77E-04*** [1.33E-05]	6.40E+00** [2.74E+00]	6.44E+00** [2.72E+00]	5.48E+00** [2.68E+00]	4.97E+00* [2.61E+00]
China	2.12E-04*** [2.32E-05]	2.67E+01*** [1.26E+00]	2.56E+01*** [1.14E+00]	2.53E+01*** [1.12E+00]	2.48E+01*** [1.10E+00]
Germany	1.92E-03*** [3.86E-05]	3.97E+01*** [1.64E+00]	4.18E+01*** [1.71E+00]	3.95E+01*** [1.75E+00]	4.26E+01*** [1.85E+00]
Japan	1.61E-04*** [9.91E-06]	1.13E+01*** [1.83E+00]	1.05E+01*** [1.82E+00]	9.92E+00*** [1.79E+00]	1.03E+01*** [1.75E+00]
United Kingdom	-2.49E-04*** [1.15E-05]	2.00E+01*** [3.52E+00]	2.03E+01*** [3.49E+00]	2.03E+01*** [3.43E+00]	1.97E+01*** [3.34E+00]
United States	1.38E-04*** [5.37E-06]	5.47E+13 [5.99E+13]	4.32E+13 [6.53E+13]	-1.15E+15*** [2.30E+14]	-3.45E+15*** [4.25E+14]
Residential REITs					
Canada	2.23E-04*** [1.20E-05]	1.38E+01*** [8.92E-01]	1.37E+01*** [8.85E-01]	1.34E+01*** [8.71E-01]	1.30E+01*** [8.51E-01]
Japan	1.29E-05* [6.72E-06]	8.42E+00*** [1.02E+00]	7.75E+00*** [1.02E+00]	7.39E+00*** [1.01E+00]	8.24E+00*** [1.01E+00]
United States	1.81E-04*** [1.26E-05]	1.22E+01*** [1.21E+00]	1.19E+01*** [1.20E+00]	1.19E+01*** [1.18E+00]	1.16E+01*** [1.15E+00]
Retail REITs					
Canada	8.26E-04*** [2.08E-05]	9.76E+00*** [2.00E+00]	5.33E+00** [2.35E+00]	4.41E+00* [2.31E+00]	4.05E+00* [2.26E+00]

China	-4.86E-04*** [3.98E-05]	1.67E+01*** [1.33E+00]	1.64E+01*** [1.27E+00]	1.65E+01*** [1.25E+00]	1.63E+01*** [1.22E+00]
Japan	1.15E-04*** [9.63E-06]	1.54E+01*** [3.80E+00]	1.67E+01*** [3.68E+00]	1.64E+01*** [3.62E+00]	1.53E+01*** [3.53E+00]
United Kingdom	1.01E-04** [3.97E-05]	8.18E+01*** [2.62E+00]	8.13E+01*** [2.60E+00]	7.99E+01*** [2.56E+00]	7.74E+01*** [2.52E+00]
United States	-1.31E-04*** [3.43E-05]	-4.12E+01*** [7.28E+00]	-4.07E+01*** [7.20E+00]	-4.17E+01*** [7.09E+00]	-4.11E+01*** [6.92E+00]
Specialty REITs					
United States	2.86E-04*** [1.53E-05]	1.05E+01*** [7.12E-01]	1.04E+01*** [7.06E-01]	1.05E+01*** [6.96E-01]	1.07E+01*** [6.80E-01]
Self-Storage REITs					
United Kingdom	-4.33E-04*** [2.12E-05]	1.83E+01*** [1.37E+00]	1.76E+01*** [1.62E+00]	1.72E+01*** [1.60E+00]	1.70E+01*** [1.56E+00]
United States	3.26E-04*** [1.29E-05]	1.18E+01*** [6.98E-01]	5.64E+00*** [7.29E-01]	5.59E+00*** [7.17E-01]	5.36E+00*** [7.00E-01]

Note: The results presented in the table are estimations of the WN-Type distributed lag predictive model for country-specific REITs realized volatility using country-specific climate policy uncertainty singly as predictors, while simultaneously accounting for inherent persistence, endogeneity, conditional heteroscedasticity and structural breaks. Column 2 presents the in-sample predictability of country-specific REITs realized volatility based on the country-specific climate policy uncertainty; Columns 3 - 6 present the Clark and West (2007) test statistics that entail a pairwise comparison of our predictive model with the benchmark AR(1) model. Each cell in the table contains the estimates and the corresponding standard errors in square brackets; while ***, ** and * indicate statistical significance at the 1%, 5% and 10% level, respectively. Under the Clark and West result columns, our predictive model is judged as preferred when the CW statistic is positive and statistically significant.

Table 4: Country-Specific REITs and Global Climate Policy Uncertainty

Country	Predictability	Forecast Evaluation			
	Parameter Estimate	In-Sample	Out-of-Sample		
			$h = 20$	$h = 60$	$h = 120$
Diversified REITs					
Canada	1.30E-03*** [5.23E-05]	1.89E+01*** [3.06E+00]	1.87E+01*** [3.04E+00]	1.84E+01*** [2.99E+00]	1.81E+01*** [2.91E+00]
China	3.84E-03*** [5.51E-05]	6.83E+00*** [1.70E+00]	6.72E+00*** [1.66E+00]	6.72E+00*** [1.66E+00]	6.93E+00*** [1.62E+00]
France	3.30E-04*** [5.22E-05]	6.06E+00** [2.37E+00]	6.78E+00*** [2.34E+00]	7.52E+00*** [2.30E+00]	3.38E+00 [2.35E+00]
Germany	1.12E-04*** [2.54E-05]	1.34E+01*** [1.04E+00]	1.32E+01*** [1.03E+00]	1.73E+01*** [1.23E+00]	1.63E+01*** [1.21E+00]
Japan	2.66E-04*** [1.92E-05]	8.65E+00*** [2.72E+00]	8.76E+00*** [2.70E+00]	8.65E+00*** [2.65E+00]	7.92E+00*** [2.59E+00]
United Kingdom	1.60E-03*** [3.94E-05]	2.89E+01*** [2.41E+00]	2.84E+01*** [2.40E+00]	2.77E+01*** [2.36E+00]	2.73E+01*** [2.30E+00]
United States	7.32E-04*** [3.52E-05]	3.56E+01*** [2.06E+00]	3.41E+01*** [2.08E+00]	3.42E+01*** [2.10E+00]	3.34E+01*** [2.06E+00]
Health Care					
Canada	6.98E-04*** [2.63E-05]	1.12E+01*** [1.37E+00]	1.16E+01*** [1.36E+00]	1.20E+01*** [1.49E+00]	1.19E+01*** [1.46E+00]
United Kingdom	2.59E-03*** [6.87E-05]	8.69E+00*** [1.30E+00]	8.61E+00*** [1.29E+00]	8.70E+00*** [1.26E+00]	8.43E+00*** [1.23E+00]
United States	2.31E-03*** [2.86E-05]	1.22E+01*** [3.18E+00]	1.21E+01*** [3.15E+00]	1.18E+01*** [3.10E+00]	1.18E+01*** [3.02E+00]
Hedge					
China	7.23E-04*** [2.20E-05]	1.49E+01*** [9.38E-01]	1.48E+01*** [9.30E-01]	1.21E+01*** [6.22E-01]	1.18E+01*** [6.12E-01]
Hotel and Hospitality REITs					
China	4.11E-11 [2.75E-11]	2.49E+01*** [1.33E+00]	2.46E+01*** [1.33E+00]	2.42E+01*** [1.30E+00]	2.29E+01*** [1.26E+00]
Japan	-7.61E-04*** [1.53E-05]	7.15E+01*** [3.32E+00]	3.96E+01*** [3.03E+00]	3.86E+01*** [2.98E+00]	3.77E+01*** [2.91E+00]
United States	2.01E-03*** [2.50E-05]	1.02E+01* [5.72E+00]	-3.01E+01*** [8.30E+00]	-3.52E+01*** [8.20E+00]	-3.99E+01*** [8.03E+00]
Industrial REITs					
Japan	1.06E-03*** [4.73E-05]	9.67E+00*** [1.55E+00]	6.89E+00*** [1.74E+00]	6.78E+00*** [1.71E+00]	6.57E+00*** [1.67E+00]
United Kingdom	1.63E-03*** [2.38E-05]	1.64E+01*** [1.37E+00]	1.62E+01*** [1.35E+00]	1.61E+01*** [1.33E+00]	1.64E+01*** [1.30E+00]
United States	7.37E-04*** [3.18E-05]	-1.51E+02*** [4.17E+01]	-1.34E+02*** [4.16E+01]	5.50E+01*** [8.48E+00]	5.69E+01*** [8.28E+00]
Office REITs					
Canada	1.06E-03*** [4.04E-05]	7.90E+00*** [2.59E+00]	7.93E+00*** [2.56E+00]	6.98E+00*** [2.53E+00]	6.60E+00*** [2.45E+00]
China	1.25E-03*** [3.94E-05]	2.55E+01*** [1.19E+00]	2.51E+01*** [1.18E+00]	2.49E+01*** [1.16E+00]	2.46E+01*** [1.14E+00]
Germany	-9.72E-05 [1.14E-04]	3.92E+01*** [1.57E+00]	4.06E+01*** [1.60E+00]	3.88E+01*** [1.62E+00]	4.11E+01*** [1.67E+00]
Japan	6.49E-04*** [3.05E-05]	8.04E+00*** [2.51E+00]	1.20E+01*** [2.17E+00]	1.19E+01*** [2.13E+00]	1.15E+01*** [2.08E+00]
United Kingdom	-1.54E-03*** [8.48E-05]	1.76E+01*** [3.33E+00]	1.81E+01*** [3.30E+00]	1.85E+01*** [3.24E+00]	1.77E+01*** [3.16E+00]
United States	1.63E-04*** [1.60E-05]	-7.36E+11 [1.03E+12]	-8.22E+11 [1.09E+12]	-1.81E+13*** [3.36E+12]	-4.26E+13*** [5.03E+12]
Residential REITs					
Canada	6.85E-04*** [1.41E-05]	1.52E+01*** [7.85E-01]	1.49E+01*** [7.82E-01]	1.59E+01*** [7.90E-01]	1.73E+01*** [7.98E-01]
Japan	5.85E-04*** [3.02E-05]	6.21E+00*** [1.86E+00]	6.21E+00*** [1.85E+00]	6.13E+00*** [1.82E+00]	5.80E+00*** [1.77E+00]
United States	2.16E-04*** [1.79E-05]	1.44E+01*** [1.18E+00]	1.43E+01*** [1.17E+00]	1.41E+01*** [1.15E+00]	1.38E+01*** [1.12E+00]
Retail REITs					
Canada	5.59E-04*** [2.88E-05]	-1.40E+01*** [5.38E+00]	-1.31E+01** [5.34E+00]	4.43E+00** [2.24E+00]	4.09E+00* [2.19E+00]
China	4.38E-04*** [2.54E-05]	1.53E+01*** [1.04E+00]	1.54E+01*** [1.03E+00]	1.17E+01*** [6.70E-01]	1.15E+01*** [6.56E-01]
Japan	5.40E-04*** [2.81E-05]	1.72E+01*** [3.56E+00]	1.74E+01*** [3.52E+00]	1.72E+01*** [3.47E+00]	1.61E+01*** [3.38E+00]
United Kingdom	1.10E-03*** [8.52E-05]	-1.45E+01** [6.44E+00]	-1.44E+01** [6.39E+00]	-1.41E+01** [6.28E+00]	-1.40E+01** [6.12E+00]
United States	-2.01E-03*** [5.57E-05]	-2.42E+01*** [5.83E+00]	-2.41E+01*** [5.78E+00]	-2.51E+01*** [5.69E+00]	-2.49E+01*** [5.56E+00]
Specialty REITs					

United States	4.20E-04*** [2.63E-05]	8.62E+00*** [1.09E+00]	1.08E+01*** [7.53E-01]	1.06E+01*** [7.41E-01]	1.07E+01*** [7.23E-01]
Self-Storage REITs					
United Kingdom	-9.38E-05*** [2.62E-05]	1.54E+01*** [1.62E+00]	1.52E+01*** [1.61E+00]	1.48E+01*** [1.58E+00]	1.45E+01*** [1.54E+00]
United States	3.68E-04*** [3.95E-05]	9.82E+00*** [5.26E-01]	9.76E+00*** [5.22E-01]	9.64E+00*** [5.13E-01]	9.50E+00*** [5.01E-01]

Note: The results presented on the table are estimations of the WN-Type distributed lag predictive model for country-specific REITs realized volatility using global climate policy uncertainty singly as predictors, while simultaneously accounting for inherent persistence, endogeneity, conditional heteroscedasticity and structural breaks. Column 2 presents the in-sample predictability of country-specific REITs realized volatility based on the global climate policy uncertainty; Columns 3 - 6 present the Clark and West (2007) test statistics that entail a pairwise comparison of our predictive model with the benchmark AR(1) model. Each cell in the table contains the estimates and the corresponding standard errors in square brackets; while ***, ** and * indicate statistical significance at the 1%, 5% and 10% level, respectively. Under the Clark and West result columns, our predictive model is judged as preferred when the CW statistic is positive and statistically significant.

3.3. Additional Results: Overall Country-Specific REITs

Shifting from the sectoral analysis to overall REITs, Table 5 presents the predictability results for the overall country-specific REITs volatility and its relationship with climate uncertainty, along with the Clark and West (2007) forecast evaluation results. Our goal is to determine the existing association between each country's overall REITs volatility and various climate uncertainty proxies. We observe a predominance of positive and significant coefficients for the climate change risk proxies (country-specific CCV, country-specific CPU, and global CPU) in predicting overall REITs volatility. This indicates that the overall REITs volatility in most countries responds positively to climate uncertainty, highlighting the resilience of REITs to adverse climate change risks. This resilience is particularly attractive to risk-loving investors, given the severe global effects of climate changes. The Clark and West (2007) results strongly support our predictive model that incorporates any of the climate uncertainty measures as predictors for country-specific REITs volatility. Additionally, our results remain robust across various forecast periods.

Table 5: Predictability of Climate Uncertainty Proxies for Overall Country-Specific REITs

Country	Predictability	Forecast Evaluation			
	Parameter Estimate	In-Sample	Out-of-Sample		
			$h = 20$	$h = 60$	$h = 120$
Country-Specific CCV					
Australia	-7.33E-01*** [6.83E-02]	-9.59E+00** [4.13E+00]	-8.54E+00** [4.10E+00]	-6.74E+00* [4.05E+00]	-2.53E+00 [3.98E+00]
Canada	4.73E-01*** [8.14E-02]	1.83E+01*** [2.10E+00]	1.79E+01*** [2.08E+00]	1.64E+01*** [2.06E+00]	1.43E+01*** [2.02E+00]
China	-9.92E-01*** [7.57E-02]	2.24E+01*** [1.41E+00]	2.19E+01*** [1.40E+00]	2.18E+01*** [1.38E+00]	2.12E+01*** [1.34E+00]
France	2.33E+00*** [1.90E-01]	9.04E+01*** [7.79E+00]	8.77E+01*** [7.78E+00]	8.55E+01*** [7.64E+00]	8.11E+01*** [7.43E+00]
Germany	1.34E+00*** [1.11E-01]	2.12E+01*** [2.23E+00]	1.81E+01*** [2.32E+00]	1.58E+01*** [2.32E+00]	1.42E+01*** [2.28E+00]
Hong Kong	7.59E-01*** [7.86E-02]	2.04E+01*** [1.26E+00]	1.98E+01*** [1.25E+00]	1.98E+01*** [1.23E+00]	1.92E+01*** [1.19E+00]
Italy	3.27E+00*** [1.71E-01]	5.57E+01*** [2.44E+00]	5.47E+01*** [2.43E+00]	5.35E+01*** [2.39E+00]	5.21E+01*** [2.33E+00]
Japan	-1.20E+00*** [7.65E-02]	-3.69E+01*** [9.77E+00]	-3.62E+01*** [9.67E+00]	-3.57E+01*** [9.47E+00]	1.57E+01*** [1.66E+00]
Mexico	-1.37E+00*** [1.31E-01]	9.80E+00 [6.14E+00]	8.77E+00 [6.09E+00]	8.38E+00*** [2.67E+00]	8.11E+00*** [2.59E+00]
New Zealand	1.50E+00*** [8.40E-02]	2.10E+01*** [6.73E-01]	2.20E+01*** [6.68E-01]	2.20E+01*** [6.58E-01]	2.21E+01*** [6.41E-01]
South Africa	1.47E+01*** [1.83E-01]	3.35E+01*** [8.06E+00]	3.25E+01*** [7.98E+00]	3.30E+01*** [7.65E+00]	3.59E+01*** [7.46E+00]
Spain	4.01E+00*** [1.76E-01]	2.75E+01*** [4.94E+00]	3.10E+01*** [4.95E+00]	4.40E+01*** [3.31E+00]	4.63E+01*** [3.23E+00]
United Kingdom	-5.13E+00*** [7.79E-02]	2.94E+01*** [3.41E+00]	2.89E+01*** [3.33E+00]	2.81E+01*** [3.26E+00]	2.62E+01*** [3.18E+00]
United States	1.37E+00*** [8.62E-02]	5.23E+07*** [1.94E+07]	3.29E+07* [1.99E+07]	-2.91E+08*** [6.65E+07]	-6.03E+08*** [9.61E+07]
Country-specific CPU					
Canada	1.99E-04*** [1.58E-05]	8.41E+00*** [1.82E+00]	8.49E+00*** [1.81E+00]	7.85E+00*** [1.79E+00]	7.41E+00*** [1.74E+00]

China	-3.41E-04*** [2.06E-05]	1.33E+01*** [7.46E-01]	1.33E+01*** [7.40E-01]	1.33E+01*** [7.28E-01]	1.31E+01*** [7.14E-01]
France	9.20E-04*** [4.35E-05]	1.25E+02*** [4.06E+00]	1.24E+02*** [4.03E+00]	1.22E+02*** [3.97E+00]	1.21E+02*** [3.88E+00]
Germany	3.47E-05*** [1.23E-05]	3.99E+01*** [1.71E+00]	4.26E+01*** [1.83E+00]	4.01E+01*** [1.88E+00]	4.10E+01*** [1.90E+00]
Japan	6.71E-05*** [3.43E-06]	7.29E+00*** [1.50E+00]	6.68E+00*** [1.49E+00]	6.53E+00*** [1.47E+00]	7.62E+00*** [1.44E+00]
United Kingdom	-6.90E-06 [8.22E-06]	6.42E+01*** [4.06E+00]	6.40E+01*** [4.02E+00]	6.35E+01*** [3.96E+00]	6.11E+01*** [3.87E+00]
United States	2.02E-04*** [8.01E-06]	-5.93E+05*** [2.22E+05]	-1.58E+05 [2.42E+05]	-4.58E+05 [2.86E+05]	-1.71E+06*** [3.57E+05]
Global CPU					
Canada	1.13E-03*** [2.77E-05]	6.33E+00*** [2.05E+00]	6.38E+00*** [2.04E+00]	5.91E+00*** [2.00E+00]	5.53E+00*** [1.95E+00]
China	3.77E-04*** [2.64E-05]	1.21E+01*** [6.34E-01]	1.21E+01*** [6.28E-01]	1.21E+01*** [6.18E-01]	1.18E+01*** [6.06E-01]
France	-4.62E-04*** [1.33E-05]	1.31E+02*** [3.75E+00]	1.30E+02*** [3.72E+00]	1.28E+02*** [3.67E+00]	1.26E+02*** [3.59E+00]
Germany	1.01E-03*** [3.19E-05]	4.06E+01*** [1.75E+00]	4.33E+01*** [1.86E+00]	4.07E+01*** [1.92E+00]	4.16E+01*** [1.94E+00]
Japan	5.77E-04*** [4.81E-05]	6.82E+00*** [2.22E+00]	6.92E+00*** [2.20E+00]	6.80E+00*** [2.16E+00]	6.19E+00*** [2.11E+00]
United Kingdom	1.55E-03*** [3.47E-05]	3.25E+01*** [1.37E+00]	3.24E+01*** [1.36E+00]	3.21E+01*** [1.34E+00]	3.07E+01*** [1.32E+00]
United States	4.73E-04*** [1.26E-05]	-1.44E+06** [6.88E+05]	2.64E+04 [7.59E+05]	-9.74E+05 [9.82E+05]	-5.69E+06*** [1.27E+06]

Note: The results presented on the table are estimations of the WN-Type distributed lag predictive model for country-specific REITs realized volatility using country-specific climate attention data singly as predictors, while simultaneously accounting for inherent persistence, endogeneity, conditional heteroscedasticity and structural breaks. Column 2 presents the in-sample predictability of country-specific REITs realized volatility based on the country-specific climate attention; Columns 3 - 6 present the Clark and West (2007) test statistics that entail a pairwise comparison of our predictive model with the benchmark AR(1) model. Each cell in the table contains the estimates and the corresponding standard errors in square brackets; while ***, ** and * indicate statistical significance at the 1%, 5% and 10% level, respectively. Under the Clark and West result columns, our predictive model is judged as preferred when the CW statistic is positive and statistically significant.

4. Conclusion

REITs are at the heart of climate change. In this research paper, we delve into the intricate relationship between various climate risk measures and REITs, building upon the work of Salisu et al. (2024). We seek to comprehensively analyse how the realized volatility of country-specific sectoral REITs is related to both country-specific and global climate risk measures covering both physical and transitional climate risks. To this end, we use daily frequency data for country-specific sectoral REITs from 14 carefully selected countries, encompassing a diverse range of sectors, including healthcare, hospitality, industrial, office, residential, retail, and others. Additionally, our analysis incorporates country-specific and global climate change physical and transition risk measures, such as climate attention, which encompasses climate change vulnerability (CCV), and climate policy uncertainty (CPU) indexes.

According to data availability, various start and end dates are used, commencing as early as January 1, 2013, and extending to the latest available date of October 19, 2022, allowing us to capture a comprehensive view of the dynamics over time. The empirical analysis offers insights through in-sample predictability and out-of-sample forecast evaluation for various periods ahead, including 20, 60, and 120-day forecasts. This allows us to contribute to a deeper understanding of the intricate relationship between climate risk uncertainty and the behaviour of REITs across various sectors and countries.

The results reveal a general positive relationship between REITs volatility and climate uncertainty, except for country-specific industrial, retail, and self-storage REITs, where the relationship is generally negative. On the one hand, the negative relationship suggests that heightened climate uncertainty tends to reduce REITs volatility, possibly due to reduced trading activities induced by investors' risk aversion. On the other, the positive relationship suggests that REITs volatility tends to increase with heightened climate uncertainty, which may imply that investors seek safe returns in the REITs market to hedge against climate risks. Additionally, there is a predominance of positive and significant coefficients for the climate uncertainty proxies (country-specific CCV, country-specific CPU, and global CPU) in predicting overall REITs volatility. This indicates that, on average, REITs volatility in most countries responds positively to climate uncertainty, highlighting the resilience of REITs to adverse climate changes. However, the results also show that both types of climate policy uncertainty lead to increased sectoral REITs volatility, emphasizing most sectors' sensitivity to climate-related policies promoting environmentally friendly and conservative energy use.

During the last decade, REITs have grown substantially as an investment instrument, driven by their accessibility for various investors, irrespective of portfolio size (Marfatia et al., 2017), and utility for asset allocation and risk reduction. According to the latest available figures, as of December 2023, the value of the REITs market listed worldwide stands at over US $3.2 trillion (Statista, 2024).[9] Understandably, accurate forecasting of the volatility of REITs due to climate related uncertainties is an important issue for market players, since volatility (as a metric of risk) plays a crucial role in portfolio diversification, derivatives pricing, hedging and financial risk management (Granger and Poon, 2003). Moreover, with real estate market uncertainty playing a crucial role in economic crises, as observed during the Global Financial Crisis of 2007-2009, accurate forecasts of REITs volatility would provide information to policymakers wanting to make timely monetary and fiscal policy decisions to reduce risks in the REITs sector and the possible associated recessionary impact on the economy (Segnon et al., 2021).

Our above analysis brings a sense of urgency to climate change physical and transition risks to the REITs market, highlighting evidence of mixed positive and negative effects on return volatility

[9] https://www.statista.com/statistics/1189675/listed-real-estate-market-size-global/.

under a global economy which is supposed to move ever faster towards decarbonization. Ultimately, the climate transition will induce new responsibilities for REITs players to revalue their portfolios and make them resilient. Potential decarbonization should attract new capital committed to net zero, and thereby new opportunities and sources of revenue associated with the climate transition.

References

Andonov, A., Kok, N., and Eichholtz, P. (2013). A global perspective on pension fund investmentsin real estate. The Journal of Portfolio Management, 39(5), 32-42.

Anderson, R., McLemore, R., Conner, P., & Liang, Y. (2003). Portfolio Implications of Apartment Investing. Journal of Real Estate Research, 25(2), 113-132.

Arteaga-Garavito, M. J., Colacito, R., Croce, M. M., and Yang, B. (2023) International Climate News. Available at SSRN: https://ssrn.com/abstract=4713016 or http://dx.doi.org/10.2139/ssrn.4713016.

Baker, M., Bergstresser, D., Serafeim, G., and Wurgler, J. (2022). The pricing and ownership of US green bonds. Annual review of financial economics, 14(1), 415-437.

Bai, J., and Perron, P. (2003). Computation and analysis of multiple structural change models. Journal of applied econometrics, 18(1), 1-22.

Battiston, S., Dafermos, Y., and Monasterolo, I. (2021). Climate risks and financial stability. Journal of Financial Stability, 54, 100867

Biasin, M., Delle Foglie, A., and Giacomini, E. (2024). Addressing climate challenges through ESG-real estate investment strategies: An asset allocation perspective. Finance Research Letters, 63, 105381.

Bolton, P., and Kacperczyk, M. (2021). Do investors care about carbon risk?. Journal of financial economics, 142(2), 517-549.

Chiang, K. (2007). Spanning tests on public and private real estate. Journal of Real Estate Portfolio Management, 13(1), 7-15.

Choi, D., Gao, Z., and Jiang, W. (2020). Attention to global warming. The Review of Financial Studies, 33(3), 1112-1145.

Clark, T. E., and West, K. D. (2007). Approximately normal tests for equal predictive accuracy in nested models. Journal of Econometrics, 138(1), 291–311.

Custodio, C., Ferreira, M. A., Garcia-Appendini, E., and Lam, A. (2022). Economic impact of climate change. Nova SBE Working Paper Series, (645).

Cvijanovic, D., and van de Minne, A. (2021). Does climate change affect investment performance? Evidence from commercial real estate. Evidence from Commercial Real Estate. MIT Center for Real Estate Research Paper No. 21/15.

Del Fava, S., Gupta, R., Pierdzioch, C., and Rognone, L. (2024). Forecasting international financial stress: The role of climate risks. Journal of International Financial Markets, Institutions and Money, 92, 101975.

Delis, M. D., Greiff, K. D., Iosifidi, M., and Ongena, S. (2019). Being stranded with fossil fuel reserves? Climate policy risk and the pricing of bank loans. Financial Markets, Institutions & Instruments, 33(3), 239-265.

Dell, M., Jones, B. F., and Olken, B. A. (2009). Temperature and income: reconciling new cross-sectional and panel estimates. American Economic Review, 99(2), 198-204.

Dell, M., Jones, B. F., and Olken, B. A. (2012). Temperature shocks and economic growth: Evidence from the last half century. American Economic Journal: Macroeconomics, 4(3), 66-95.

Engle, R. F., Giglio, S., Kelly, B., Lee, H., and Stroebel, J. (2020). Hedging climate change news. The Review of Financial Studies, 33(3), 1184-1216.

Giglio, S., Maggiori, M., Rao, K., Stroebel, J., and Weber, A. (2021a). Climate change and long-run discount rates: Evidence from real estate. The Review of Financial Studies, 34(8), 3527-3571.

Giglio, S., Kelly, B., and Stroebel, J. (2021b). Climate finance. Annual review of financial economics, 13(1), 15-36.

Guo, K., Li, Y., Zhang, Y., Ji, Q., and Zhao, W. (2023). How are climate risk shocks connected to agricultural markets? Journal of Commodity Markets, 32, 100367.

Hoesli, M., and Oikarinen, E. (2012). Are REITs real estate? Evidence from international sector level data. Journal of International Money and Finance, 31(7), 1823-1850.

Huynh, T. D., and Xia, Y. (2021). Climate change news risk and corporate bond returns. Journal of Financial and Quantitative Analysis, 56(6), 1985-2009.

Lee, S., and Stevenson, S. (2005). The case for REITs in the mixed-asset portfolio in the short and long run. Journal of Real Estate Portfolio Management, 11(1), 55-80.

Marfatia, H. A., Gupta, R., and Cakan, E. (2017). The international REIT's time-varying response to the US monetary policy and macroeconomic surprises. The North American Journal of Economics and Finance, 42, 640-653.

Narayan, P. K., and Gupta, R. (2015). Has oil price predicted stock returns for over a century? Energy Economics, 48, 18–23.

Oestreich, A. M., and Tsiakas, I. (2015). Carbon emissions and stock returns: Evidence from the EU Emissions Trading Scheme. Journal of Banking & Finance, 58, 294-308.

Phan, D.H.B., Sharma, S.S., and Narayan, P.K. (2015). Stock return forecasting: some new evidence. International Review of Financial Analysis, 40, 38–51, 276.

Poon, S-H., and Granger, C.W.J. (2003). Forecasting volatility in financial markets: A review. Journal of Economic Literature, 41(2), 478-539.

Salisu, A.A. and Akanni, L. (2020). Constructing a global fear index for the COVID-19 pandemic. Emerging Markets Finance and Trade, 56 (10), 2310-2331.

Salisu, A.A., Cuñado, J., Isah, K., and Gupta, R. (2021a). Oil Price and Exchange Rate Behaviour of the BRICS. Emerging Markets Finance and Trade, 57(7), 2042-2051.

Salisu, A.A., Cuñado, J., Isah, K., and Gupta, R. (2021b). Stock markets and exchange rate behavior of the BRICS. Journal of Forecasting, 40(8), 1581-1595.

Salisu, A.A., Ogbonna, A.E., Oloko, T.F., and Adediran, I.A. (2021c). A New Index for Measuring Uncertainty Due to the COVID-19 Pandemic. Sustainability, 13, 3212. https://doi.org/10.3390/su13063212.

Salisu, A. A., Hammed, Y. S., and Ouattara, I. N. (2023a). Climate change, technology shocks and the US equity real estate investment trusts (REITs). Sustainability, 15(19), 14536.

Salisu, A., Omoke, P., and Fadiya, O. (2023b). Climate policy uncertainty and crude oil market volatility. Energy Research Letters, 4(1). https://doi.org/10.46557/001c.38781.

Salisu, A. A., Ogbonna, A. E., and Vo, X. V. (2024) Climate risks and the REITs market. International Journal of Finance & Economics, 1-17. https://doi.org/10.1002/ijfe.2983.

Segnon, M., Gupta, R., Lesame, K., and Wohar, M. E. (2021). High-frequency volatility forecasting of US housing markets. The Journal of Real Estate Finance and Economics, 62(2), 283-317.

Wheaton, W. C. (1999). Real estate "cycles": some fundamentals. Real Estate Economics, 27(2), 209-230

Wei, P., Mao, X., Chen, X., Ren, X., and Cheng, Y. (2022). Market implied volatility and natural disasters: international evidence. Environmental Science and Pollution Research, 29(56), 84962-84988.

Westerlund, J. and Narayan, P.K. 2012. Does the choice of estimator matter when forecasting returns? Journal of Banking and Finance, 36:2632–40.

Westerlund, J. and Narayan, P. K. (2015). Testing for predictability in conditionally heteroscedastic stock returns. Journal of Financial Econometrics, 13 (2):342–375.

Yaya, O. S. and Ogbonna, A. E. (2019). Do we Experience Day-of-the-week Effects in Returns and Volatility of Cryptocurrency? MPRA Paper 91429, University Library of Munich, Germany. https://mpra.ub.uni-muenchen.de/91429/1/MPRA_paper_91429.

Zhang, J., Lai, Y. and Lin, J. (2017). The day-of-the-Week effects of stock markets in different countries. Finance Research Letters, 20, 47-62.