POLITECNICO
MILANO 1863

School of Architecture, Urban Planning and Construction Engineering

School of Industrial and Information Engineering

Double Master Degree Course in Management of Built Environment - Management Engineering

Class of Degree LM 24 – Building Systems Engineering

Class of Degree LM 31 – Management Engineering

REITs and the recognition of climate change related events as a potential source of systemic risk

Supervisor Professor:

Prof. Gianandrea CIARAMELLA

Co-supervisor Professor:

Prof. Andrea Antonio CARAGLIU

Master Thesis of:

Federico BELLOSTA ID Number - 903964

Academic Year 2020 – 2021

INDEX

CHAPTER 7

CHAPTER 8

CHAPTER 9

INDEX OF FIGURES

EXECUTIVE SUMMARY

Hardly a day goes by without yet another report, editorial commentary or prediction about climate change and its risks, evidenced convincingly by countless scientific studies. Observable, measurable evidence includes increasing ocean and land temperatures; weather patterns and weather-related events of abnormal frequency and intensity such as hurricanes, flooding and wildfires; changing biosphere patterns; accelerating glacial melting at the poles and extreme northern and southern latitudes with consequent rising sea level. For many years, climate change for the finance industry has been understood by market players and regulators as a totally exogenous perturbation that would be nothing more than a bunch of weather perturbations that already occur potentially everyday everywhere, and would eventually, if things go bad in several decades, be addressed through their operational risk framework. This point is crucial, a potential world wide phenomenon has not being recognized as sytemic risk but instead treated as a normal day by day operational risk, without understanding that climate related effects can indeed wipe out or strain the foundations of financial institution operations. Climate fragilities increase financial fragilities.

Real estate assets across the nations are susceptible to both gradual and more acute climate risks, depending on geographical location and other factors. The ULI (Urban Land Institute) - Heitman Report published by IRE-BS (International Real Estate Business School) in 2017 and again in 2018, pointedly cited insurance industry volatility ***(β)*** stemming from uncertainty about an unknowable future and potentially skyrocketing premiums necessary to cover ever larger losses and claims. Viable and affordable insurance, a key to risk management, depends on being able to recognize and reasonably evaluate future risks.

This thesis has as its objective in the study of the relationship between real estate investment funds and site climatic events linked more widely to global climate change. The set objective is to understand whether these funds, in considering the risks in undertaking new investments, or even more simply in the risks of day-by-day operations, consider, in the world general ongoing situation of intensification both in terms of strength and in terms of frequency of severe events, the climatic phenomena as a potential source of systemic risk. To do so, a sample population of 32 different REITs based in three different countries, USA, Japan, Hong Kong, has been analyzed to unveil if really the perception of local extreme climated events linked to the wider global change, are actually matter of concern and taken into consideration as a potential source of a systemic risk for the entire industry and economy. The indicator used to trace the risk is the beta of the company. This coefficient is widely used in financial analysis to depict the systemic risk of security, and we usually refer to it as “volatility”. It compares the measure of the dispersion of returns for a given security or market index and in most of the cases, what it reflects is that the higher the volatility, the riskier the security for a given investor, but generally higher returns. The analysis is carried out researching the selected REITs’ beta trends for the last ten years, considereing all markets in which the funds invest, to then compare them with the other variable, the independent one, of climate events that characterize areas in which funds largely invest. Already in this first phase of the study some interesting elements stood out, pointing out a more aggressive behavior of eastern REITs, that follow a more standard type of investments with less attention to environmental protection, energy efficiency building, but more on the profitability items. While on the western side a more defensive approach by REITs also uncover a more climate oriented behavior, at least for some of them,

investing in proper corporate structered plans, also with external actors, to better respond to future needs of the portfolios.

The beta coefficient is really important and it is linked to multiple other financial coefficients and measures. Values returned by the systemic risk beta are indeed used in the computation of the cost of equity in the capital asset pricing model, that in turn is also linked to the computation of the cost of capital, important information since it reflects the compensation required by the suppliers of capital to the company. But also, the cost of capital is widely used in the computaton of maybe the most used tool to calculate the viability of investments in the real estate sector, that is the the net present value. The higher the cost of capital the lower the net present value.

The analysis then proceeded with a second step, aimed at unveil and investigate whether or not an association between the two variables under analysis is present, making use of a multiple correlation analysis. This analysis, also supported by graphical representation of the variables through proper scatterplots, points out specifically which of the funds take more into consideration climate events as a source of sistemic risk, and also depict to which typology of events a particular fund is more subjected. The results of this second step mainly confirm the previous ones, again pointing out a more widespread association, and thus recognition, of the western REITs compared to eastern ones.

The challenge for Real Estate sector in the upcoming years will be to better understand and recognize climate events as a potential source of systemic risk through the proper tools. Some of the sector operators and investors are already doing so exploiting new technologies, construction materials and external professionals expertise to build proper corporate environmental ESG funds. Unfortunately the majority instead still rely on old instruments and don't even think climate change is a real risk, postponing the issue to future generation of managers. What is sure is that climate risks affect not just the sustainability and physical resilience of properties, but also as their value (at present and in the future), capital appreciation, revenue and liquidity. Common "Tools" used by the majority of real estate companies, like Sustainability Due Diligence and KPIs are nowaday sufficiently spread, but surely they are not up to the situation. Strategic planning approaches like scenario analysis are almost totally lacking. This is due to the lack of awareness of long-term consequences, including the functional chain. Traditional tools and models rely strongly on the derived implications based on historical quantitative analysis, and so does also the real estate and construction sector, generally reluctant to big changes. In contrast of course, most of the risk related to climate change related extreme events involves forward looking data and studies which are often only available in a more qualitative form. To obtain a clear view on possible outcomes of future performance, the uncertainty and fundamental shifts of the real estate industry must be captured with appropriate tools.

CHAPTER 1

1. WHAT IS CLIMATE CHANGE?

Climate change is a change in the pattern of weather, and related changes in oceans, land surfaces and ice sheets, occurring over time scales of decades or longer. While weather is the state of the atmosphere, its temperature, humidity, wind, rainfall and so on, over hours to weeks. It is influenced by the oceans, land surfaces and ice sheets, which together with the atmosphere form what is called the 'climate system'. Climate, in its broadest sense, is the statistical description of the state of the climate system.
Climate change is a change in the statistical properties of the climate system, that persists for several decades or longer. These statistical properties include averages, variability and extremes. Climate change may be due to natural processes, such as changes in the Sun's radiation, volcanoes or internal variability in the climate system, or due to human influences such as changes in the composition of the atmosphere or land use.

What clearly emerges is that global average temperatures have increased over the past century. Climate and sea level were relatively stable over thousands of years of recorded human history up to the 19th century, although with some variations ***(Figure 1b)***. However, globally averaged near-surface air temperature rose by around 0.8°C between 1850 and 2012 ***(Figure 1c)***. The rate of warming increased in the mid-1970s, and each of the most recent three decades has been warmer than all preceding decades since 1850.

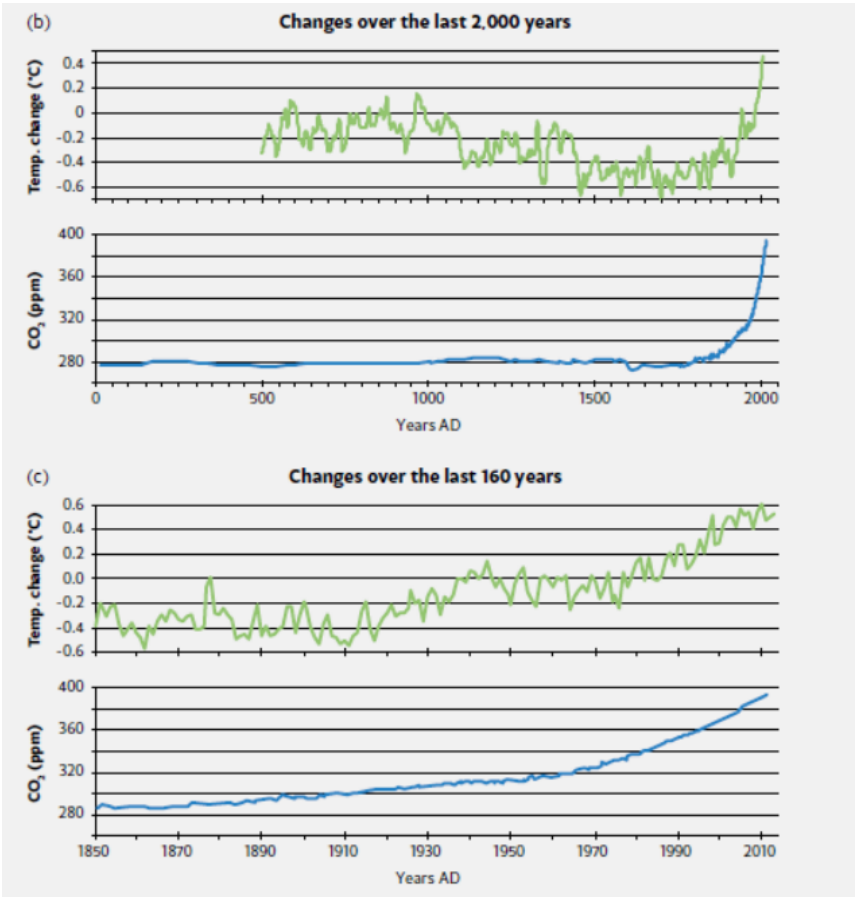


Figure 1b,1c *- These graphs show the changes from long-term average temperature (oC) and average atmospheric CO_2 concentration (parts per million) over the last (b) 2,000 years and (c) 160 years. The temperature changes in (b) and (c) are global averages. Source: "Global Carbon Project."*

Changes consistent with an increase in global temperature have been observed in many components of the climate system, as can be seen in the following list provided by IPCC:

- Mountain glaciers have been shrinking and contributing to global sea-level rise since about 1850. Melting accelerated significantly in the 1990s.
- The Greenland and West Antarctic Ice Sheets have both lost ice since 1990, further contributing to sea-level rise as discussed in Question 6. This is from increased discharge of ice into the ocean, and also increased surface melting in Greenland. The rate of loss from Greenland appears to be increasing.
- The area of the Arctic Ocean covered by sea ice has decreased significantly since 1990s. The thickness of the ice has also decreased by more than 30% over the last 30 years.
- In the Southern Ocean, there are strong regional differences in the changes to areas covered by sea ice, but a small increase in total coverage, driven by shifts in winds and ocean currents in a warming Southern Ocean. Strengthening circumpolar winds around Antarctica have also been linked in part to thinning of the ozone layer.
- The amount of water vapour in the atmosphere has increased since the 1980s, which is consistent with warmer air.
- The surface of the ocean in rainy parts of the world is becoming less salty, which is consistent with freshwater dilution from increased rainfall.
- Some ocean currents have changed in response to changes in surface winds, ocean temperature and ocean saltiness. The changes include a southward shift of the Antarctic Circumpolar Current and increasing southward penetration of the East Australian Current.
- An increasing number of plants and animals, on land and in the oceans, are undergoing shifts in their distribution and lifecycles that are consistent with observed temperature changes.

1.1. ARE HUMAN ACTIVITIES CAUSIG CLIMATE CHANGE?

There are close connections between temperature, atmospheric water vapour, the extent of polar ice sheets and the concentrations of long-lived greenhouse gases in the atmosphere. Today, human activities are directly increasing atmospheric concentrations of CO_2, methane and nitrous oxide, plus some chemically manufactured greenhouse gases such as halocarbons. These humangenerated gases enhance the natural greenhouse effect and further warm the surface. Since the 19th century, human-induced CO_2 emissions from fossil fuel combustion, cement manufacture and deforestation have disturbed the balance, adding CO_2 to the atmosphere faster than it can be taken up by the land biosphere and seas. "*On average over the last 50 years, about 25% of total CO_2 emissions were absorbed by oceans making sea water more acidic, 30% was taken up on land, largely by increased plant growth stimulated by rising atmospheric CO_2, increased nutrient availability, and responses to warming and rainfall changes, while the remaining 45% of emissions were accumulated in the atmosphere*". ***(Figure 2)***

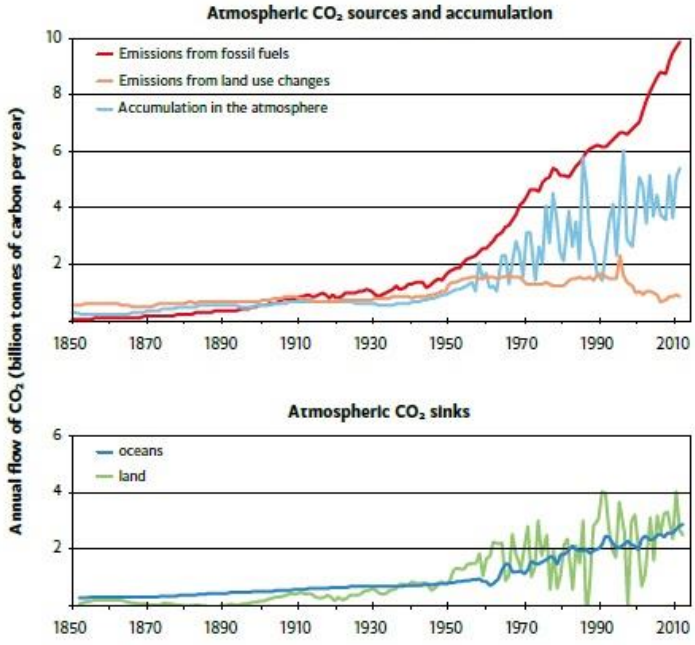


Figure 2 - *Atmospheric CO_2 budget amount of carbon in net amounts of CO_2 entering, leaving and accumulating in the atmosphere. Source: "Global Carbon Project."*

Most of the observed recent global warming results from human activities. Climatic warming or cooling arises from changes in the flows of energy through the climate system that can originate from a number of possible driving factors. The main drivers that have acted over the last century are:

- increases in atmospheric CO_2 and other long-lived greenhouse gases (methane, nitrous oxide and halocarbons).
- increases in short-lived greenhouse gases (mainly ozone).
- changes to land cover (replacement of darker forests with paler croplands and grasslands).
- increases in aerosols (tiny particles in the atmosphere).

The human-induced drivers have been dominant over the past century. Changes in greenhouse gas concentrations, dominated by CO_2, caused a large warming contribution. Some of this has been offset by the net cooling effects of increased aerosol concentrations and their impact on clouds. Black carbon or soot has probably exerted a smaller, warming influence. The net effect of all aerosol types including soot remains hard to quantify accurately.

Additional proves that human activities are causing climate changes are provided by a team of IPCC, that using climate models, proved that it is possible to separate the effects of the natural and human-induced influences on climate. Those models can successfully reproduce the observed warming over the last 160 years ***(Figure 1c)*** when both natural and human influences are included, but not when natural influences act alone ***(Figure 3)***. This is both an important test of the climate models against observations and also a demonstration that recent observed global warming results largely from human rather than natural influences on climate.

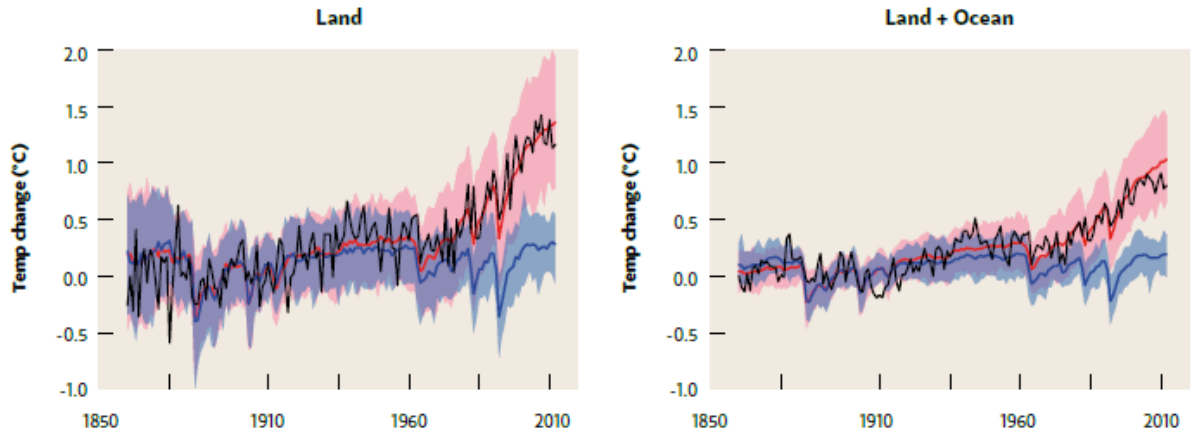


Figure 3 *- Comparison of observed changes (black lines) in global temperatures (°C) over land (left) and land plus ocean (right) with model projections including both natural plus human influences (red lines) and natural influences only (blue lines). Shadings around model results indicate 5-95% confidence bands. Taken from IPCC (2013), Fifth Assessment Report, Working Group 1.*

The amount of future global warming is closely related to cumulative CO_2 emissions ***(Figure 4)***. For example, to have a 50:50 chance of keeping global average temperatures to no more than 2°C (above this value the climate wuold be out of scale in terms of observations looking back for hundred thousands years) above preindustrial levels, the total CO_2 emitted from human activities would have to stay below a 'carbon quota' between 820 and 950 billion tonnes of carbon. So far, humanity has emitted well over half of this quota. Between 1870 and 2013 cumulative emissions were 530 billion tonnes. The remaining quota is equivalent to around 30 years worth of current emissions. To stay within such a carbon quota, long-term global emissions reductions would have to average between 5.5% and 8% per year, accounting for time required to turn around present emissions growth. **We are in 2021 and yet the global emissions between 2013 and 2019 have increased by 4,17%.**

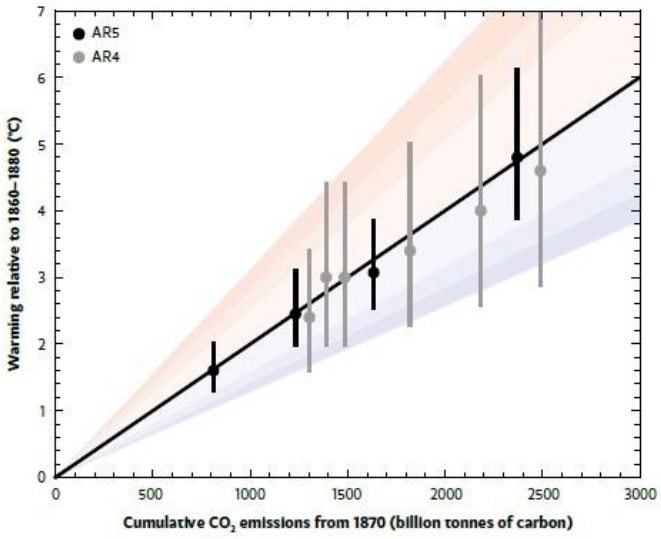


Figure 4 *- Points represent Intergovernmental Panel on Climate Change projections from the Fourth and Fifth Assessments (IPCC AR4, AR5); coloured bands represent uncertainty, by showing the relationship if the climate were more (red) or less (blue) sensitive to disturbance than current best estimates. Source: Working Group for this document, with data from IPCC AR4 and AR5.*

1.2. POSSIBLE EVOLUTION OF CLIMATE

If society continues to rely on fossil fuels to the extent that it is currently doing, then carbon dioxide (CO_2) concentrations in the atmosphere are expected to double from pre-industrial values by about 2050, and triple by about 2100. This 'high emissions' pathway for CO_2, coupled with rises in the other greenhouse gases, would be expected to result in a globalaverage warming of around 4.5°C by 2100, but possibly as low as 3°C or as high as 6˚C. A 'low emissions' pathway, based on a rapid shift away from fossil fuel use over the next few decades, would see warming significantly reduced later this century and beyond. ***(Figure 5)***

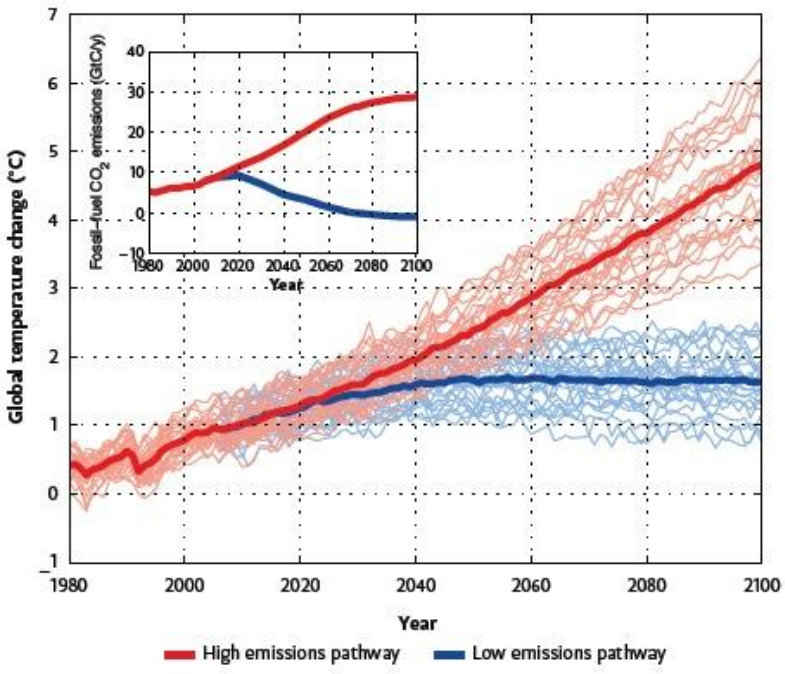


Figure 5 - *Future projected climate change depends on net emissions of greenhouse gases. The corresponding two emissions pathways, including all industrial sources, are included in the inset. Emission units are gigatonnes (billion tonnes) of carbon per year (GtC/y). Source: "Global Carbon Project."*

1.3. IMPLICATIONS FOR EXTREME EVENTS

Human-induced climate change is superimposed on natural variability. In a warming climate, extremely cold days occur less often and very hot days occur more often. These changes have already been observed. For example, in recent decades, hot days and nights have become more frequent, more intense and longer lasting in tandem with decreases in cold days and nights for most regions of the globe. Since records began, the frequency, duration and intensity of heatwaves have increased. *Source: "Global Carbon Project."* ***(Figure 6).***

Because a warmer atmosphere contains more moisture, rainfall extremes are also expected to become more frequent and intense as global average temperatures increase. This is already being observed globally: heavy rainfall and tropical cyclones events over most land areas have become more frequent and intense in recent decades, although these trends have varied notably between regions and seasons.

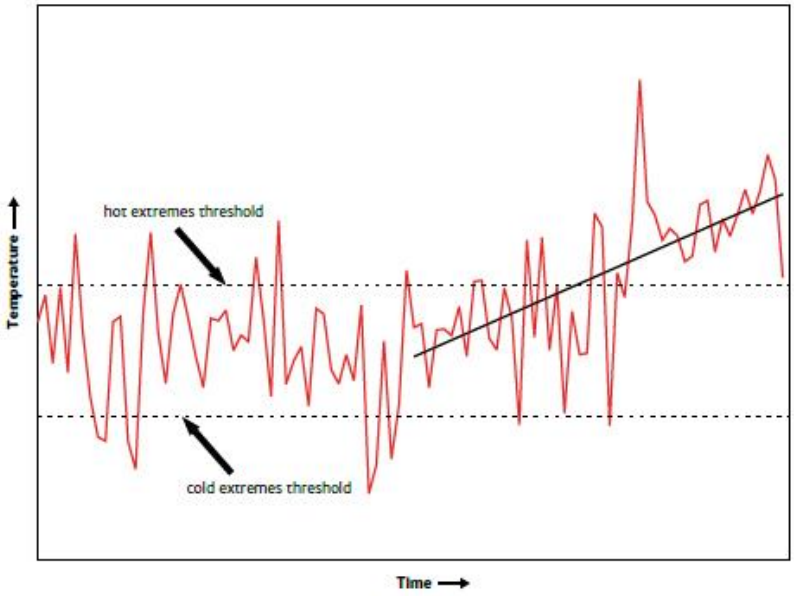


Figure 6 - *Temperature extremes change as average temperature increases. Source: "Global Carbon Project."*

Over most continents, a heavy rainfall event that occurs only once in 20 years today is expected to occur at least twice as often by end of the 21st century. The map ***(Figure 7)*** shows projections, under a high emission pathway, of the return period during 2081–2100 for daily precipitation values that have a 20-year return period during 1986–2005.

The maximum temperature in any 20-year time period is expected to increase with time, being substantially higher at the end of the 21st century than today. The map ***(Figure 8)*** shows projections under a high emissions pathway of the change from 1986–2005 to 2081–2100 in 20-year return values of daily maximum temperatures.

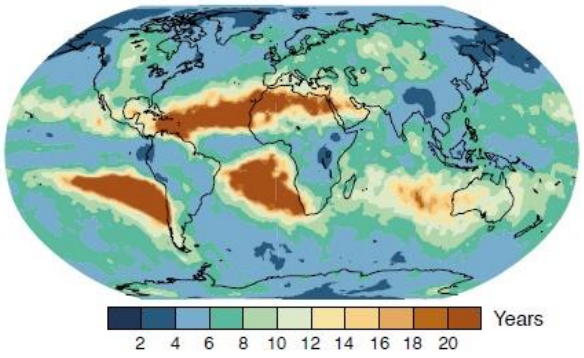


Figure 7 – *Source: IPCC (2013) Fifth Assessment Report.*

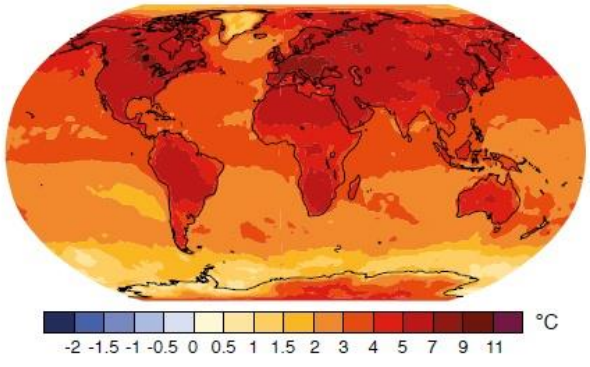


Figure 8 – *Source: IPCC (2013) Fifth Assessment Report.*

CHAPTER 2

2. WHAT IS A SYSTEMIC RISK

Systemic risk in a very general sense is by no way a phenomenon limited to economics or the financial system. Maybe the most natural illustration of the concept is possible in the area of environmental events and health/epidemic diseases. While contamination effects may also occur in other sectors of the economy, the likelihood and severity in financial systems is often regarded as considerably higher. A full systemic crisis in the financial system may then have strong adverse consequences for the real economy and general economic welfare.

In the area of economics it has been argued that systemic risk is a particular feature of financial systems, even though there is not yet a commonly accepted definition but one that describe it as the risk of experiencing a "*strong"* systemic event ***(Figure 9)***. With *"strong"* systemic event it is meant that the intermediaries concerned fail or that the markets concerned become dysfunctional (in theoretical terms this is often a non-linearity or a regime change). In the narrow sense a systemic event could also be identified as *"strong"* if the institutions affected in the second round or later actually fail as a consequence of the initial shock, although they have been fundamentally solvent ex ante, or if the markets affected in later rounds also crash and would not have done so without the initial shock. We denote these strong instances of systemic events in the narrow sense as "*contagion".*

- Contagion is inherent to the systemic risk and occurs when systemic risk materializes *(Martínez-Jaramillo et al., 2010).* It is the main mechanism through which financial instability becomes so widespread (Domino Effect) that a crisis reaches systemic proportions. Contagion effect can therefore be defined as the probability that the instability of the given institution (instrument, market, infrastructure, financial system sector) will spread to other parts of the financial system with negative effects, leading to a system-wide crisis.

On the other side if the external effect is less than a failure or a crash, it is possible to denote a systemic event, in the narrow sense, as weak. ***(Figure 9)*** Similarly, systemic events related to systematic shocks are weak, if a significant part of the financial institutions/markets simultaneously affected by them do not actually fail/crash.

Types of systemic risk can be classified into various groups. "*Allen and Carletti" - (2011)* identify six types of systemic risk, namely:

- Common exposure to asset price bubbles, particularly real estate bubbles;
- Liquidity provision and mispricing of assets;
- Multiple equilibria and panics;
- Contagion;
- Sovereign default;
- Currency mismatches in the banking system;

2.1. WHAT IS A SYSTEMIC EVENT

We define a *systemic event* ***(Figure 9)*** in the a narrow sense as an event where the release of "bad news" about a financial institution, or even its failure, or the crash of a financial market leads in a sequential fashion to considerable adverse effects on one or several other financial institutions or markets, e.g. their failure or crash. Systemic events adversely affects a number of systemically important intermediaries or markets, including potentially related infrastructures. For example the failure of a large and complex financial institution (such as that of Lehman Brothers in September 2008) implied a particularly high risk.

The trigger of a systemic event is composed of two important elements itself, shocks and propagation mechanisms. Following the terminology of financial theory, *shocks* can emerge *exogenously*, that means they could be *idiosyncratic* or *systematic* ***(Figure 9)***. In an extreme sense idiosyncratic shocks are those which, initially, affect only the health of a single financial institution or only the price of a single asset, while systematic (or widespread) shocks - in the extreme - affect the whole economy, e.g. all financial institutions together at the same time.

Alternatively, the event could emerge *endogenously* from within the financial system or from within the economy at large. One can also distinguish between a "*horizontal*" perspective of systemic risk, where attention is confined to the financial system, and a "*vertical*" perspective of systemic risk in which the two-sided interaction between the financial system and the economy at large is taken into account.

Systemic events in the financial system

Type of initial shock	Single systemic events (affect only one institution or one market in the second round effect)		Wide systemic events (affect many institutions or markets in the second round effect)	
	Weak (no failure or crash)	Strong (failure of one institution or crash of one market)	Weak (no failure or crash)	Strong (failures of many institutions or crashes of many markets)
Narrow shock that propagates				
– Idiosyncratic shock	✓	✓ contagion	✓	✓ contagion leading to a systemic crisis
– Limited systematic shock	✓	✓ contagion	✓	✓ contagion leading to a systemic crisis
Wide systematic shock			✓	✓ systemic crisis

Figure 9 *– Systemic Events in financial systems. Note: ✔ means that the combination of events defi ned by the cell is a systemic event. The shaded area describes cases of systemic events in the narrow sense. Systemic events in the broad sense also include the cells with ✔ in the last row. Source: European Central Bank – Working Paper N° 35, Novemeber 2000.*

A second key element in systemic events, in the narrow sense, is the mechanism through which shocks propagate from one financial institution or market to the other. This is the very core of the systemic risk concept. The propagation of shocks within the financial system, which work through physical exposures or information effects (including potential losses of confidence), must be "special". This, from a conceptual point of view, is important since the *transmission* of shocks is a natural part of the self-stabilising adjustments of the market system to a new equilibrium. What is dangerous in such propagation, including those taking the form of externalities, it's the emrgence of particularly violent features, such as cumulative reinforcement (non-linearities) and price jumps (discontinuities).

2.2. THE FINANCIAL FRAGILITY HYPOTHESIS

Why is it then that systemic risk, in particular potential contagion effects, are of special concern in the financial system? There are two possible interrelated features that can provide a basis for this fragility hypothesis:

I. *The interconnection of financial institutions through direct exposures and settlement systems*. There is a complex network of exposures among banks, asset and equity management companies, investment funds (and potentially some other financial intermediaries) through the interbank money market, the large-value payment and security settlement systems (Committee on Payment and Settlement Systems, 1996). Banks tend to play a key role in wholesale and retail payment and settlement systems. At certain points during the business day, these exposures could become very large, so that the failure of one bank or another financial actor to meet payment obligations can have an immediate impact on the ability of other banks and actors to meet their own payment obligations. Even worse, a crisis situation can trigger difficulties in the technical completion of the different steps of the payment and settlement process, which would amplify effective exposures and domino effects. Various techniques used in securities and derivatives markets, such as margin requirements and asset portfolio insurance, although intended to limit risk ex ante can also account for large and immediate payments needs by banks and other intermediaries ex post, namely in times of large asset price changes. To the extent that financial conglomerates encompass banks and other financial intermediaries, securities or insurance subsidiaries might also play a role in these interlinkages.

II. *The information intensity of financial contracts and related credibility problems.* Financial decisions aim at the intertemporal allocation of purchasing power for consumption and are, therefore, based on expectations on what the value of the respective asset is going to be in the future or whether the future cash flows promised in a financial contract are going to be met. Hence, when uncertainty increases or the credibility of a financial commitment starts to be questioned, market expectations may shift substantially and "individually rationally" in short periods of time and so may investment and disinvestment decisions. For example, this can lead to large asset price fluctuations, whose sizes and sometimes also directions are virtually impossible to explain through "fundamental" analysis alone (Shiller, 1989b).

2.3. SYSTEMIC RISK AND PUBLIC POLICY

On the basis of the conceptual considerations presented so far, a first assessment to which extent systemic risk is relevant for economic and financial policies can be undertaken. Musgrave and Musgrave (1973) have introduced the "classical" distinction of three functions for public policies:

- The allocation function, or the stabilisation function and the distribution function. It appears that systemic risk is, first, relevant for allocation policies. Indeed strong systemic events, such as contagious failures, may involve external effects; i.e. the private costs of the initial failure can be lower than the social costs. As a consequence, individually rational bank management may lead to a higher level of systemic risk than would be socially optimal.

- Second, a systemic crisis affecting a large number of financial institutions or markets can - through "credit crunch" or "debt deflation" - lead to a recession or even to a depression. In such situations macroeconomic stabilisation policies, such as monetary or fiscal expansions, may be used to maintain an adequate level of liquidity in the *banking system as a whole* ("lending to the market" by the central bank) and dampen the recessionary impact on the real economy. Interestingly, in the case of systemic risk, allocation and stabilisation problems can be closely intertwined. If contagion is very strong, then the microeconomic risk allocation problem can degenerate to a macroeconomic destabilisation. So, the ex ante (regulation and supervision) and ex post (crisis management) policies described in the previous paragraph can both be seen as stabilisation policies.

- It is now widely recognised that public (and private) safety nets, whether they take the form of deposit insurance or lender of last resort facilities, apart from the beneficial stabilisation effects bear the risk of creating moral hazard. For example, if deposit insurance premiums do not reflect the banks. relative portfolio risks, then the protection may incite the insured to take on higher risks (Merton, 1976, 1978). Moreover, market expectations could be created that large financial institutions with substantial market, clearing and settlement links with many other players in the financial system are "too big to fail" or "too sophisticated to fail". However, if the measures to control moral hazard are not successful, then the insured institutions could become more vulnerable to adverse shocks, so that the likelihood of propagation across institutions may rise as well. This latter scenario would imply a higher level of systemic risk through inadequate safety net provisions or, in other words, high costs of maintaining the safety net.

CHAPTER 3

3. ADDRESSING CLIMATE CHANGES AS SYSTEMIC RISK

Climate change impacts human societies and economies in both a non linear and unpredictable ways. Tipping points can arise and irreversibly change both the state of the planet, and the way we live on it. Some of these changes happen slowly, accumulating unnoticed disequilibria over long periods of time; some are very sudden and unpredictable, arising at some specific point of the planet, with potentially broader contagion affects.

There is thus a high level of uncertainty on the exact timing and impact of such events, not only because of the physical processes themselves, but also because they are intimately linked with humans' reactions and policies. In such a theoretical framework: "*Climate policies should be looking more at insurance theory than at traditional externality theory, trying to make visible for investors the role of climate events. But specifics and consequences of such approach are never fully developed, so that final recommendations remain stuck with the usual anthem: "Price carbon, cap the flow of emissions, there is no other way out*" (Weitzman, 2015).

The notion of systemic risk, which has been widely rediscovered to analyze the fragility of the financial sector right after the 2008 financial crisis, and its policy implications in order to stabilize the system, can partly be used to tackle climate change issues. Many foundamental reasons can justify this transposition of this financial concept to climate:

- Climate change impacts are systemic in nature. They affect the whole planet, in most of its dimensions, but have different local effects at the same time . They have the ability to profoundly change the Earth system as we currently know it. This is a first-level definition of a climate systemic risk. Of course they affect society on the way, either through global damages or through localized extreme events which can propagate to larger portions of territory using different channels, physical, social or financial.

- This leads us to the second reason why the notion of systemic risk is relevant for climate issues. In the world of efficient markets, and perfectly rational self-interested agents, a carbon price only policy could do the job, realigning prices and portfolios according to the collective value given to the climate externality, given anticipated scenarios of climate damages. But in such a world, a systemic risk is also impossible, because it contradicts the fundamental hypothesis that markets give the full available information on prospective scenarios of climate damages.

- Following the Fourth National Climate Assessment Frequent (Vol.11) extreme weather events are leading to mounting economic losses. Physical risks from rising global temperatures – up 1.8° F since the mid-20th century – are the most immediate threats to economy. Catastrophic flooding, droughts, wildfires and storms are becoming more frequent and extreme and have caused billions of dollars in financial losses. As global greenhouse gas (GHG) emissions and temperatures continue to rise, deeper economic losses are projected for the years ahead.

- The Fourth National Climate Assessment (Vol.11), based on the work of thousands of researchers, suggests that unmitigated climate change could reduce for examples the U.S. economy by as much as 10% annually by 2100. In a 2019 CDP survey, 215 of the world's largest listed companies reported nearly $1 trillion at risk from climate impacts, much of it in the next five years. A London School of Economics study projects that, unless it is addressed, climate change could reduce the value of global financial assets by as much as $24 trillion – resulting in permanent damage that would far eclipse the scale of the 2007-2009 financial crisis.

- Social and environmental factors are exacerbating the economic impacts. Unmitigated climate change and extreme weather events will have significant health impacts, including respiratory issues, the spread of diseases and premature deaths. Climate change and extreme weather events will also create major productivity losses, particularly in industries that require workers to be outside. Migration forced by climate change has already displaced an average of 26.4 million people per year globally between 2008 and 2015. By 2050, climate change will force 50 to 700 million people to emigrate. Finally, the rapid loss of forests and other ecosystems is starting to impact ecosystem-dependent industries such as agriculture, tourism, drinking water and pharmaceuticals.

- Climate impacts are already manifesting in the largest state economies. In just the last few years, California has experienced recording-breaking wildfires, in both number and size, that have taken hundreds of lives, bankrupted the state's largest utility, left millions regularly without power and brought home insurability into question. Florida is facing rapidly rising sea levels and now-routine flooding that are eroding coastal property values and wiping out freshwater supplies. Texas experienced two devastating once-in-a-thousand-years flood events between 2016 and 2019, each caused by torrential rains of 40 inches or more.

- An unplanned transition to a low-or-zero-carbon economy could cripple key industries. Changes in government policies, consumer sentiment, liability risks and technological innovation could cause significant losses for high-carbon industry sectors, and those that rely on them. Given the large size of these industries, these cumulative losses could send broad, intersecting and amplifying financial ripples on major financial institutions holding related assets.

- Economists and financial leaders say the scale of the losses from climate change could eclipse the subprime mortgage securities meltdown that triggered bank failures and, ultimately, a deep global recession a dozen years ago. "Even if only a fraction of the [climate] science is right, this is a much more structural, long-term crisis [than the 2007-2009 recession]," said BlackRock CEO Larry Fink in 2020. Despite these risks, national and global efforts to mitigate climate change's impacts could create enormous clean energy investment opportunities that would translate into economic growth and job creation. Research suggests that transitioning to a low-carbon sustainable economy could deliver direct economic gains of $26 trillion through 2030, compared to business as usual.

- Insurance companies, banks and REITs are on the frontlines of risk. The insurance and real estate sectors are particularly vulnerable to the physical impacts of climate change, and have already faced growing losses; insurers' investments are also at risk. Banks and financial institutions that have lent to and invested in risky, carbon-intensive sectors have the potential to have their investments become "stranded" in the face of the transition to a low-or-zero-carbon future.

- The cumulative and unpredictable nature of climate impacts poses a risk to financial market stability. While any of the impacts outlined above are significant, their cumulative, correlated and nonlinear nature poses the real risk to financial market stability. To put it simply, the whole is not only greater than the sum of its parts – it magnifies them, as well. If climate change affects markets suddenly and unexpectedly, it could burst a "carbon bubble," which could pose grave dangers to financial markets and the real economy, already weakened from the ongoing coronavirus pandemic. At the same time, the response to the pandemic has also underscored the power financial regulators have to buttress markets in the face of a disruptive risk. With that power, regulators also have the responsibility to assess market vulnerability to such risks, and take action to make the economy resilient to such shocks. As stewards of the largest economy in the world, U.S. financial regulators, including the Federal Reserve, the SEC and others, have critical roles to play. They can send the appropriate market signals about the risks posed by climate change to the U.S. and global economy, and take the necessary steps to recalibrate our financial system.

Figure 10 *– A house is surrounded by floodwater from the Red River on April 11, 2011 Fargo, North Dakota - Scott Olson | Getty Images.*

3.1. HOW CLIMATE SYSTEMIC EVENTS ARISE

A systemic event is defined in economics by three essential elements: a shock, which can be a broad shock simultaneously affecting a wide range of institutions, or a limited shock followed by an important domino effect; contagion effects through a web of interrelations; and the endogenous nature of this shock, meaning that it is caused by cumulated disequilibria over time.
The possible transposition ***(Figure 11)*** to climate change impacts on Earth, societies and their economies is striking:

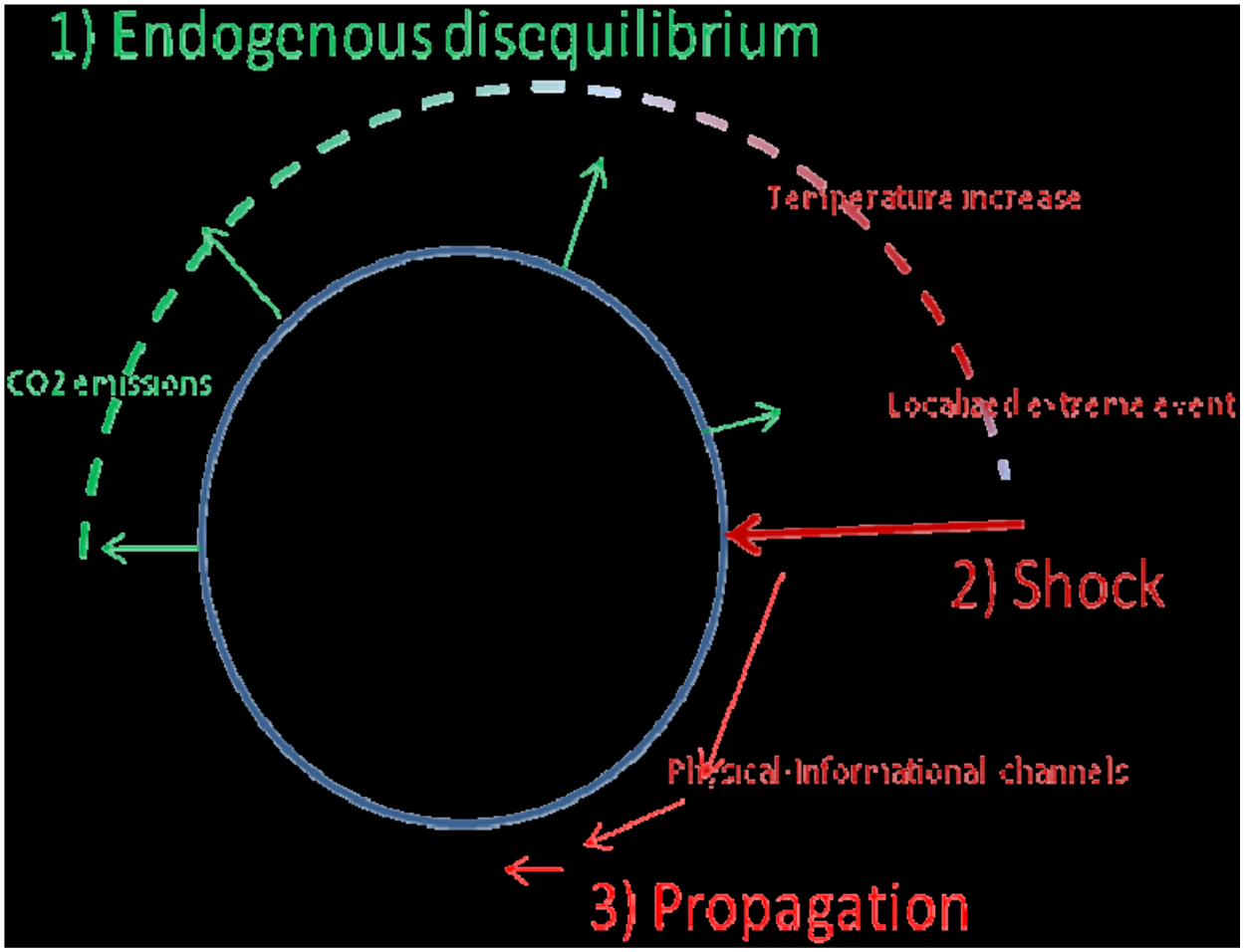


Figure 11 – *Climate Systemic Risk arise. From "Global Carbon Project".*

IPCC (2014) shows that we evidently have the possibility of a global shock through an irreversible increase in temperature levels and more localized shocks through extreme events of all sorts; most of these shocks have been proved to be caused by human action (Pachauri - 2014). Both types of shocks can of course be intertwined, leading to severe losses.

3.1.1. SHOCKS

Shocks that do not propagate widely are insurable in the sense that investors can protect themselves against them by diversification, or that society can easily pay for the incurred damages. On the contrary, systemic shocks are by definition non insurable or non diversifiable. But the limit between the two crucially depends on the possibilities of propagation. Three interrelated features can provide a basis for the propagation mechanisms:

- The structure of societies in relation with local risks of extreme events, i.e. their relative level of adaptation to climate change.
- The interconnection of different societies through direct and indirect exposures.
- The information intensity of social, economic and financial contracts regarding emission intensity or exposure to climate damages.

Societies are currently not adapted for the projected outcomes of the current emission trajectories. *Pachauri et al. (2014)* for example show that global warming will very likely lead to an increased number and the return period of record temperatures, droughts, and extreme rainfalls.
The question of the attribution of a particular event to a global warming cause remains essential. *Schaller et al. (2016)* show for example how a succession of storms in South England in 2013/2014 increased flood risks from the Thames, which itself put nearby properties at risk. Property and insurance companies are then tempted to increase their risk premium in relation with the perception of higher future flood risks.

3.1.2 PROPAGATION

At the same time, the interconnections have never been so high, potentially transforming a localized event into a full-blown shock. We can distinguish between physical, and financial interconnections. If trade relations have stalled a little bit in the past few years since the 2008 crisis, they still keep growing at approximately the same pace as world growth. Such a level of financial interconnection in a politically fragmented world can just increase the chance of sudden stops, or brutal reversals of financial expectations.

3.1.3 ENDOGENEITY

This leads us to the endogeneity of systemic climate risk. It is now an almost certain feature displayed by climate science. Human actions are a major cause of the increase in global temperatures, through emissions. The global endogeneity of global warming cannot be put into question.

3.2. CLIMATE AND FINANCIAL FRAGILITIES

Climate systemic risk is a potential source of financial disruption. Climate fragilities increase financial fragilities. For many years, climate change for the finance industry has been understood by market players and regulators as a totally exogenous perturbation that would be nothing more than a bunch of weather perturbations that already occur potentially everyday everywhere, and would eventually, if things go bad in several decades, be addressed through their operational risk framework. This point is crucial, due to the fact that a potential sytemic risk has been treated as a normal day by day operational risk, without recognising that climate related effects can indeed wipe out or strain the foundations of financial institution operations. The main feeling was indeed along the line of “Move along, nothing to see”, as climate change was not supposed to concern financial sector, ife ver a reality, but rather a long term issue for policy makers.

The development of “Socially Responsible Investment” (SRI) and “Environmental Social Governance Funds” (ESGF) in the early 2000s, progressively put climate change on the agenda of

investors, starting from charity funds, and joined by ESG-engaged pension funds and asset management funds.

In summary, until about 2010 climate change for banks, REITs and other related financial institutions, was essentially limited to carbon markets and project finance, while the responsibility for GHG emissions was fully left to their clients' decisions. On the investor side, climate change started to be included to some of the most committed SRI narratives and strategies, having basically no concrete impact on investment decisions and portfolios composition, due to lack of ambition of climate policies after landmark Kyoto Protocol.

The mechanism of associating climate change and finance could have continued its slow catch on from then, but a combination of several events and initiatives lead up to a significant acceleration, especially in the build-up to the 2015 COP21 in Paris. Indeed since Paris Agreement, ratified by 185 countries, the objective of climate mitigation is clear: limitating global tempearture increase "well below +2°C" by the second half of the century. *It must be nodted that despite this lofty goal, no actual system or external third party or impartial regulator has been established to monitor the signatory countries for the achivement of the target. Indeed the memebers are free to left the agreement whenever they want, and to notify, or not, the results to the communty.* Investors are not directly involved in this process, since the duty of applying the general agreements is on the central states shoulders. The states will then establish internal targets (generally not restrictive), and given this freedom of movement, the majority market investors see these objectives more as a moral ace to be used only in some occasion, and not a real operational level and strategic target.

Climate change imposes itself as a "new" source of financial risk, it represents the addition to an already fragile financial system, which have the potential to transform an idiosyncratic event into a financial crisis. The current state of the financial system is admittedly highly vulnerable and could also be a powerful driver and accelerator of the realization of a climate systemic risk. The usual risk framework in finance, approaching risks through liquidity, interest rate, credit, market and operational risk, is currently not capturing risks coming from effects of climate change. There is thus a strong need for the financial sector to anticipate such an outcome. Key channels through which climate change can affect financial stability:

- ***Physical risk***: impacts on the value of financial assets due to climate events such as floods, storms, *etc…* It's the physical impact of climate events themselves. If the initial effect of climate change is temperature rise, the indirect impacts are much more diverse. First, the warming effect from climate change is global, but with very high geographical and temporal heterogeneities, the nit is the indirect consequences of this warming that will impact most of our societies through modifications of climate regimes (intensity and frequency of extreme events). Physical risks affect the operations of organisations, potentially damaging their assets or affecting their supply chains or conditions work, as well as the demand side from clients and citizens. As such, physicl risks can have financial implications for those organisations or financial institutions, which may propagate to their valuations or risk profiles via impacts on their income, cash flows, or balance sheet. ***(Figure 12)***

- ***Transition risk***: the financial risk that would result from an adjustment to a decarbonized economy. Changes in policies, technologies, institutions and behaviors might lead to a new valuation of a whole set of assets once costs and benefits of climate action become more and more apparent. The transition to a globalnet-zero carbon economy will undoubtedly have significant consequences on economic agents, generating winners (typically those industries that can provide the economy with alternatives to carbon-intensive technologies) and losers (in particular sectors relying on fossil fuels or coals). Those consequences will very probably impact the risk and profitability of real and financial assets. The more delayed and abrupt the transition will be, the harder those consequences of sudden adjustment from economic agents will be, and accordingly on financial assets, potentially leading to the quick stranding of carbon-intensive portfolio assets ***(see also CHAPTER 4 – "OUTCOMES OF REPORT 1")*** , and related propagation to a systemic financial instability. This constitutes the "transition risk" to the financial system, i.e. the financial risk coming from the energy and industrial transition in the context of climate change mitigation. ***(Figure 12)***

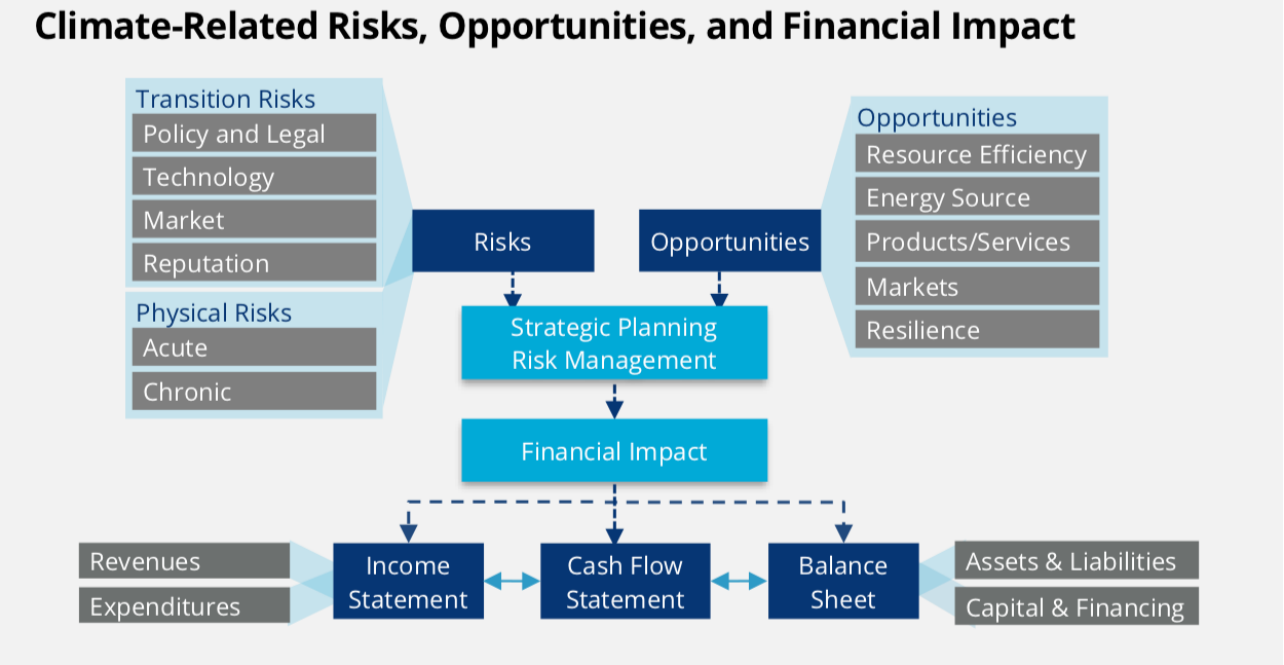


Figure 12 – *Climate-related risks, opportunities, and financial impact, from "Climate change and financial risk" by Hugues Chenet – April 2019 (TCFD, 2017).*

- ***Liability risk***: impacts of lawsuits by those who might have been victims of natural disasters that they would try to link to climate change, aimed at those deemed responsible for these changes. This risk currently seems to be far-fetched (Munich Re, 2010). But we can see early signals of such liability procedures from numerous NGOs and civil society, which may become a powerful political force in case of realization of a physical risk.

But are those new types of risk priced by market? Of course, risks coming from climate change, both physical and transition risks, are not completely new and have somehow affected financial assets in the past. As such, climate related risks should be captured by usual risk management frameworks, and would therefore not need specific attention compared to other types of risk.

But there are several reasons why those risks parameters are probably not currently captured, i.e. not priced or mispriced, by financial markets, tending to turn down the pricing efficiency of markets. If so, this mispricing and subsequent misallocation justify the current specific attention devoted to climate-related risks in the finacial sector, and the development of ad hoc approaches to manage them, both inside the market via dedicated tools and from a regulatory perspective via policies to fix market failures.

CHAPTER 4

4. EXISTING STUDIES THAT UNDERLINE THE PROBLEM

The following CHAPTER explain and summarize the results of two studies. The first one made on 50 subjects operating in the real estate sector (Property Funds, Asset Management Companies, Property Companies, Banks, REITS, Pension Funds etc.), called "*Climate change implications for real estate portfolio allocation – Business as usual or game shift?*" by *Prof. Dr. Sven Bienert for IRE BS (***REPORT 1***).* The second one made on 321 REITS and their portfolio at risk under climate change and its effects, called "*Climate Risk, Real Estate, and the Bottom Line"* by *Geophy and 427 Company (***REPORT 2***).*

This over overview has been performed to understand what type of measures the real estate sector is taking to face the risk implications stemming from climate change on its portfolio. Also references to "*Assogestione – Mappatura dei Rischi Immobiliari dei Fondi Real Estate*" and "*Applicazione del project risk management e indici di performance nel settore delle costruzioni: un caso studio*" have been included.

4.1. OUTCOMES OF REPORT 1

- **Top 5 climate-change-related impacts which influence Real Estate Investments TODAY**

***** 80% of the survey participants argue that higher operational costs and changing technological requirements due to climate change have at least a moderate influence on their real estate investments today.
***** Increasing regulations (e.g. related laws regarding energy savings) also have significant impact on current real estate investment decisions (72% of participants expect at least a moderate influence).
***** Rising sea levels, food security, deterioration of air quality and water shortages are not yet an issue for most of the participants.

- **Top 5 climate-change-related impacts that are expected to increase in the FUTURE**

***** Increasing regulation (88%), changing technological requirements (82%), higher operational costs (67%), higher construction costs due to adaptation (65%) and rising fuel prices (63%) are the Top 5 climate-change-related impacts that are expected to increase within the next ten years.

- **Climate change risk assessment for real estate portfolios**

***** Only five out of 50 participants (10%) perform climate-change risk assessment in a substantial manner. 18% of the investors partially assess the risks of climate change, while 25% only conduct climate-change risk assessment rudimentarily. 47% of investors do not assess climate-change risks at all. If investors perform climate-change risk assessments for a portfolio, mostly sustainable due diligence for new acquisitions are conducted (89% of participants did this for at least 26% of their portfolio). Measurement of Key Performance Indicators and sustainability due diligence for existing buildings are also quite widely used instruments.
***** Although scenario and sensitivity analysis may be the most suitable instruments for assessing the risks of climate change for real estate portfolios, most of the investors do not use these tools for their climate-change risk assessments.
Only two participants perform sensitivity analysis for 26% to 75% of their portfolios. Scenario analysis is only used by one of the investors for more than 75% of the real estate portfolio.
***** Risks due to climate change are in most cases not assessed sufficiently: – only five out of 50 participants perform climate change risks in a substantial manner. 72 % of the investors at present ignore these risks. Most participants do not intend to change this approach in next few years. Common "Tools" are generally understood and used – like Sustainability Due Diligence and KPIs, *but* strategic planning approaches like scenario analysis are almost totally lacking. This is due to the lack of awareness of long-term consequences, including the functional chain.

- **Asset analysis and new approaches.**

***** Traditional tools and models rely strongly on the derived implications based on historical quantitative analysis. In contrast of course, most of the risk related to climate change involves forward looking data and studies which are often only available in a more qualitative form. To obtain a clear view on possible outcomes of future performance, the uncertainty in and fundamental shifts of the real estate industry must be captured with scenario analysis or other appropriate tools. Long-term asset value can only be protected if risks are identified and integrated into scenarios and simulations of future climate change. As stated in IPCC AR.4 and AR.5, since the links between manmade emissions, rising GHG concentration and climate change are not yet fully understood, potential impacts on assets and regions remain highly uncertain. ***(Figure 13)***

Figure 13 – *Climate Risk Assessment and Management Cycle from "Climate change implications for real estate portfolio allocation – Business as usual or game shift?".*

- **Location and property scores might lead to portfolio changes.**

Depending on the property and location-specific results, different norm-strategies regarding the analyzed portfolio may then be applied and lead to shifts that must be executed in day-today portfolio management. One result may be disinvestment in certain regions or investments in regions where the investor has not been active to date. ***(Figure 14)***

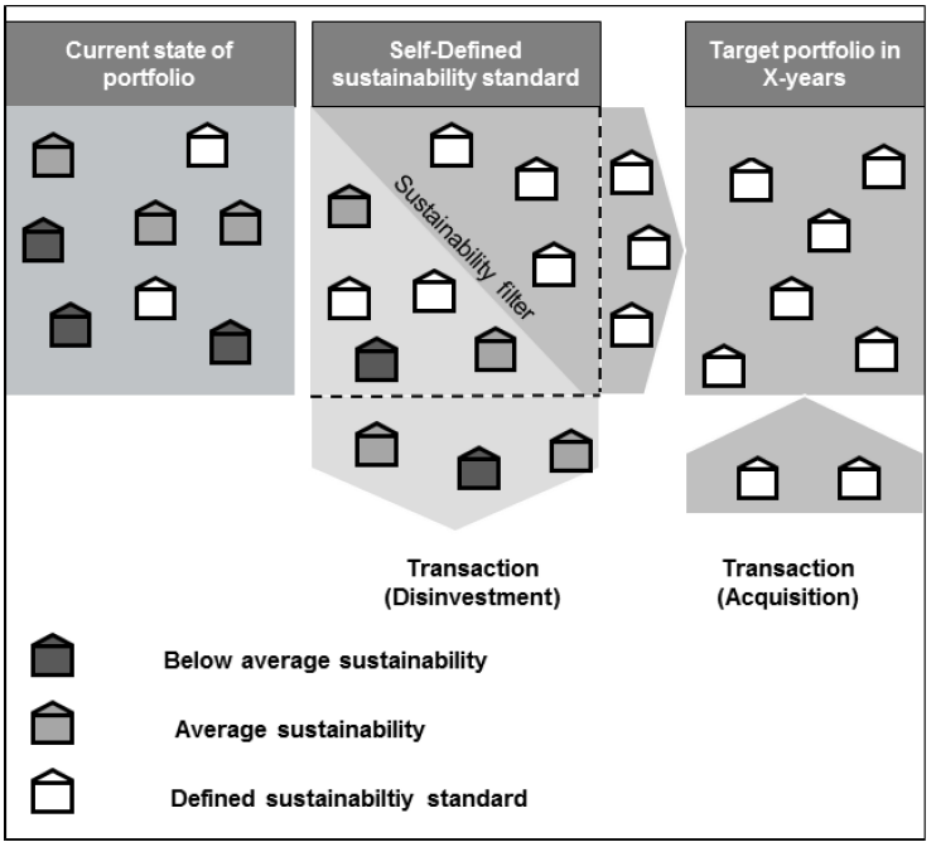


Figure 14 *– From current portfolio to target portfolio. From "Climate change implications for real estate portfolio allocation – Business as usual or game shift?".*

4.2. OUTCOMES OF REPORT 2

Four Twenty Seven and GeoPhy have partnered to bring together risk-driven analytics on physical climate risk exposure with in-depth structured data on the global real estate market. The combination of cutting-edge datasets and models allows for highly granular observations of the impacts of climate change on the real estate investment market. The result is a scientific assessment of REITs' exposure to climate risk. This white paper highlights key findings from the analysis of 73,694 properties owned by 321 listed REITs as of Q2 2018.

Of these 73,694 REITs properties 35% is exposed to climate hazard, mainly 17% to flood risk, 6% to rising sea level, and 12% to cyclones. Visive outcome of this can be seen in the following graph, where the enterprise value and the exposure to dangerous climate events have been crossed. ***(Figure 15)***

Figure 15 – *Percentage of Company Portfolio and Enterprise Value ratio. From: "Climate Risk, Real Estate, and the Bottom Line" - Geophy and 427 Company.*

Each dot represents a REIT. The x-axis shows a REIT's Enterprise Value (Factset, September 2018) and the y-axis shows that REIT's Climate Risk Score. The color of the dots denotes the percent of properties with red flags for any of the five climate hazards considered (sea level rise, hurricanes and ty-phoons, flood, water stress, heat stress. Red dots indicate REITs that hold sites where half or more of the sites are ex-posed to one of the climate hazards. The size of the dots represent the REITs' value.

The most exposed REITs are primarily geographically concentrated in Asia – Japan, Hong Kong and Singapore in particular. Champion REIT stands out due to the geographic concentration of its properties in Hong Kong, and the city's high ex-posure to flood, sea level rise and typhoons. Sun Hung Kai Properties, Sumitomo Realty & Develop-ment and Mitsui Fudosan also rise to the top as the most exposed large REITs with high exposure in their portfolio.

In the U.S., REITs with a large number of coastal properties such as Equity Residential also exhibit high risk portfolios, with a third of their portfolio ex-posed to climate risk. Key markets at risk include the San Francisco Bay Area, the New York City metro area, Miami and Fort Lauderdale in Florida. Among U.S. REITs, Vornado Realty Trust stands out, with 76 out of 78 properties exposed to sea level rise, primarily concentrated in the New York area, while Equity Residential is the REIT second-most ex-posed to sea level rise. The REIT invested exclusively in coastal properties and has properties exposed to sea level rise in all of its major markets, including New York, San Francisco and Washington, D.C..

In the following table are reported the top 10 at risk REITs to sea level rise. ***(Figure 16)***

REIT	Enterprise Value (USD)	Average Sea Level Rise Risk Score	No. of Red Flags	No. of Properties exposed	% Portfolio Exposed	Key Markets Exposed
New World Development	$26.9B	49	5	10	38%	Hong Kong
Sun Hung Kai Properties	$56.6B	41	8	20	28%	Hong Kong
Vornado Realty Trust	$25.8B	41	1	12	15%	New York
Henderson Land Development	$34.2B	35	3	9	19%	Hong Kong
Swire Properties	$23.7B	31	2	4	8%	Hong Kong and Miami
Cheung Kong Property	$36.9B	30	11	22	22%	Hong Kong and Singapore
Sumitomo Realty & Development	$47.7B	29	7	28	14%	Tokyo
Mitsui Fudosan	$48.4B	27	16	54	21%	Tokyo
Mitsubishi Estate	$42.3B	25	11	24	12%	Tokyo, New York
Equity Residential	$32.9B	25	14	35	13%	New York, San Francisco and Washington D.C.

Figure 16 *– Percentage of Company Portfolio Exposed to climate events. From: "Climate Risk, Real Estate, and the Bottom Line" - Geophy and 427 Company.*

The impacts of climate change are already affecting real estate markets, but the widespread, long-term consequences for economies, economic growth and equity are just starting to emerge. For institu-tional REIT investors, but also for investors in private equity real estate equity funds and direct investors in real estate, understanding exposure to any form of risk is paramount. The duty of investors towards clients and trustees is the foundation of the capital market.

4.3. TAKEAWAYS

- **What are the real estate typologies that retain the higher risk?**

What can be understood is that the hazards that can increasingly affect the real estate sector are growing world wide. There is not a single cathegory of investment under risk, since the majority of REITs' portfolio is diversified, but for the outcomes of the reports, intrinsic characteristics (fragmentation, number, territorial persistence etc.) and location, the residential and infrastructural environment are the most exposed.

- **What are the climate change related risks that can affect Real Estate investments?**

It has to be clear that climate change is directly influencing on two major factors, the frequency and the intensity of events. Hazards for the real estate sector come in the form of floods, storms, droughts, heatwaves, more intensive typhoones etc. The effects on build environment, in relation to what stated in "*Assogestione – Mappatura dei Rischi Immobiliari dei Fondi Real Estate"* will impact mainly on:

- Purchase of properties and land: in relation to the location and local market, more or less influenced by local effects, of the single property.
- Purchase of properties and land: characteristics of real estate portfolio (lack of geographical and sectorial diversification).
- Sale of land and buildings: sale of the property at a lower value for direct damages or for possible future damages because exposed to dangerous events. Drafting of contracts will be more complicated to ensure the necessary precautions and guarantees.
- Ordinary management: the composition of due diligence and governance structure.
- Extraordinary management: for external factors, like the occurrence of accidental events that can affect the estate value of the REIT, or on the related insurance coverage.
- Maintenance: execution of extraordinary maintenance interventions due to unexpected events.

Furthermore it seems clear that climate hazards affect all the chain:

- Land/location choice: due to local events.
- Construction: as previously stated, new climate conditions can bring to new construction and energy saving laws constraints and higher costs for special materials and more elaborate projects.
- Management: higher operational costs.

CHAPTER 5

5. FACTORING THE EFFECTS OF CLIMATE CHANGE INTO REAL ESTATE INVESTMENTS

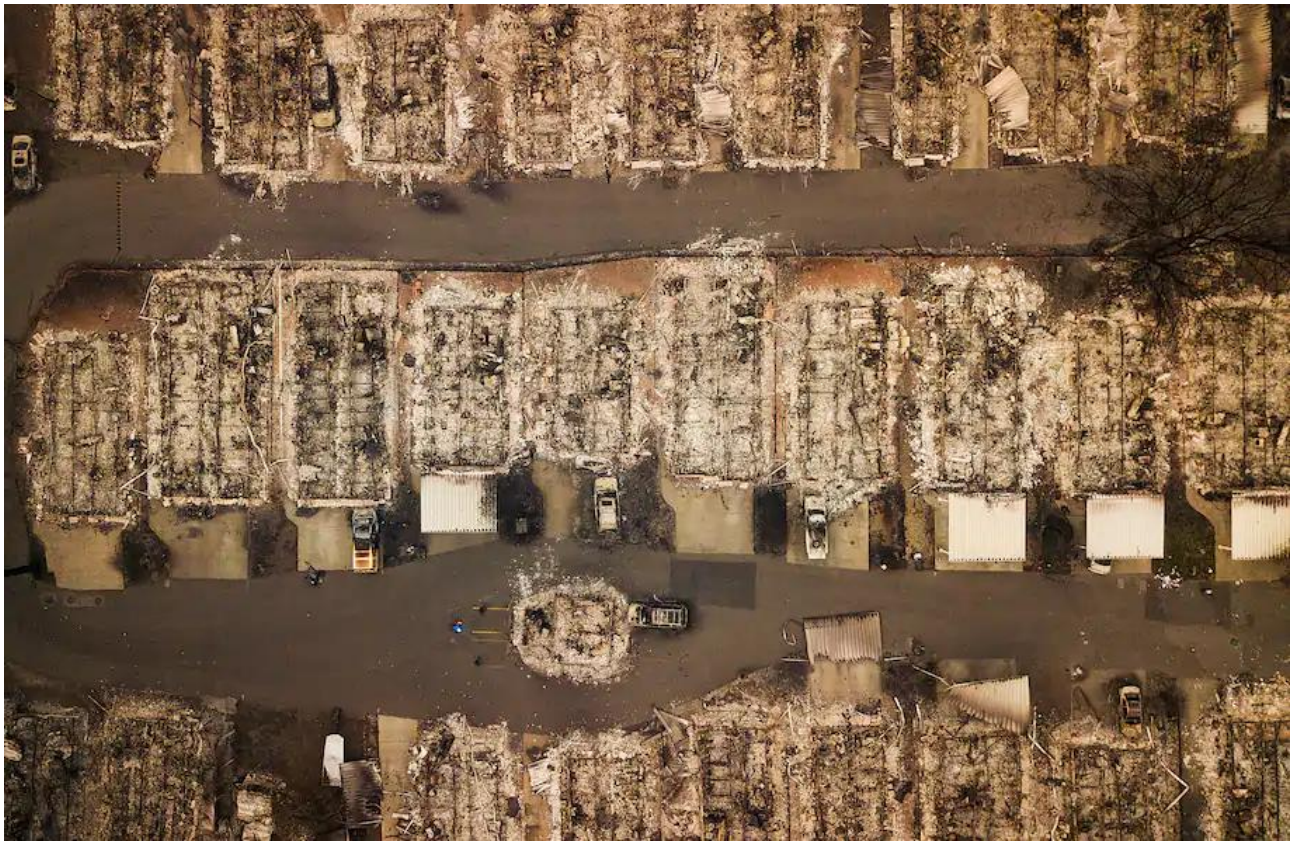


***Figure 17** – Residences leveled by the wildfire line in a neighborhood in Paradise, California. By Noah Berger/Associated Press.*

Hardly a day goes by without yet another report, editorial commentary or prediction about climate change and its risks, evidenced convincingly by countless scientific studies. Observable, measurable evidence includes increasing ocean and land temperatures; weather patterns and weather-related events of abnormal frequency and intensity such as hurricanes, flooding and wildfires; changing biosphere patterns; accelerating glacial melting at the poles and extreme northern and southern latitudes; and rising sea level. But it is not necessary to be a scientist to understand that economic and physical climate change effects could adversely affect real estate. Risks exist at all geographic scales and places: along seacoasts; within watersheds; on hillsides; and in vulnerable urban, suburban and exurban areas. Individual buildings likewise are at risk, depending on their location and construction.

As it has already been understood in ***CHAPTER 3 – PARAGRAPH 3.2.***, physical risks are those caused directly by specific catastrophic events, hurricanes, sea level rise, drought, wildfires and so on, that are ultimately attributable to climate change and shifting weather patterns. Among the many negative impacts of such events are greatly increased cost of maintaining, repairing and reconstructing seriously damaged or destroyed structures; soaring costs of property insurance; and post-event business and economic productivity losses.

Real estate assets across the nations are susceptible to both gradual and more acute climate risks, depending on geographical location and other factors. Gradual climate risks might include sea-level changes, varying weather patterns (such as an increased frequency of rain or wind), drought and higher or lower average temperatures. While investors may not see an immediate impact or risk from these gradual weather events, shifting climate patterns can lead to increased wear and tear on properties and the potential need for more or alternative resources. Increased wear and tear can eventually lead to higher maintenance costs, while the need to add resources like cooling/heating methods or water sources can lead to increased operating costs. Indeed longer summer heat waves will stretch the capacity of building air conditioners and increase utility costs, extended periods of drought will restrict building water usage and increase the prevalence of wild fires, and stronger and more frequent hurricanes will require a higher resiliency of building materials. In addition, properties already suffering from the effects of gradual climate risks are likely to experience an exaggerated impact if a catastrophic climate event does take place.

Less obvious are transition risks ***(CHAPTER 3 – PARAGRAPH 3.2.)*** over time not attributable to single catastrophic events. Progressive climate change could depress real estate market growth and viability, as well as property values. Public policies and regulations aimed at mitigating climate change effects could increase investment and ownership expenses, including taxes, insurance, code compliance, infrastructure and financing. Essential resources, such as energy and water, could become increasingly scarce and ever more costly.

5.1. RECENT CLIMATE EVENTS AND THEIR IMPACT ON THE MARKET

The ULI(Urban Land Institute)-Heitman Report published by IRE-BS (International Real Estate Business School) in 2017 and again in 2018, pointedly cites insurance industry volatility ***(β)*** stemming from uncertainty about an unknowable future and potentially skyrocketing premiums necessary to cover ever larger losses and claims. Viable and affordable insurance, a key to risk management, depends on being able to recognize and reasonably evaluate future risks. The global existent damage and related costs as a result of catastrophic climate events paid by insurance companies hit the record of $135 billion for damage caused by storms and natural disasters, but this figure is not representative of the actual damages (which in the United States alone were $307 billion).

A clear testimony of what described above came in September 2018, when Hurrican Florence resulted in economic losses fo over $10 billion, damaging thousands of real estate investment properties and commercial properties. Many of the demaged properties were insured with flood insurance, but the outflow of investment in the market led to a rise for flood insurance. Home sales, new construction and vacation rental market all saw direct effects from this event.

More recently, in August 2019, Hurricane Dorian devastated the Bahamas, causing over $7 billion in property demage to as many as 13.000 properties and resulting in up to $3 billion in insurance payouts. Though the path of the hurricane changed, indeed the original trajectory threatened over 6.6 million U.S. household amounting to $1.7 trillion woth of residential real estate.

The damage from the 2011 floods in Thailand amounted to around 10 percent of Thailand's GDP, not even considering all the indirect costs through a loss in economic activity in the country and abroad. By some estimates, the total costs of the 2018 wildfires in California were up to $350 billion, or 1.7 percent of U.S. GDP. Every year, climatic disasters cause human suffering as well as large economic and ecological damage. Over the past decade, direct damages of such disasters are estimated to add up to around US$ 1.3 trillion (or around 0.2% of world GDP on average, per year).

Individual country characteristics matter. Countries with more fiscal space will be able to deploy a swift response to the disaster in the form of financial relief and reconstruction efforts. Also, well-developed risk-sharing mechanisms such as insurance reduce or redistribute the disasters' losses and limit the impact on domestic equity prices. But the insurance industry has its limits, since premiums are typically based on retroactive data, whereas extreme weather events, increasingly exacerbated by climate change, are expected to continue to ramp up over the next several years. Furthermore, with the heightened prevalence of flooding in coastal areas, it is likely that a substantial number of properties could become uninsurable. In addition, it should be noted that insurance does not cover value losses at the time of property reversion or disposition. With large sea level increases projected over the next ten years, there are significant risks to reversion values at the end of holding periods for a vast number of coastal properties.

The challenge for Real Estate sector in the upcoming years is figuring out how to measure and mitigate future climate change risks affecting the sustainability and physical resilience of property, as well as property value, capital appreciation, revenue and liquidity.

CHAPTER 6

6. SYSTEMIC RISK IN THE REAL ESTATE MOST USED FINANCIAL TOOLS, THE CAPM MODEL AND THE MEASUREMENT OF THE RISK

The CAPM, acronym for Capital Asset Pricing Model, was first proposed by financial economist and Nobel laureate in economics William Sharpe in his 1970 book "Portfolio Theory and Capital Markets". The model is based on the idea that investments contains two types of risk:

Systemic risk: It is the risk that cannot be diversified. The risk that affects the portfolio due to prevailing market conditions such as interest rate, recession, wars, etc.

Unsystematic Risk: Also referred to as specific risk, it is a risk that can be diversified by adding several stocks to the portfolio. In more technical terms, it represents the component of the security's return that is not related to general market changes.

In analytical terms:

$$Ke = rf + \beta * (market\ premium) = rf + \beta * (rm - rf)$$

Where:

- *Ke* = Cost of equity
- β = Systemic risk coefficient
- *rm* = Market return
- *rf* = Risk Free rate
- β * *(rm – rf)* = Equity Risk Premium or Market Premium

- The Cost of equity (*Ke*) is what the company has to remunerate to the equity holders. As a consequence, this is what equity holders expect for their investment in the company. A rational investor would expect a remuneration that is a function of the taken and perceived risk.

- The Risk Free Rate (*rf*) is the rate whose actual return is exactly equal to the expected return – i.e., there is no uncertainty around the expected return. A risk-free investment should have no default risk and no reinvestment risk. These two conditions make the government bonds of very stable and well-consolidated countries or areas ideal risk-free securities that let analyst assess the risk-free rate. However, it should be clear that not all government bonds are riskless, and there are some companies that could be though to be. For EURO-dominated cash flows, the German 10-Year Bond can be considered a reference for the risk-free rate.

- The Risk Premium *(β * (rm – rf))* is instead the premium investors' demand for investing in a riskier investment relative to the risk-free rate. I should be computed as the difference between the riskier returns and the risk-free rate. The Risk Premium considers an equity market risk premium calculation and a systemic risk coefficient that can explain how equity investment is related to equity market. The equity market risk premium is given by the difference beyween stock market returns and risk-free rates.

Usually, the stock market return is proxied by a stock exchange index that measure the value of the stock market and how it changes over time. It is representative of different stocks included in the index and their changes (e.g. the S&P 500 index in the United States or the FTSE index in Italy).

- The risk coefficient β. In September 1964 William Sharpe introduces what nowadays is commonly indicated as β: " a consistent relationship between the equity expected returns and the market return. By definition the market returns are representative of the systemic risk." The bet also represents the part of an asset's risk which is due to its correlation with different factors on a combination that cannot be diversified away when the asset is added to the combination. Regression analysis determines how an independent variable affects a dependent variable. Statistically, this means that by collecting a large amount of data it is possible to study the relationship between the shares owned and the market portfolio. In fact, the goal is to determine to what extent the stock we are analyzing is more or less risky than the market portfolio. Once the data has been collected, they can be represented on a two-axis graph (x, y) forming a line ***(Figure 11)***. The Beta indicates the slope of that line. In short, the higher the Beta, the greater the slope of the line and vice versa. In statistics, this type of regression is also called linear regression. If the line shows a positive inclination, a positive correlation emerges between sensitivity to the systematic risk of an action (measured by β) and expected return. Conceptually, a progressive increase in risk will result in a higher expected return.

In analytical terms, the risk coefficient or company beta for *listed companies* is computed as the ratio between the covariance of the asset with the market portfolio and the variance of the market of the market portfolio (i.e., an ideal portfolio composed of all the stocks present in the market).

$$\beta = \frac{cov(Ri\ Rm)}{Var(Rm)}$$

Where:

- β = Company beta
- *Ri* = return of the share "i".
- *Rm* = return of market portfolio
- *Cov* =Covariance, in analytical terms: $Cov(X,Y) = \frac{\sum(Xi-x\hat{})(Yj-Y\hat{})}{n-1}$
- Var = Variance, in analytical terms: $Var(X) = E[(x - \mu)^2]$

The beta could assume different values, in particular:

- β < 0 means that the security has moved against the market.
- β < 1 means that the security has been less volatile than the market, and the security is said to be "defensive".
- β = 1 means that the security has moved with the market.
- β > 1 means that the security has been more volatile than the market and the security is said to be "aggressive".

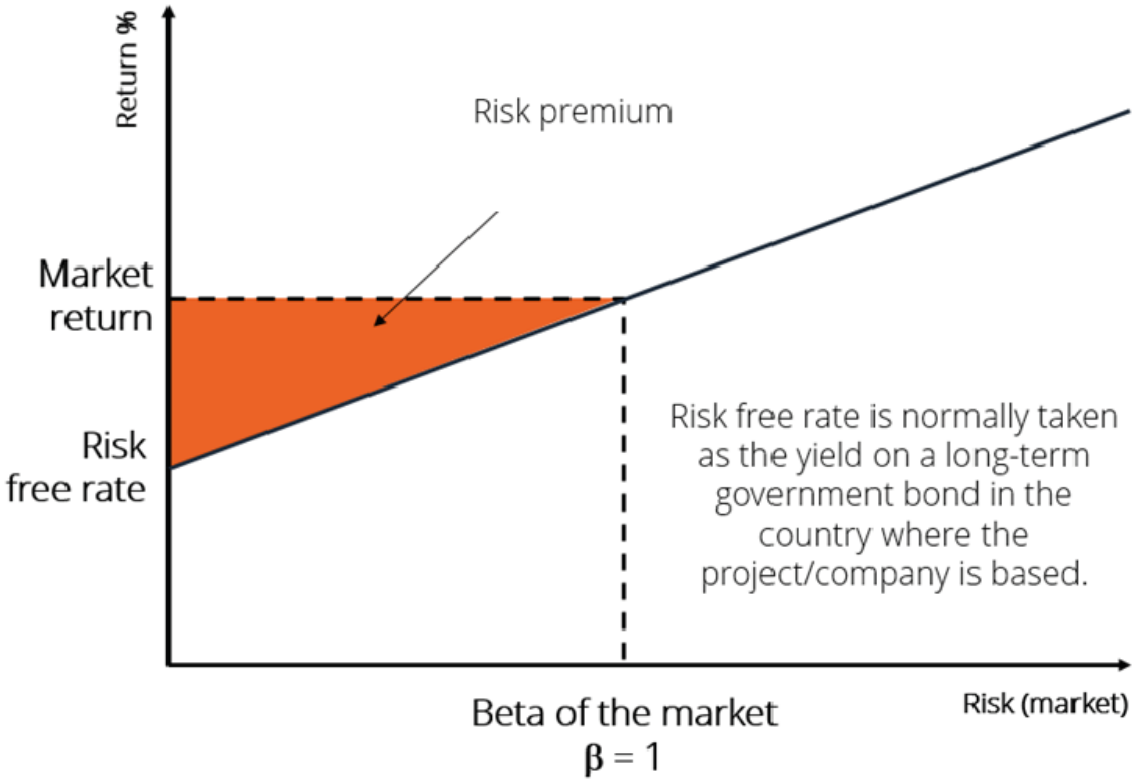


Figure 18 *– CAPM Beta, Risk-free rate and Market premium representation.*

Sharpe (1964) reports indeed that it is common for investment advisors to accept a lower expected return from defensive securities than they require from aggressive ones. There are some determinants for the beta:

- The industry effect: related to the beta sensitivity of demand and costs the company faces against macroeconomic factors like for example in the real estate sector, the sensitivity to changes caused by extreme climate events potentially affecting as previously said the demand in typology and quality of properties.
- The operating leverage: that measures the mix between the firm fixed and variable costs. Generally, companies with higher operating leverage have higher betas. The degree of operating leverage of a company is proxied by analyzing how muchthe earnings before interests and taxes (EBIT) changes in the case of an increase of 1% in sales.

$$DOL = \frac{\%\ change\ in\ EBIT}{\%\ change\ in\ sales}$$

- The financial leverage: ratio between debt and equity, proxied by analysing how much the EPS changes in the case of an increase of 1% in EBIT. Similarly to the previous case it measures the mix between the firm fixed and variable financial expenses. Companies with higher interest payments are those with higher betas.

For the sake of completeness in the following rows it will explained also the method used to compute the beta in case of *not listed companies*.

A common way to proceed is to find some comparable listed companies for which it is possibile to estimate their beta. Yet the available beta is levered (β^L), which means that is affected by the company debt-to-equity ratio and tax rate, diminishing comparability. Once comparable companies have been identified:

For each comparable must be computed its unlevered beta (β^U) considering its debt-to-equity ratio and tax rate.

$$\beta^U_{Comparable\ 1} = \frac{(\beta^L\ Comparable\ 1)}{1+(1-Tr\ Comparable\ 1)*(\frac{D}{E}\ Comparable\ 1)}$$

Then compute the average unlevered beta. I twill be then possibile to use the average unlevered beta and releverage it considering the target company data:

$$\beta^L_{Target} = \beta^U * [1 + (1 - Tr\ target) * \left(\frac{D}{E}\ Target\right)]$$

6.1. CONNECTION OF RISK WITH WACC, NPV AND IRR

It should be clear that having a higher beta in the computation of the CAPM does not end its implications in having a correspondent higher Ke (Cost equity). Indeed the Ke is a component in the calculation of the WACC or Weighted Average Cost of Capital that represents the average cost of debt and equity capital used to finance a real estate investment, and has the power of amplify or diminish the final value of the cost of capital. In analytical terms:

$$WACC = [\left(Ke * \left(\frac{E}{D+E}\right)\right) + \left(Kd * (1 - Tr) * \left(\frac{D}{D+E}\right)\right)]$$

Where:

- *Ke* = Cost of Equity
- *E* = Equity
- *D* = Debt
- *Kd* = Cost of Debt
- *Tr* = Tax Rate

In turn the computation of the WACC is foundamental to another important instrument used by the Real Estate Industry to evaluate investments, that is the Net Present Value or NPV computation. The NPV offers investors the best option to measure the present value of future cash flows of a project, while taking the discount rate into consideration, and it is given by the sum of the cash inflow/outflow discounted back to its present value. It is a comprehensive way to calculate whether a proposed project will be financially viable or not. The calculation of NPV encompasses many financial topics in one formula: cash flows, the time value of money, the discount rate over the duration of the project (WACC), terminal value and salvage value. In analytical terms:

$$\text{NPV} = \sum_{t=1}^{n} \frac{Rt}{(1+i)^t}$$

Where:

- Rt = Net cash inflow / outflows during a single period t.
- i = Discount rate or return that could be earned in alternative investments. Here can be used the WACC.
- t = Number of time periods.

Money in the present is worth more than the same amount in the future due to inflation and to earnings from alternative investments that could be made during the intervening time. In other words, a euro earned in the future won't be worth as much as one earned in the present. The discount rate or WACC element of the NPV formula is a way to account for this.

Net present value is a money amount (not a percentage rate) and will always result in one of the following amounts.

- **Greater than zero** - this means that the discounted value of the future cash flows is greater than the initial investment and thus you're getting a higher rate of return than you desired
- **Equal to zero** - this means that the discounted value of the future cash flows is exactly equal to your initial investment and thus you're getting the return you desired exactly
- **Less than zero** - this means that the discounted value of the future cash flows is less than the initial investment and thus you're getting a lower rate of return than you desired

As stated earlier, net present value is commonly used in real estate sector by investors and analysts to evaluate investment real estate opportunities. It is for sure not be used as the only factor to decide whether a rental property provides a good buying opportunity, but NPV does offer the investor a quick and easy way to determine whether a property might yield the investor's desired rate of return. Again as before it should be noted the relationship between values of the beta and the computation of NPV and the correlated implications in investment decision making. Higher values of β will take down the values of WACC but up the values of the NPV pointing out the recognition and the following higher compensation for the higher risk taken.

Following the chain of the connections another instrument and indicator commonly used in the Real Estate sector is the IRR, or the Internal Rate of Return. The IRR considers the time value of money and is frequently referred to, as the time adjusted rate of return. It is defined as the discount rate that makes the present value of the cash inflows equal to the present value of the cash outflows in a capital budgeting analysis, where all future cash flows are discounted to determine their present values. In analytical terms:

$$0 = \text{NPV} = \sum_{t=1}^{n} \frac{Rt}{(1+IRR)^t} - R0$$

Where:

- *R0* = Total initial investment cost.

The higher an internal rate of return, the more desirable an investment is to undertake. In general, when comparing investment options whose other characteristics are similar, the investment with the highest IRR would probably be considered the best.

The following table ***(Figure 12)*** will show the relationships between the three main instruments analyzed till now.

- If the present value of the expected cash outflows is greater than the present value of the expected cash inflows then NPV < 0.
- If the present value of the expected cash outflows is equal to the present value of the expected cash inflows then NPV = 0.
- If the present value of the expected cash outflows is less than the present value of the expected cash inflows then NPV > 0.

RELATIONSHIP BETWEEN IRR, NPV WACC		
IF	THEN	DECISION
NPV < 0	IRR < COST OF CAPITAL	Reject the investment from the cash flow perspective. But other factors could be important
NPV = 0	IRR = COST OF CAPITAL	Provide the minimum return.
NPV > 0	IRR > COST OF CAPITAL	Screen in for further analysis. Other investments may provide better returns and capital should be rationed.

Figure 19 *– Relationship between IRR, NPV, WACC. Source:Managing and Accounting Web.*

CHAPTER 7

7. DATA SETTING: REITs PRESENTATION, BETAS COMPUTATION AND CLIMATE RELATED EVENTS DISPLAY

After having introduced the basing concepts of "Climate change", "Systemic risk", the correlations between the two and the possible implications that could be reflected into the financial instruments and valuations tools used by the Real Estate Sector and its main actors (REITs, Banks, Asset Management Founds etc.) to assess the viability of investments, it is now possible to present the main objective of this study. Are the Betas of REITs somehow related to the changes of climate related events?

To answer this question a subset of 32 different REITs has been set up, considering three different locations: Hong Kong, Japan, USA, for which it was possibile to easily and freerly collect a sufficient amount of data. The choice of the funds has been carried out trying to consider the greatest possibile variety in terms of Real Estate operating sectors of the companies, ranging from logistic and industrial, residential, retail, commercial, etc., so to include in the analysis as much variance as possibile and to depict the possible different sensibilities of the sectors to events.

Also, the choice of these three particular countries is given by the fact that all of them are subject to main effects of climate change, from hurricanes, storms, tornadoes, wildfires etc.. Again this is usefull to understand which typology of the funds is more subjected to the events, and to introduce as more variety as possible.

All the 32 funds were part of a previous study, already mentioned before that is: *"Climate Risk, Real Estate, and the Bottom Line"* by *Geophy and 427 Company*. Knowing that all the selected REITs have a consistent portion of their portfolio (from 5% to 50%) under climate events risks (floods, rising sea level, thunderstorms, heavy rain and winds etc.), the purpose of this analysis is to proove whether or not there is a commensurate consideration of the risk exposure in the company's financial assessment instruments.

7.1. REITs PRESENTATION

Before introducing the proper calculation of the betas and the representation of the climate events characterizing the areas of investment, a brief introduction of the REITs taken into consideration must be carried out. In the following paragraph the three different countries' fund will be displayed using resuming tables.

- **USA based** ***(Figure20)***: the investment funds taken into consideration are eight Public Companies all listed in the S&P 500 stock market. They are all more or less new and with a substantial portfolio formed by a large amount of properties located for the majority of times in USA inland territory. Some of them have also invested in foreign countries like Ventas Group, Prologis and American Tower.

NAME	YEAR	TYPE	REAL ESTATE SECTOR	PORTFOLIO DIMENSIONS	AREA OF INVESTMENT	ASSET VALUE (2019)	STOCK MARKET
SL GREEN REALTY	1997	Real Estate Investment Trust - Public Company	Office Landlord	40,6 Million Sqm	New York	$12,8 Billions	S&P500
ALEXANDRIA REAL ESTATE EQUITIES	1994	Real Estate Investment Trust - Public Company	Differenciated	34,3 Million Sqm	USA	$18,4 Billions	S&P500
VENTAS GROUP	1998	Real Estate Investment Trust - Public Company	Healthcare	*Not Specified*	USA, Canada	$24,7 Billions	S&P500
SIMON PROPERTY GROUP	1993	Real Estate Investment Trust - Public Company	Retail, Commercial Malls	22,4 Million Sqm	USA	$31,3 Billions	S&P500
PROLOGIS	1983	Real Estate Investment Trust - Public Company	Industrial Plants, Logistics	75,6 Million Sqm	USA, Europe, Asia	$40,2 Billions	S&P500
EQUITY RESIDENTIAL	1969	Real Estate Investment Trust - Public Company	Residential	*Not Specified*	USA	$21,2 Billions	S&P500
VORNADO REALTY TRUST	1982	Real Estate Investment Trust - Public Company	Office, Retail, Residential	2,5 Million Sqm	New York, San Francisco, Chicago	$18,3 Billions	S&P500
AMERICAN TOWER	1995	Real Estate Investment Trust - Public Company	Communication Infrastructures	*Not Specified*	Worldwide	$33 Billions	S&P500

Figure 20 *– USA REITs presentation. Author's elaboration.*

- **JAPAN based** ***(Figure 21)*****:** the investment funds taken into consideration are twelve Public Companies all listed in the NIKKEI 225 stock market. They are much more new compared to ones based in the USA, and possibly for this reason they own smaller portfolios with properties located exclusively in Japan inland territory.

NAME	YEAR	TYPE	REAL ESTATE SECTOR	PORTFOLIO DIMENSIONS	AREA OF INVESTMENT	ASSET VALUE (2019)	STOCK MARKET
MITSUBISHI ESTATE	2015	Real Estate Investment Trust - Public Company	Logistics	0,9 Million Sqm	Japan	¥142,1 Billions	NIKKEI 225
AEON REIT	2013	Real Estate Investment Trust - Public Company	Retails	3,7 Million Sqm	Japan	¥343,4 Billions	NIKKEI 225
GLP J-REIT	2012	Real Estate Investment Trust - Public Company	Logistics	3,6 Million Sqm	Japan	¥741,1 Billions	NIKKEI 225
ORIX JREIT	2002	Real Estate Investment Trust - Public Company	Officies, Residential	1,6 Million Sqm	Japan	¥649 Billions	NIKKEI 225
TOKYO TATEMONO	1896	Real Estate Investment Trust - Public Company	Differentiated	*Not specified*	Japan	*Not specified*	NIKKEI 225
NIPPON BUILDING FUND	2001	Real Estate Investment Trust - Public Company	Retails, Officies	1,2 Million Sqm	Japan	¥1,4 Billions	NIKKEI 225
NOMURA REAL ESTATE HOLDING	2004	Real Estate Investment Trust - Public Company	Differentiated	*Not specified*	Japan	*Not specified*	NIKKEI 225
KENEDIX REIT	2014	Real Estate Investment Trust - Public Company	Differentiated	2,5 Million Sqm	Japan	¥226,3 Billions	NIKKEI 225
SUMITOMO REALTY&DEVELOPMENT	1949	Real Estate Investment Trust - Public Company	Residential	2,3 Million Sqm	Japan	¥163,6 Billions	NIKKEI 225
HULIC REIT	2013	Real Estate Investment Trust - Public Company	Differentiated	0,35 Million Sqm	Japan	¥0,72 Billions	NIKKEI 225
JAPAN LOGISTIC FUND	2005	Real Estate Investment Trust - Public Company	Logistics	0,31 Million Sqm	Japan	¥1,3 Billions	NIKKEI 225
MITSUI FUDOSAN	1941	Real Estate Investment Trust - Public Company	Differentiated	*Not specified*	Japan	*Not specified*	NIKKEI 225

Figure 21 *– Japan REITs presentation. Author's elaboration.*

- **HONG KONG based** ***(Figure22)***: the investment funds taken into consideration are twelve Public Companies all listed in the HKEX stock market. Compared to the ones of USA and Japan they have been mostly established further back in time. Their portfolios are more similar to the ones of Japan funds than USA based. The reduced territories of Hong Kong and the strong "relationship" with China underline that a substantial amount of investments have been carried out in the mainland. Some of them have also invested in London, Sydney and in all the coutries of neighboring Asia.

NAME	YEAR	TYPE	REAL ESTATE SECTOR	PORTFOLIO DIMENSIONS	AREA OF INVESTMENT	ASSET VALUE (2019)	STOCK MARKET
CHAMPION REIT	2006	Real Estate Investment Trust - Public Company	Offices	0,27 Million Sqm	Hong Kong	HK$ 72,1 Billions	HKEX
FORTUNE REIT	2003	Real Estate Investment Trust - Public Company	Commercial	0,28 Million Sqm	Hong Kong	HK$ 42,8 Billions	HKEX
HYSAN DEVELOPMENT	1970	Real Estate Investment Trust - Public Company	Residential, Offices	0,42 Million Sqm	Hong Kong	HK$ 82,1 Billions	HKEX
HANG LUNG PROPERTIES	1960	Real Estate Investment Trust - Public Company	Offices	*Not Specified*	Hong Kong, China	HK$ 4,2 Billions	HKEX
NEW WORLD DEVELOPMENT	1970	Real Estate Investment Trust - Public Company	Differentiated	*Not Specified*	Hong Kong, China	HK$ 60 Billions	HKEX
SUN HUNG KAY PROPERTIES	1972	Real Estate Investment Trust - Public Company	Residential, Offices, Retail	4,5 Million Sqm	Hong Kong, China	HK$ 14,7 Billions	HKEX
HENDEROSN LAND DEVELOPMENT	1981	Real Estate Investment Trust - Public Company	Differentiated	5,9 Million Sqm	Hong Kong, China	HK$ 24,2 Billions	HKEX
CHEUNG KONG PROPERTY HOLDING	1950	Real Estate Investment Trust - Public Company	Hotel, Offices	0,86 Million Sqm	Hong Kong, China, England, Singapore	HK$ 42,4 Billions	HKEX
HONG KONG LAND	1889	Real Estate Investment Trust - Public Company	Residential, Offices	0,85 Million Sqm	Asia	HK$ 40,6 Billions	HKEX
SWIRE PROPERTIES	1972	Real Estate Investment Trust - Public Company	Offices, Hotel, Residential	2,5 Million Sqm	Hong Kong, China, Singapore, USA	HK$ 32,6 Billions	HKEX
LINK REIT	2004	Real Estate Investment Trust - Public Company	Office, Retail	1,5 Million Sqm	Hong Kong, China, Sydney, London	HK$ 23,2Billions	HKEX
THE WHARF PROPERTY HOLDING	1886	Real Estate Investment Trust - Public Company	Logistic, Hotel, Offices	3,3 Million Sqm	Hong Kong, China	HK$ 17,8 Billions	HKEX

Figure 22 *– Hong Kong REITs presentation. Author's elaboration.*

7.2. REITs BETA CALCULATION

Now that all the REITs used in the analysis have been introduced it is possible also to explain the procedure followed in order to obtain the "beta values" to be used in the correlation analysis with the climate related events to depict wether or not the funds actually take into cosideration climate change as a source of potential risk for their operations.

As explained in "***CHAPTER 6***" the beta is computed as the ratio between the covariance of the asset with the market portfolio and the variance of the market of the market portfolio (i.e., an ideal portfolio composed of all the stocks present in the market). To compute this formula it has been necessary to collect the "adjusted closing prices" of both the REIT under evaluation and the stock market in which it is listed. Those data have been collected through historical records taken from the archives of Yahoo Finance on a monthly base for each year, going back for eleven years to cover an adeguate time horizon. ***(Figure 23, 24, 25, 26, 27)***

The decison to unbundle and setting the time frame at twelve observations (monthly base) for the collection of the data was made to leverage on an adeguate number of observations to compose the calculus of the beta. Also daily observations could have been used but in that way the amount of data would have been too large to handle, and the benefits of having observations, certainly more precise in following trends, wuold have been outweighed by the emerging complications in managing them.

An important consideration must be made on the use of "adjusted close price" and not of "close price". Stock values are stated in terms of the closing price and the adjusted closing price. The latter is the raw price, which is just the cash value of the last transacted price before the market closes, while adjusted closing price factors in anything that might affect the stock price after the market closes. It amends a stock's closing price to reflect that stock's value after accounting for any corporate actions, and it is often used when examining historical returns or doing a detailed analysis of past performance. A stock's price is typically affected by supply and demand of market participants. However, some corporate actions, such as stock splits, dividends, and rights offerings, affect a stock's price.

After the collection of the adjusted close prices of both REITs and stock markets it has then been possible to estimates the values of the monthly returns used in the beta calculation expressed in percentage terms. The formula used is really simple and it is the adjusted closing price in each monthby divided by the previous adjusted monthly closing, minus 1. ***(Figure 23, 24, 25, 26, 27)***

Once obtained the returns values, it was possible to compute firstly the value of the *variance*, calculated as: $Var(X) = E[(x - \mu)^2]$; of the REIT returns, and then the *covariance* calculated as $Cov(X, Y) = \frac{\sum(Xi - x\hat{})(Yj - Y\hat{})}{n-1}$; between the returns of the REIT and of the stock market. Those two values are the most important to then compute the annual value of beta for the single fund.

Finally, after having computed the returns it was possible to calculate the REIT univocal annual beta for the specific year divideing the covariance by the variance, resulting in values that can range as follow : $\beta < 0$ / $\beta = 0$ / $\beta < 1$ / $\beta = 1$ / $\beta > 1$. ***(Figure 23, 24, 25, 26, 27)***

VENTAS GROUP						
2017	VENTAS GROUP	S&P500	RETURNS		VARIANCE	COVARIANCE
DATE	ADJUSTED CLOSE	ADJUSTED CLOSE	V.G.	S&P500	0,001446313	-0,000148969
01/12/2017	50.618.591	2.673.610.107	-6,25%	3,43%	β VENTAS GROUP	-0,10
01/11/2017	53.992.607	2.584.840.088	2,01%	0,37%		
01/10/2017	52.929.794	2.575.260.010	-2,57%	2,22%		
01/09/2017	54.324.448	2.519.360.107	-4,84%	1,93%		
01/08/2017	57.085.300	2.471.649.902	1,62%	0,05%		
01/07/2017	56.176.128	2.470.300.049	-1,93%	1,93%		
01/06/2017	57.281.109	2.423.409.912	4,50%	0,48%		
01/05/2017	54.816.063	2.411.800.049	3,87%	1,16%		
01/04/2017	52.771.500	2.384.199.951	-0,39%	0,91%		
01/03/2017	52.980.343	2.362.719.971	-0,02%	-0,04%		
01/02/2017	52.988.503	2.363.639.893	5,48%	3,72%		
01/01/2017	50.235.203	2.278.870.117				

Figure 23 *– USA based REIT named Ventas Group, beta calculation. Author's elaboration.*

Figure 23 shows the calculation of the beta for the year 2017 of the USA based REIT Ventas Group, and it is possible to notice how the value is negative, stating that for that particular year the security moved against the market.

SL GREEN REALTY						
2019	SL GREEN REALTY	S&P500	RETURNS		VARIANCE	COVARIANCE
DATE	ADJUSTED CLOSE	ADJUSTED CLOSE	SL.G.R.	S&P500	0,001367614	2,86888E-06
01/12/2019	86.095.299	3.230.780.029	7,68%	2,86%	β SL GREEN REALTY	0,00
01/11/2019	79.957.680	3.140.979.980	2,07%	3,40%		
01/10/2019	78.336.601	3.037.560.059	3,33%	2,04%		
01/09/2019	75.811.913	2.976.739.990	1,91%	1,72%		
01/08/2019	74.393.051	2.926.459.961	-1,06%	-1,81%		
01/07/2019	75.190.582	2.980.379.883	1,97%	1,31%		
01/06/2019	73.739.861	2.941.760.010	-6,55%	6,89%		
01/05/2019	78.905.403	2.752.060.059	-2,65%	-6,58%		
01/04/2019	81.052.368	2.945.830.078	-0,81%	3,93%		
01/03/2019	81.717.003	2.834.399.902	-0,88%	1,79%		
01/02/2019	82.444.016	2.784.489.990	-1,85%	2,97%		
01/01/2019	83.998.016	2.704.100.098				

Figure 24 *– USA based REIT named SL Green Realty, beta calculation. Author's elaboration.*

Figure 24 shows the calculation of the beta for the year 2019 of the USA based REIT SL Green Realty, and it is possibile to see how the value is equal to zero meaning that the security movement is uncorrelated with the market.

ALEXANDRIA REAL ESTATE EQUITIES						
2018	ALEXANDRIA REAL ESTATE EQUITIES	S&P500	RETURNS		VARIANCE	COVARIANCE
DATE	ADJUSTED CLOSE	ADJUSTED CLOSE	A.R.E.E.	S&P500	0,001153392	0,001033183
01/12/2018	108.983.856	2.506.850.098	-7,44%	-9,18%	β ALEXANDRIA REAL ESTATE EQUITIES	0,90
01/11/2018	117.741.150	2.760.169.922	1,86%	1,79%		
01/10/2018	115.594.391	2.711.739.990	-2,09%	-6,94%		
01/09/2018	118.057.480	2.913.979.980	-1,99%	0,43%		
01/08/2018	120.460.106	2.901.520.020	0,71%	3,03%		
01/07/2018	119.606.056	2.816.290.039	1,76%	3,60%		
01/06/2018	117.531.837	2.718.370.117	1,00%	0,48%		
01/05/2018	116.367.416	2.705.270.020	0,28%	2,16%		
01/04/2018	116.041.382	2.648.050.049	0,49%	0,27%		
01/03/2018	115.481.094	2.640.870.117	2,95%	-2,69%		
01/02/2018	112.170.792	2.713.830.078	-6,47%	-3,89%		
01/01/2018	119.928.711	2.823.810.059				

Figure 25 *– USA based REIT named Alexandria Real Estate Equities, beta cakculation. Author's elaboration.*

Figure 25 shows the calculation of the beta for the year 2018 of the USA based REIT Alexandria Real Estate Equities, and it is possibile to see how the beta value is positive but less than one, meaning that the security has been less volatile than the market, and the security is said to be "defensive".

SUN HUNG KAY PROPERTIES						
2014	S.H.K.P.	HKEX	RETURNS		VARIANCE	COVARIANCE
DATE	ADJUSTED CLOSE	ADJUSTED CLOSE	S.H.K.P.	HKEX	0,002941513	0,002969543
01/12/2014	96.958.565	147.847.778	6,54%	1,66%	β HONG KONG	1,01
01/11/2014	91.004.539	145.436.752	-1,90%	-1,75%		
01/10/2014	92.770.065	148.020.004	5,00%	2,87%		
01/09/2014	88.356.247	143.886.795	-6,38%	-5,24%		
01/08/2014	94.375.069	151.837.585	-0,25%	2,65%		
01/07/2014	94.615.829	147.915.909	10,91%	20,07%		
01/06/2014	85.306.725	123.192.215	0,28%	0,14%		
01/05/2014	85.065.964	123.021.698	8,55%	4,54%		
01/04/2014	78.365.013	117.680.382	3,85%	18,79%		
01/03/2014	75.461.273	99.063.820	-4,33%	-2,33%		
01/02/2014	78.876.877	101.422.470	4,75%	-1,23%		
01/01/2014	75.302.391	102.686.035				

Figure 26 *– Hong Kong based REIT named Sun Hung Kay Properties, beta calculation. Author's elaboration.*

Figure 26 shows the calculation of the beta for the year 2014 of the Hong Kong based REIT Sun Hung Kay Properties, and it is possibile to see how the beta value is almost equal to one, meaning that the security has been as volatile as the market, they moved together.

HENDERSON LAND DEVELOPMENT						
2015	H.L.D.	HKEX	RETURNS		VARIANCE	COVARIANCE
DATE	ADJUSTED CLOSE	ADJUSTED CLOSE	H.L.D.	HKEX	0,004362684	0,011592506
01/12/2015	25.413.212	175.199.295	-0,52%	-1,73%	β HONG KONG	2,66
01/11/2015	25.547.001	178.288.422	-3,83%	-0,88%		
01/10/2015	26.563.515	179.877.136	9,01%	15,27%		
01/09/2015	24.368.151	156.046.524	-3,46%	-1,26%		
01/08/2015	25.240.349	158.034.729	-6,74%	-13,32%		
01/07/2015	27.063.995	182.321.045	-1,92%	-23,17%		
01/06/2015	27.593.796	237.312.302	-6,71%	-7,64%		
01/05/2015	29.577.394	256.946.899	0,40%	0,61%		
01/04/2015	29.459.202	255.396.973	14,42%	56,11%		
01/03/2015	25.747.276	163.605.591	2,74%	6,15%		
01/02/2015	25.061.579	154.133.698	-4,33%	0,22%		
01/01/2015	26.196.434	153.789.261				

Figure 27 *– Hong Kong based REIT named Henderson Land Development, beta calculation. Author's elaboration.*

Figure 27 shows the calculation of the beta for the year 2015 of the Hong Kong based REIT Henderson Land Development, and it is possible to see how the beta value is much grater than one, meaning that the security has been more volatile than the market and the security is said to be "aggressive".

Some of the funds, as can be seen at the beginning of this chapter, also have invested in other foreign countries and they are listed also in other stock markets, a part from the ones of where they are based. In order to consider also that, and to increase the number of observations, it has been decided to calculate the corrispondent beta for the REIT in the countries in which it invested. It is possible to see an example in the ***Figure 28***, where Hang Lung Properties fund, based in Hong Kong, also have investments in the Mainland China, a common thing in Hong Kong.

HANG LUNG PROPERTIES								
2010	H.L.P.	HKEX	SSE 50 COMPOSITE	RETURNS			VARIANCE	COVARIANCE
DATE	ADJUSTED CLOSE	ADJUSTED CLOSE	ADJUSTED CLOSE	H.L.P.	HKEX	SSE 50 COMPOSITE	0,00457108	0,001403184
01/12/2010	25.606.766	136.138.840	2.808.076.904	0,55%	-0,90%	-0,43%	β HONG KONG	0,31
01/11/2010	25.465.881	137.374.344	2.820.180.908	-3,37%	4,28%	-5,33%	0,00457108	0,0018007
01/10/2010	26.354.980	131.737.289	2.978.834.961	0,13%	11,65%	12,17%	β MAINLAND CHINA	0,39
01/09/2010	26.320.255	117.992.157	2.655.657.959	9,06%	27,27%	0,64%		
01/08/2010	24.132.690	92.706.764	2.638.798.096	7,25%	-4,54%	0,05%		
01/07/2010	22.500.696	97.117.752	2.637.502.930	7,46%	4,16%	9,97%		
01/06/2010	20.938.147	93.239.136	2.398.370.117	10,04%	2,51%	-7,48%		
01/05/2010	19.028.366	90.957.588	2.592.145.996	-3,86%	-6,09%	-9,70%		
01/04/2010	19.792.274	96.860.275	2.870.611.084	-8,95%	-0,23%	-7,67%		
01/03/2010	21.736.784	97.084.999	3.109.104.980	6,21%	-0,23%	1,87%		
01/02/2010	20.465.673	97.309.738	3.051.943.115	11,89%	-1,81%	2,10%		
01/01/2010	18.291.412	99.107.613	2.989.291.992					

Figure 28 *– Hong Kong based REIT named Hang Lung Properties, beta calculation. Author's elaboration.*

Since the time span of the observations is eleven years, from 2010 to 2020, both included, in some cases, as again it is possbile to see in paragraph "***7.2. REITs PRESENTATION***", several funds were not active for all the time taken into consideration. To keep trace of this, and to validate, or not, the results coming from the computations, "dummy variables" were used.

A dummy variable (aka, an indicator variable) is a numeric variable that represents categorical data. Technically, dummy variables are dichotomous, quantitative variables. Their range of values is small; they can take on only two quantitative values. As a practical matter, regression results are easiest to interpret when dummy variables are limited to two specific values, 1 or 0. A dummy independent variable (also called a dummy explanatory variable) which for some observation has a value of 0 will cause that variable's coefficient to have no role in influencing the dependent variable, while when the dummy takes on a value 1 its coefficient acts to alter the intercept. Typically, 1 represents the presence of a qualitative attribute, and 0 represents the absence. In this case a value equal to 1 means that the REIT was active in that particular year under investigation, while 0 means that the REIT was not active.

In ***Figure 29*** and ***Figure 30*** it is possible to see a case in which the fund under analysis, in this case Mitsui Fudosan was always active during the period of the analysis, while in ***Figure 31*** and ***Figure 32*** it is possible to see how the fund Mitsubishi Estate was not active for all the duration of the analysis.

YEAR	β MITSUI FUDOSAN	REIT ACTIVITY	DUMMY VARIABLE
2020	0,43	YES	1
2019	-0,21	YES	1
2018	0,67	YES	1
2017	0,40	YES	1
2016	0,54	YES	1
2015	0,62	YES	1
2014	0,24	YES	1
2013	0,37	YES	1
2012	0,51	YES	1
2011	0,44	YES	1
2010	0,33	YES	1

Figure 29 – *Japan based REIT Mitsui Fudosan, beta results per year and fund activity. Author's elaboration.*

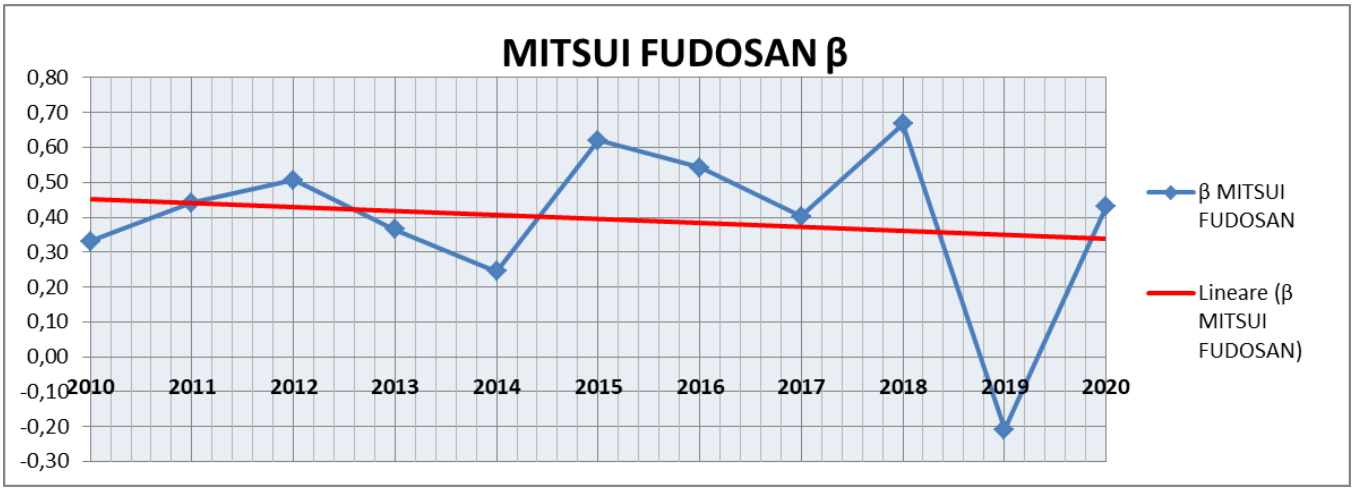


Figure 30 – *Japan based REIT Mitsui Fudosan, scatter plot of beta results per year and linear trend. Author's elaboration.*

YEAR	β MITSUBISHI ESTATE	REIT ACTIVITY	DUMMY VARIABLE
2020	0,58	YES	1
2019	-0,55	YES	1
2018	0,62	YES	1
2017	0,44	YES	1
2016	0,00	NO	0
2015	0,00	NO	0
2014	0,00	NO	0
2013	0,00	NO	0
2012	0,00	NO	0
2011	0,00	NO	0
2010	0,00	NO	0

Figure 31 *– Japan based REIT Mitsubishi Estate, beta results per year and fund activity. Author's elaboration.*

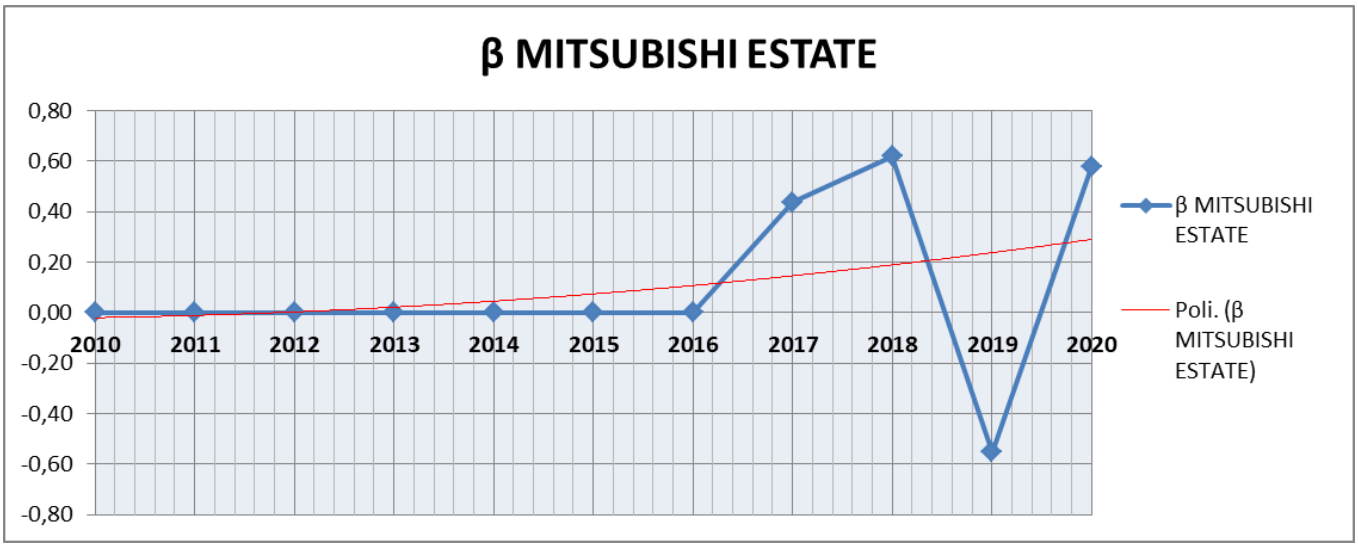


Figure 32 *– Japan based REIT Mitsubishi Estate, scatter plot of beta results per year and linear trend. Author's elaboration.*

7.2.1. BETA COMPUTATION - RESULTS

Now that the procedure on how the beta values have been computed and plotted, and that the possible outcomes results have been understood, it is viable to present the grouped results of the three different geographycal locations: USA, Hong Kong, Japan.

- **USA based:** the investment funds analysed were 8, so the final number of collected observations is 88. The overall trend of the beta is generally decreasing with time, presenting a more common spread behaviour between 2013 and 2017 where betas do not deviate so much, while i the last years the observations seem to be more disperse. The beta results never go over the value of 1 all along the time span under analysis, pointing out an overall lower volatility in rispect to the stock market benchmark, thus avoiding ups and downs of the stocks, emphasizing a defensive attitude on the part of the REITs. ***(Figure 33)***

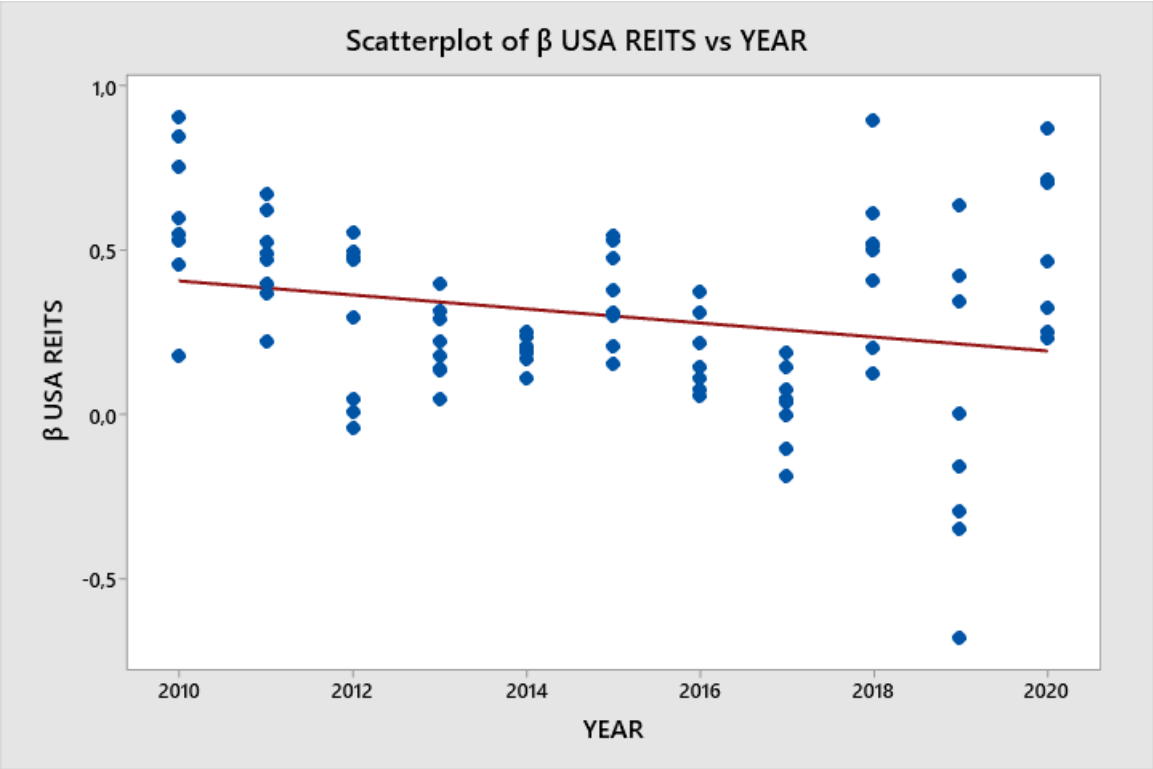


Figure 33 *– Scatterplot of USA based REITs betas versus year and overall trend. Author's elaboration.*

- **Japan based:** the investment funds analysed were 12, so the final number of collected observations should be 132, but considering that not all the REITs where active alla long the time, the actual number of observations is 110. Also here the overall trend of the betas in the last 11 years seems to decrease, but here the values are much more disperse in respect to the ones of the USA based funds. Commonly also for Japanese real estate actors the beta values never go over the value of 1, underlining a defensive behaviour and more steady volatility. ***(Figure 34)***

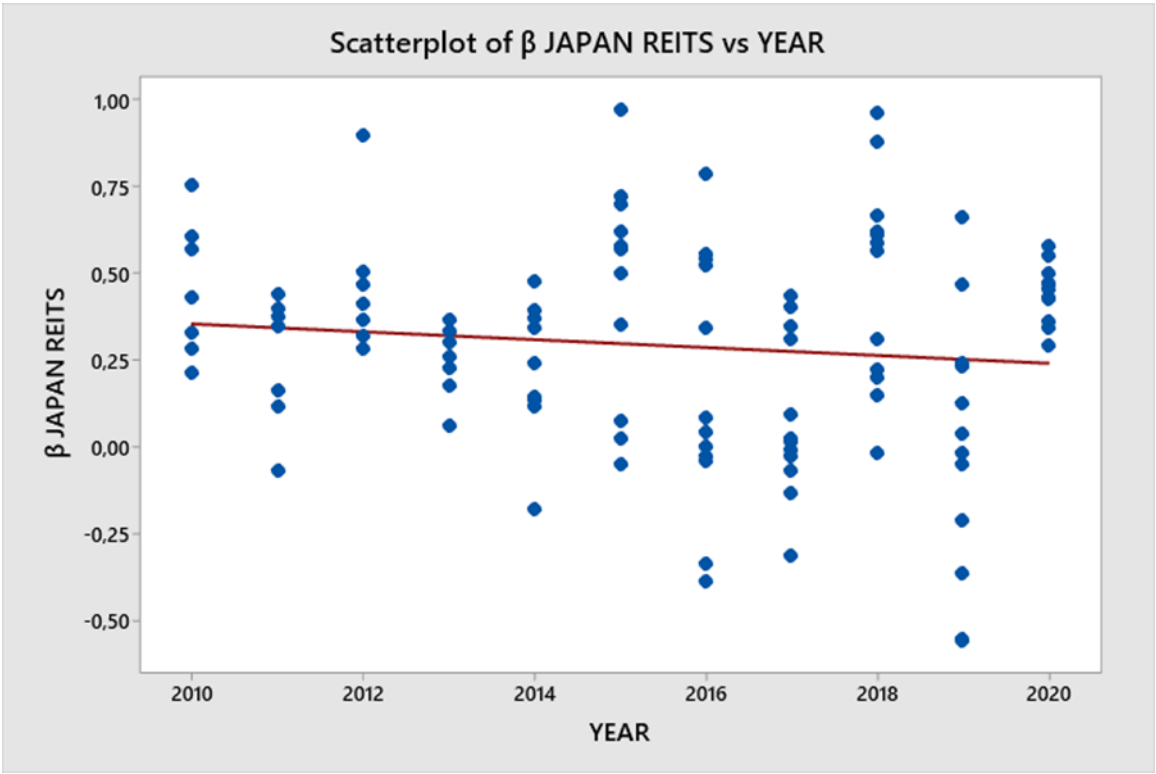


Figure 34 *– Scatterplot of Japan based REITs betas versus year and overall trend. Author's elaboration.*

- **Hong Kong based:** the investment funds analysed were 12, so the final number of collected observations in this case resulted in a complete number equal to 132. Again also in this case the overall betas values follow a decreasing trend from the starting date of the analysis. Contrary to the REITs based in Japan the ones based in Hong Kong present annual values that are more compacted, probably due to the fact that the funds are much more similar within them in repsect to the Japanese ones. Differently from the two previous cases the results of the betas are much more higher, with some values that are well above 2, all concentrated in 2015, and with a quite amount of observations over 1. This underline a general aggressive behaviour for the Hong Based funds, with a volatility greater than the one of the stock market, pointing out a security's value can potentially be spread out over a larger range of values. This means that the price of the security can change dramatically over a short time period in either direction. In most cases, the higher the volatility, the riskier the security. ***(Figure 35)***

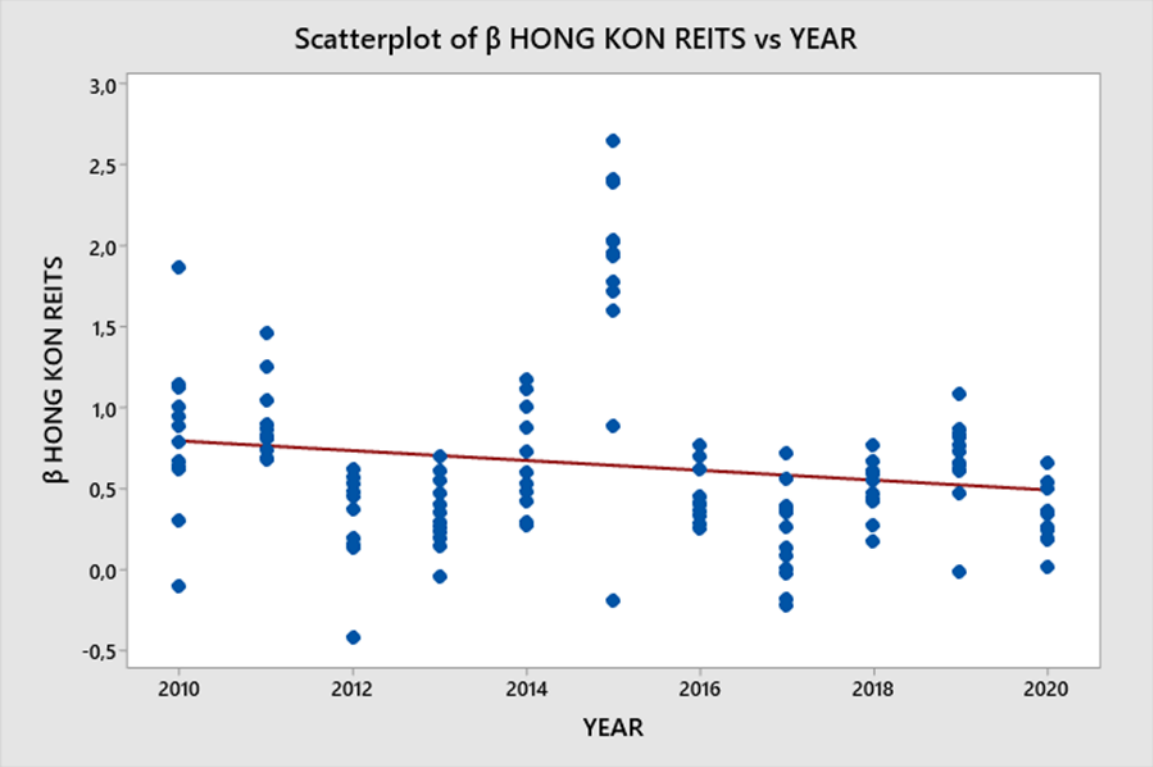


Figure 35 *– Scatterplot of Hong Kong based REITs betas versus year and overall trend. Author's elaboration.*

Also the results provided by an average standard deviation analysis on the REITs provide results that underline the higher volatility of the Hong Kong (STD = 0,560) and Japan (STD = 0,302) based funds ***(Figure 38 and 37)***, while a more steady and stable trend of the USA (STD = 0,266) based ones ***(Figure 36)***.

	YEAR	β SL GREEN REALTY	β ALEXANDRIA REAL ESTATE EQUITIES	β VENTAS GROUP	β SIMON PROPERTY GROUP	β PROLOGIS	β EQUITY RESIDENTIAL	β VORNADO REALTY TRUST	β AMERICAN TOWER
USA	2020	0,25	0,71	0,32	0,23	0,72	0,46	0,32	0,87
	2019	0,00	-0,68	-0,16	0,42	0,64	-0,29	0,35	-0,35
	2018	0,51	0,90	0,20	0,52	0,61	0,41	0,50	0,13
	2017	0,05	0,19	-0,10	0,07	-0,18	0,04	0,14	0,00
	2016	0,22	0,37	0,14	0,22	0,31	0,08	0,11	0,06
	2015	0,47	0,53	0,15	0,21	0,30	0,31	0,38	0,54
	2014	0,19	0,17	0,11	0,25	0,24	0,20	0,21	0,19
	2013	0,29	0,40	0,05	0,22	0,32	0,13	0,18	0,14
	2012	0,47	0,55	-0,04	0,29	0,48	0,01	0,49	0,05
	2011	0,40	0,49	0,62	0,67	0,37	0,53	0,47	0,22
	2010	0,53	0,60	0,90	0,85	0,75	0,46	0,55	0,18
AVERAGE STD	0,266	0,185	0,412	0,317	0,232	0,269	0,249	0,157	0,310

Figure 36 *– Standard deviation analysis of USA based REITs betas. Author's elaboration.*

HONG KONG

YEAR	β CHAMPION REIT	β FORTUNE REIT	β HYSAN DEVELOPMENT	β HANG LUNG PROPERTIES	β NEW WORLD DEVELOPMENT	β SUN HUNG KAY PROPERTIES	β HENDEROSN LAND DEVELOPMENT	β CHEUNG KONG PROPERTY HOLDING
2020	0,34	0,66	0,26	0,66	0,02	0,36	0,54	0,50
2019	0,84	0,61	0,66	0,66	-0,01	0,77	0,62	1,09
2018	0,18	0,44	0,48	0,67	0,55	0,77	0,48	0,48
2017	0,36	0,39	0,38	0,27	0,01	-0,18	-0,22	0,73
2016	0,26	0,70	0,77	0,42	0,41	0,29	0,70	0,34
2015	1,72	-0,19	2,40	1,60	1,95	2,04	2,66	2,41
2014	0,30	0,73	0,28	0,42	0,60	1,01	1,12	0,48
2013	0,20	0,35	0,24	0,26	0,48	0,30	0,62	0,70
2012	0,58	-0,42	0,16	0,62	0,46	0,57	0,54	0,63
2011	1,05	1,25	0,69	0,69	0,69	0,87	0,74	0,83
2010	1,87	1,15	0,67	0,31	0,65	0,80	1,01	0,95
	0,608	0,499	0,621	0,374	0,538	0,564	0,703	0,571

YEAR	β HONG KONG LAND	β SWIRE PROPERTIES	β LINK REIT	β THE WHARF PROPERTY HOLDING
2020	0,19	0,20	0,36	0,24
2019	0,82	0,47	0,73	0,87
2018	0,61	0,27	0,42	0,59
2017	0,09	0,14	0,56	-0,02
2016	0,62	0,37	0,46	0,37
2015	1,96	2,03	0,89	1,78
2014	1,18	0,88	0,53	0,88
2013	-0,04	0,41	0,15	0,56
2012	0,37	0,19	0,14	0,49
2011	0,81	0,90	1,46	0,82
2010	0,89	1,13	-0,10	0,62
	0,564	0,569	0,423	0,463

AVERAGE STD
0,560

Figure 37 *– Standard deviation analysis of Hong Kong based REITs betas. Author's elaboration.*

JAPAN

YEAR	β MITSUI FUDOSAN	β MITSUBISHI ESTATE	β AEON REIT	β GLP J-REIT	β ORIX JREIT	β TOKYO TATEMONO	β NIPPON BUILDING FUND	β NOMURA REAL ESTATE HOLDING
2020	0,43	0,58	0,55	0,29	0,34	0,45	0,50	0,47
2019	-0,21	-0,55	0,66	-0,05	0,04	0,13	-0,36	0,47
2018	0,67	0,62	0,15	0,20	0,96	0,61	0,88	0,59
2017	0,40	0,44	-0,07	-0,01	0,02	0,31	-0,13	0,09
2016	0,54	0,00	0,35	-0,33	0,08	0,53	-0,39	0,79
2015	0,62		0,50	0,70	0,08	0,57	-0,05	0,35
2014	0,24		0,14	0,37	0,37	0,12	-0,18	0,39
2013	0,37			0,30	0,23	0,26	0,18	0,26
2012	0,51				0,29	0,32	0,90	0,47
2011	0,44				0,12	0,40	-0,07	0,38
2010	0,33				0,43	0,21	0,76	0,28
	0,236	0,495	0,263	0,312	0,271	0,171	0,489	0,181

YEAR	β KENEDIX REIT	β SUMITOMO REALTY&DEVELOPMENT	β HULIC REIT	β JAPAN LOGISTIC FUND
2020	0,36	0,43	0,43	0,48
2019	-0,02	0,23	0,24	-0,56
2018	-0,02	0,56	0,22	0,31
2017	-0,03	0,35	0,01	-0,31
2016	-0,04	0,56	-0,03	0,04
2015	0,72	0,58	0,02	0,97
2014		0,15	0,34	0,48
2013		0,33		0,06
2012		0,41		0,36
2011		0,35		0,16
2010		0,61		0,57
	0,314	0,151	0,177	0,424

AVERAGE STD
0,302

Figure 38 *– Standard deviation analysis of Japan based REITs betas. Author's elaboration.*

7.3. CLIMATE CHANGE RELATED EVENTS IMPACTING ON ANALYSED REITs

Till now it has been presented just one part of the analysis, that is the beta and its computation for the different REITs under analysis. It is now the moment to present the counterparts used to assess if the systemic risk deriving from the climate change is taken into account by the funds. Those counterparts are the climate events, and in the following paragraph will be presented the ones categorizing the area of investment of the funds. In addition, taking into consideration what has been said all along this dissertation, one of the responsible for global temperatures increase are CO2 particles. For this reason for all the REITs, also the amount (measured in millio/billion tons) of CO2 emission of the belonging area, has been compared to the beta trends.

7.3.1. MOST SIGNIFICANT CLIMATE CHANGE RELATED EVENTS IMPACTING USA

The typology of events that could be possibly taken into account when talking about real estate investment trusts that operate and invest in the United Stated of America are multiple. But surely among all, the ones that most strongly threaten the fifty states are: Atlantic and Pacific Hurricanes (they include also what are called "Tropical Storms", less destructive but still dangerous in terms of floods), Tornadoes and Wildfires.

Only in 2005 Atlantic Hurricane Katrina resulted in $ 125 Billion nominal damage. In 2017 a series of catastrophic hurricanes (Harvey, Maria, Irma ***(Figure 39)***) hit the USA, with a resulting estimated demage of $ 290 billions. The most at risk States are obviously the costal ones, in particular Florida, Louisiana, Missisipi, Texas, Alabama, Georgia, South Carolina, North Carolina. The Pacific Hurricanes are less powerfull, and as a consequence less destructive and costly compared to the Atlantic ones, but the trend is certainly increasing in terms of frequency and impact on land. Indeed in the decade 2000-2010 damages from Pacific Hurricanes in US were $ 1.54 billion, while in decade 2010-2020 are $ 10,4 billion.

Figure 39 *– Hurricane Irma hitting Miami Beach, Florida, USA. 10 September 2017. Credit: EFE News Agency / Alamy Stock.* .

The overall trend of the hurricanes hitting the two coasts can be seen in ***Figure 40*** and ***Figure 41***.

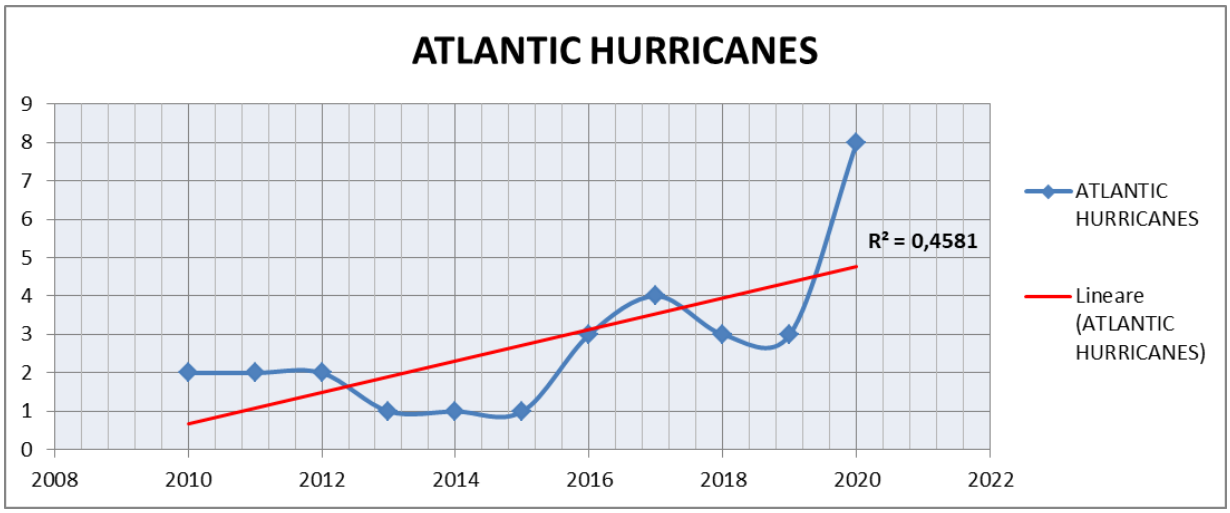


Figure 40 *– Trend of the Atlaintic Hurricanes hitting the USA east coasts. Data taken from USA National Weather Service – National Oceanic and Atmospheric Administration – U.S. Department of Commerce.*

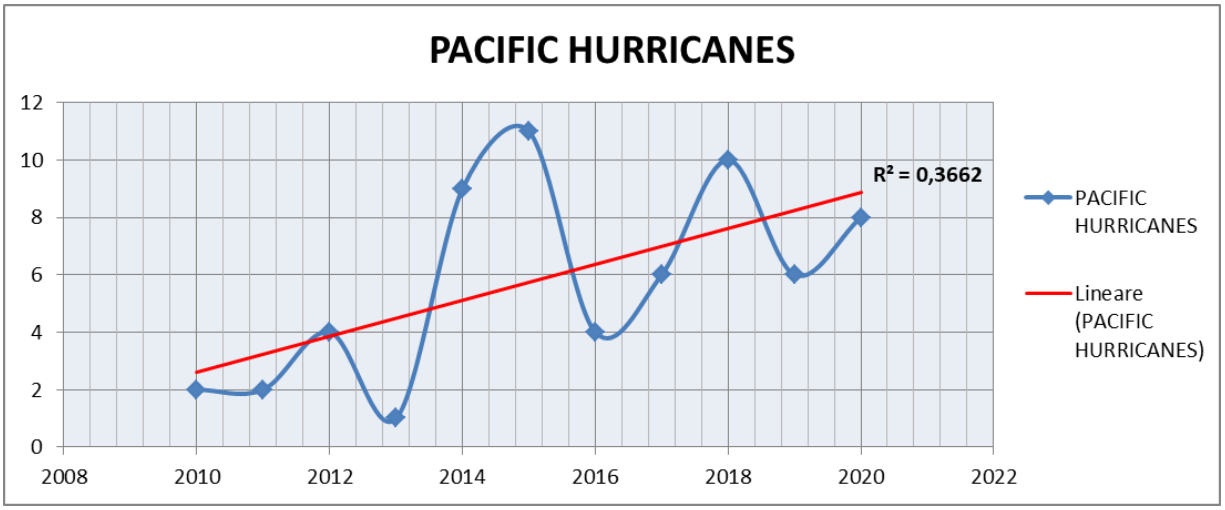


Figure 41 *– Trend of the Pacific Hurricanes hitting the USA west coasts. Data taken from USA National Weather Service – National Oceanic and Atmospheric Administration – U.S. Department of Commerce.*

Another typology of climate related events that are increasingly threatening USA in the more internal States, or the so called "Tornado Alley" (North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Colorado, Texas), are indeed tornadoes. Economic dameges to properties, infrastructures and agricoltural fields caused by these events reached in the decade 2010-2020 a value of $ 27 Billion ***(Figure 42)***. Less easier to forecast compared to hurricanes, for which it possible to trace the probable path with a certain accurancy grade, for these events is much difficult to understand where their are going to hit and the intensity with which they will do it. This, and their direct connection with atmosphere states, in turn conditioned by temperatures, make tornadoes closely connected with global warming and climate change. The number of events categorising the US is massive, in terms of thousands tornadoes (with different categories spanning from F0 to F5 (Fujita Scale) with increasing intensity). After 2011, outbreak season in terms of twisters, the trend seemed to decline, but since then it started growing slowly but constantly year after year, till 2020 where number of events almost hit the same quota of 2011, as it possible to see in ***Figure 43***.

Figure 42 *– Greensburg, Kansas State, May 2017, F4 tornado trail.*

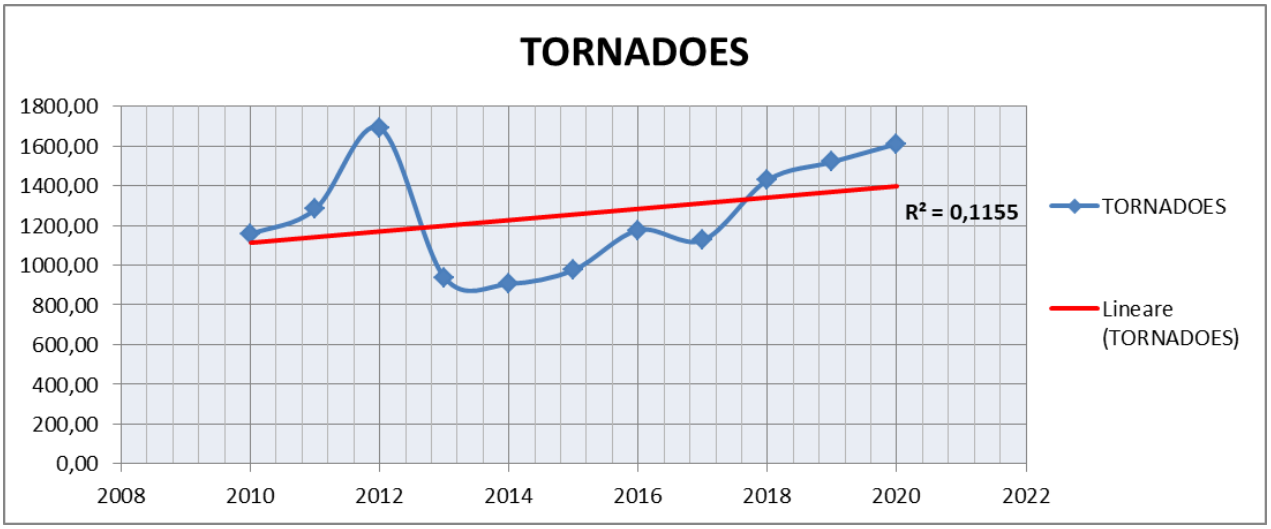


Figure 43 *– Trend of Tornadoes hitting the US. Data taken from USA National Weather Service – National Oceanic and Atmospheric Administration – U.S. Department of Commerce.* .

Another typology of extreme and dangerous events substantially impacting the US are wildfires. They became particularly "famous/infamous" in the last two or three years, because they hit important parts of San Francisco, San Diego and in general all the land of California State and Alaska. Increasing temperatures and droughts are causing more and more problems, the acres burned in 2020 touch the record of 10, 27 million (4,04e+10 sqm), but also in the previous year of 2019 a record was established, and the same consecutively till 2017. A study made by the University of California and China's Tsinghua University, published on Nature Sustainability, uncovered that only in 2018 wildfires in California ***(Figure 44)*** caused a loss of $ 150 billion, 0,7% of USA GDP, of which 19% ($ 28,5 billion) were destroied building and homes. The overall evolution trend is visible in ***Figure 45***.

Figure 44 *- Residences leveled by the wildfire line in a neighborhood in Paradise, California. By Noah Berger/Associated Press..*

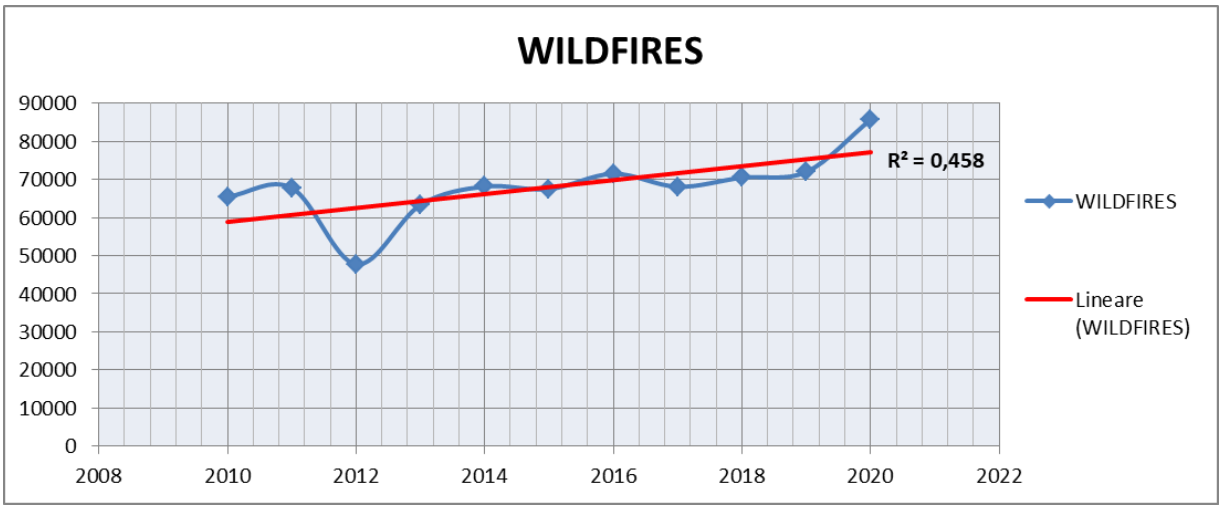


Figure 45 *– Trend of wildfires in the US. Data taken from USA National Weather Service – National Oceanic and Atmospheric Administration – U.S. Department of Commerce.* .

The last comparable taken into account to understand wether or not there is presence of correlation between REITs betas and climate change related events are the emissions of GHG (Carbon Dioxite - CO2, Methane, Nitrous Oxide, Fluorinated Gasses) referable to the area of investment of the funds. GHG are considered the main cause of global warming, and the race against time to lower them is nowadays shared within all developed countries. The US emission saw a 7 percent increase since 1990 but a 7 percent decrease since 2005. The main sources accounting for the production of GHG emissions in USA in 2019 according to United States Environmental Protection Agency (EPA) are respectively: Production of Energy and Heat 25%, Industry Manufacturing and

Production 21%, Agricolture and Land Use 24%, Transportation 14%, Buildings 12%, Others 4%. The overall trend from 2010 to 2020 can be see in ***Figure 46***.

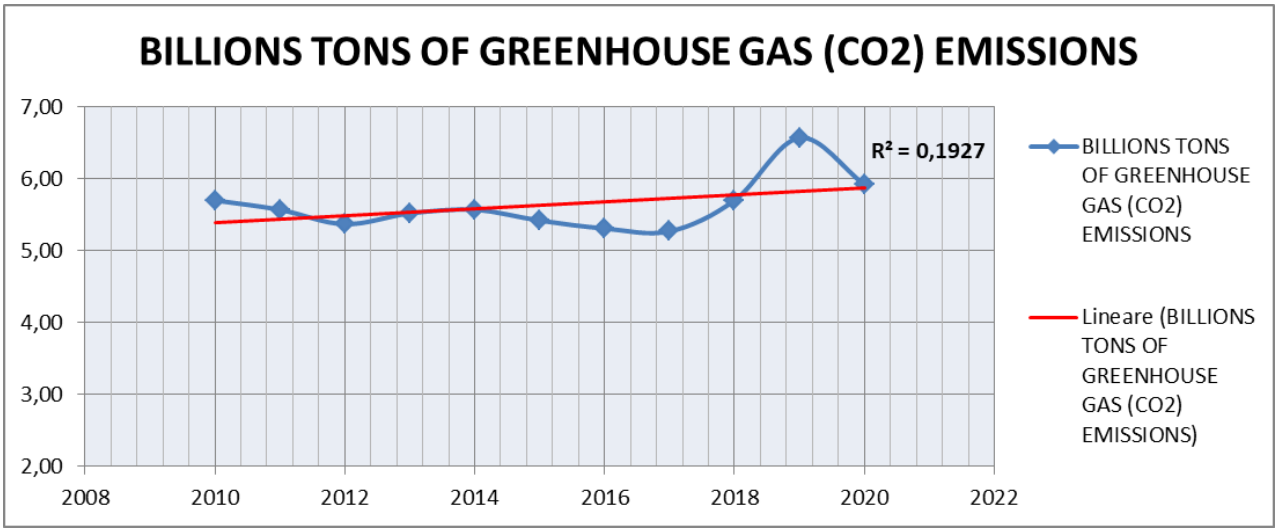


Figure 46 *– Trend of GHG emission in the US. Data taken from USA National Weather Service – National Oceanic and Atmospheric Administration – U.S. Department of Commerce.* .

Among the eight REITs based on USA two of them, namely SL Green Realty and Vornado Realty Trust, have no investments outside the area of New York. Comparing these two funds' betas with national scale events woul have no meaning, therefore specific climate events impacting on New York City and New York State have been selected. Specifically: Hurricanes ***(Figure 47 and 48)***, Floods ***(Figure 49)***, Blizzards ***(Figure 50)***, Storms caracterised by strong rain and winds ***(Figure 50)***. Many reports underline how New York City could be under the sea level by 2100 if waters continue to rise at this rhythm (sea level since its first measurment in NYC in 1950 has grown of almost 12 inches, or 30,5 cm, revealing a growth rate of 0,5 cm per year). The city in 2012 experienced one of the major climate disasters with Hurricane Sandy, which combined heavy rain and winds, leaving parts of New York without electricity for two weeks, and the entire metro sistem stopped for one week. The City is currently undergoing a small part of huge plan accounting for $ 20 Billion called "Resiliency Plan" enforced by the U.S. Department of Housing and Urban Development's National Disaster Resilience Competition for the development of different projects aimed at protecting the city against future climate events.

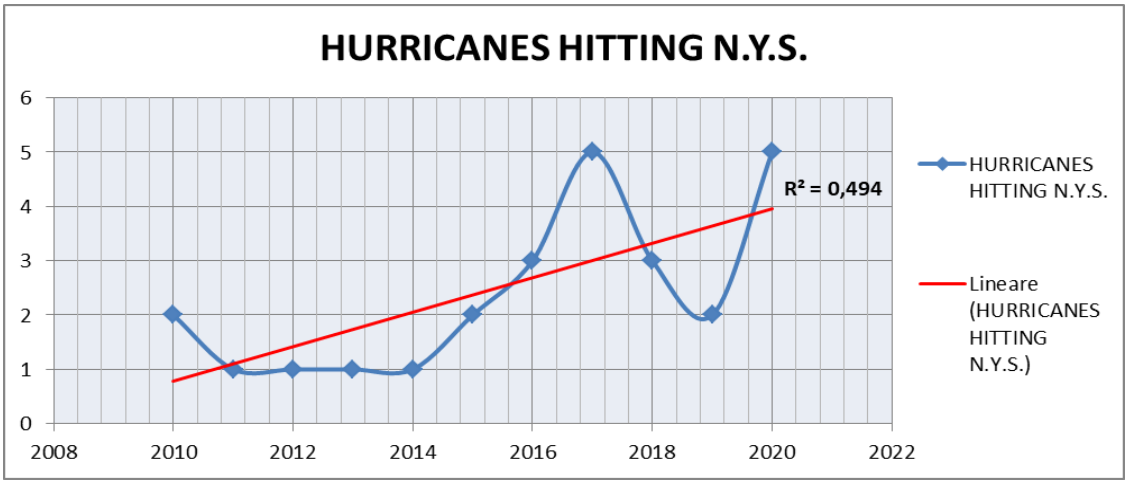


Figure 47 *– Trend of hurricanes hitting New York State. Data taken from USA National Weather Service.*

Figure 48 *– The remains of burned homes in the Breezy Point neighborhood of Queens, with the Manhattan skyline in the distance after Superstorm Sandy, on October 31, 2012.*

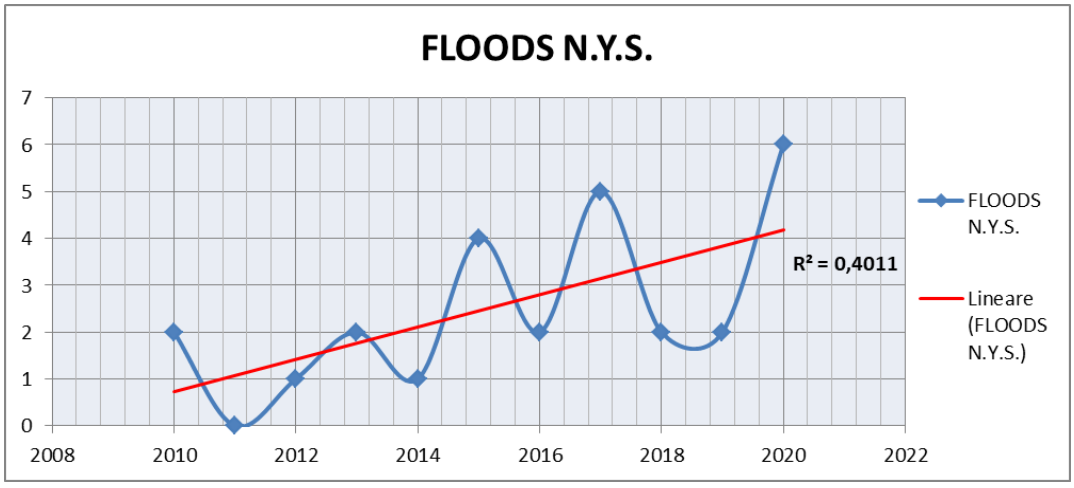


Figure 49 *– Trend of floods hitting New York State. Data taken from USA National Weather Service.*

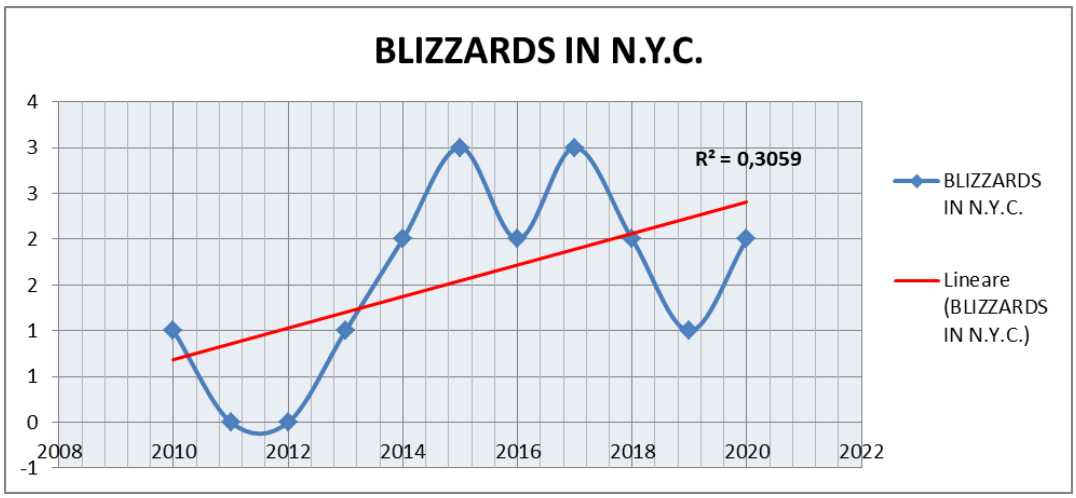


Figure 50 *– Trend of blizzards hitting New York State. Data taken from USA National Weather Service.*

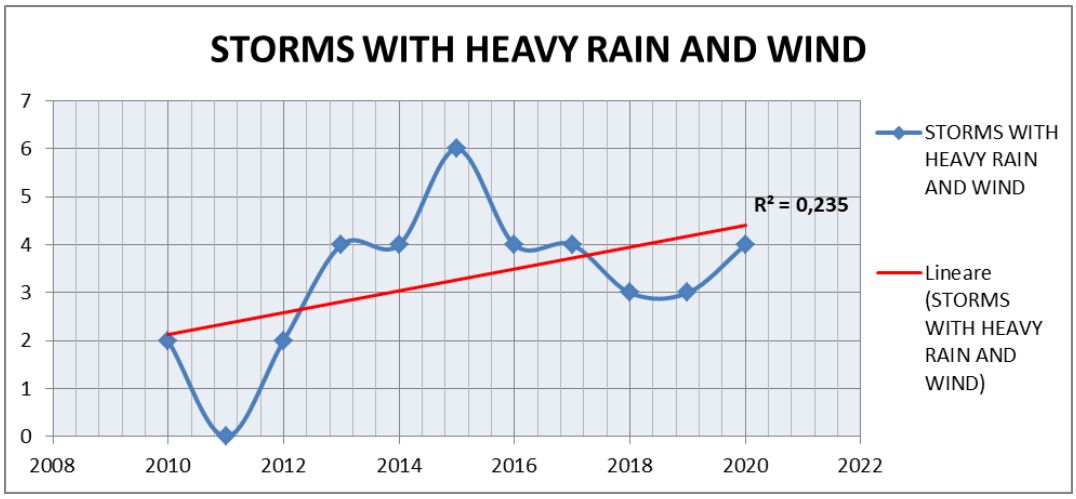


Figure 51 *– Trend of storms with heavy rain and winds hitting New York State. Data taken from USA National Weather Service.*

Also in this case the emissions of GHG coming from NYC annd NYS have been considered. They should not be though as a direct link between the funds and the climate events but more as an awareness of these latter of the possible consequences stemming from higher emissions and the commitment to route towards ecological investments. ***(Figure 52)***.

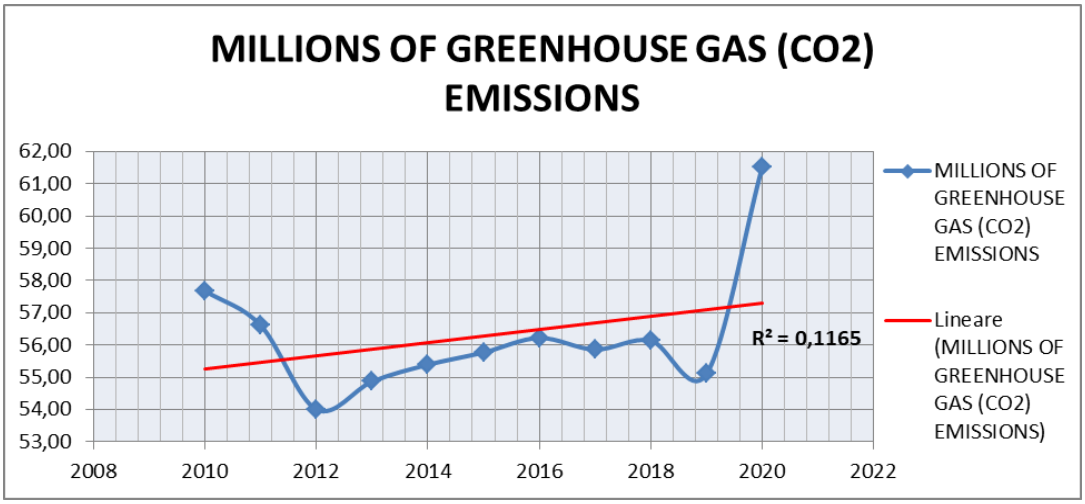


Figure 52 *– Trend of storms with heavy rain and winds hitting New York State. Data taken from USA National Weather Service.*

7.3.2. MOST SIGNIFICANT CLIMATE CHANGE RELATED EVENTS IMPACTING JAPAN

As for the USA based funds, the typology of events that could be possibly taken into account when talking about REITs that operate and invest in the Japan are multiple. But surely among all, the ones that most strongly threaten the Land of the Rising Sun are: Tropical Cyclones, Heavy Rain events, Extremely hot days and Floods.

The term "tropical cyclone" describes a closed atmospheric circulation that forms over warm oceans. When the sustained maximum wind speed of such storm systems exceeds 119 km per hour, they are called typhoons in the Pacific Ocean, hurricanes in the Atlantic Ocean, and cyclones elsewhere. It is now clear that the relationship between GHG emission, global warming and thus water warming affects the formation of more frequent cyclones.

Japan is extremely vulnerable to tropical storms ***(Figure 53)***, experiencing an average of 26.7 annually for the past 30 years. The country therefore already experiences much physical damage and other indirect economic consequences. It is important to understand how the amount of time and money lost due to these phenomena could increase.

According to the results of a simulation made by United Nations University, the annual economic damage due to periods of typhoon-caused inactivity could amount to 0.15% of Japanese GDP in the year 2085 (based on 1990 GDP figures). If this were to happen to the Japanese economy as it is today, it would mean a loss of more than ¥687 billion (US$7 billion, or the equivalent of US$60 per capita) every year from typhoons alone.

This future potential for will be higher in urban areas due to economic and demographic developments. More people and economic assets will be exposed to natural hazards in particularly again, coastal urban areas as a result of population growth driven by the relatively attractive economic conditions of these regions.

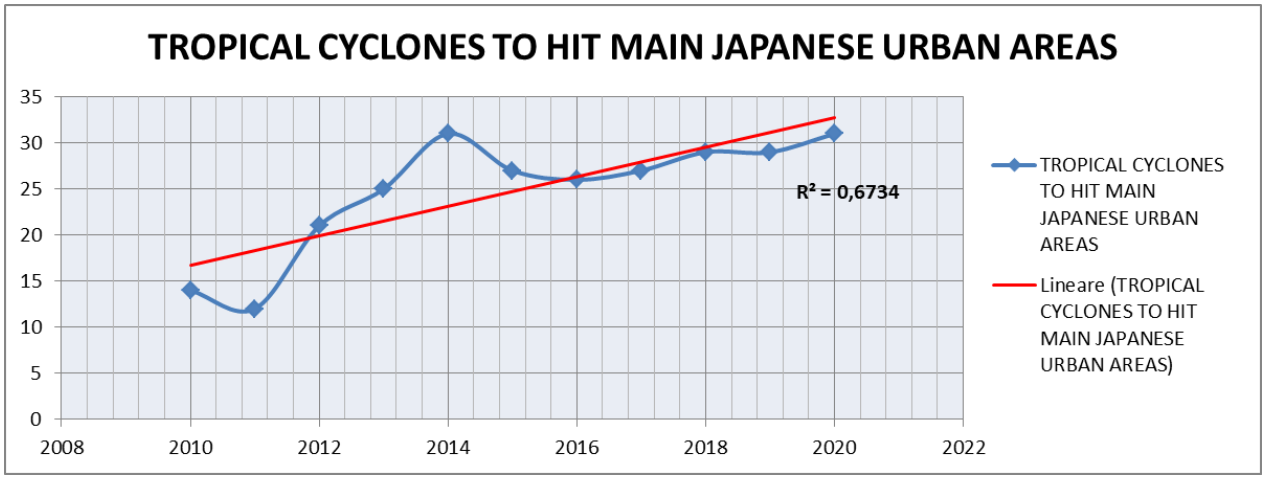


Figure 53 *– Trend of tropical cyclones that hit main Japanese urban and costal areas. Data taken from Japanese Ministry of Environment and Japanese Ministry of Land, Infrastructures and Tourism.*

Another typology of events strictly related to tropical cyclones are heavy rains. With heavy rains it is meant an amount that is over the 50 mm per hour, that could potentially flash flood substantial parts of land, particularly if these areas are intensely cemented and poorly drained like the urban district of Tokyo. Events like this can cause devastating floods impacting billion of worth value in properties and infrastractures. For this reasons and due to the increasing trend of heavy rains and thus floods (victims and damages) (***Figure 54, Figure 55, Figure 56***) the Urban District of Tokyo started in 1992 the construction of the *Metropolitan Area Outer Underground Discharge Channel*, a massive underground water infrastructure to store the excesses of floods and rains.

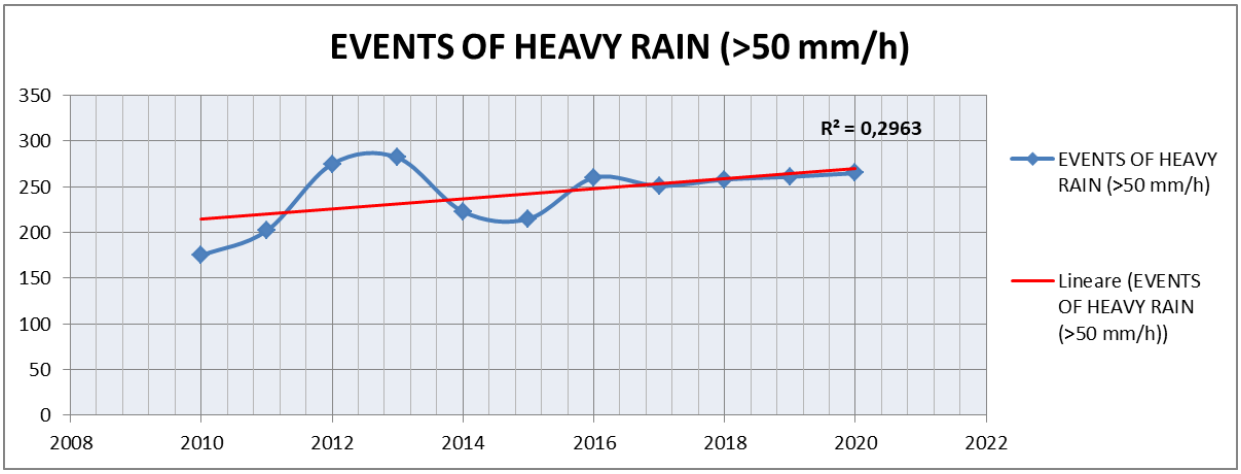


Figure 54 *– Trend of events of heavy rain over the 50mm/h in Japan. Data taken from Japanese Ministry of Environment and Japanese Ministry of Land, Infrastructures and Tourism.*

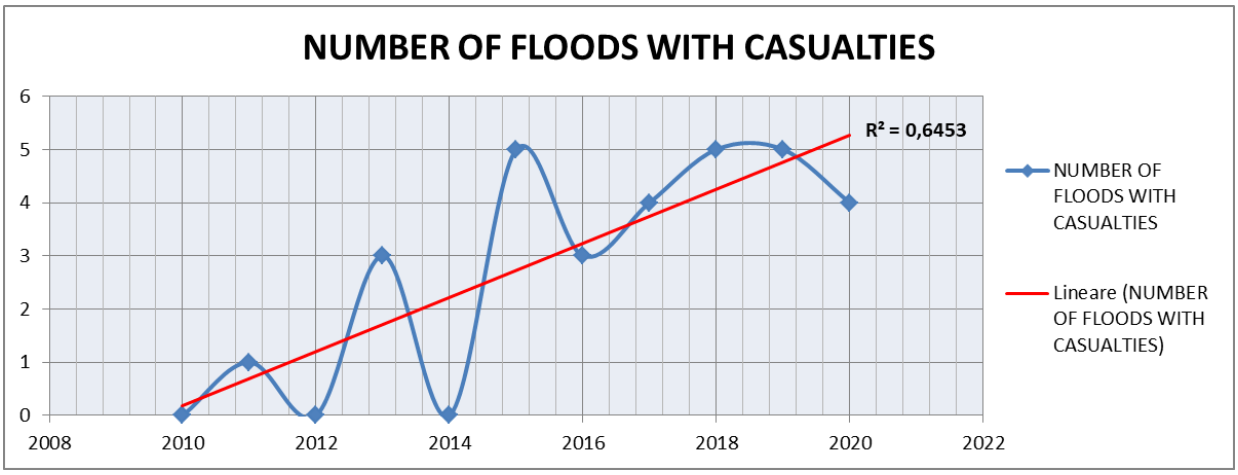


Figure 55 *– Trend of the number of floods with casualties in Japan. Data taken from Japanese Ministry of Environment and Japanese Ministry of Land, Infrastructures and Tourism.*

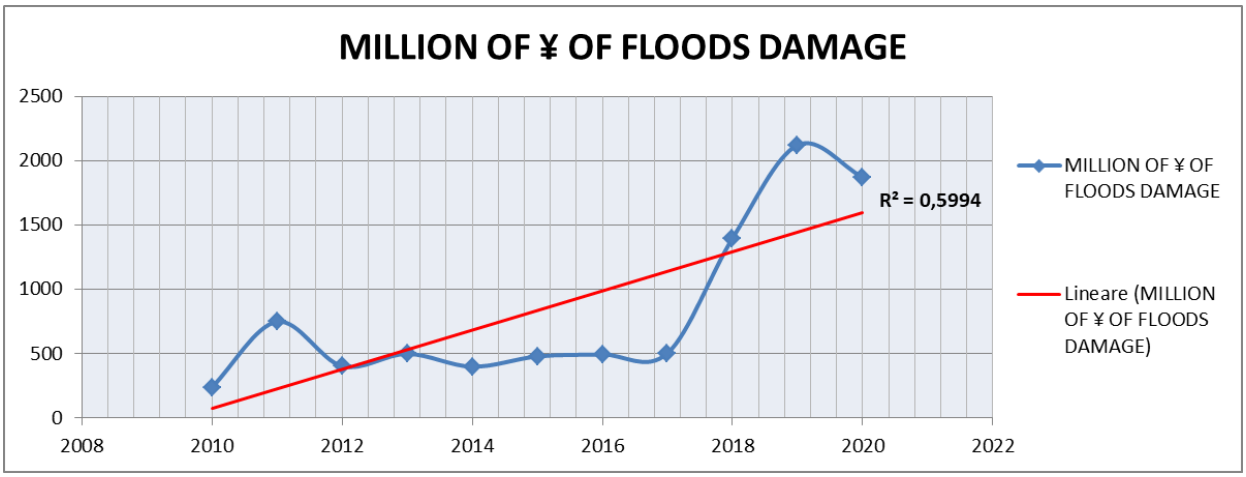


Figure 56 *– Trend of damages in monetary termsof floods in Japan. Data taken from Japanese Ministry of Environment and Japanese Ministry of Land, Infrastructures and Tourism.*

Is it also possible to observe how these three different events are also correlated between themselves in ***Figure 57***.

	TROPICAL CYCLONES TO HIT MAIN JAPANESE URBAN AREAS	*EVENTS OF HEAVY RAIN (>50 mm/h)*	*NUMBER OF FLOODS WITH CASUALTIES*	*MILLION OF ¥ OF FLOODS DAMAGE*
TROPICAL CYCLONES TO HIT MAIN JAPANESE URBAN AREAS	1			
EVENTS OF HEAVY RAIN (>50 mm/h)	0,58	1		
NUMBER OF FLOODS WITH CASUALTIES	0,59	0,41	1	
MILLION OF ¥ OF FLOODS DAMAGE	0,44	0,37	0,60	1

Figure 57 *– Correlation analysis between tropical cyclones, events of heavy rain, number of floods with casualties and economic damages caused by floods in Japan. Data taken from Japanese Ministry of Environment and Japanese Ministry of Land, Infrastructures and Tourism.*

Another element that can be analysed are growing temperatures, since their impact on real estate properties can, and is already having an important impact in maintenance (retrofitting, covers, new HVAC systems etc.) and operative costs due to higher energy bills. Rising temperatures are bringing Japan to an increase of extremely hot days with more than 30° C, and "tropical nights" (the ones where temperatures do not go below 27° C). ***(Figure 58)***

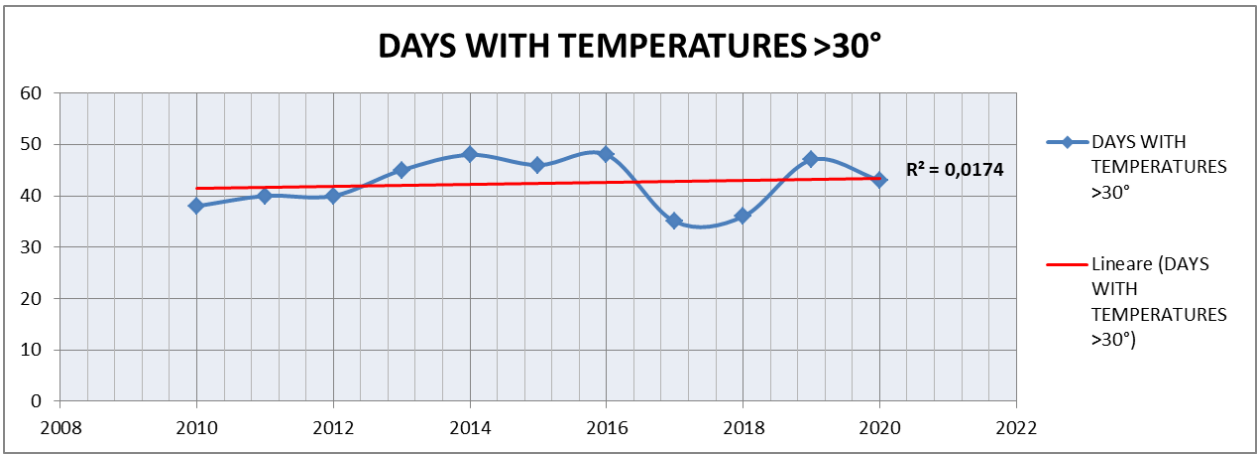


Figure 58 *– Trend of days with temperatures >30° in Japan. Data taken from Japanese Ministry of Environment and Japanese Ministry of Land, Infrastructures and Tourism.*

Again also in this case the trend of the emissions of GHG at the national scale have been taken into account to be compared with REITs' betas ***(Figure 59)***.

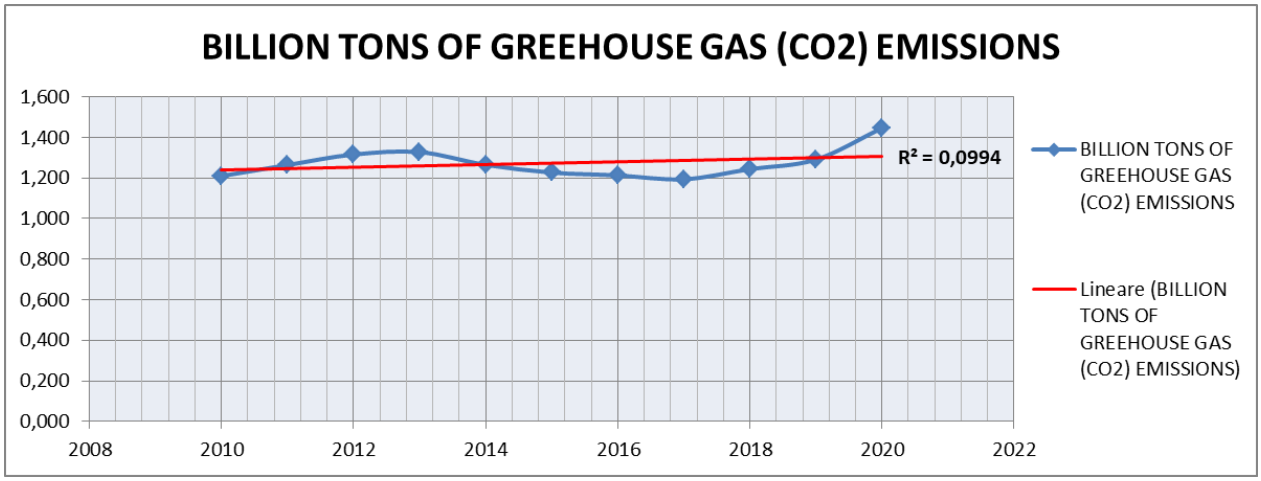


Figure 59 *– Trend of billion tons of GHG emissions in Japan. Data taken from Japanese Ministry of Environment and Japanese Ministry of Land, Infrastructures and Tourism.*

7.3.3. MOST SIGNIFICANT CLIMATE CHANGE RELATED EVENTS IMPACTING HONG KONG

As for the USA and Japan based funds, the typology of events that could be possibly taken into account when talking about REITs that operate and invest in Hong Kong and Mainland China are multiple. But surely among all, the ones that most strongly threaten them it is possible to find: Tropical Cyclones, Heavy Rain events, Thunderstorms, Extremely hot days. For what instead concerns Mainland China, where the majority of the REITs also invest, we can find Floods, Tropical Storms and Typhoons.

On average, there are about seven tropical cyclones (TCs) affecting Hong Kong each year. With modern infrastructures and effective warning systems, casualties, damages and losses due to TCs have been significantly reduced over the last years. Nevertheless, densely populated coastal cities like Hong Kong will need to continuously enhance its resilience to high winds, heavy rain and storm surges brought by TCs, especially with the growing concern of the challenges induced by climate change and the sea level rise. The trend of tropical cyclones can be seen in ***Figure 60***. While on ***Figure 61*** we can see the effects of 2018 Typhoon Mangkhut a huge storm at landfall, with hurricane-force winds that extended out up to 100 miles (160 km) from the center, and tropical storm-force winds that extended out up to 285 Km/h, causing million of USD damages.

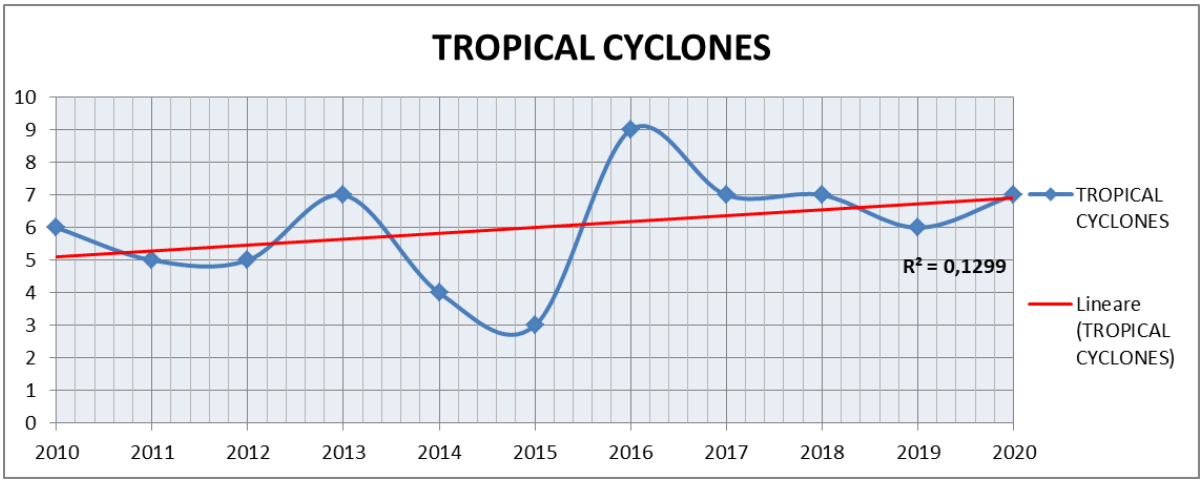


Figure 60 *– Trend of tropical cyclones in Hong Kong. Data taken from Hong Kong Climate Observatory.*

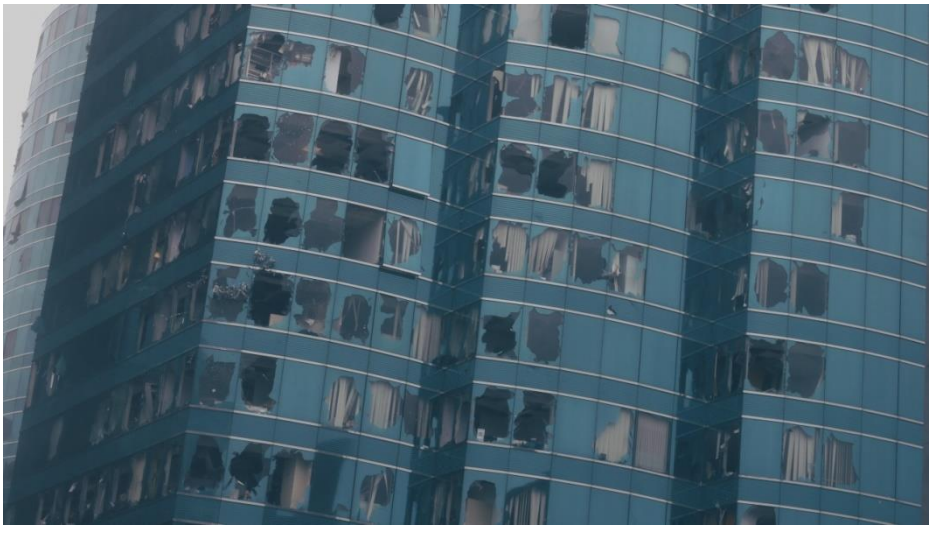


Figure 61 *– Commercial building damaged by Typhoon Mangkhut on Sept. 16, 2018, in Hong Kong.*

Another typology of events that can be considered strictly related to tropical cyclones are again as in the case of Japan the events of heavy rains ***(Figure 62)*** and thunderstorms ***(Figure 63)***. Events like this can cause devastating floods impacting billion of worth value in properties and infrastractures. For this reasons and due to the increasing trend of heavy rains and thunderstorms the Urban District of Hong Kong started the "Hong Kong Observatory" a permanent weather forecast agency with the duty of moitoring the evolution of possible climate events affecting the city. Again also in this case the trend of very hot days (>35°C) and the GHG emissions characterising the city have been taken into account to be compared with REITs' betas ***(Figure 64 and Figure 65)***.

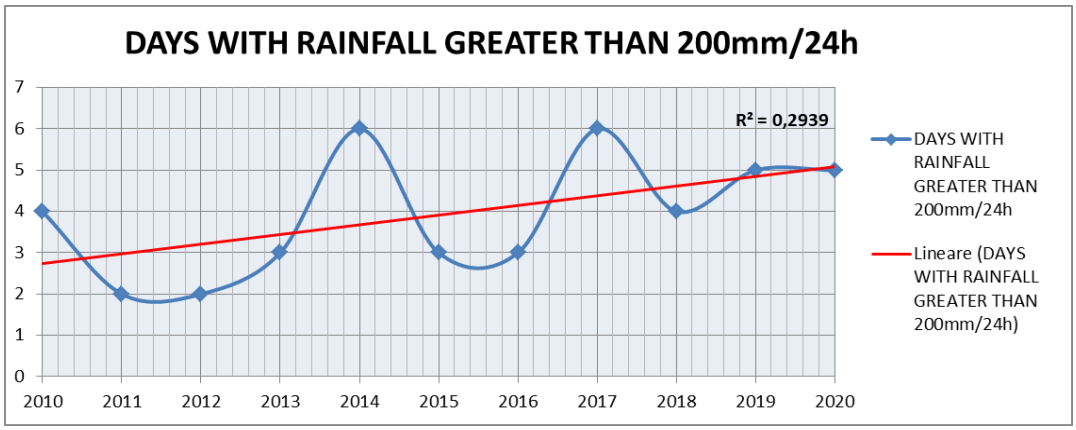


Figure 62 *– Trend of days with heavy rainfall in Hong Kong. Data taken from Hong Kong Climate Observatory.*

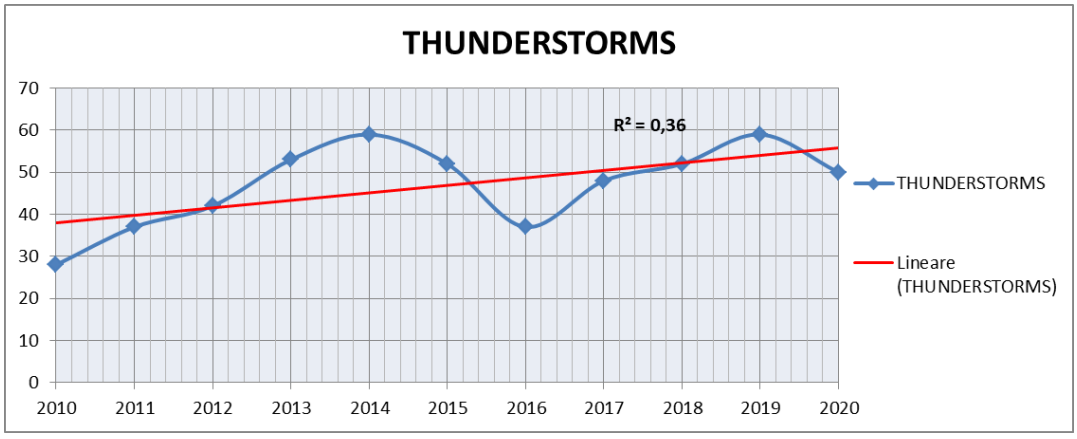


Figure 63 *– Trend of thunderstorms in Hong Kong. Data taken from Hong Kong Climate Observatory.*

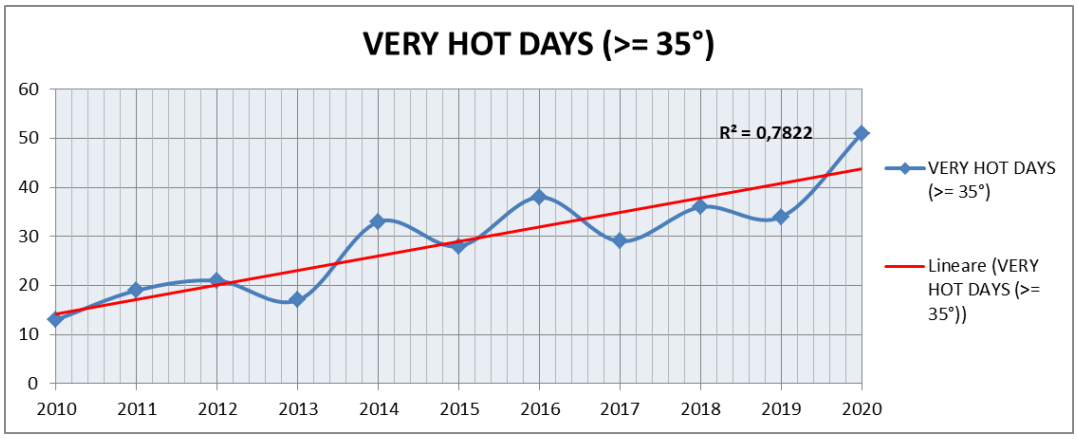


Figure 64 *– Trend of very hot days in Hong Kong. Data taken from Hong Kong Climate Observatory.*

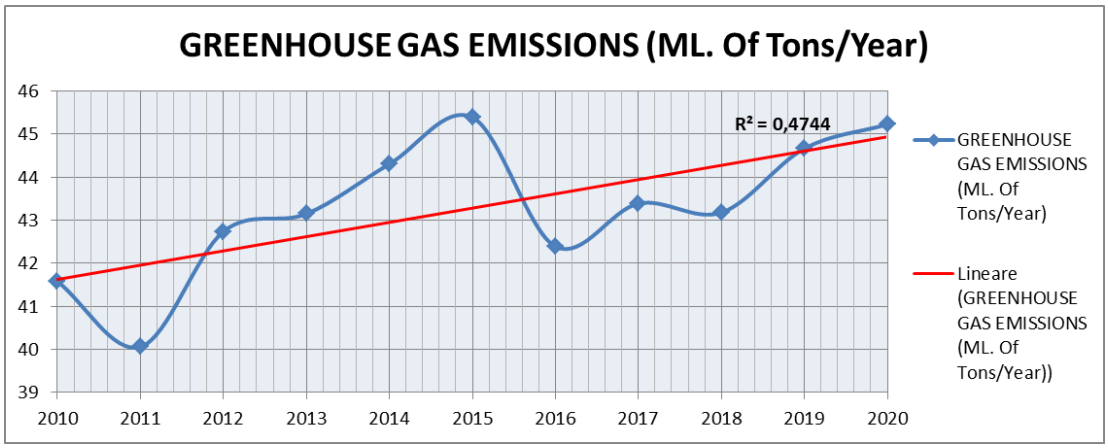


Figure 65 *– Trend of GHG emissions in Hong Kong. Data taken from Hong Kong Climate Observatory.*

As for the case of some of the USA based REITs, again some of the Hong Kong based ones have also investments in other urban areas in other countries. Due to the tight relation with Chinac these funds have also a substantial part of their portfolio based in the main coastal cities. To expand the number of observations the betas have been calcultated also on the base of these foreign markets and thus consequently the same had to be done for the corresponding impacting local climate events, such as Floods ***(Figure 66)***, to which China is particularly subjected, Tropical Storms with strong winds ***(Figure 67)*** and Typhoons ***(Figure68)***.

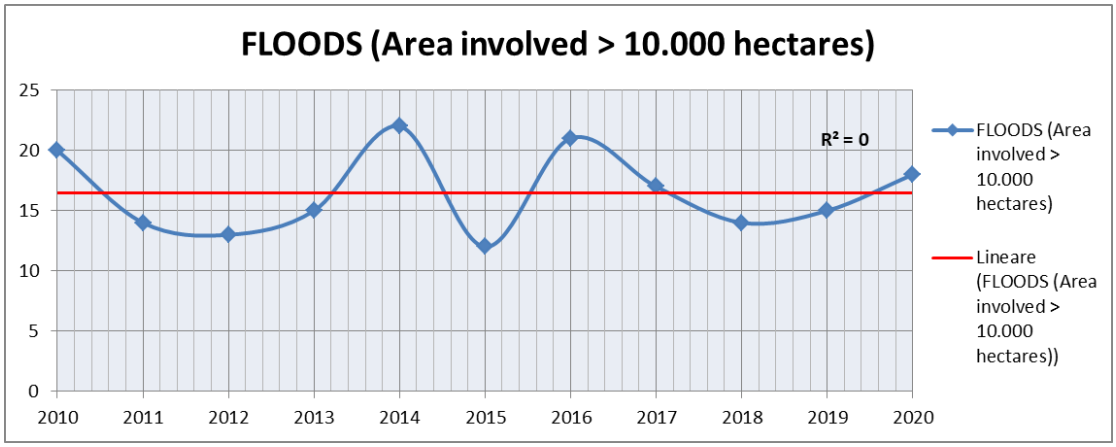


Figure 66 *– Trend of floods involving more 10.000 hectares in main coastal Chinese cities. Data taken from China Ministry Of Water Resources and Floodlist.*

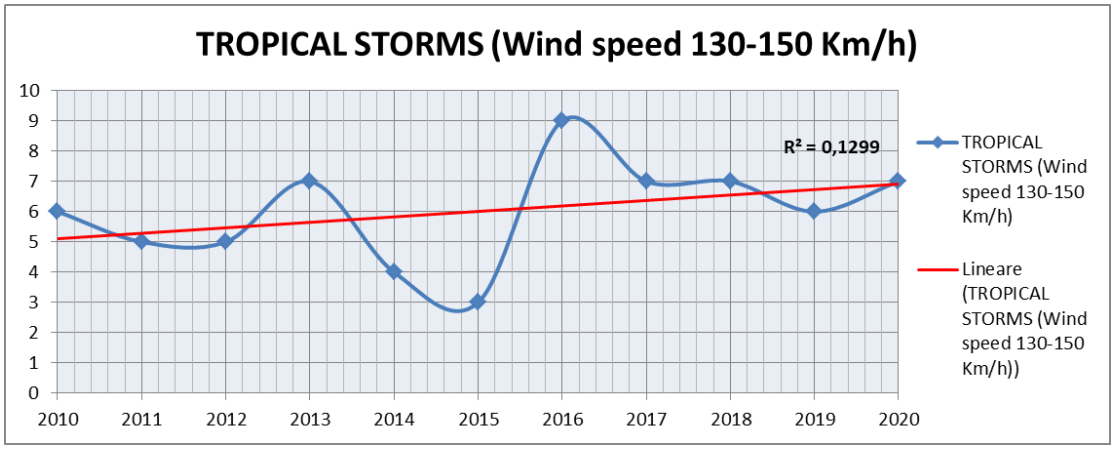


Figure 67 *– Trend of tropical storms in main coastal Chinese cities. Data taken from China Misnistry Of Water Resources.*

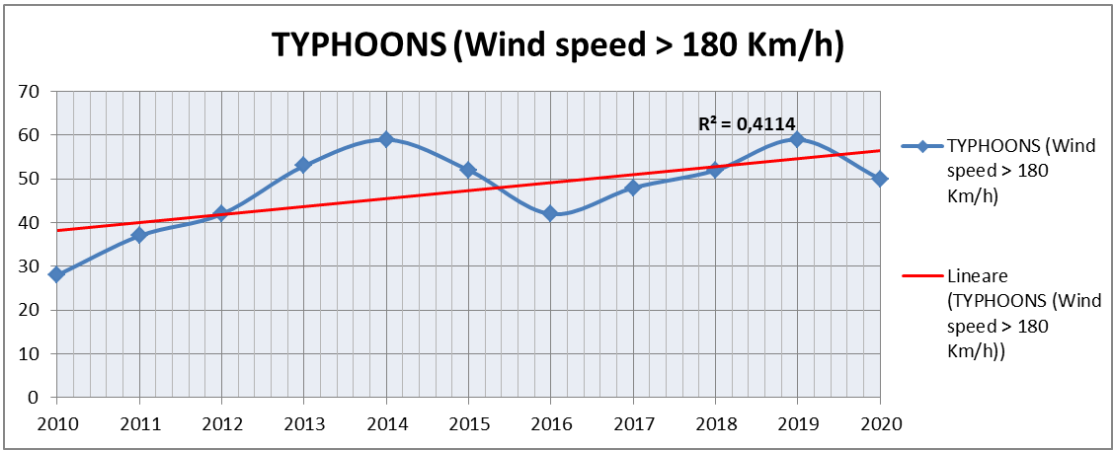


Figure 68 *– Trend of typhoons hitting main coastal Chinese cities. Data taken from China Misnistry Of Water Resources.*

CHAPTER 8

8. THE CORRELATION ANALYSIS

Now that both variables, the dependent one that are the betas and the independent one that are climate change related have been explained, it is the moment to understand how and if they share some communalities. To do so a correlation analysis with Pearson Coefficient was conducted.

8.1. PEARSON CORRELATION COEFFICIENT

Pearson's correlation coefficient is a statistics test that measures the statistical relationship, or association, between two continuous variables. It is known as one of the best method of measuring the association between variables of interest because it is based on the method of covariance. It gives information about the magnitude of the association, or correlation, as well as the direction of the relationship. It does so returning a number between -1 and +1 that indicated to which extent the two variables are linearly related. In analytical terms the formula to compute the Pearson coefficient for two variables (X and Y) is the following:

$$r\,XY = \frac{\sum_{i=1}^{n}(Xi - \bar{X})\,(Yi - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(Xi - \bar{X})^2}\,\sqrt{\sum_{i=1}^{n}(Yi - \bar{Y})^2}}$$

- Correlations are never lower than -1. A correlation of -1 indicates that the data points in a scatter plot lie exactly on a straight descending line; the two variables are perfectly negatively linearly related. ***(Figure 68)***

- A correlation of 0 means that two variables don't have any linear relation whatsoever. However, some non linear relation may exist between the two variables. ***(Figure 68)***

- Correlation coefficients are never higher than 1. A correlation coefficient of 1 means that two variables are *perfectly* positively linearly related; the dots in a scatter plot lie exactly on a straight ascending line. ***(Figure 69)***

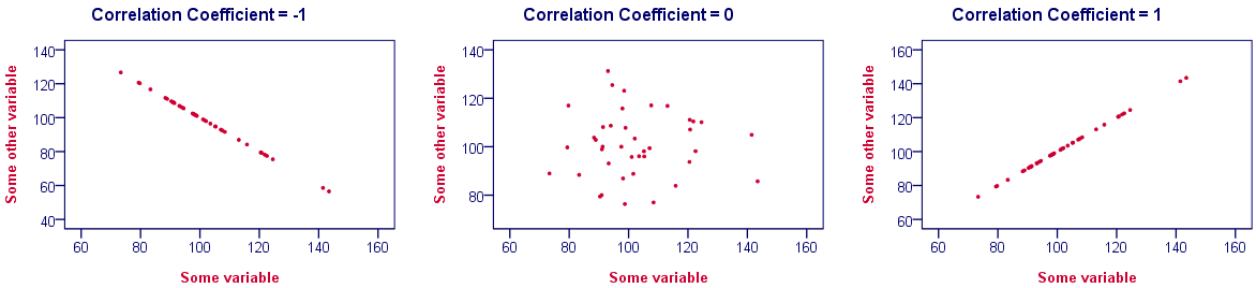


Figure 69 *– Scatterplots of the Pearson coefficient equal to -1, 0 , and +1.*

- Correlations may or may not indicate causal relations. Reversely, causal relations from some variable to another variable may or may not result in a correlation between the two variables if the amount of the observation is not sufficient.

- Correlations are very sensitive to outliers; a single unusual observation may have a huge impact on a correlation. Such outliers are usually easy to detect by a quick inspection a scatterplot.

As has been said the coefficient can assume all a range of values between –1 and +1, resulting in strong or weak correlations. For this reason and to better understand how strong or weak the relationship between REITs betas and climate related events, a more detailed scale of different possible results has been adopted and can be seen in ***Fogure 70***.

CORRELATION RESULT	*INTERPRETATION*
0 (+/-)	NO ASSOCIATION
0 to 0,25	NEGLIGIBLE ASSOCIATION
0,25 to 0,5	WEAK ASSOCIATION
0,5 to 0,75	MODERATE ASSOCIATION
0,75 to 1	STRONG ASSOCIATION
1	PERFECT ASSOCIATION

Figure 70 *– Scale ranges of the possibles correlation results between REITs betas' trend and climate related events, and the corresponding interpretation.*

8.2 RESULTS PRESENTATION

The results of the correlation analysis between climate related events impacting in the ares of investments of the 32 different REITs and their beta trends will be presented below with the help of matrices resuming tables, divided in the three different geographical areas investigated, where cells take the correspondent colour associated with the correlation value explained in ***Figure 70***.

8.2.1. USA BASED REITS

As previously mentioned in Chapter 7, the USA based REITs are 8, and two of them actually operate and invest only in New York State and New York City, mainly SL Green Realty and Vornado Realty Trust, while the other six operates in all the fifty states.

The climate change taken into consideration for the two funds in N.Y.S. are hurricanes, blizzards, floods, storms characterized by strong rain and winds and the emissions of GHG of the state and of the city. While for the case of the other six funds operationg a t national level the events taken into consideration are wildfires, atlantic cyclones, pacific cyclones, tornadoes and again GHG emission at the country level.

The results of this analysis can be seen in the following figures, ***Figure 71*** and ***Figure 72***.

USA - N.Y.S. & N.Y.C. BASED REITS BETAS' CORRELATION WITH CLIMATE RELATED EVENTS						
	HURRICANES HITTING N.Y.S.	*BLIZZARDS IN N.Y.C.*	*FLOODS N.Y.S.*	*STORMS WITH HEAVY RAIN AND WIND*	*MILLIONS OF GREENHOUSE GAS (CO2) EMISSIONS*	β
β SL GREEN REALTY	0,40	0,30	0,50	0,35	0,21	1
β VORNADO REALTY TRUST	0,18	-0,24	0,17	-0,23	0,34	1

Figure 71 – *Correlation analysis results between REITs betas' trend and climate related events. Author's elaboration.*

USA BASED REITS BETAS' CORRELATION WITH CLIMATE RELATED EVENTS						
	BILLIONS TONS OF GREENHOUSE GAS (CO2) EMISSIONS	*WILDFIRES*	*ATLANTIC CYCLONES*	*PACIFIC CYCLONES*	*TORNADOES*	β
β ALEXANDRIA REAL ESTATE EQUITIES	0,12	-0,17	0,17	0,37	0,30	1
β VENTAS GROUP	0,64	0,51	0,70	0,25	0,52	1
β SIMON PROPERTY GROUP	0,61	0,38	0,72	0,14	0,84	1
β PROLOGIS	0,42	0,14	0,46	0,10	0,63	1
β EQUITY RESIDENTIAL	0,29	0,06	0,32	0,15	0,39	1
β AMERICAN TOWER	0,09	0,00	-0,04	-0,35	-0,14	1

Figure 72 – *Correlation analysis results between REITs betas' trend (USA) and climate related events. Author's elaboration.*

As it can be seen, the final results do not present a good correlation if not for certain cases. Only two out of the eight funds present a good association between betas and climate events, mainly Ventas Group and Simon Property Group. In the other cases the correlations can be considered as negligible or with no association at all. The majority of results (32% - ***Figure 73***) highlights an overall weak association of the two considered variables. But despite the 45% of the observations are negligible or null, the other 55% is divided into weak association, moderate association and only one out of 40 as strong relationship.

The overll mean association, computed with the weighted average, results in a coefficient of 0,27, pointing out a weak correlation between funds systemic risk coefficient (or volatility) and the events that impact the areas in which they invest.

CORRELATION RESULT	INTERPRETATION	NUMBER	PERCENTAGE
0 (+/-)	NO ASSOCIATION	6	15,00%
0 to 0,25	NEGLIGIBLE ASSOCIATION	12	30,00%
0,25 to 0,5	WEAK ASSOCIATION	13	32,50%
0,5 to 0,75	MODERATE ASSOCIATION	8	20,00%
0,75 to 1	STRONG ASSOCIATION	1	2,50%
1	PERFECT ASSOCIATION	0	0,00%
TOT OBSERVATIONS		**40**	**100,00%**

Figure 73 – *Correlation analysis final results for USA based REITs betas' trend and climate related events. Author's elaboration.*

To dispel any doubt of possible outliers that could possibly impact the results of the correlation analysis on the two REITs that present a more significant respondence to climate events, scatterplots of the two variables have been made. This graphical representation is usefull to detect if in the relationship there are some values, or even one value, that drive away the results from the real mean of the population, so to enable a more realistic analysis.

For example Ventas Group seems to have a good correlation with almost all the climate related events. This does appear to be confirmed by the scatterplots (***Figure 74, Figure 75, Figure 76***) except for the atlantic cyclones relationship (***Figure 77***).

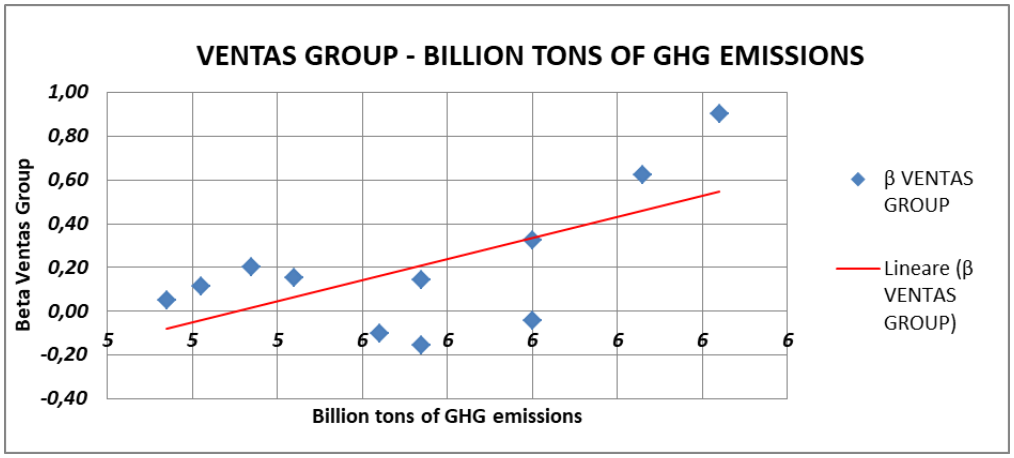


Figure 74 – *Scatterplot of Ventas Group Betas and Billion Tons of GHG emissions in USA. Author's elaboration.*

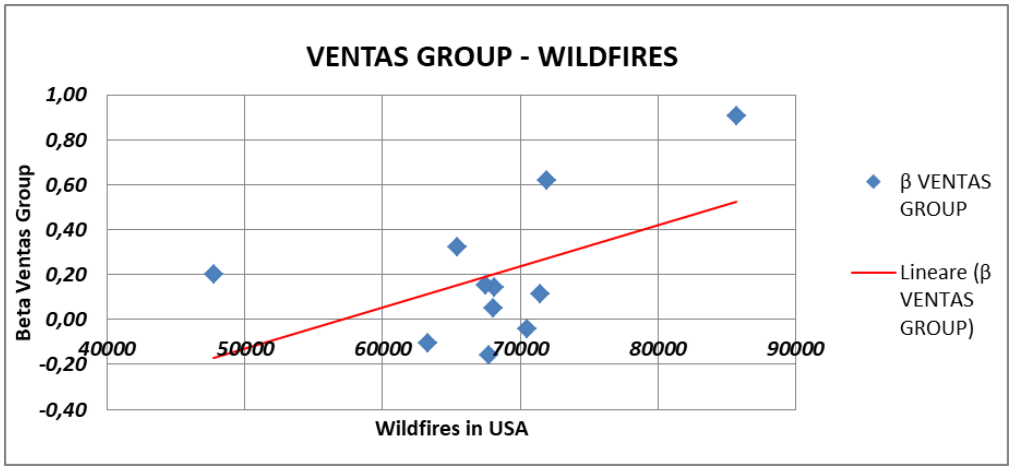


Figure 75 – *Scatterplot of Ventas Group Betas and wildfires in USA. Author's elaboration.*

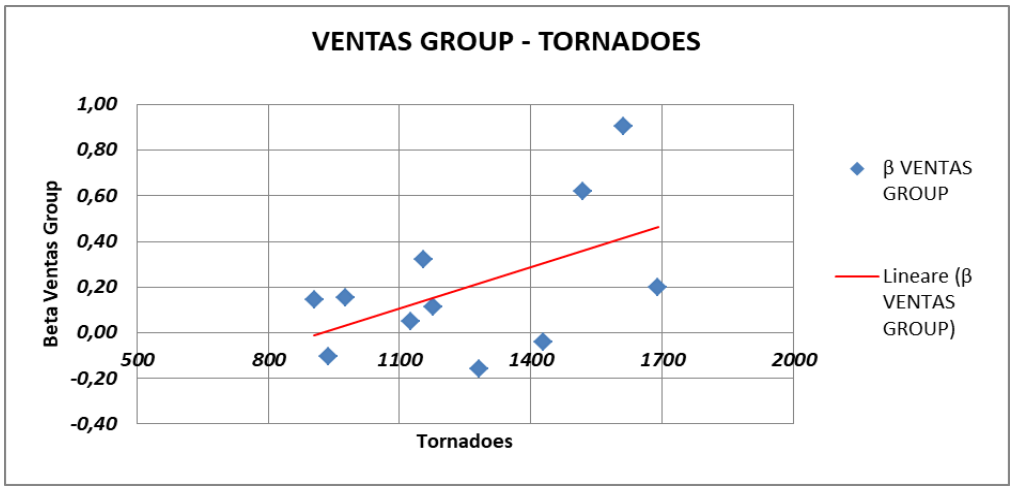


Figure 76 – *Scatterplot of Ventas Group Betas and tornadoes in USA. Author's elaboration.*

Differently from the ather graphs in the scatterplot of the betas with respect to the Atlantic Cyclones the pretty high correlation coefficient (0,70 – see ***Figure 72***) seems to be given by the presence of an outlier in the dataset of the climate events, as it can be clearly seen in ***Figure 77***. This type of result is given by the fact that the number of reit observation are not sufficiently high (in terms of observations that cover events happened before 2010) to compensate the presence of the outlier event, and that the presence in year 2020 of significantly higher number of cyclones compared to the previous years put the observation to far away from the group mean.

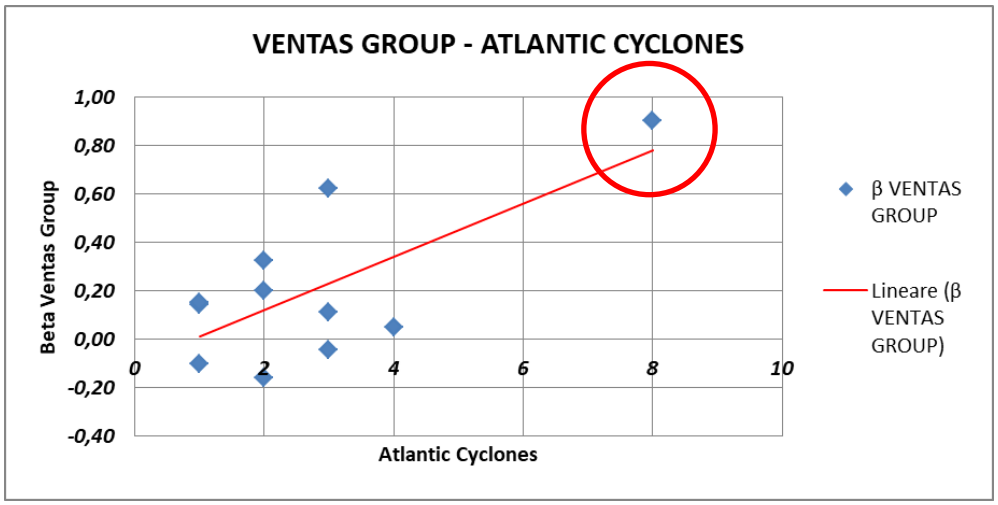


Figure 77 – *Scatterplot of Ventas Group Betas and Atlantic Cyclones in USA. Author's elaboration.*

If however the singular observation is brought to a value that is similar to the mean of the rest of the population (by eliminationg the outlier from the analysis – this lower the number of observation in the population but is the only way to mitigate its effects) we observe a dramatic drop of the correlation coefficient value from 0,70 to 0,16, thus falling (following the scale of ***Figure 70***) in the range of negligible observations.

Given the fact that the presence of this anomaly could affect also the correlation of the other REITs, a remodulation of the correlation analysis has been made, retaking the analysis by delating the 2020 observatio for this particular typology of events.

This results obviously change the overall judgement of the analysis of correlation between betas and Atlantic Cyclones; in particular the values will change as follow:

- Alexandria Real Estate Equities: *from 0,17 (negligible) to 0,05 (negligible).*
- Ventas Group: *from 0,7 (moderate) to 0,16 (negligible).*
- Simon Property Group: *from 0,72 (moderate) to 0,33 (weak).*
- Prologis: *from 0,46 (weak) to 0,22 (negligible).*
- Equity Residential: *from 0,32 (weak) to 0,09 (negligible).*
- American Tower: *from -0,04 (null) to -0,07 (null).*

Following the same approach also the other event populations were examined but fortunately no other outliers have been detected, thus leaving the other results unchanged. Despite this, the new values concerning Atlantic Cyclones transformed the already weak results of the overall correlation for all the REITs based in the USA (***Figure 78, Figure 79***), changing the coefficient from 0,27 (Weak) to 0,23, stating a final judgement of the relationship between USA base REITs' betas and climate change related events as "negligible".

USA BASED REITS BETAS' CORRELATION WITH CLIMATE RELATED EVENTS						
	BILLIONS TONS OF GREENHOUSE GAS (CO2) EMISSIONS	*WILDFIRES*	*ATLANTIC CYCLONES*	*PACIFIC CYCLONES*	*TORNADOES*	β
β ALEXANDRIA REAL ESTATE EQUITIES	0,12	-0,17	0,05	0,37	0,30	1
β VENTAS GROUP	0,64	0,51	0,16	0,25	0,52	1
β SIMON PROPERTY GROUP	0,61	0,38	0,33	0,14	0,84	1
β PROLOGIS	0,42	0,14	0,22	0,10	0,63	1
β EQUITY RESIDENTIAL	0,29	0,06	0,09	0,15	0,39	1
β AMERICAN TOWER	0,09	0,00	-0,07	-0,35	-0,14	1

Figure 78 – *New correlation analysis results between REITs betas' trend (USA) and climate related events. Author's elaboration.*

CORRELATION RESULT	*INTERPRETATION*	*NUMBER*	*PERCENTAGE*
0 (+/-)	NO ASSOCIATION	6	15,00%
0 to 0,25	NEGLIGIBLE ASSOCIATION	15	37,50%
0,25 to 0,5	WEAK ASSOCIATION	12	30,00%
0,5 to 0,75	MODERATE ASSOCIATION	6	15,00%
0,75 to 1	STRONG ASSOCIATION	1	2,50%
1	PERFECT ASSOCIATION	0	0,00%
TOT OBSERVATIONS		**40**	**100,00%**

Figure 79 – *New correlation analysis results between REITs betas' trend and climate related events. Author's elaboration.*

Although the negligible results, one of the correlation results stands out alone. Indeed the correlation between the betas of Simon Property Group and the trend of tornadoes, reflects a strong correlation. To confirm the goodness of the results also here a scatterplot of the observations has been made, and as it can be seen in ***Figure 80***. To further investigate why such a good correlation result came out a deeper analysis of the corporate configuration and targets was necessary.

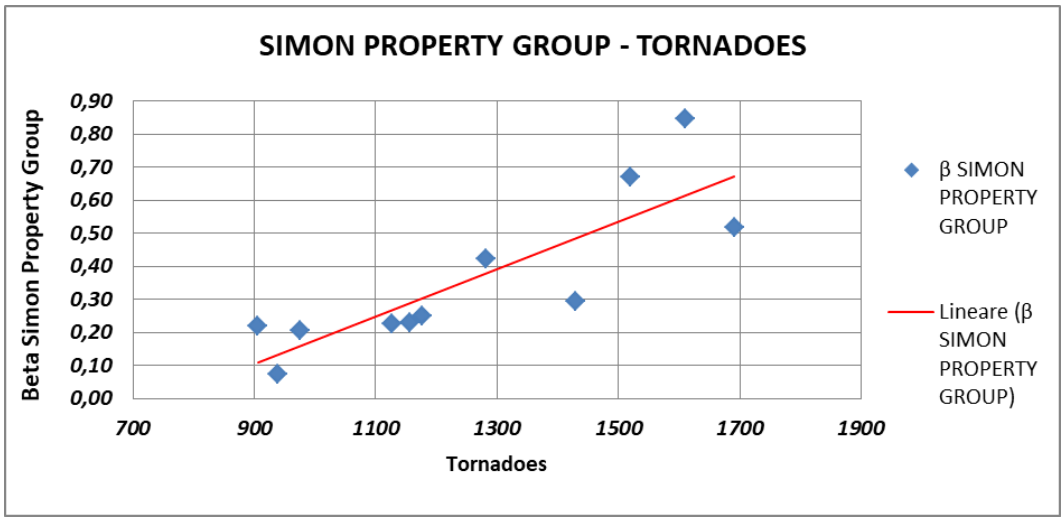


Figure 80 – *Scatterplot of Simon Property Group Betas and Tornadoes in USA. Author's elaboration.*

This positive correlation seems to be confirmed also by a specific program called "StormReady" undertaken and promoted by the NOAA – National Oceanin and Atmospheric Administration, part of the USA National Weather Service.

This designations recognize to Simon Property Group properties (209 malls – retail) the preparedness to handle all types of severe and potentially life-threatening weather situations through communications infrastructures, community outreach and hazardous weather training.

StormReady program and certificate is a USA nationwide program which began in the summer of 2000. It is a voluntary program designed to help companies, counties and communities to take a proactive approach and role to the kinds of severe weather that affect their areas by improving local hazardous weather operations and heightening public awareness. Companies work with the National Weather Service, State Emergency Management, and the media to become StormReady. By participating in this program, it is possible to earn recognition for jurisdiction by meeting the guidelines established by the N.W.S. in partnership with federal, state, and local emergency management professionals. Some of the things the StormReady program is intended to do are:

- Improve the timeliness and effectiveness of hazardous weather warnings.
- Provide detailed and clear recommendations by which local emergency managers may establish and improve effective hazardous weather operations.
- Reward hazardous weather mitigation programs that have achieved a desired performance level.
- Provide a means of acquiring additional Community Rating System points assigned by the Insurance Services Organization.
- Provide an "image incentive" to companies that can identify themselves as being Strom Ready.

Now, just because a company is recognized as being StormReady, it doesn't mean that is StormProof. Mother nature will still unleash her fury at times but what is important is the fact that this REIT has been rewarde as one with the best preparedness program to deal with hazardous climate events such storms and tornadoes.

8.2.2. JAPAN BASED REITS

The Japan based REITs are 12, and all of them have their area of investment only in main japanese urban areas.

The climate change events taken into consideration for these funds are tropical storms, events of heavy rain (>50 mm/h), extremely hot days (>30°), damages by floods and GHG emissions at country level.

The results of this analysis can be seen in the following figure, ***Figure 81.***

JAPAN BASED REITS BETAS' CORRELATION WITH CLIMATE RELATED EVENTS						
	TROPICAL STORMS TO HIT MAIN JAPANESE URBAN AREAS	*EVENTS OF HEAVY RAIN (>50 mm/h)*	*DAYS WITH TEMPERATURES >30°*	*BILLION TONS OF GREEHOUSE GAS (CO2) EMISSIONS*	*MILLION OF ¥ OF FLOODS DAMAGE*	β
β MITSUI FUDOSAN	-0,11	-0,02	-0,35	-0,14	-0,43	1
β MITSUBISHI ESTATE	0,10	-0,15	-0,74	0,08	-0,51	1
β AEON REIT	0,14	0,14	0,61	0,55	0,61	1
β GLP J-REIT	0,21	-0,52	0,05	0,23	-0,15	1
β ORIX JREIT	0,11	0,00	-0,41	0,08	0,15	1
β TOKYO TATEMONO	0,08	0,11	-0,19	-0,06	0,06	1
β NIPPON BUILDING FUND	-0,23	0,02	-0,60	0,27	-0,02	1
β NOMURA REAL ESTATE HOLDING	0,21	0,28	0,40	0,11	0,29	1
β KENEDIX REIT	0,09	-0,76	0,30	0,26	-0,17	1
β SUMITOMO REALTY&DEVELOPMENT	-0,26	-0,23	-0,32	-0,27	-0,18	1
β HULIC REIT	0,98	0,17	0,10	0,82	0,60	1
β JAPAN LOGISTIC FUND	-0,11	-0,44	0,05	0,06	-0,38	1

Figure 81 – *Correlation analysis results between REITs betas' trend (Japan) and climate related events. Author's elaboration.*

As it can immediatly be seen, the final results do not present a good correlation if not for just some cases, concentrated in two funds. Apart from this there are only some other cases of weak correlations, mainly with the events characterized by high temperatures and GHG emissions. In the other cases the correlations can be considered for the majority as null and negligible. The majority of results (43,33% - ***Figure 82***) highlights an overall null or negligible association of the two considered variables. Only the 10% of the observations present a moderate or strong association and another 10% of weak but albeit present correlation.

The overll mean association, computed with the weighted average, results in a coefficient of 0,00, pointing out a null correlation between funds systemic risk coefficient (or volatility) beta and the events that impact the areas in which they invest.

CORRELATION RESULT	*INTERPRETATION*	*NUMBER*	*PERCENTAGE*
0 (+/-)	NEGATIVE / NO ASSOCIATION	26	43,33%
0 to 0,25	NEGLIGIBLE ASSOCIATION	22	36,67%
0,25 to 0,5	WEAK ASSOCIATION	6	10,00%
0,5 to 0,75	MODERATE ASSOCIATION	4	6,67%
0,75 to 1	STRONG ASSOCIATION	2	3,33%
1	PERFECT ASSOCIATION	0	0,00%
TOT OBSERVATIONS		**60**	**100,00%**

Figure 82 – *Correlation analysis final results for Japan based REITs betas' trend and climate related events. Author's elaboration.*

Again to dispel any doubt of possible outliers that could impact the results of the correlation analysis on the REITs, scatterplots of the two variables have been made. Some examples are provided below.

In the following ***Figure 83*** and ***Figure 84*** it is possible to observe two of the highest observations that characterized the Japan based REITs, and in particular they both refer to Hulic REIT that presents the most promising values. They represent the correlation between fund's betas and tropical storms, and between fund's betas and GHG emissions at the country level. As the results suggest there seems to be a high correlation with two major factors that impact one on human societies, namely tropical storms, and one on both climate variations and life quality, that are green house gasses emissions. Looking into the fund's financial statements it emerges that they undertook commitments to reduce carbon foorprint through proper ESG strategies and to protect their properties with engineering solutions able to capture major rains and to resist to strong winds.

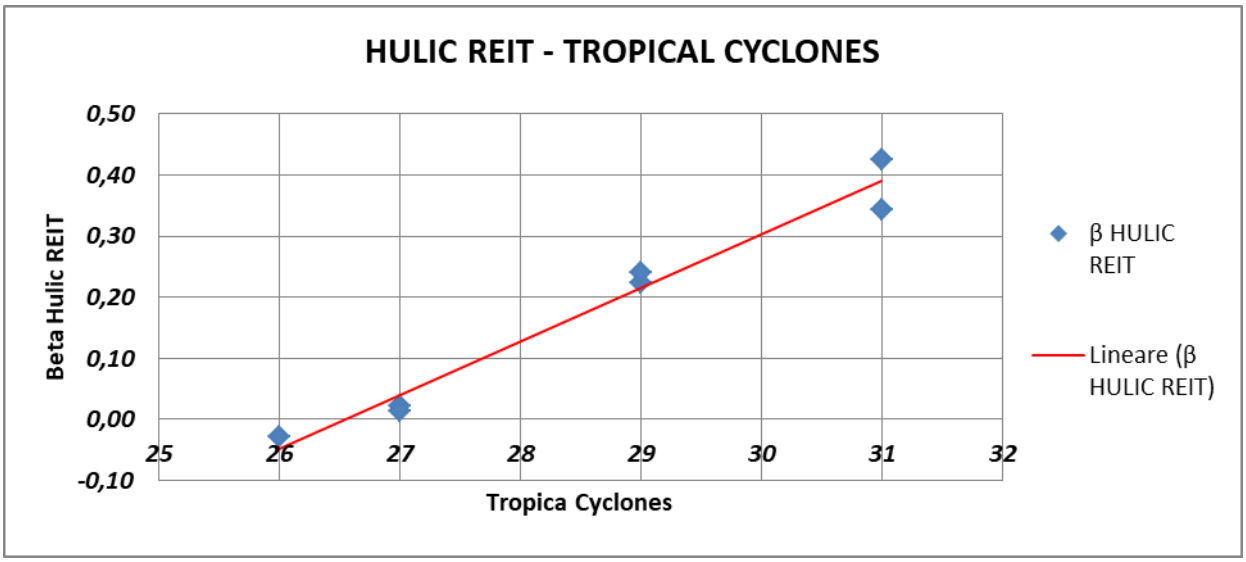


Figure 83 – *Scatterplot of Hulic REIT betas and tropical cyclones in Japan. Author's elaboration.*

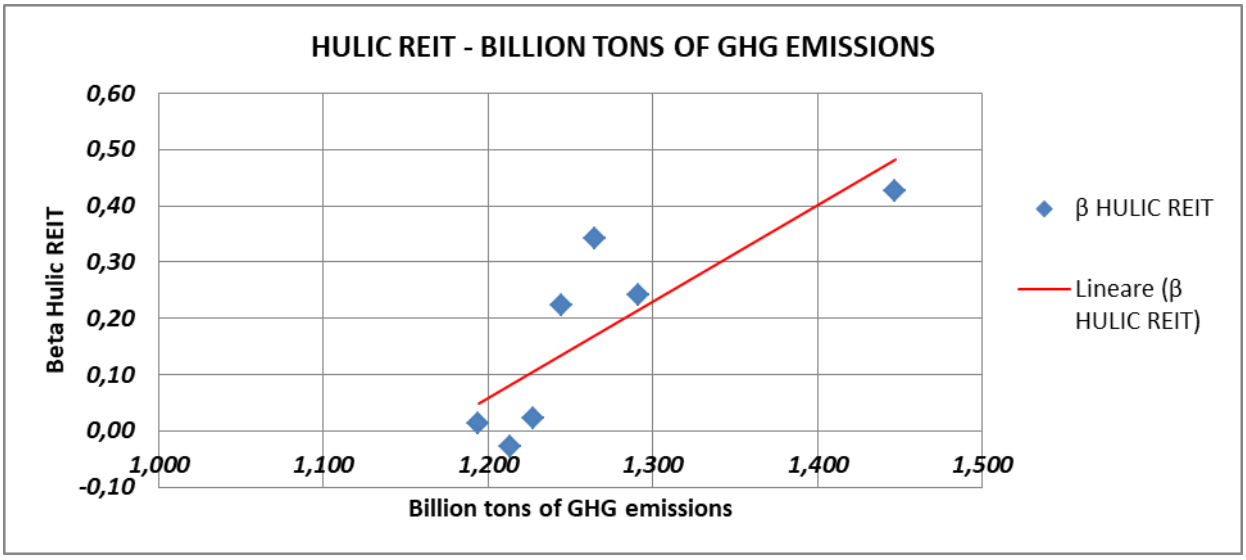


Figure 84 – *Scatterplot of Hulic REIT betas and GHG emissions in Japan. Author's elaboration.*

In these two cases of Hulic REIT the results are pretty significant, in one case almost perfect, but they are heavily affected by the fact that the fund started its activity just in 2014, leaving out three other observations with respect to others cases. This leads to a lower number of obserations and to a possible lower reliability of the correlation analysis, but given the fact that the fund is operationally based on a complex set of ESG targets such as:

- Compliance and Risk Management with ESG regulations and commitments
- Prevention of Global Warming through energy-saving initiatives involving renovations or building management and promoting the reduction of greenhouse gas (GHG) emissions.
- Recycling-Oriented Society: recycling-oriented society by promoting water-saving measures and the 3Rs of "Reduce, Reuse, Recycle."
- Environmental Awareness and Education for Employees and Officers,
- Collaboration with Stakeholders and Disclosure of Information to Stakeholders

It is reasonably possible to think that the correlation points out an actual presence of awareness by the fund of climate related events as potential source of systemic risk.

Another example of moderate association with climate related events is Aeon REIT that presents good results with extremely hot days (>30°), GHG emissions and Floods damages. The results seems in line with the portfolio typology of the fund, that operates in the retail sector detaining 43 large shopping malls. Indeed extremely hot days could impact in significant terms on HVAC systems and operational costs needed to keep temperatures in the buildings, while GHG emissions are part of a detailed program of the fund in which the target is to lower as much as possible the carbon footprint of the portfolio. Finally also for floods the association seems to be confirmed by the fatc that all the malls are considered "disarter ready". This means that they have been projected and built above the the water leves and that they can host people displaced in case of critical events. The scatterplots can be seen in ***Figure 85***, ***Figure 86*** and ***Figure 87***.

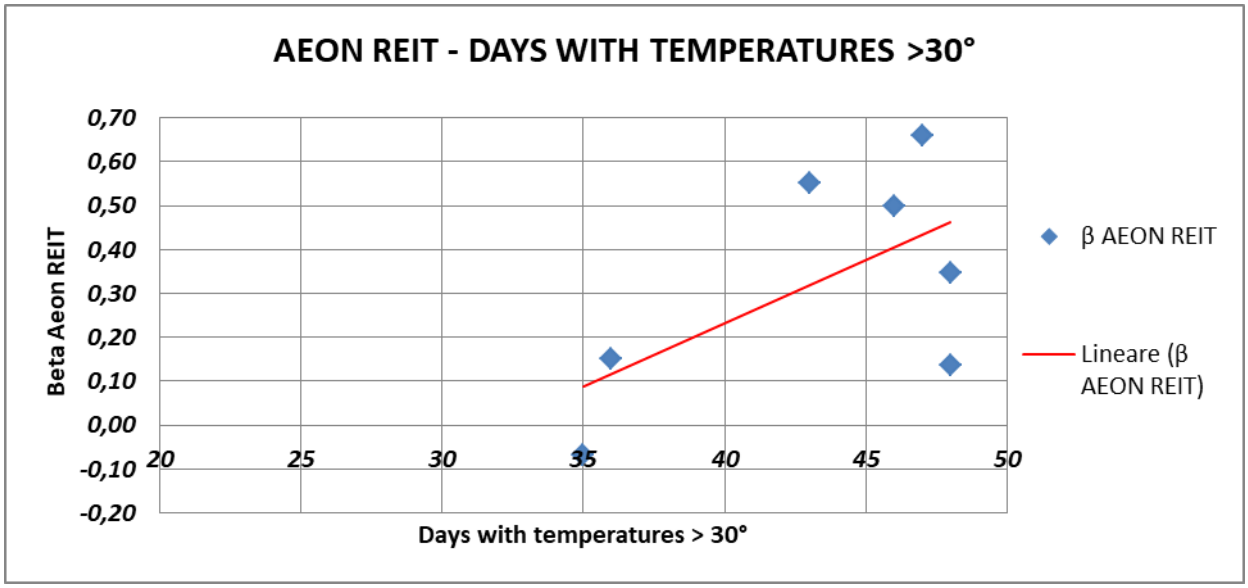


Figure 85 – *Scatterplot of Aeon REIT betas and hot days withtemperatures >30° in Japan. Author's elaboration.*

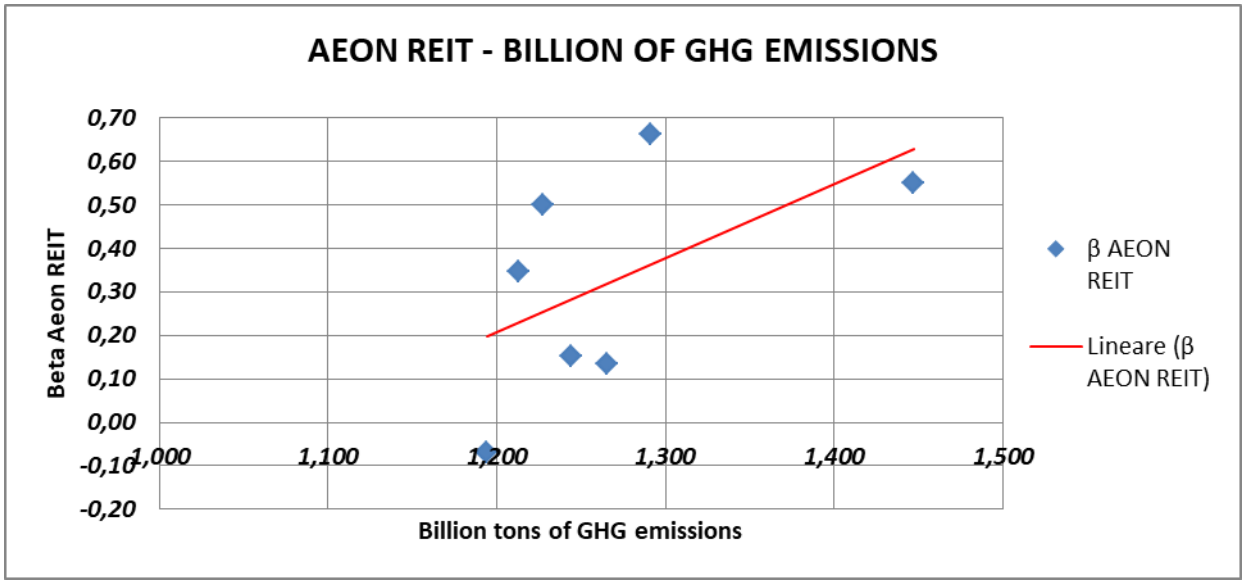


Figure 86 – *Scatterplot of Aeon REIT betas and GHG emissions in Japan. Author's elaboration.*

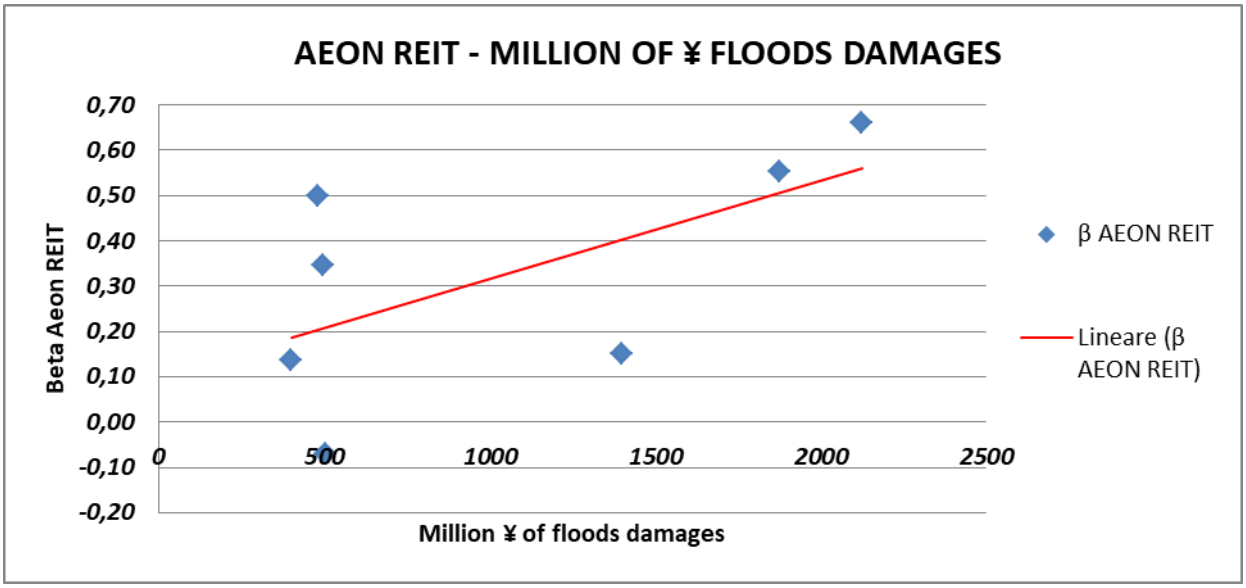


Figure 87 – *Scatterplot of Aeon REIT betas and damages of floods in Japan. Author's elaboration.*

Also in these cases regarding Aeon REIT the results are pretty significant, but again they are heavily affected by the fact that the fund started its activity just in 2014, leaving out three other observations with respect to others cases. This leads to a lower number of obserations and to a possible lower reliability of the correlation analysis, but also in this case the fund is committed in a complex set of ESG targets, thus it is reasonably possible to think that the correlation points out an actual presence of awareness by the fund of climate related events as potential source of systemic risk.

8.2.3. HONG KONG BASED REITS

The selected Hong Kong based REITs are 12, and apart from the investements carried out in the City governed by a special autonomous system, for 9 of them coexist investments undertaken in the mainland China urban areas. This system is well know as “one sytem – two countries” and allows a coexistence of socialism and capitalism under one country that is “Mainland China”.

The climate change related events taken into consideration for Hong Kong are tropical cyclones, events of heavy rain (>200 mm/day), extremely hot days (>35°), thunderstoms and GHG emissions at city level. For the ones that also have part of their portfolio located in main Chinese urban areas the climate related events for which it has been possible to collect data are floods in urban areas that involved more than 10.000 hectares, tropical storms with wind speed between 130 – 150 Km/h and thypoons that reached wind speed of 200 Km/h. The results of this analysis can be seen in the following figure, ***Figure 88, Figure 89.***

HONG KONG BASES REITS' BETAS CORRELATION FOR HONG KONG						
	DAYS WITH RAINFALL GREATER THAN 200mm/24h	*TROPICAL CYCLONES*	*THUNDERSTORMS*	*MILLION OF TONS OF GREENHOUSE GAS (CO2) EMISSIONS*	*VERY HOT DAYS (>= 35°)*	β
CHAMPION REIT β	-0,25	-0,54	-0,43	-0,14	-0,49	1
FORTUNE REIT β	0,21	0,27	-0,36	-0,49	-0,03	1
HYSAN DEVELOPMENT β	-0,25	-0,47	0,00	0,26	-0,05	1
HANG LUNG PROPERTIES β	-0,30	-0,61	0,22	0,42	0,16	1
NEW WORLD DEVELOPMENT β	-0,43	-0,66	-0,06	0,08	-0,31	1
SUN HUNG KAY PROPERTIES β	-0,25	-0,79	0,15	0,25	-0,13	1
HENDEROSN LAND DEVELOPMENT β	-0,27	-0,68	0,08	0,31	-0,11	1
CHEUNG KONG PROPERTY HOLDING β	-0,19	-0,65	0,12	0,34	-0,23	1
HONG KONG LAND β	-0,09	-0,71	0,07	0,21	-0,06	1
SWIRE PROPERTIES β	-0,20	-0,72	-0,07	0,10	-0,32	1
LINK REIT β	-0,15	-0,35	0,15	-0,13	0,09	1
THE WHARF PROPERTY HOLDING β	-0,27	-0,77	0,24	0,26	-0,19	1

Figure 88 – *Correlation analysis results between REITs betas’ trend (Hong Kong) and climate related events. Author’s elaboration.*

HONG KONG BASED REITS' BETAS CORRELATION FOR MAINLAND CHINA				
	FLOODS (Area involved > 10.000 hectares)	*TROPICAL STORMS (Wind speed 130 - 150 Km/h)*	*TYPHOONS (Wind speed > 180 Km/h)*	β
HANG LUNG PROPERTIES β	-0,53	0,06	-0,30	1
NEW WORLD DEVELOPMENT β	-0,55	-0,41	0,00	1
SUN HUNG KAY PROPERTIES β	-0,57	-0,68	0,21	1
HENDEROSN LAND DEVELOPMENT β	-0,37	-0,31	-0,04	1
CHEUNG KONG PROPERTY HOLDING β	-0,50	-0,13	0,00	1
HONG KONG LAND β	-0,63	-0,37	-0,21	1
SWIRE PROPERTIES β	-0,42	-0,12	-0,12	1
LINK REIT β	-0,11	-0,01	-0,03	1
THE WHARF PROPERTY HOLDING β	-0,50	-0,39	-0,10	1

Figure 89 – *Correlation analysis results between REITs betas’ trend (Hong Kong – Mainland China) and climate related events. Author’s elaboration.*

As it can immediatly be seen, the final results given by the 87 total observations do not present a good correlation at all in both cases analysed (Hong Kong – Hong Kong/Mainland China). Apart from this there are only some other cases of weak correlations, all concentrated in the GHG emissions. In the other cases the correlations can be considered for the majority as null and negligible. The majority of results (67,82% - ***Figure 90***) highlights an overall null or negligible (20,69 %) association of the two considered variables. Only the 11,49 % of the observations present a weak association, while no considerable correlation come out of the analysis.

The overll mean association, computed with the weighted average, results in a coefficient of -0,20, pointing out a null correlation between funds systemic risk coefficient (or volatility) beta and the events that impact the areas in which they invest.

CORRELATION RESULT	*INTERPRETATION*	*NUMBER*	*PERCENTAGE*
0	NEGATIVE / NO ASSOCIATION	59	67,82%
0 to 0,25	NEGLIGIBLE ASSOCIATION	18	20,69%
0,25 to 0,5	WEAK ASSOCIATION	10	11,49%
0,5 to 0,75	MODERATE ASSOCIATION	0	0,00%
0,75 to 1	STRONG ASSOCIATION	0	0,00%
1	PERFECT ASSOCIATION	0	0,00%
TOT OBSERVATIONS		**87**	**100,00%**

Figure 90 – *Correlation analysis final results forHong Kong based REITs betas' trend and climate related events. Author's elaboration.*

In the following two scatterplots (***Figure 91, Figure 92***) it is possible to observe the relationship between GHG emissions and betas of two Hong Kong based funds where a weak but present correlation emerges. A part from these two examples the relationship seems to be spread also in the other selected REIT underlining an, albeit low, consideration of the problem at a general level.

This seems also to be confirmed by the fact that all listed companies in Hong Kong have the possibility to declare their GHG emissions on a public list developed by the Hong Kong Environmental Protection Department. This carbon disclosure initiative is supported by Hong Kong Exchanges and Clearing Limited (HKEx). HKEx also promulgated an Environmental, Social and Governance Reporting Guide (ESG Guide) in August 2012. As a recommended practice, the REIT ESG guide stipulates that listed companies should report their greenhouse emissions and intensity, and to describe the measures adopted to mitigate emissions and the results achieved. This is made to facilitate listed companies to take lead in the community to adopt regular carbon auditing practices, and to showcase their commitments and good practices in carbon management. The Environmental Protection Department has developed this Carbon Reporting Website for listed companies: *https://www.carbon-footprint.hk/node/202*.

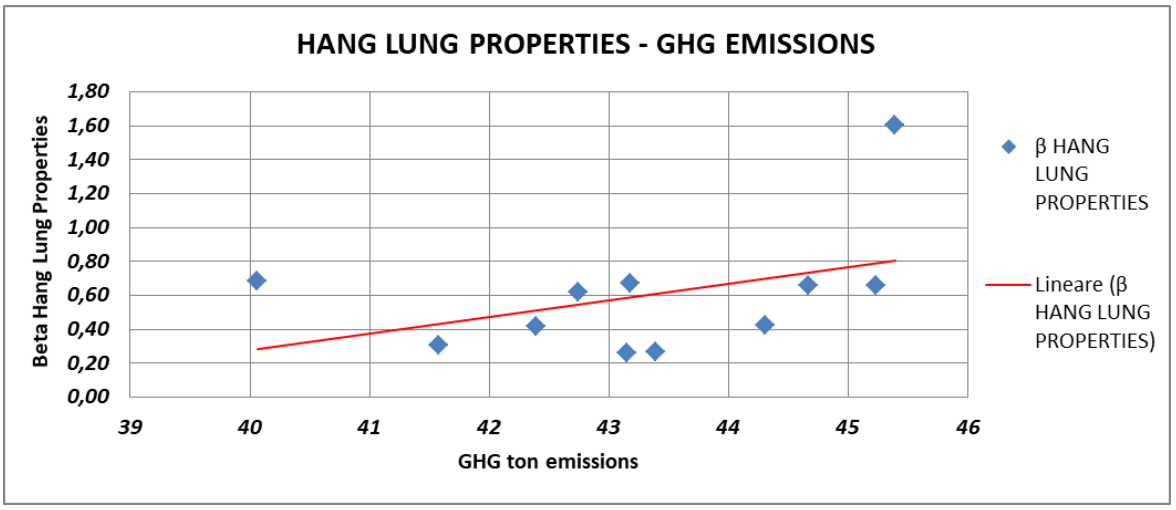


Figure 91 – *Scatterplot of Hang Lung Properties' betas and GHG emissions in Hong Kong. Author's elaboration.*

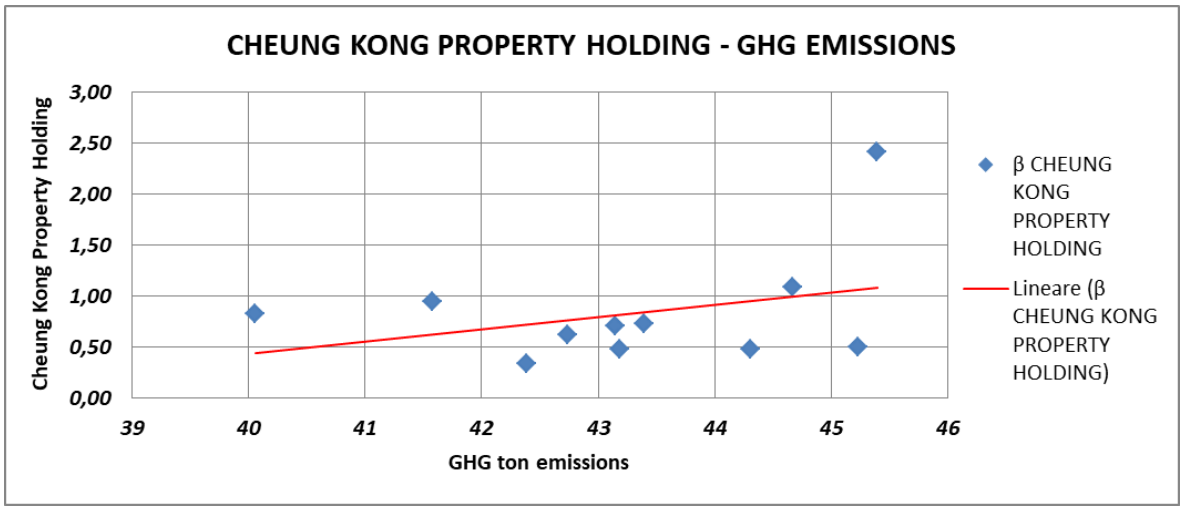


Figure 92 – *Scatterplot of Cheung Kong Property Holding's betas and GHG emissions in Hong Kong. Author's elaboration.*

Contrary to the other two cases of USA based and Japan based REITs where at least some of the observations where actually strong or moderate here in the case of Hong Kong based funds it is not possible to observe any type of association and thus of recognition by the companies of climate related events as a potential source of systemic risk, if not for the weak recognition of the possible commitments toward carbon emissions. This seems also to be confirmed by looking at a scatterplot panel data analysis between all the beta observations, referred specifically to each of the three areas under analysis, and the site climate related events. Indeed also here the observation that seems to be linked in an overall trend of all the results come from the USA and Japan based REITs. See results in the Attachments section at page 101, 103, 105.

CHAPTER 9

9. ANALYSIS TAKEAWAYS AND CONCLUSIONS

Following the results of the three comprehensive geographical areas analysed, what clearly emerges is that in none of them the perception of climate related risks as a pontential source of systemic risk for the sector is a a matter of concern, at least based on the beta (correlation with market performance) analysis. Even if the USA based funds seem to be more responsive, in general terms, they do actually present an overall weak association with climate change. This is of particular concern since the United States are one of the major countries that were, are, and will be affected by the effects of global warming, sea rising levels, cyclones, thunderstorms, drought and other social and economical impacting events.

In the other two cases, apart from some isolated Japanse funds that stand out with really high associations values, that could be also given by a staistical error given in turn by the lower number of observations due to the REIT activity in period under analysis, the overall recognition of the risk, despite all the climate related events present a growing trend in terms of frequency, seems not to be reflected in the REITs systemic risk coefficient beta. The Hong Kong based funds really point out a total non association and this could be due to the fact that the city grown out more as a financial haven that protects its investors with tax shields and anonimity, thus privilaging older typologies of investments and favouring environmental, social and governance oriented internal policies.

But why the risk stemming out of climate change related events does not reflect into an effective recognition by REITs investors in the risk coefficient or if it does, it does so in just a small number of cases? The anwers to this question, unfortunately, are multiple and they can actually be:

- The analysis is taking into consideration a small portion of 32 the real amount of real estate investment funds, even if some of them are at the top level, thus potentially not depicting the entire situation related to the other actors that may, or may not, perceiving climate change as systemic risk.

- The correlation analysis itself, as mentioned in the previous chapter (**CHAPTER 8**), could be affected by statistical errors given by outliers or by wrong data. Correlations may or may not indicate causal relations and reversely, causal relations from some variable to another variable may or may not result in a correlation between the two variables. Again correlation analysi are very sensitive to outliers; a single unusual observation may have a huge impact on a correlation. Such outliers were detected by a quick inspection a scatterplot, and observations not in line have been delated to allow more correct results.

- The betas can be affected by regional and national economic factors, such as tax and interest rate policies. These can significantly contribute to the directional change of the market and greatly influence volatility. For example, in many countries, when a central bank sets the short-term interest rates for overnight borrowing by banks, their stock markets react violently. Also changes in inflation trends, plus industry and sector factors, can influence the long-term stock market trends and volatility. For example, a major weather event in a key oil-producing area can trigger increased oil prices, which in turn spikes the price of oil-related stocks.

This means that betas can be affected by multiple factors, where the ones caused by climate events can spark only in some occasions and thus not influencing the overall trend. This is undoubtely worrying because it underlines a discretional behaviour towards what instead should be treated as a systemic systems.

- Still too few investment funds perform climate-change risk assessment in a substantial manner. 15,6% (5 out 32 that have moderate or strong association) of the investors analyzed in this thesis partially assess the risks of climate change, while only 9,4% seem to conduct climate-change risk assessment rudimentarily. The other 75% of investors seem finally to not assess climate-change risks at all. If investors perform climate-change risk assessments for a portfolio, the majority of them will do so through the use of sustainable due diligence for new acquisitions, or with the measurement of Key Performance Indicators and technical due diligence for existing buildings. Despite those are nowaday quite widely used instruments, others most advanced should instead be considered, like for example "scenario" and "sensitivity analysis", that may be the most suitable instruments for assessing the risks of climate change for real estate portfolios. Most of the investors do not use these tools for their climate-change risk assessments. Indeed what emerges from financial and sustainability reports of the analized population of funds is that the 75% of the participants do not plan to start or increase their climate-change risk assessment activities at least in the next two years. This main market barrier that characterizes and slows the majority of funds under analysis for a faster uptake of green retrofit technology could be given by the investor-user-dilemma (*Landlords who renovate a rented flat can refinance the renovation by means of a surcharge on the rent. This mechanism has been the subject of intense debate in the recent past, as some landlords are accused of misusing this levy to drive tenants out of their flats through high rent surcharges. In terms of climate protection, the mechanism in its current form is unsuitable, as it is not based on a reduction in energy demand or CO_2 emissions, but purely on the investment costs that the landlord has incurred.*), followed by high transaction costs for green technologies and construction materials, the issue of imperfect information and inadequate service levels. But also inadequate access to financing and high discount rates on green technology are least relevant for a faster green uptake.

- While informed professionals in many sectors (science, national security, insurance and major corporations) generally see climate risk as one the biggest risks the world faces, most investment professionals give it a much lower priority. Many of the investors who acknowledge the materiality of the issue are not yet awake to the fact that the likely damage due to climate change cannot be avoided by conventional techniques such as diversification, stock picking or hedging. Even divest-invest and portfolio decarbonisation strategies – which have considerable value in sending political-market signals and as smart beta strategies respectively – are indirect routes to promoting an orderly transition.

- Investors respond to the wishes of the asset owners whose assets they manage. If asset owners are concerned only with fees and performance – and not for example, increasing exposure of properties to storms, sea levels, floods, droughts etc. – there is little incentive for investors to

take action which: a) peers can avoid/free-ride on with impunity; b) which might damage relative performance in the short-term; c) might damage asset gathering activities, because of how corporate and other pension funds allocate mandates. In addition, it is now well recognised how remuneration design causes investment professionals to focus on relative performance over the short-term to the detriment of long-term fund performance and the well being of investee companies. This is akey point. The perception of climate change effects is shifted so much ahead that they is not recognized as possible source of risk in the medium term, thus postponing the implementation of all interventions usefull to mitigate abrout shocks.

- Despite abrupt transitions within sectors are well known - from horse and carriage to car, or from whale oil powered to electric-powered light - no-one, investors included, can really imagine what climate change will be like – both because of uncertainty and because it lies outside the realm of human experience. It may be more fruitful to focus discussion on sectoral transformation, within the wider backdrop of climate change.

- The feedback loops of climate change are long. Investors, like the rest of us, operate with an implicit mental model that the effects of 'bad' things should be visible within a finite timescale. There is also an implicit assumption that the worst effects of climate change will surface when the next generation of investment professionals are at the helm. And finally, having collectively picked up the procrastinator's penalty with regards to climate, there are no non-radical options left on the table. Embracing disruption is not an easy thing for any human to do, particularly when there are financial and other incentives to avoid reality. Conversely, in an attempt to avoid 'doom and gloom' scenarios, there is an element of self-censorship, or 'speed limits' on the rate of change. So investors may be being shielded from the information they really need to absorb. The habit of "climate bright siding" is particularly problematic.

- There is not yet a shared understanding of the responsibilities of all players in the world economy to take action on climate change, so investors are uncertain about where their fiduciary responsibility begins and ends. And within the investment system, there are decades of experience of playing the 'blame game' between different parts of the investment chain.

- The concept of climate recognition as a systemic risk that could affect the entire financial and real economy is often contested. Here are some of the arguments that have been heard from private equities investors and financial operators:

    1. "*Systemic risk is for regulators to deal with: this is not for institutional investors to address.*" This mind-set played a significant part in helping to create the Global Financial Crisis (2007-8) and to the extent that it is being repeated again, this simply highlights how little this very powerful industry learns.

    2. "*We survived the banking crash and if there is a correction, markets will solve the problem on their own – our role is not to interfere.*" Investors (and banks) survived the crash because of a) a taxpayer bailout and b) quantitative easing. Governments have no resource to do a "climate bailout", even if it were possible.

3. "*Technology developments (e.g. net emissions technology like carbon capture and storage and new forms of nuclear energy) will happen in a time frame that can prevent catastrophic climate change.*" Technology does indeed have a big role to play but simply relying on technology to reduce GHGs at the pace needed will fail. Reliance on unproven technologies (which in some cases have been under development for decades) could be viewed as a higher risk strategy than trying to prevent climate change. Moreover, there is no reason at all why investors could not take all the technology bets they want, either directly or via the companies they invest in – but also support these transition plans.

4. "*There is no evidence of a possible aggregated impact of climate change events, as opposed to sector-by-sector impact.*" This assertion is contradicted by detailed research from the Economist Intelligence Unit (EIU – internal division of ""The Economist") and Professor Simon Dietz (London School of Economics). The value at risk for a portfolio due to business-as-usual emissions has been estimated by Dietz et al, to have an expected value of around 2% but with a 1% chance that it is 17% or more. The long tail of high potential losses is what constitutes the systemic risk from climate change. The value at risk to manageable assets from climate change calculated in EIU report is US$4.2trn, in present value terms. While the tail risks are more extreme; 6°C of warming could lead to an increase of the present value loss worth of US$13.8trn, using private-sector discount rates. From the public-sector perspective, 6°C of warming represents present value losses worth US$43trn (30% of the entire stock of the world's manageable assets.). Impacts on future assets will come not merely through direct, physical harms but also from weaker growth and lower asset returns across the board. The interconnected nature of the problem will reduce returns, even on investments unharmed by physical damage. Although direct damage will be more localised, indirect impacts will affect the entire global economy; accordingly, asset managers will face significant challenges diversifying out of assets affected by climate change. Institutional investors need to assess their climate-related risks and take steps to mitigate them; but from the results of this thesis and from other reports mentioned in it, very few have begun to do so.

9.1. WHAT CAN REITs AND FINANCIAL INVESTORS DO?

In this following paragraph some suggestions will be made on how REITs' managers, but not only them, can follow to be more prepared to forecast, react, and act to mitigate or avoid possible future climate risks in their investments. These risks cannot be removed, even if the temperatures will be contained within the 2° C increase in 2030 (rather optimistic thought) the emissions and the damages caused so far will be felt for tens of years. Thus the recognition of systemic risk that can possibly affect, starting from the operational level and then spreading to real economy is a key point. So, what can REITs and financial investors actually do?

- Common “Tools” used by the majority of real estate companies are generally understood and used, like Sustainability Due Diligence and KPIs, but strategic planning approaches like scenario analysis are almost totally lacking. This is due to the lack of awareness of long-term consequences, including the functional chain. Traditional tools and models rely strongly on the derived implications based on historical quantitative analysis. In contrast of course, most of the risk related to climate change related extreme events involves forward looking data and studies which are often only available in a more qualitative form. To obtain a clear view on possible outcomes of future performance, the uncertainty and fundamental shifts of the real estate industry must be captured with scenario analysis or other appropriate tools. Accordingly, investors have to use new tools to more precisely integrate and model systemic risks like climate change. Historic data and a focus on volatility as we understood from this thesis will be not sufficient to capture this “new” investment environment. Long-term asset value can only be protected if risks are identified and integrated into scenarios and simulations of future climate change. Since the links between manmade emissions, rising GHG concentration and climate change are not yet fully understood, potential impacts on assets and regions remain highly uncertain. Investors must integrate special climate risk assessment knowhow (potentially via NatCatSERVICE2 that is the best world provider of datasets for natural anc climate disasters since 1980) into their own analysis (PMSoftware, Due Diligence, Insurance analysis, asset and portfolio valuation etc.) – especially since existing methods and tools are becoming more and more mature. Their capability to address risks due to climate change is becoming increasingly important, also for the selection of asset managers. These aspects should be integrated into Investment Management Agreements.

- Watch potential “winner” and “loser” regions: Do not invest in regions that are heavily affected in the future and have limited public resources for and awareness of this topic (high vulnerability and limited adaptation are a bad combination). Screen portfolios for highly vulnerable properties in regions with significant extremes, and either exit or adapt. IPCC describes in detail the various climate-related risks and potential differences with regard to regions. Their experts also stress that urban areas and the built environment are severely (negatively) effected by climate change. Especially the need for clear governance and smart policy, in order to ensure more resilience for the real estate industry, is highlighted. Other institutions like the World Bank have also published reports analyzing in detail how regions and sectors might be affected. These reports also focus explicitly on the complex functional chains which are of crucial relevance in order to derive strategic decisions.

- Strategic planning needed: Investors must read and process climate reports for strategic planning of business. They should also focus on indirect and consequential effects. It makessense to plan with a scenario analysis for a 2 or 4 degree temperature rise.

- Identify low-risk and low-carbon investments: Carbon risk assessments and an active focus on low carbon assets is still in its early stages in the real estate industry. Investors should more closely analyze and manage climate risks and opportunities in their portfolios, as well as invest in low-carbon solutions.

- Besides the inside-dimension analyzed so far, the assessment of environmental and other context factors of the portfolio must also be carried out on outside dimension. The external conditions cannot be controlled or influenced by the managers and investor, which reveals the compelling need for more focused analysis on this subject in the light of climate change. In order to assess the impacts of climate change on investment, a differentiation can be made between three main aspects, according to a concept first suggested by Mercer, namely the socalled "TIP"-risk-assessment -concept:

    - Technology (T) – the rate of progress and investment flows into technology related to sustainability, low carbon and efficiency, impacting on the pay-off of these properties (e.g. innovation rate, consumer preferences).

    - Impacts (I) – negative implications due to climate change (e.g. extreme weather events, rising sea level etc., and also consequences like migration and reduced economic activity in certain regions).

    - Policy (P) – intensity and timing of climate policies also affecting changes in the cost of carbon and emissions levels, as well as increasing or reducing the need for adaptation (e.g. global commitments, regional/EU regulation, national regulation).

- Support for < 2°C transition plans. The goal is to get companies in all heavy impact sectors (i.e. not just fossil fuel companies) to change their operations, capex, innovation/R&D, incentives and lobbying strategies so they rapidly decarbonize and align with a < 2° C world. The same is true for key enabling sectors (e.g. insurance, banks, asset management funds, real estate managers). Having a < 2° C business plan is a pre-requisite for companies really engaging with the specific changes needed be it on lobbying or capex. And it is highly implausible that traditional investors will vote in favour of what they consider to be micro-management resolutions if they have not first understand the need to support transition plan resolutions. When investors require the companies they own to publish such plans – and whether this comes quickly as a result of private engagement or through voting for AGM resolutions – they are practising forceful stewardship. Investors are powerful agents of change here but need to see they are part of an ecosystem of change agents and that the sum of the whole is what is really effective.

- Enlightened regulators. As suggested by IPE Real Asset (an essential summit of institutional investors looking to understand where the asset classes are going and how best to invest in them) there is a fear that investors who do the right thing vis a vis forceful stewardship, but who are atypical in doing so, may get 'punished'. Often the expressed fear is about impact on returns or costs but in reality it is a fear that forceful stewardship activities could work against the all important asset gathering function. Regulators have a key role to play in reducing any perceived first mover disadvantage. More can be done: for example, regulators could add climate risk into "Know Your Client" (KYC) requirements on the ground that climate risk is at least as important systemic threat as bribery and corruption. Similarly, governments could require that investment consultants are clients if they want to add climate to their "Risk Register".

- Showcase the Leaders. Best in class companies will in many cases already be thinking about transition and Physical climate risks. Investors need to encourage this process where it is already in train and help to stimulate it where it is not. Investors should expect the leadership of companies to recognise and embrace the challenges and opportunities of an energy transition to achieve a low carbon economy. This is as relevant to sustainability investment managers as it is to traditional ones – indeed the former could be said to have a responsibility to set the agenda with their "good practice" companies. Similarly, private equity investors who assert their ESG credentials – and who do not need AGMs (Annual General Meetings) to have corporate influence – should also be expected to set the pace.

- Investment ecosystem must shift. The three key players of the institutional investment ecosystem (i.e. asset owners, fund managers and investment consultants) need to make this shift together. A critical mass in each part of the ecosystem will need to act. This will be best done by informed and assertive clients acting collaboratively. Financial systems act as they a third part that only manages money, interest rates, quotations and trends, not influenced by the external conditions. This attitude is extremely dangerous because all the systems are affected by external conditions, and climate change is one of the most impacting ones.

- Corporate governance forums must support change. The bigger the percentage of investors supporting the resolution, the clearer the signal to companies but also key information intermediaries like sell side and credit rating analyst, voting advisers and auditors. To get powerful signals happening, and also to cover more companies in more sectors, the professional / trade groups need to transform the 'cottage industry' resolution process into an institutional scale one.

- International networks must support change. All investor networks could do more to a bigger part of the solution, in particular the networks focused on corporate governance (traditionally defined). Internationally, this means the International Corporate Governance Network (ICGN) in addition to the UN Principles of Responsible Investment (PRI).

- Key stakeholders review how they can assist. Stakeholders that influence investors could back forceful stewardship, specifically < 2° C transition plan resolutions, in the same way that they currently back other strategies (e.g. divest-invest or portfolio decarbonisation). Each stakeholder can focus on what it is best suited to do. For example:

    - Regulators could "press" investors through public speeches and also amend "know your client" rules to include climate related systemic risk.

    - Investment consultants could ask asset owners who have not put climate risk on their risk registers to explain in writing why they did not do so.

    - Actuaries could review discount rates to reflect the reduction in future returns on investment that might be a consequence of systemic climate risk.

9.2. CONCLUDING REMARK

Climate change is real, and is already impacting our day by day life in all the planet with different typologies of events. We as human beings are responsible for its abroupt appearence in the last decades, and we will see and experience all the related effects.

I decided to carry out this thesis with the intent of putting in the spotlight that the real estate sector will probably face the most dangerous effects and will have to face the most challenging changes in the upcoming years due to climate change, but since now it seems to be unaware and unprepared to face them in the correct way. Too few companies in the sector recognise the risk and we saw the whys of that, but the latest events have shown us to what type of damages we are incurring, and I sincerely hope that this is right shock that will start a changing movements that must affect all the financial sectors.

Anyway this is far from being just a potential source of systemic risk for an already fragile financial system. We need to act not only for better and safer financial systems and markets, and we do not need to act in order to save The Planet (it will go on one way or another, with or without us), but we need to act for ourself today to have better life conditions, for the future generations to have safe places, houses and land where to live and for all the species that cohabit with us. This argument is probably being repeated many times in all communication channels but from the results it seems that it has not yet been understood.

ACKNOWLEDGEMENTS

At the end of this paper I would like to thank all the people who contributed in order for me to get at the end of my University career.

First of all I would like to thank my parents, who have always pushed me to look to the highest peak and to never give up even when the climb was difficult and the desire to go back was great. I sincerely thank you and i would like you to know that I have the greatest respect and esteem for you. Thank you.

To Tatiana, who has been with me for a lifetime in all the choices I have made and who has always supported me in any occasion, this end of a journey is for us, and I can't wait to find out what will follow. Forever.

To my two friends who shared with me the moments of satisfaction and concern of this jurney, Giulia and Luca. Our path won’t divide here, we will continue to laugh and joke as we have done in recent years. Cheers!

To my lifelong friends, Lorenzo, Giacomo and Matteo, who will always be there.

I thank the Supervisor Professors who guided me in the drafting of this document, Professor Andrea Antonio Caragliu and Professor Gianandrea Ciaramella. Furthermore, I thank the institutions of the Politecnico Di Milano for providing all the possibilities and opportunities I have used.

Thank you!

At the end of my University career I would also like to report two important quotes from two of my favorite authors:

"Much has been written about the end of the world. Hundreds of books (and few films) give shape to apocalypses in dark and dramatic colors, in which man is often portrayed as a helpless and innocent victim of hostile forces superior to him. I will try to explain how the real dangers that must be guarded against are not those heralded by visionaries and self-styled experts fasting in science, but those that we ourselves create. But it is far more convenient to believe in Nostradamus or the Maya than to take note of the changing climate or the resources that are starting to run out. The climate is not an alien thing, it is just humanity translated into bad weather."

Mario Tozzi

"One can see from space how the human race has changed the Earth. Nearly all of the available land has been cleared of forest and is now used for agriculture or urban development. The polar icecaps are shrinking and the desert areas are increasing. At night, the Earth is no longer dark, but large areas are lit up. All of this is evidence that human exploitation of the planet is reaching a critical limit. But human demands and expectations are ever-increasing. We cannot continue to pollute the atmosphere, poison the ocean and exhaust the land. There isn't any more available."

Stephen Hawking

BIBLIOGRAPHY

- Carolyn Hayman and Raj Thamotheram from Preventable Surprises, June 2016 - "*Climate related systemic risk: a guide for investor action*".

- Prof. Dr. Sven Bienert from International Real Estate Business School, Urban Land Institute, University of Regensburg, 2016 edition - *"Climate change implications for Real Estate portfolio allocation, business as usual or game shift?"*.

- Prof. Hugues Chenet, Honorary Senior Research Associate at University College London (UCL) and Associate Researcher, Chair Energy and Prosperity (ENS/X/ENSAE), working paper April 2019 - *"Climate change and financial risk."*.

- The Economist Intelligence Unit and Aviva, 2019 press, -*"The cost of inaction: Recognising the value at risk from climate change."*.

- Robert H. Edelstein and Konstantin Magin, November 2013 - *"The equity risk premium for securized Real Estate: The case for Real Estate Investment Trusts."*.

- Glenn R Mueller from University of Denver and Karl-Werner Schulte from Universität Regensburg, January 2006 - *"Determining Real Estate Betas for Markets and Property Types to Set Better Investment Hurdle Rates"*.

- Pawel Smaga from Warsaw School of Economics, August 2014 - *"The Concept of Systemic Risk"*.

- Haakon Vennemo from Oslo Metropolitan University, January 2014 - *"A portfolio approach to climate investments: CAPM and endogenous risk."*.

- Simon Dietz, Christian Gollier, LouiseKessler, from ESRC Centre for Climate Change Economics and Policy, Grantham Research Institute on Climate Change and the Environment, and Department of Geography and Environment, London School of Economics and Political Science, Toulouse School of Economics, July 2017 - *"The climate beta."*.

- Mark Allen, Korin Crawford, Jérôme Théot, Luca Toscani, from Stanford Graduate School of Business, May 2015 - *"Climate change and capital markets."*.

- Stéphane Martin and Pierre Bernat, from Deloitte, May 2015 - *"Real Estate Predictions 2020, Article 1, Climate change and the real estate sector. From pleading guilty to delivering solutions."*.

- Olivier De Bandt and Philipp Hartmann, from European Central Bank, November 2000, *"European Working Paper number 35 - Systemic risk: a survey."*.

- Veena Ramani from Ceres – Accelerator for Sustainable Capital markets, January 2017 - *"ADDRESSING CLIMATE AS A SYSTEMIC RISK: A call to action for U.S. financial regulators."*.

- Karydas, Christos; Xepapadeas, Anastasios, Economics Working Paper Series, No. 19/311, Provided in Cooperation with: ETH Zurich, CER-ETH – Center of Economic Research, January 2019 - "*Pricing climate change risks: CAPM with rare disasters and stochastic probabilities.*".

- Lingxiao Li, Associate Professor of Finance at California State University and Fullerton College of Business and Economics, April 2012 - *"The Determinants of REIT Volatility."*.

- Four Twenty Seven and GeoPhy, October 2018 - *"Climate Risk, Real Estate, and the Bottom Line."*.

- MSCI paper, October 2018 - "*Real Estate Climate Value-at-Risk (Climate VaR) Methodology: A TRANSPARENT APPROACH TO CALCULATING CLIMATE VALUE-AT-RISK*".

- Bjørnar Karlsen Kivedala, Trond Arne Borgersen from Nordic Journal of Surveying and Real Estate Research and Østfold University College, May 2018 - "*Commercial Real Estate at the ZLB: Investment Demand and CAPM-WACC Invariance."*.

- Jung HEE Noh from Pusan National University, January 2018 - *"Relationship between Climate Change Risk and Cost of Capital"*.

- Etienne Espagne from Agence Française de Développement/Centre d'Etudes et de Recherche en Développement International, February 2016 - *"Climate and Finance Systemic Risks: more than an analogy? The climate fragility hypothesis."*.

- Fengyun Liu, Shuji Matsuno, Reza Malekian, Jin Yu, Zhixiong Li, from School of Management, China University of Mining & Technology, October 2016 - *"A Vector Auto Regression Model Applied to Real Estate Development Investment: A Statistic Analysis."*.

- Assogestioni, September 2006 - "*Mappatura dei rischi immobiliari dei fondi Real Estate*".

- Andrea Ciaramella, Department of Architecture, Urban Planning and Construction Engineering of Politecnico Di Milano, June 2013 - "*Applicazione del project risk management e indici di performance nel settore delle costruzioni: un caso di studio*".

- Michela Arnaboldi, Giovanni Azzone, Marco Giorgino, Department of Industrial and Management Engineering, Politecnico di Milano, September 2014 - "*Performance Measurement and Management for Engineers*".

USA based REITs' financial statements and sustainability reports:

- SL Green Realty Corp. Sustainability report 2020: https://sustainability.slgreen.com/wp-content/uploads/2020/12/SLG-2020-ESG-Report.pdf

- Alexandria Real Estate Equities financial report 2019: https://s2.q4cdn.com/884574073/files/doc_financials/2019/ar/ARE2019.pdf

- Ventas Group Sustainability report 2020: https://www.ventasreit.com/sites/default/files/flipbooks/csr-2020/index.html#p=2

- Simon Property Group Sustainability report 2020: https://simon-malls.cld.bz/Simon-Sustainability-Report-2020

- Prologis ESG Impact report 2019: https://www.prologis.com/sites/corporate/files/documents/2020/06/2019-prologis-esg-impact-report.pdf

- Equity Residential ESG report 2020: https://s1.q4cdn.com/843629197/files/doc_downloads/sustainability/Equity_Residential_ESG_Report_2020_Final.pdf

- Vornado Realty Trust ESG report 2019: http://books.vno.com/books/vntz/#p=10

- American Tower Corporate Sustainability report 2019: https://www.americantower.com/corporate-responsibility/

Japan based REITs' financial statements and sustainability reports:

- Mitsui Fudosan Sustainability report 2020: https://www.mitsuifudosan.co.jp/english/corporate/esg_csr/pdf/2020/mf_esg2020_all.pdf

- Orix JREIT annual report 2020: https://www.orix.co.jp/grp/en/pdf/ir/library/annual_report/AR2020E.pdf

- Tokyo Tatemono annual report 2020: https://pdf.irpocket.com/C8804/mxGt/P0pT/HCTa.pdf

- Nippon Building Fund ESG report 2020: https://www.nbf-m.com/nbf_e/profile/sustainability/doc/esg_report.pdf

- Nomura Real Estate Holding CSR report 2020: https://www.nomura-re-hd.co.jp/english/csr/download/pdf/2020/nomura_re_hd_csr_2020.pdf

- Kenedix Sustainability report 2019: https://www.kenedix.com/eng/sustainability/report/pdf/sustainability_report2019_eng.pdf

- Sumitomo Realty Development Integrated Report 2019: http://www.sumitomo-rd.co.jp/english/ir/ir_news/files/2010_0002/SRD_IR2020.pdf

- Hulic REIT CSR report 2020: https://www.hulic.co.jp/en/sustainability/report/pdf/integrated_report2020_e.pdf

Hong Kong based REITs' financial statements and sustainability reports:

- Champion REIT Sustainability Report 2020: https://stg.championreit.com/files/en/e_ChampionREIT%20Sustainability%20Report%202020.pdf

- Fortune REIT Financial Report 2020: https://media2.fortunereit.com/20200320152125176196 1310_en.pdf

- Hysan Development Sustainability report 2019: https://www.hysan.com.hk/app/uploads/2020/08/e_Hysan_Sustainability-Report-2019.pdf

- Hang Lung Properties Sustainability Report 2019: https://www.hanglung.com/getmedia/ff5ee725-9e0e-4196-b890-bd0fd5ab142a/hlp_sr_2019_en.pdf?ext=.pdf

- New World Development Sustainability report 2019: https://sustainability.nwd.com.hk/wp-content/uploads/2020/08/NWD_SR2019_EN.pdf

- Sun Hung Kay Sustainability report 2020: https://www.shkp.com/Html/CSR/SHKPSReport/SR2020/en_index.html

- Henderson Land Development Sustainability report 2019: https://www.hld.com/en/pdf/investor/annual/2019/CSR_E.pdf

- Honk Kong Land Sustainability report 2020: https://hklandblob.blob.core.windows.net/assets/sustainability-report/2020/en/hongkong-land-sustainability.pdf
- Cheung Kong Property Holding Annual report 2019: https://www.ckah.com/uploaded_files/news/1066_e_content.pdf

- Link REIT Annual report 2019: https://www.linkreit.com/linkcorp/api/v1/file/SiteAssets/CorporateWebsite/InvestorRelations/FinancialReports/EW00823Book1.pdf?y=d8efbeb7d6363b4595704831c253839a

- Swire Properties Sustainability report 2019: https://sd.swireproperties.com/2019/pdf/en/SwirePropertiesSustainableDevelopmentReport2019_EN.pdf

- The Wharf Holdin Ltd Sustainability report 2019: https://sd.swireproperties.com/2019/pdf/en/SwirePropertiesSustainableDevelopmentReport2019_EN.pdf

SITOGRAPHY

- Factoring the effects of climate change into real estate investments: https://www.washingtonpost.com/realestate/factoring-the-effects-of-climate-change-into-real-estate-investments/2019/03/07/aa60f186-3f7f-11e9-a0d3-1210e58a94cf_story.html

- Considering Climate Risks When Investing In Real Estate: https://www.forbes.com/sites/forbesrealestatecouncil/2019/10/10/considering-climate-risks-when-investing-in-real-estate/?sh=4ae329527cf2

- How Do REITs Develop Environmental Goals for Action & Impact? - https://www.reit.com/investing/reits-sustainability/reits-and-environmental-stewardship

- IRR and WACC in Real Estate Investment: https://property-investment.net/2020/04/16/irr-and-wacc-in-real-estate-investment/

- Relationships Between the Internal Rate of Return (IRR), Cost of Capital, and Net Present Value (NPV): https://maaw.info/IRRNPVandCostofCapital.htm

- Australian Academy of Science: https://www.science.org.au/learning/general-audience/science-climate-change/1-what-is-climate-change

- Stock markets are not pricing in the risk of climate change, warns IMF: https://www.weforum.org/agenda/2020/11/equity-investors-climate-change-physical-risk/

- How is the real estate sector tackling climate change? - https://www.ampcapital.com/europe/en/insights-hub/articles/2020/february/how-is-the-real-estate-sector-tackling-climate-change

- Facts + Statistics: Wildfires: https://www.iii.org/fact-statistic/facts-statistics-wildfires

- List of costliest Atlantic hurricanes:
  https://en.wikipedia.org/wiki/List_of_costliest_Atlantic_hurricanes

- Record 2017 hurricane season driven by warm Atlantic Ocean, study says:
  https://www.carbonbrief.org/record-2017-hurricane-season-driven-by-warm-atlantic-ocean-study-says

- Hurricane Sandy: The Aftermath:
  https://www.theatlantic.com/photo/2012/11/hurricane-sandy-the-aftermath/100397/

- Wilder Typhoons May Mean Bigger Yen Losses:
  https://ourworld.unu.edu/en/wilder-typhoons-may-mean-bigger-yen-losses

- Hong Kong Observatory:
  https://www.hko.gov.hk/en/informtc/tcMain.htm

- Carbon Footprint Repository for Honk Kong Listed Companies:
  https://www.carbon-footprint.hk/node/202

- China Ministry of Water Resources:
  http://www.mwr.gov.cn/english/inbeijing.html

- Japanese Ministry of Environment:
  https://www.env.go.jp/en/

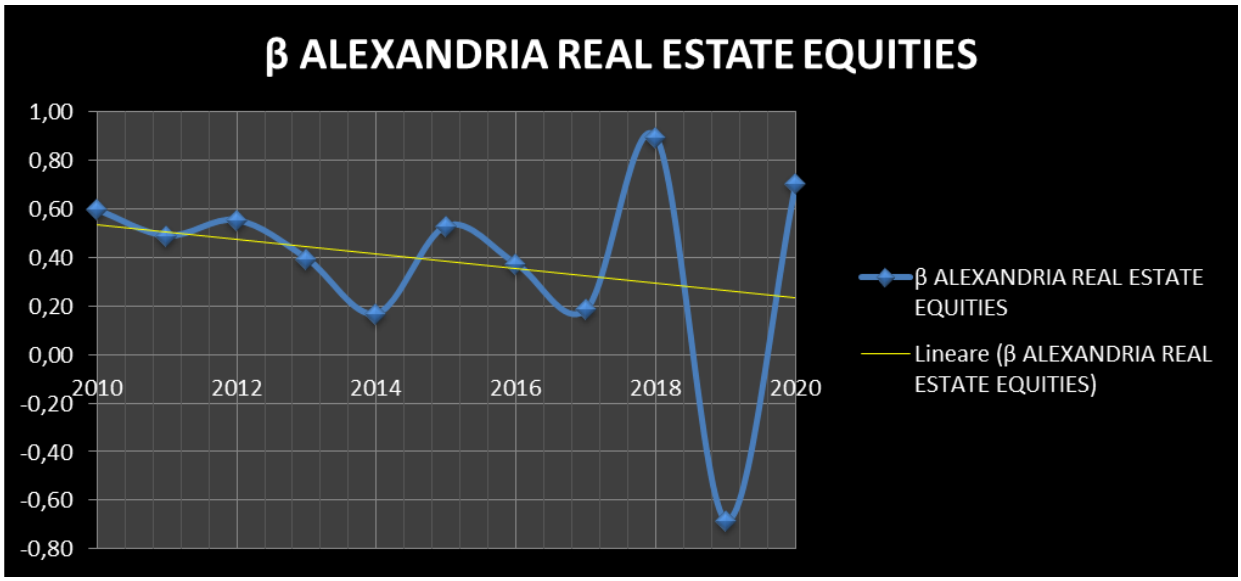
- Japanese Ministry of Land, Infrastructures and Tourism:
  https://www.mlit.go.jp/en/

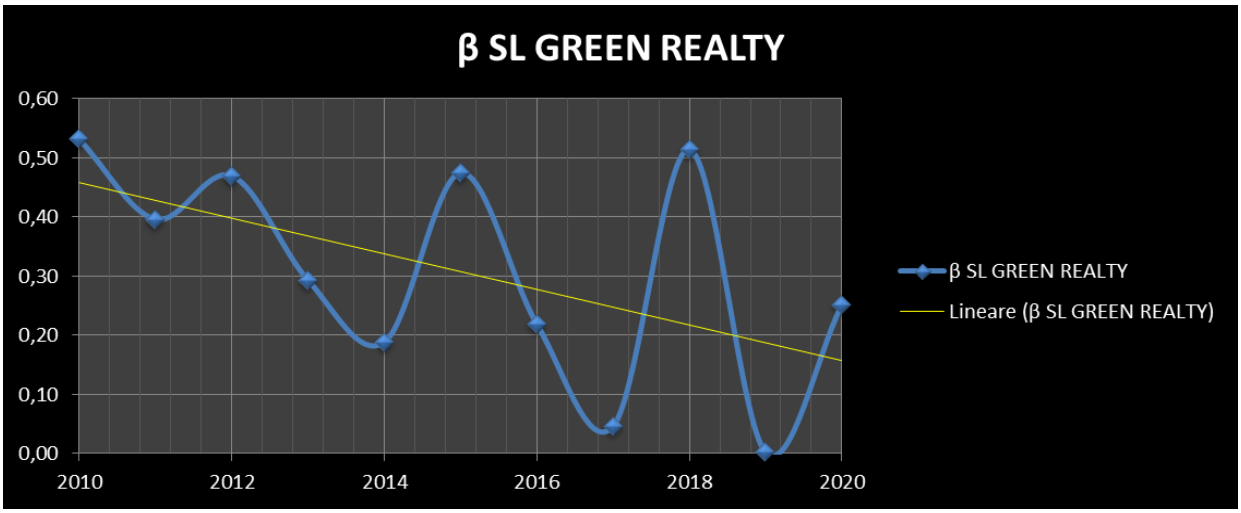
- U.S.A. National Weather Service:
  https://www.weather.gov/

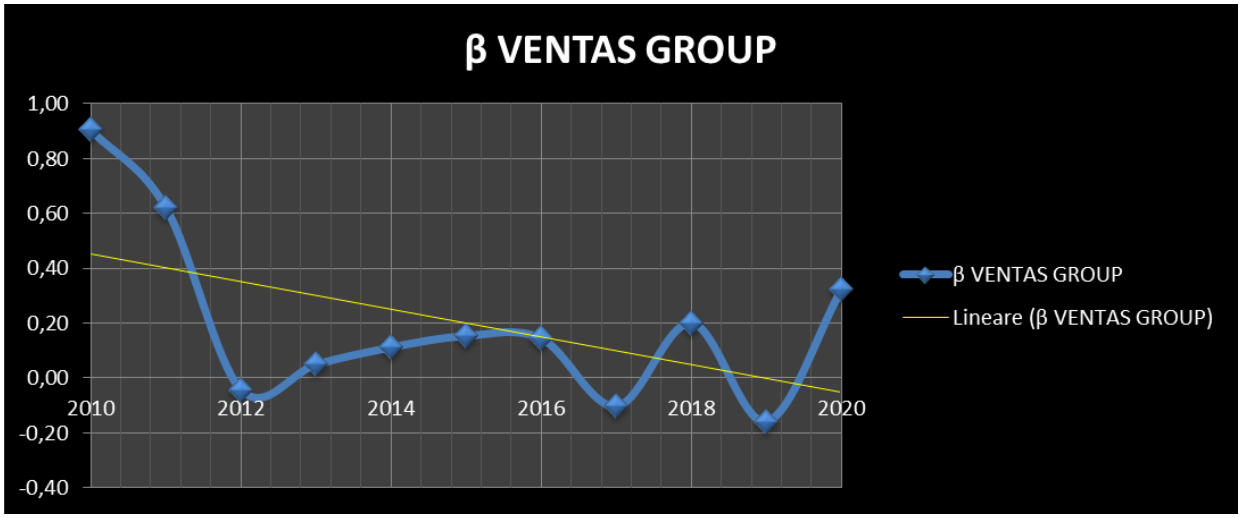
- N.Y.S. Mayor's Sustainability Office:
  https://www1.nyc.gov/site/sustainability/index.page

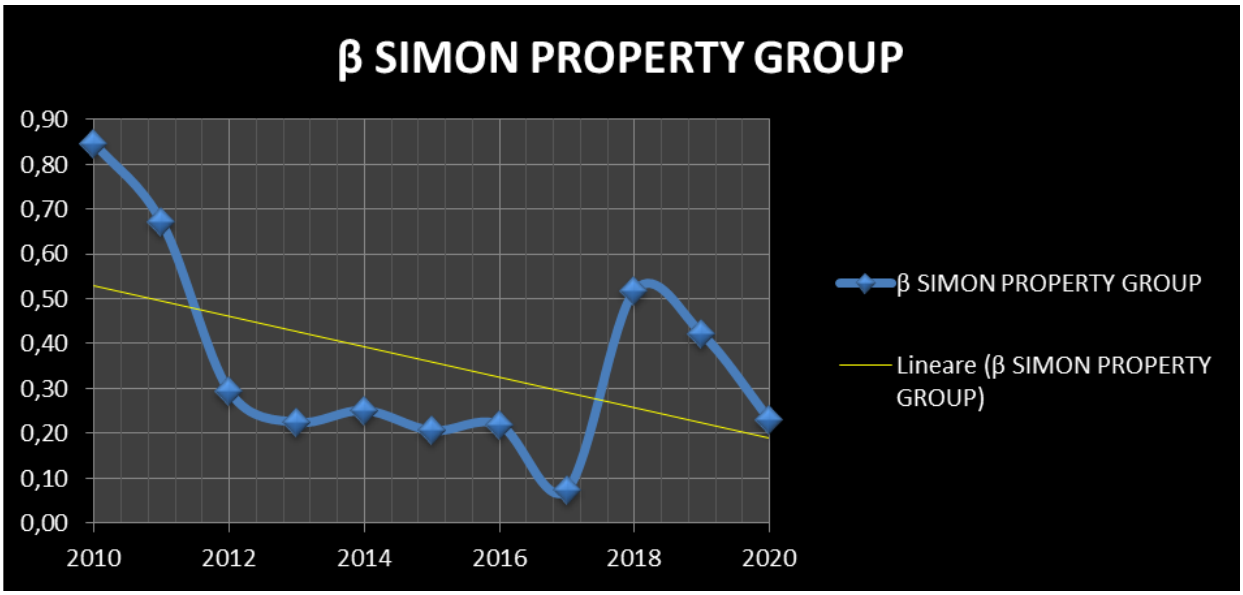
ATTACHMENTS

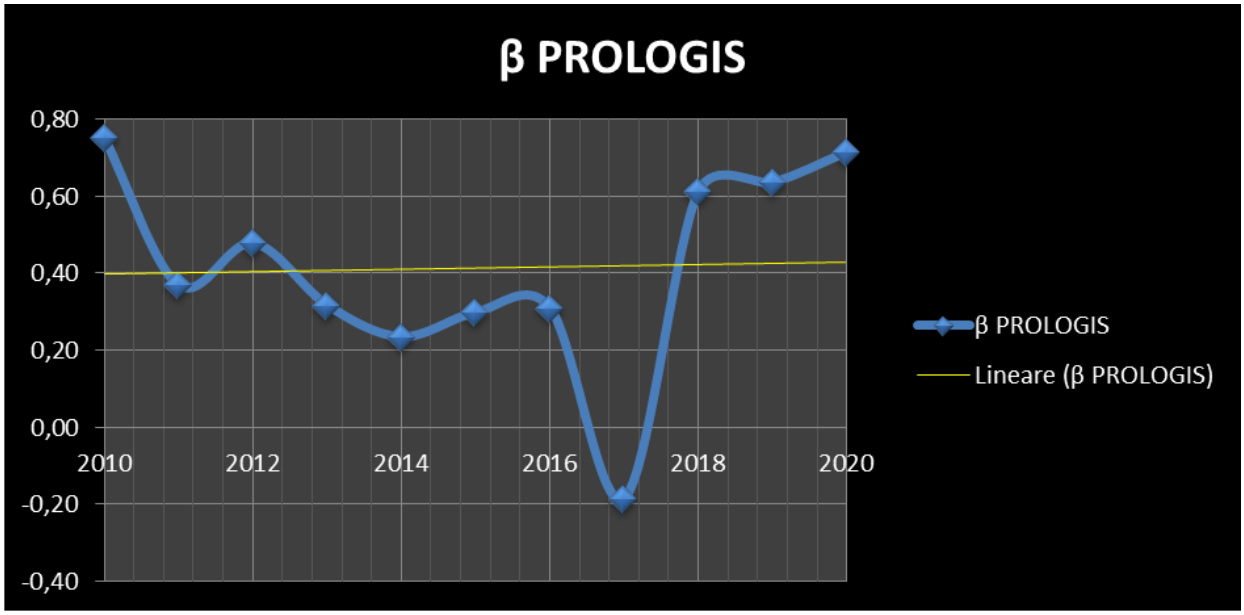
- **USA based REITs scorporated beta's trends**

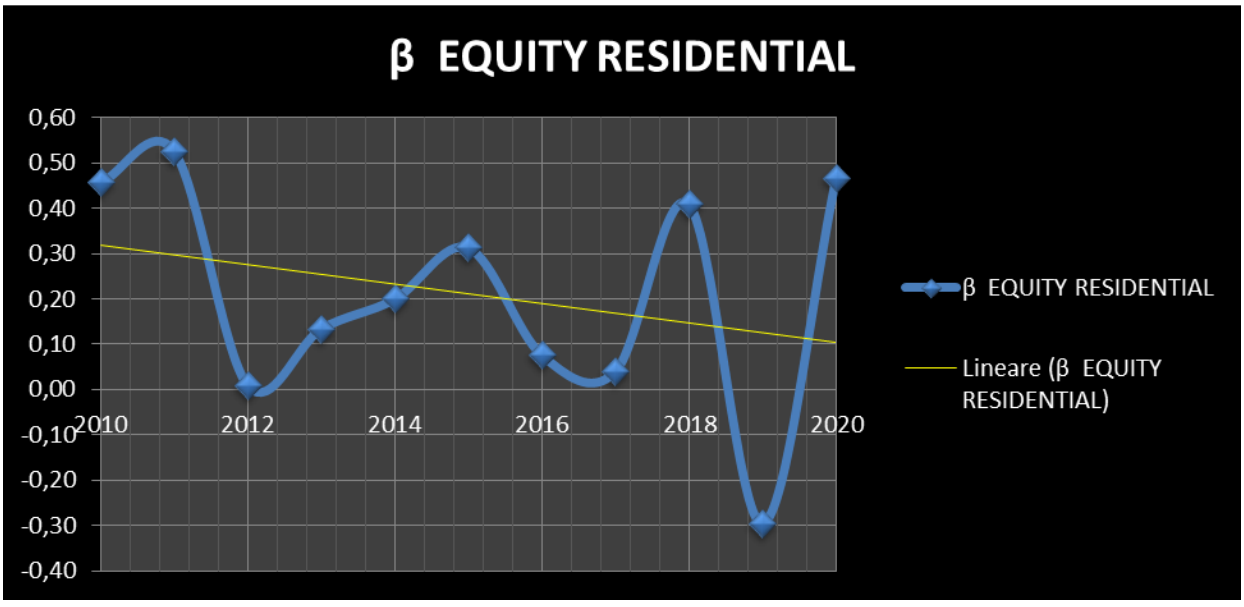


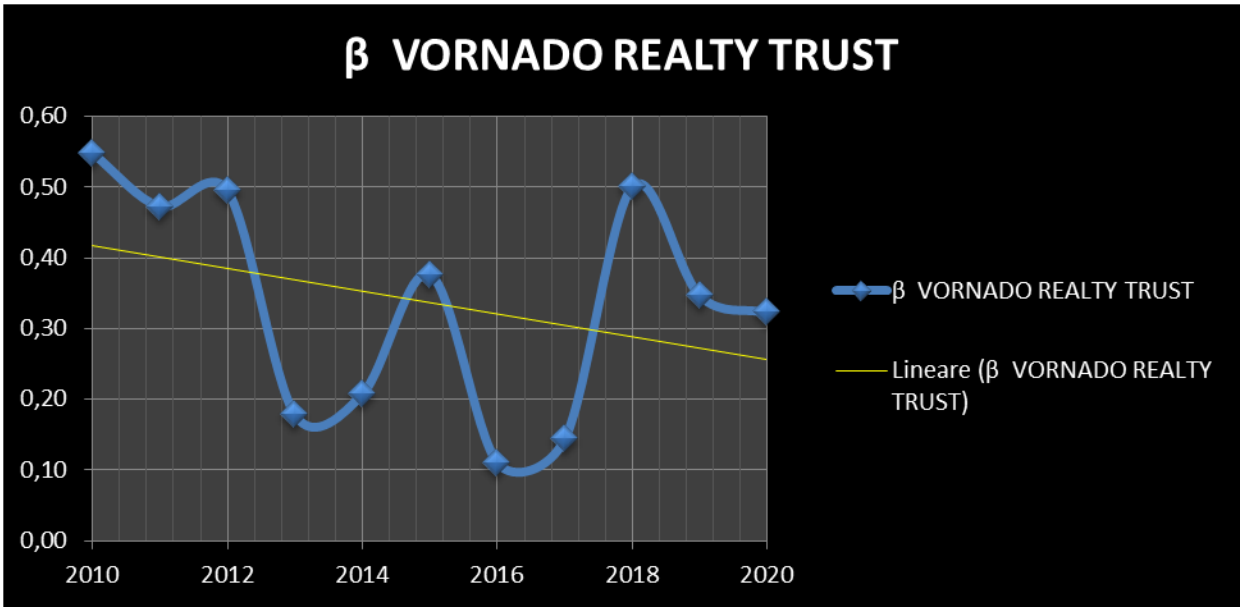


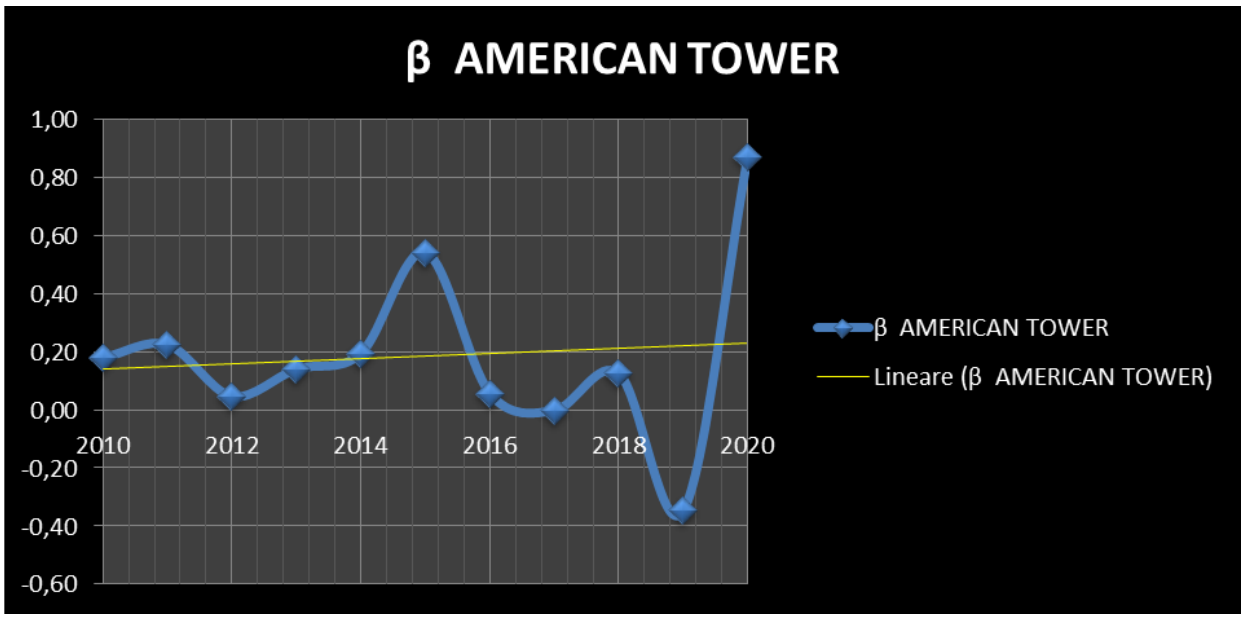



β SIMON PROPERTY GROUP
0,90
0,80
0,70
0,60
0,50
0,40
0,30
0,20
0,10
0,00
2010
2012
2014
2016
2018
2020
β SIMON PROPERTY GROUP
Lineare (β SIMON PROPERTY GROUP)

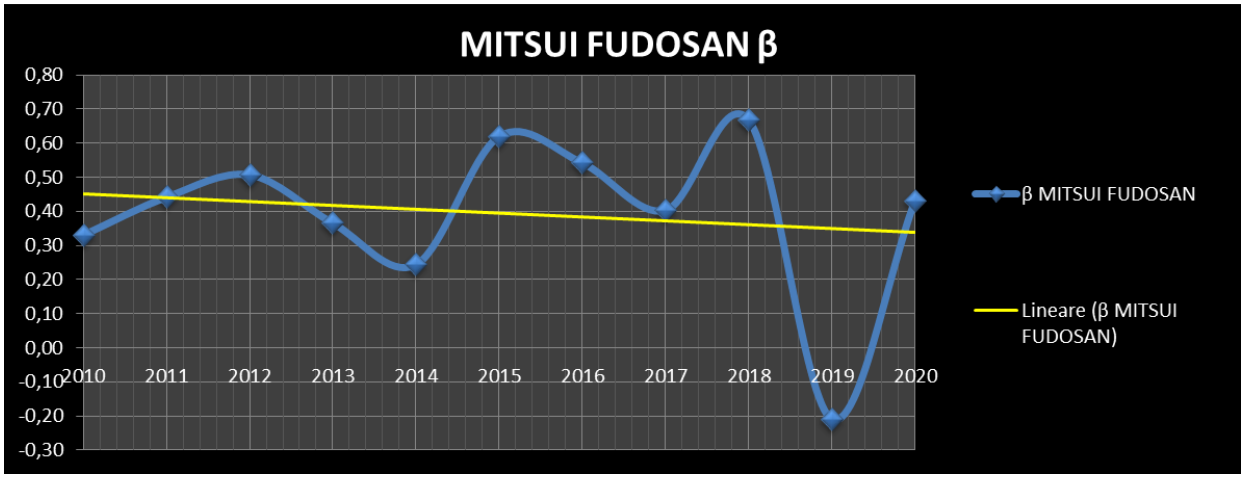

β PROLOGIS
0,80
0,60
0,40
0,20
0,00
-0,20
-0,40
2010
2012
2014
2016
2018
2020
β PROLOGIS
Lineare (β PROLOGIS)

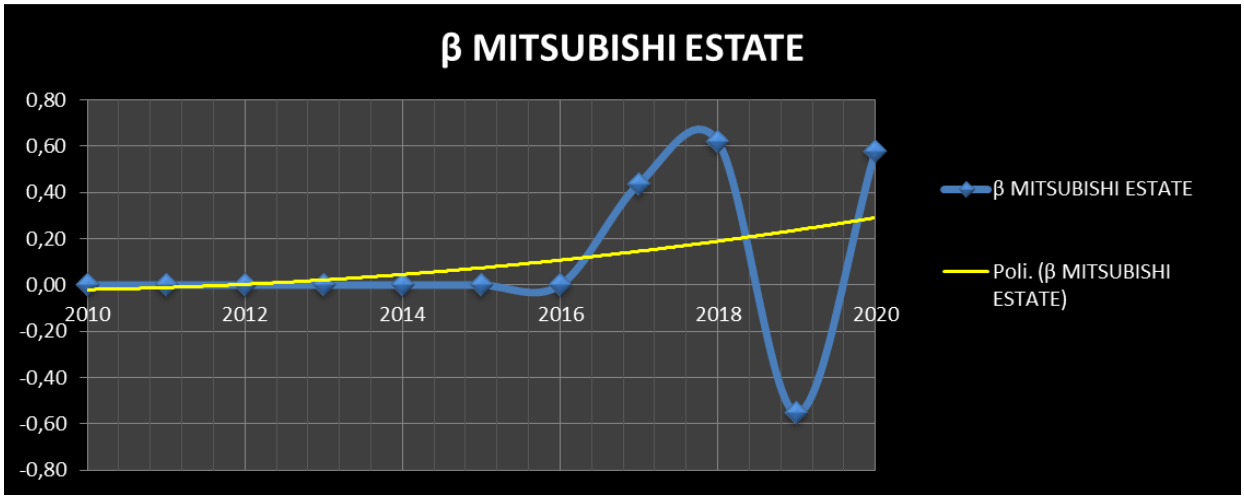

β EQUITY RESIDENTIAL
0,60
0,50
0,40
0,30
0,20
0,10
0,00
-0,10
-0,20
-0,30
-0,40
2010
2012
2014
2016
2018
2020
β EQUITY RESIDENTIAL
Lineare (β EQUITY RESIDENTIAL)

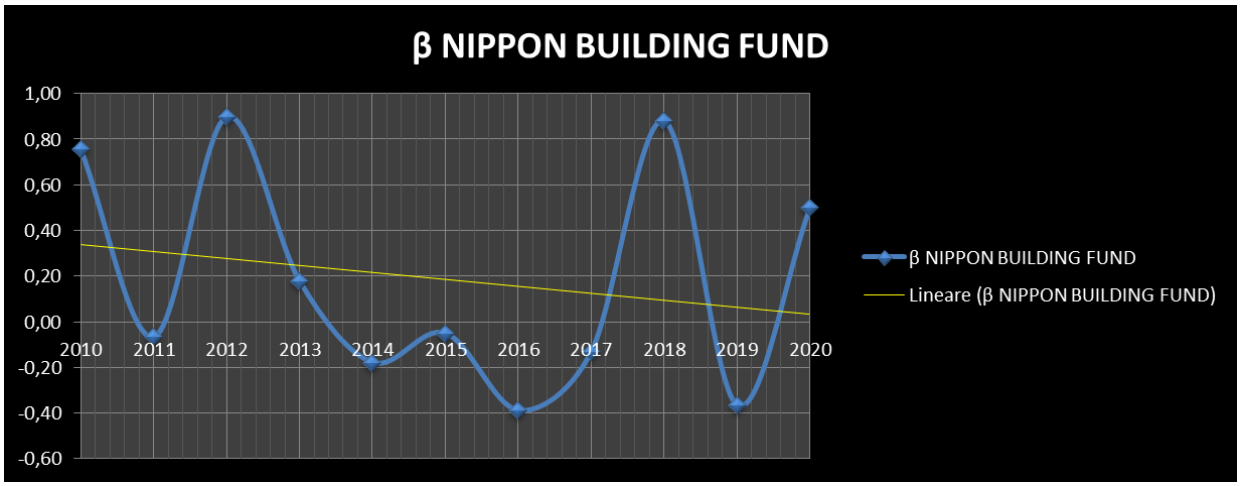

β VORNADO REALTY TRUST
0,60
0,50
0,40
0,30
0,20
0,10
0,00
2010
2012
2014
2016
2018
2020
β VORNADO REALTY TRUST
Lineare (β VORNADO REALTY TRUST)

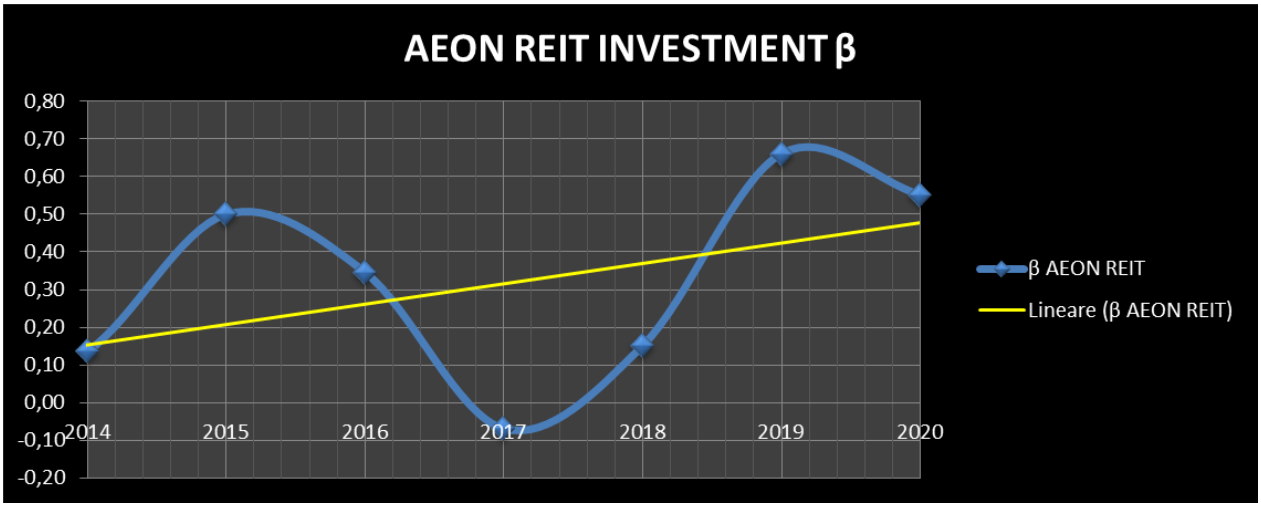

β AMERICAN TOWER
1,00
0,80
0,60
0,40
0,20
0,00
-0,20
-0,40
-0,60
2010
2012
2014
2016
2018
2020
β AMERICAN TOWER
Lineare (β AMERICAN TOWER)

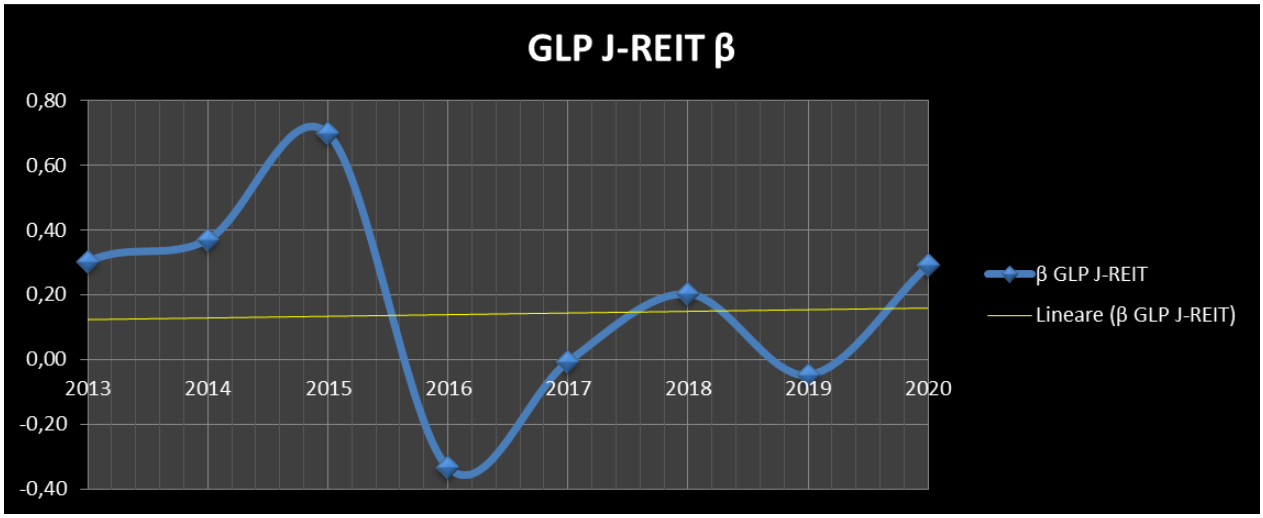
- **Japanese based REITs scorporated beta's trends**

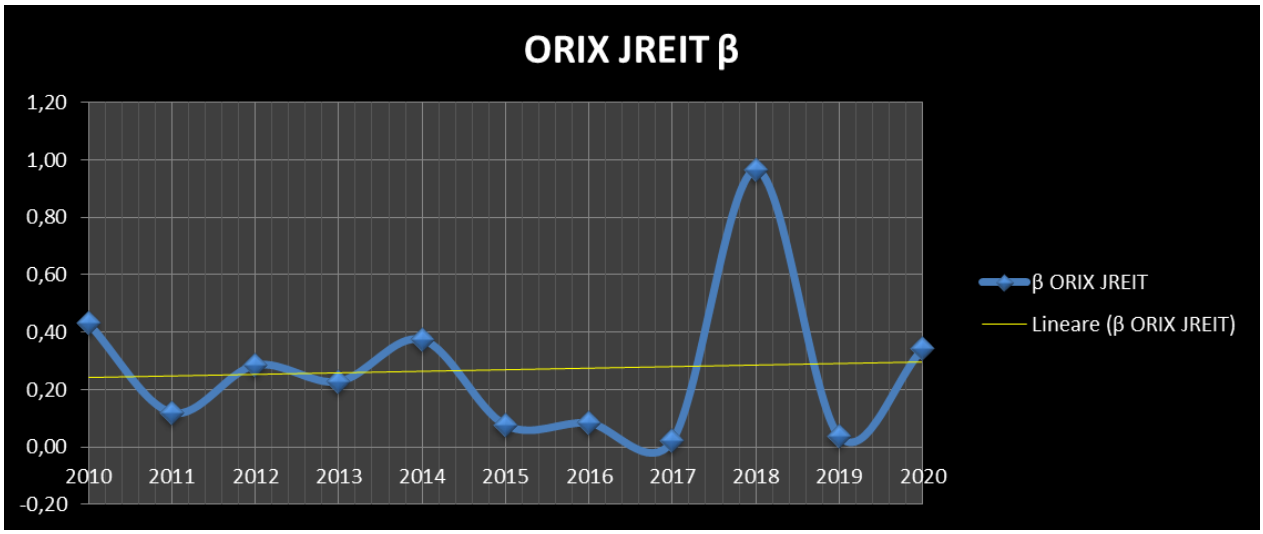


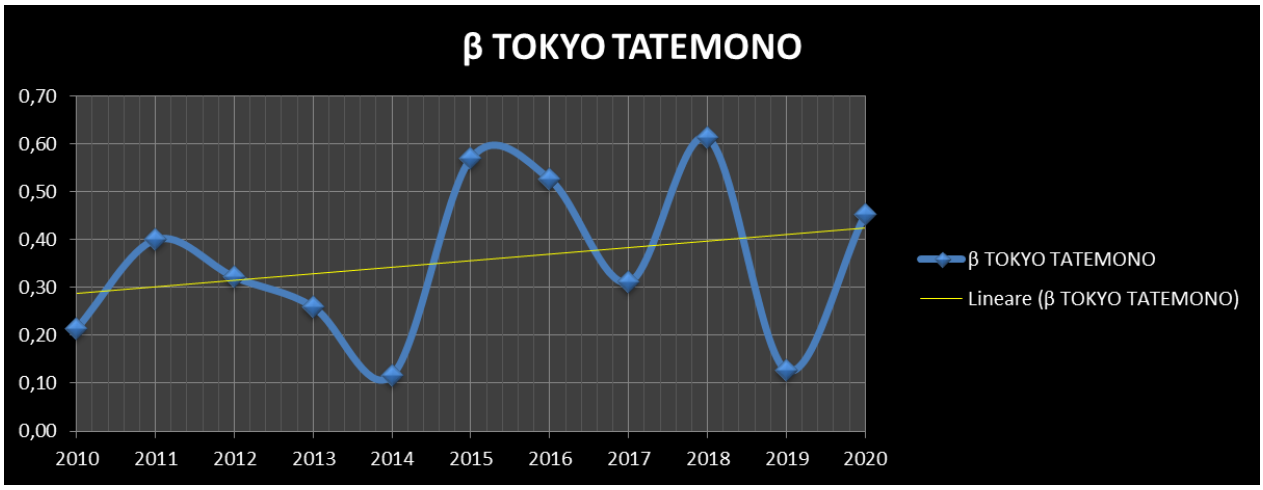


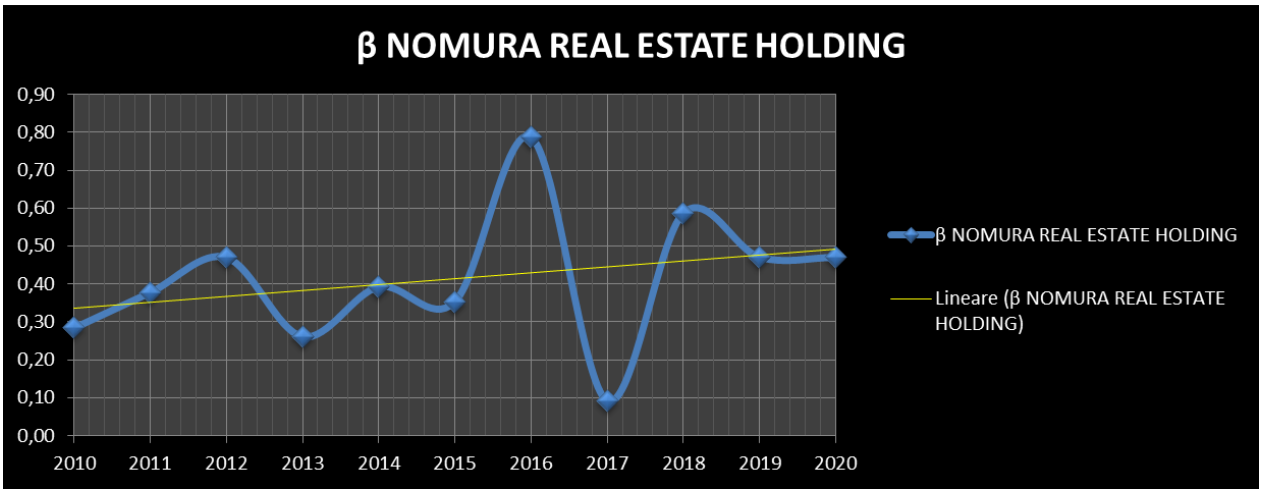


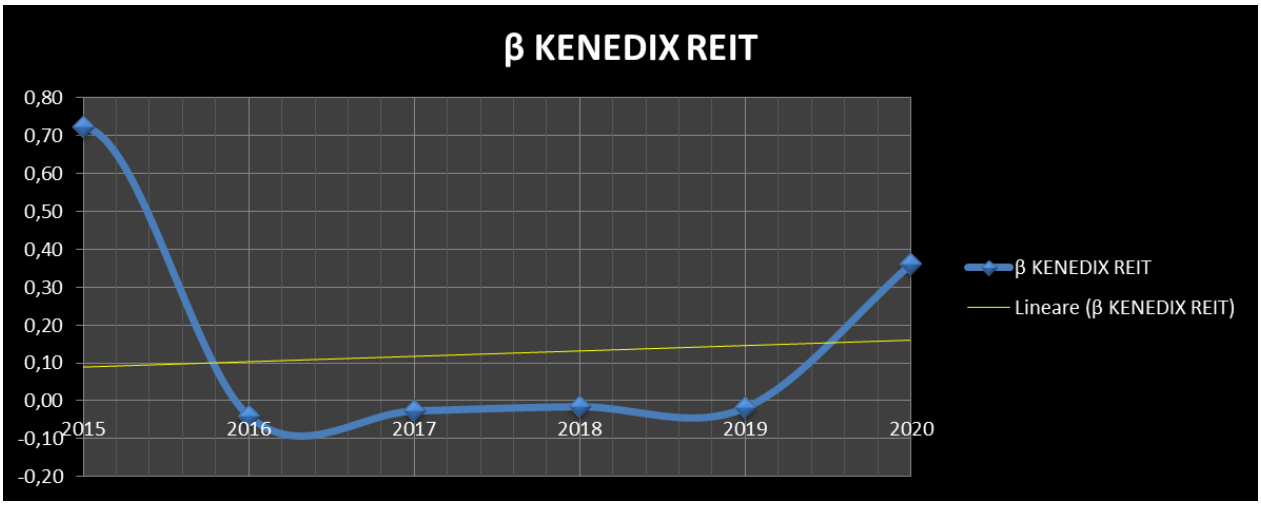

AEON REIT INVESTMENT β
0,80
0,70
0,60
0,50
0,40
0,30
0,20
0,10
0,00
-0,10
-0,20
2014
2015
2016
2017
2018
2019
2020
β AEON REIT
Lineare (β AEON REIT)

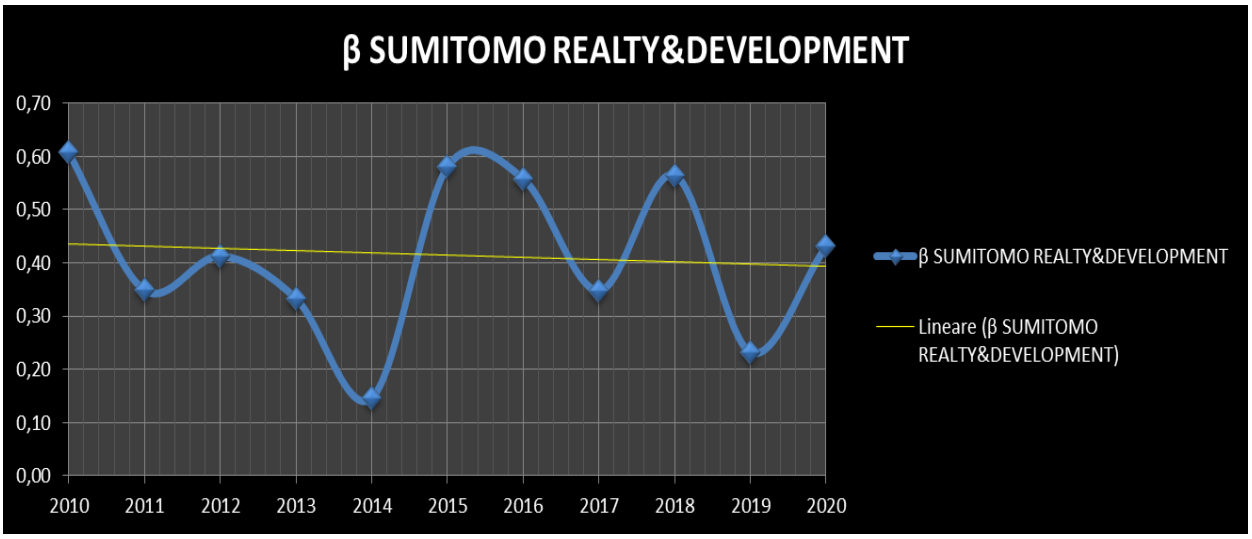

GLP J-REIT β
0,80
0,60
0,40
0,20
0,00
-0,20
-0,40
2013
2014
2015
2016
2017
2018
2019
2020
β GLP J-REIT
Lineare (β GLP J-REIT)

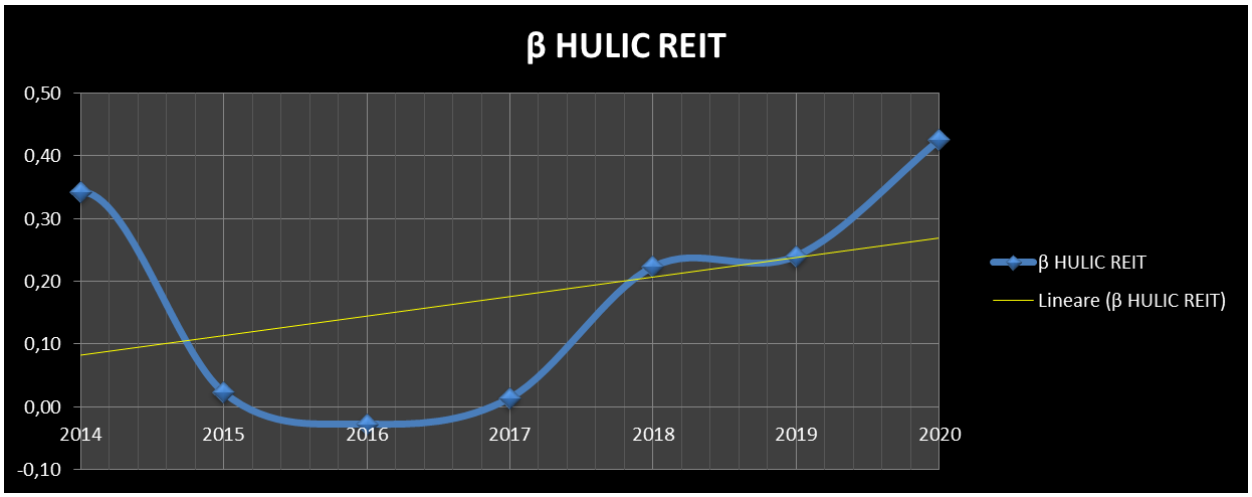

ORIX JREIT β
1,20
1,00
0,80
0,60
0,40
0,20
0,00
-0,20
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
β ORIX JREIT
Lineare (β ORIX JREIT)

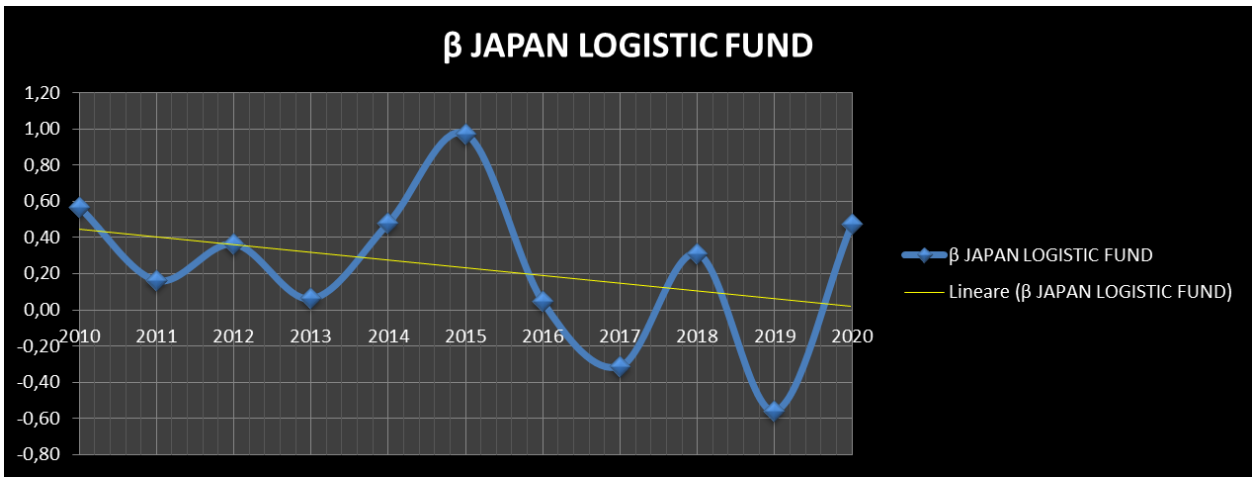

β TOKYO TATEMONO
0,70
0,60
0,50
0,40
0,30
0,20
0,10
0,00
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
β TOKYO TATEMONO
Lineare (β TOKYO TATEMONO)


β NOMURA REAL ESTATE HOLDING
0,90
0,80
0,70
0,60
0,50
0,40
0,30
0,20
0,10
0,00
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
β NOMURA REAL ESTATE HOLDING
Lineare (β NOMURA REAL ESTATE HOLDING)

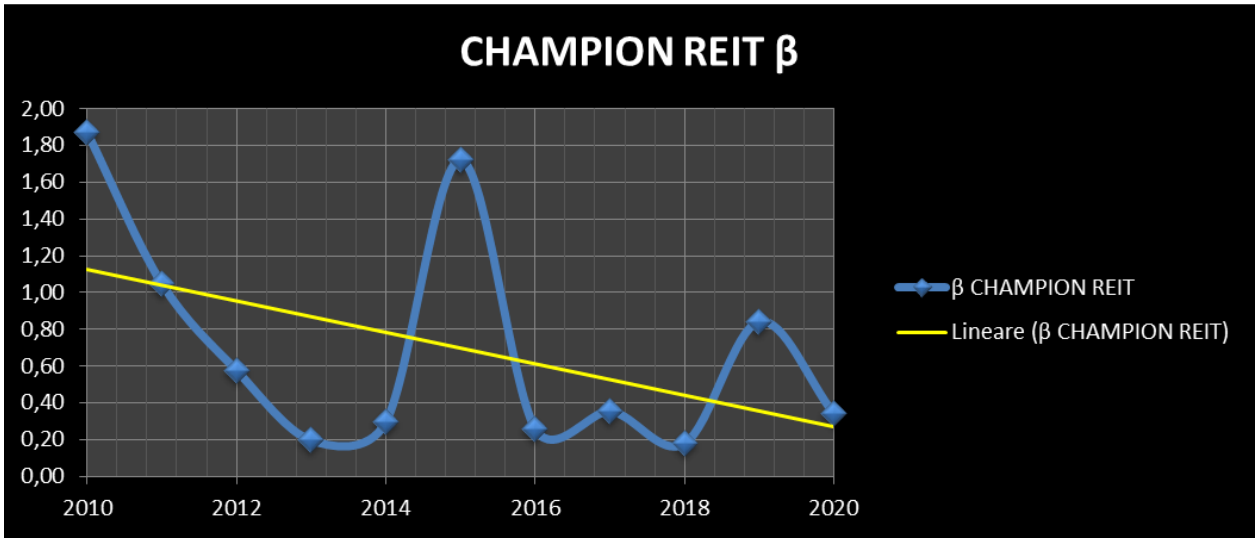

β KENEDIX REIT
0,80
0,70
0,60
0,50
0,40
0,30
0,20
0,10
0,00
-0,10
-0,20
2015
2016
2017
2018
2019
2020
β KENEDIX REIT
Lineare (β KENEDIX REIT)

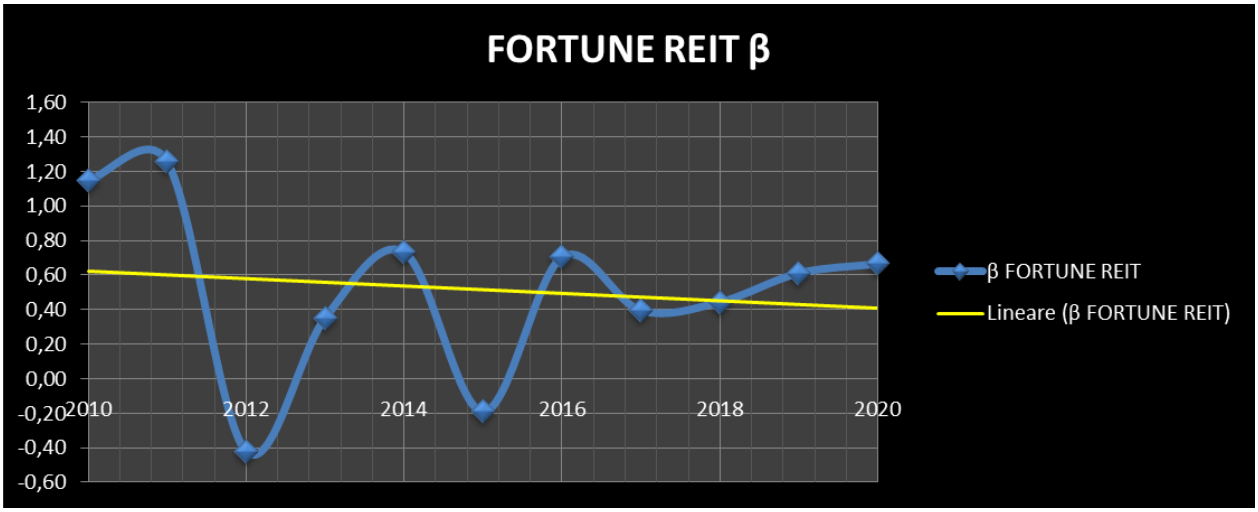

β SUMITOMO REALTY&DEVELOPMENT
0,70
0,60
0,50
0,40
0,30
0,20
0,10
0,00
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
β SUMITOMO REALTY&DEVELOPMENT
Lineare (β SUMITOMO REALTY&DEVELOPMENT)

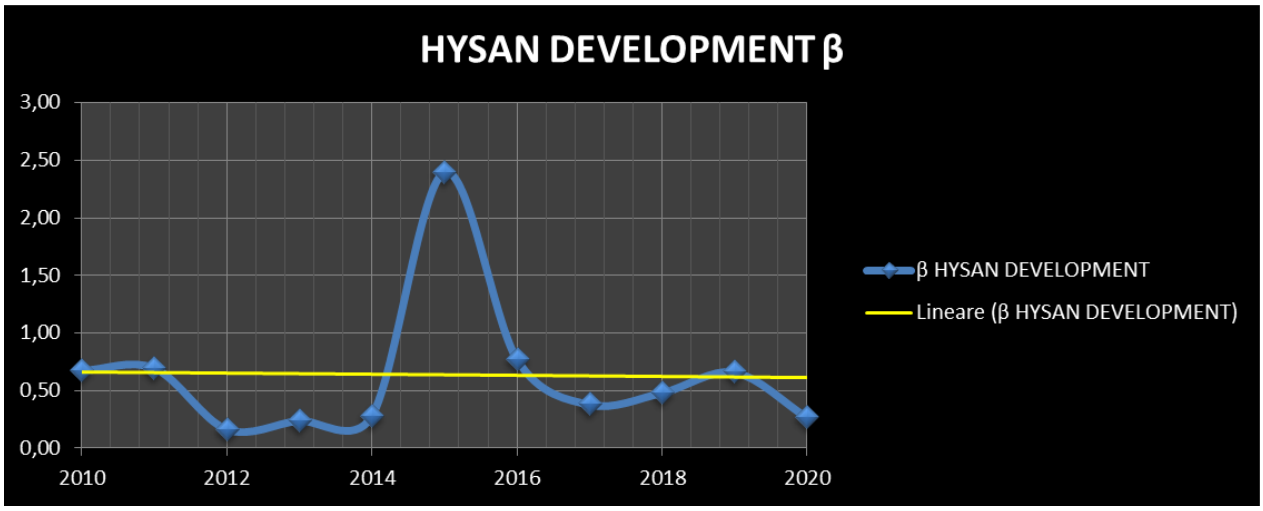

β HULIC REIT
0,50
0,40
0,30
0,20
0,10
0,00
-0,10
2014
2015
2016
2017
2018
2019
2020
β HULIC REIT
Lineare (β HULIC REIT)

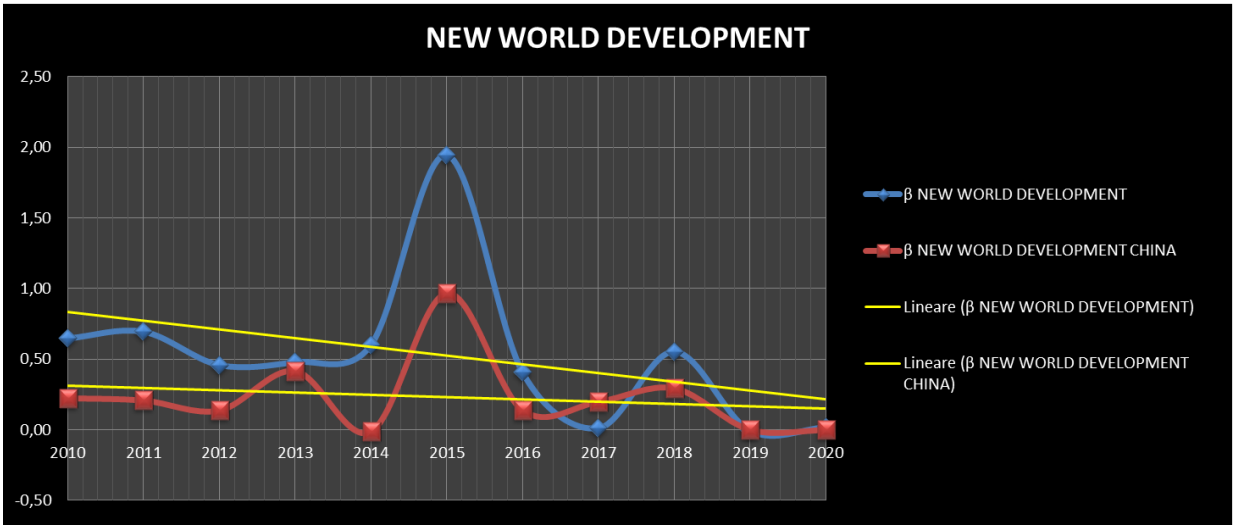

β JAPAN LOGISTIC FUND
1,20
1,00
0,80
0,60
0,40
0,20
0,00
-0,20
-0,40
-0,60
-0,80
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
β JAPAN LOGISTIC FUND
Lineare (β JAPAN LOGISTIC FUND)

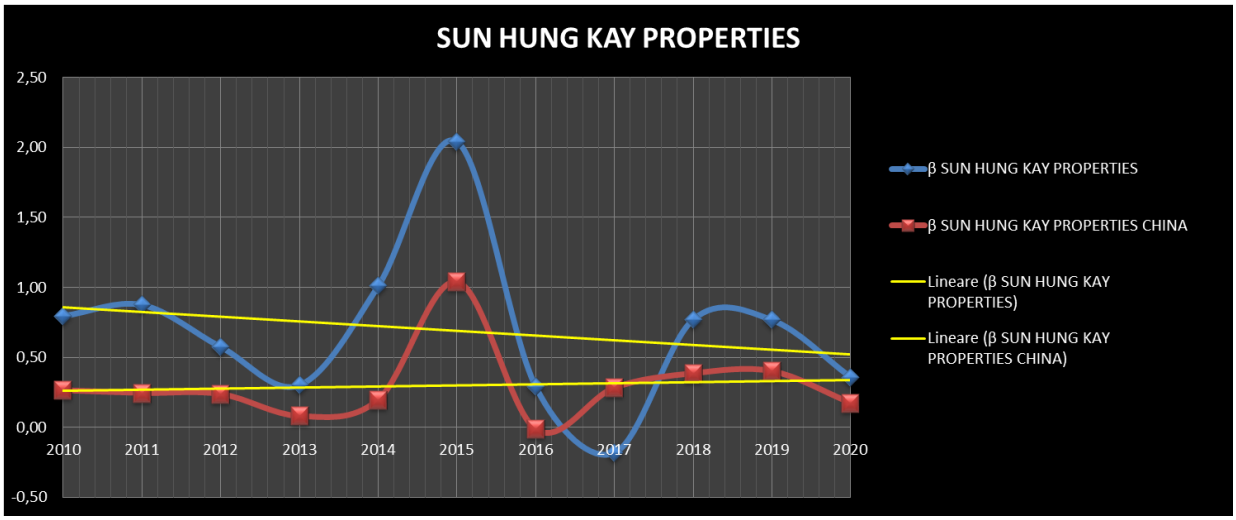
- **Hong Kong based REITs scorporated beta's trends**

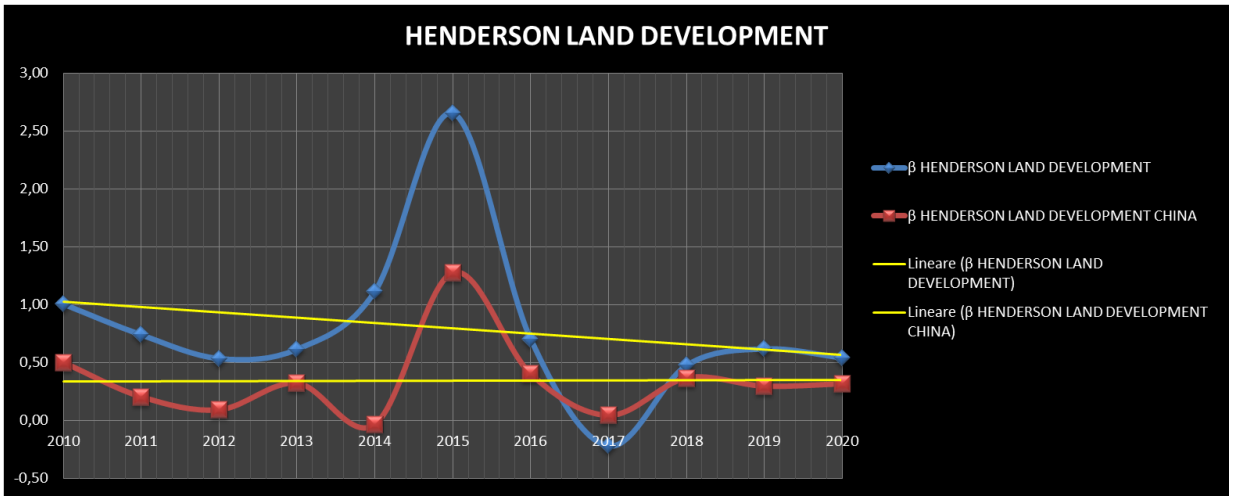


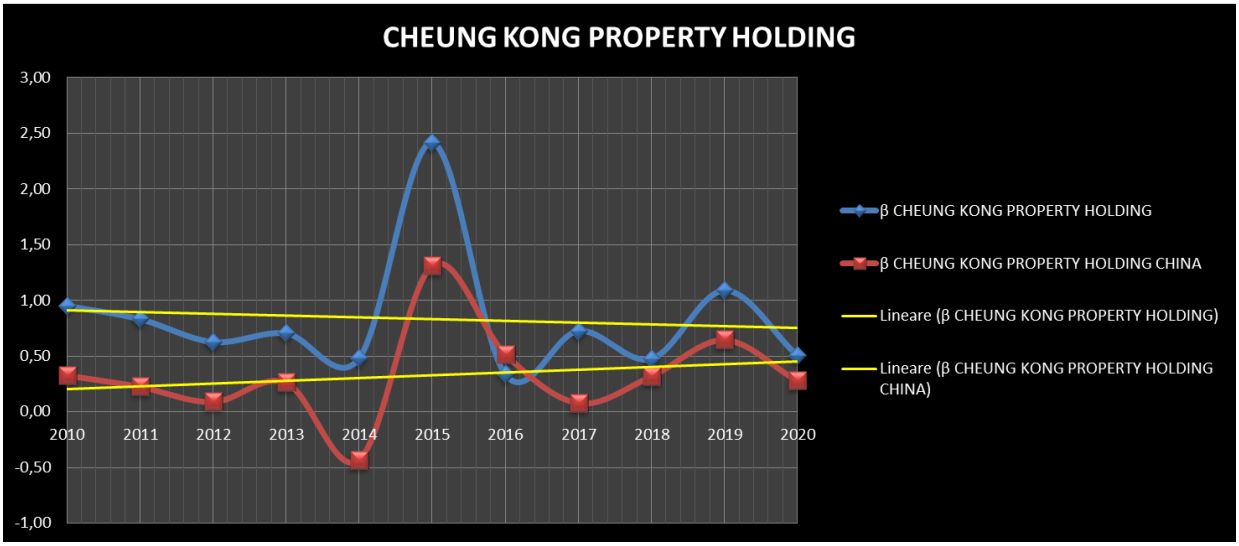


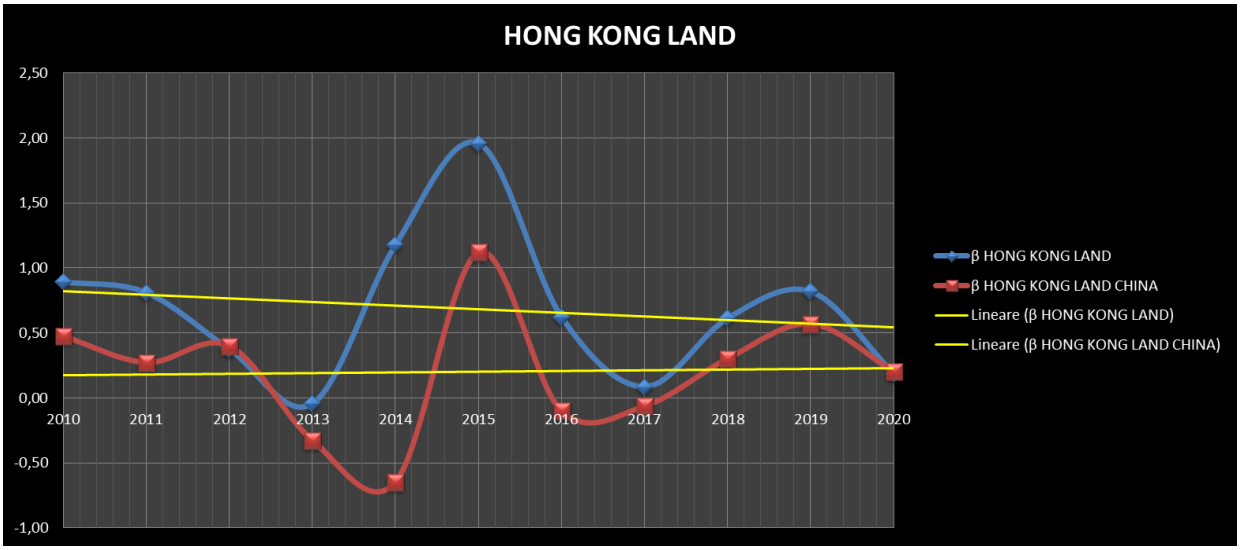


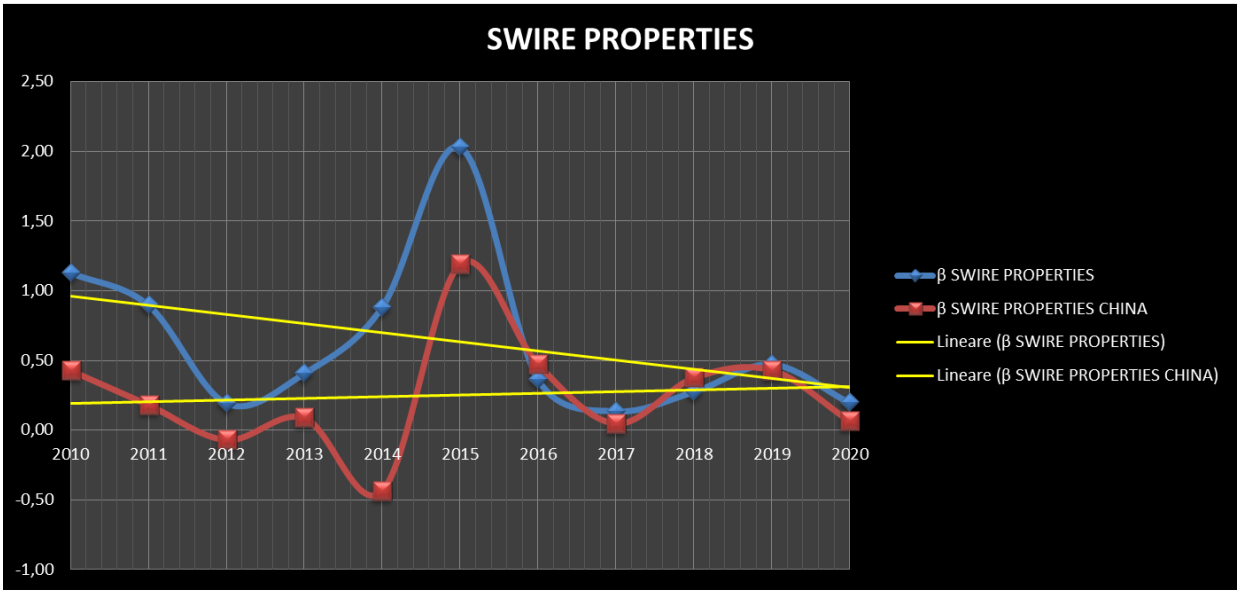

NEW WORLD DEVELOPMENT
2,50
2,00
1,50
1,00
0,50
0,00
-0,50
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
β NEW WORLD DEVELOPMENT
β NEW WORLD DEVELOPMENT CHINA
Lineare (β NEW WORLD DEVELOPMENT)
Lineare (β NEW WORLD DEVELOPMENT CHINA)

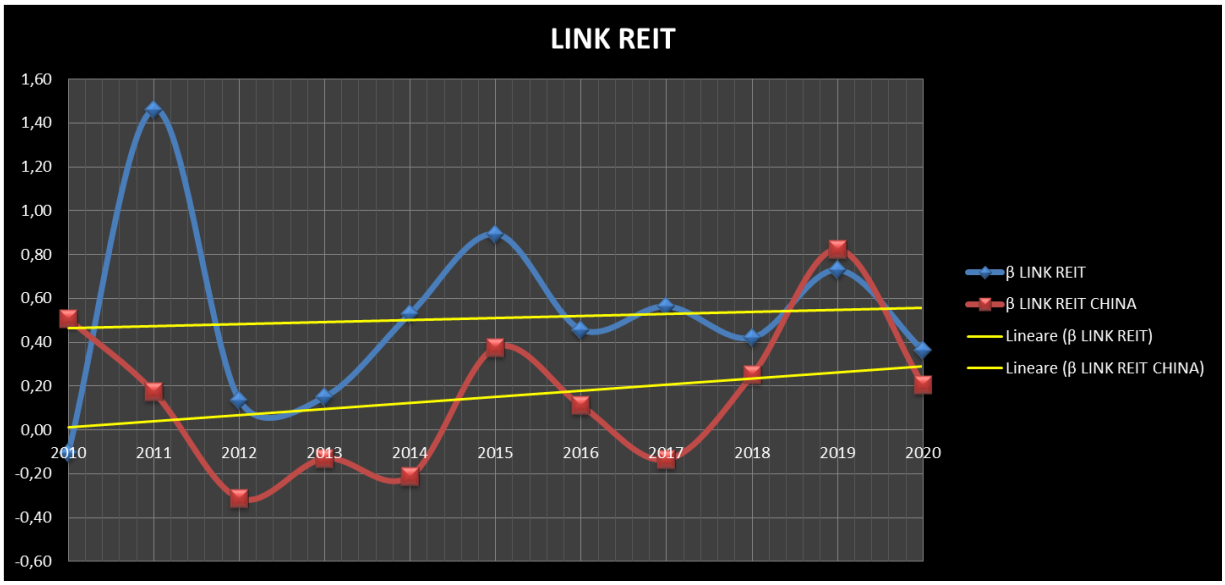

SUN HUNG KAY PROPERTIES
2,50
2,00
1,50
1,00
0,50
0,00
-0,50
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
β SUN HUNG KAY PROPERTIES
β SUN HUNG KAY PROPERTIES CHINA
Lineare (β SUN HUNG KAY PROPERTIES)
Lineare (β SUN HUNG KAY PROPERTIES CHINA)

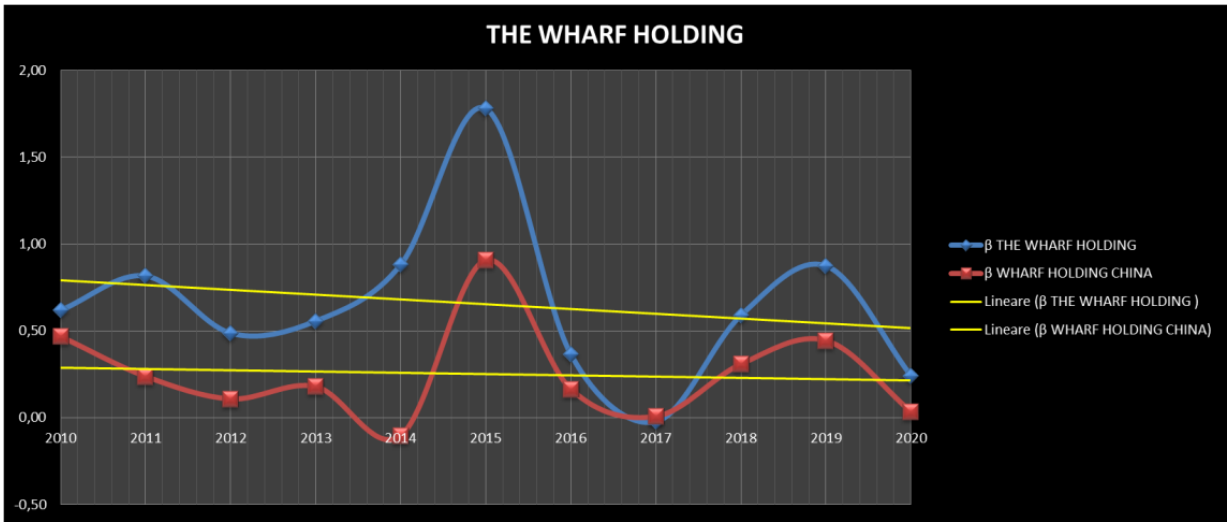

HENDERSON LAND DEVELOPMENT
3,00
2,50
2,00
1,50
1,00
0,50
0,00
-0,50
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
β HENDERSON LAND DEVELOPMENT
β HENDERSON LAND DEVELOPMENT CHINA
Lineare (β HENDERSON LAND DEVELOPMENT)
Lineare (β HENDERSON LAND DEVELOPMENT CHINA)

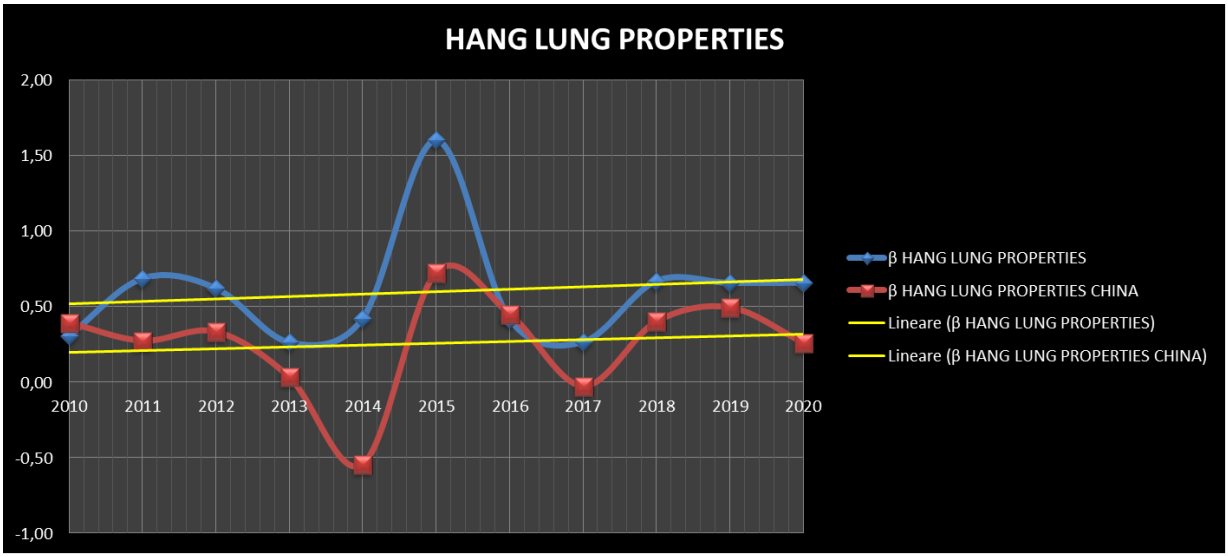

CHEUNG KONG PROPERTY HOLDING
3,00
2,50
2,00
1,50
1,00
0,50
0,00
-0,50
-1,00
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
β CHEUNG KONG PROPERTY HOLDING
β CHEUNG KONG PROPERTY HOLDING CHINA
Lineare (β CHEUNG KONG PROPERTY HOLDING)
Lineare (β CHEUNG KONG PROPERTY HOLDING CHINA)


HONG KONG LAND
2,50
2,00
1,50
1,00
0,50
0,00
-0,50
-1,00
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
β HONG KONG LAND
β HONG KONG LAND CHINA
Lineare (β HONG KONG LAND)
Lineare (β HONG KONG LAND CHINA)

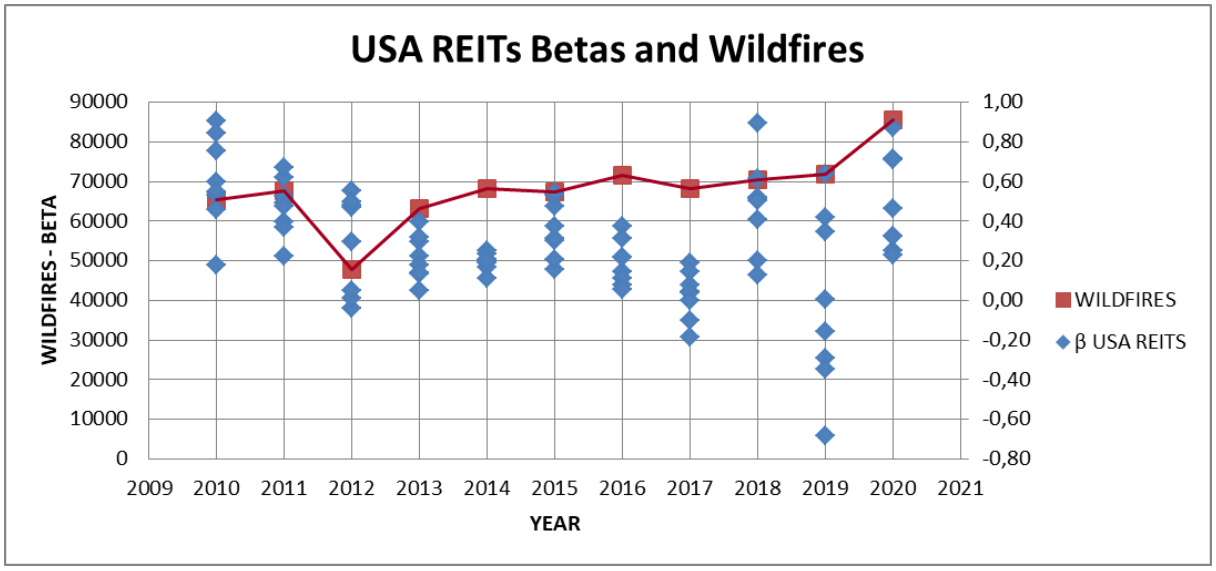

SWIRE PROPERTIES
2,50
2,00
1,50
1,00
0,50
0,00
-0,50
-1,00
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
β SWIRE PROPERTIES
β SWIRE PROPERTIES CHINA
Lineare (β SWIRE PROPERTIES)
Lineare (β SWIRE PROPERTIES CHINA)

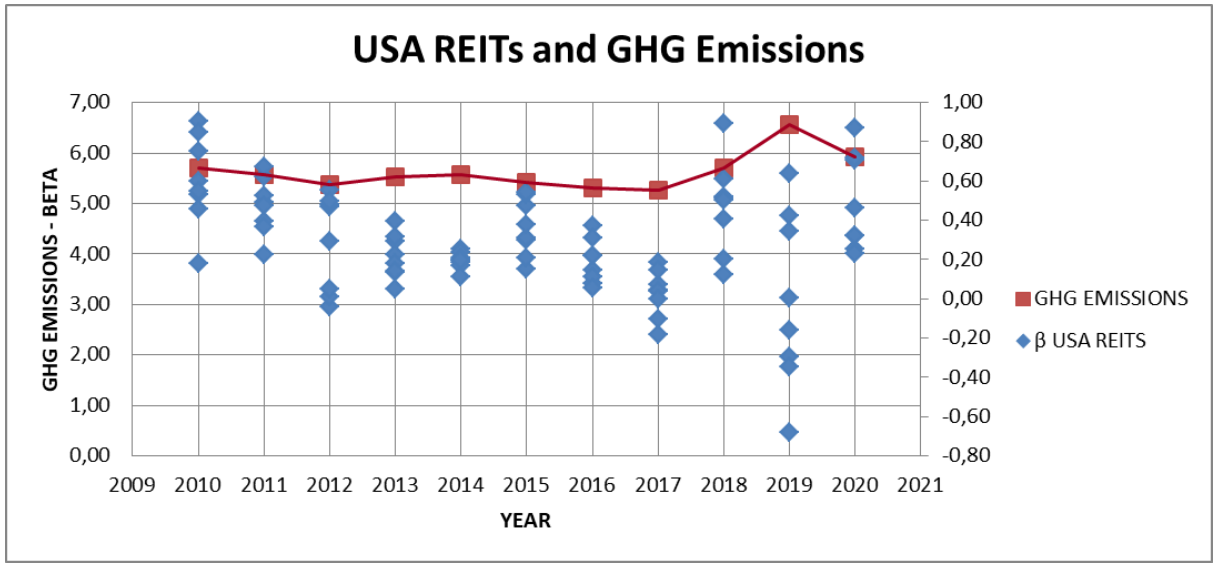

LINK REIT
1,60
1,40
1,20
1,00
0,80
0,60
0,40
0,20
0,00
-0,20
-0,40
-0,60
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
β LINK REIT
β LINK REIT CHINA
Lineare (β LINK REIT)
Lineare (β LINK REIT CHINA)

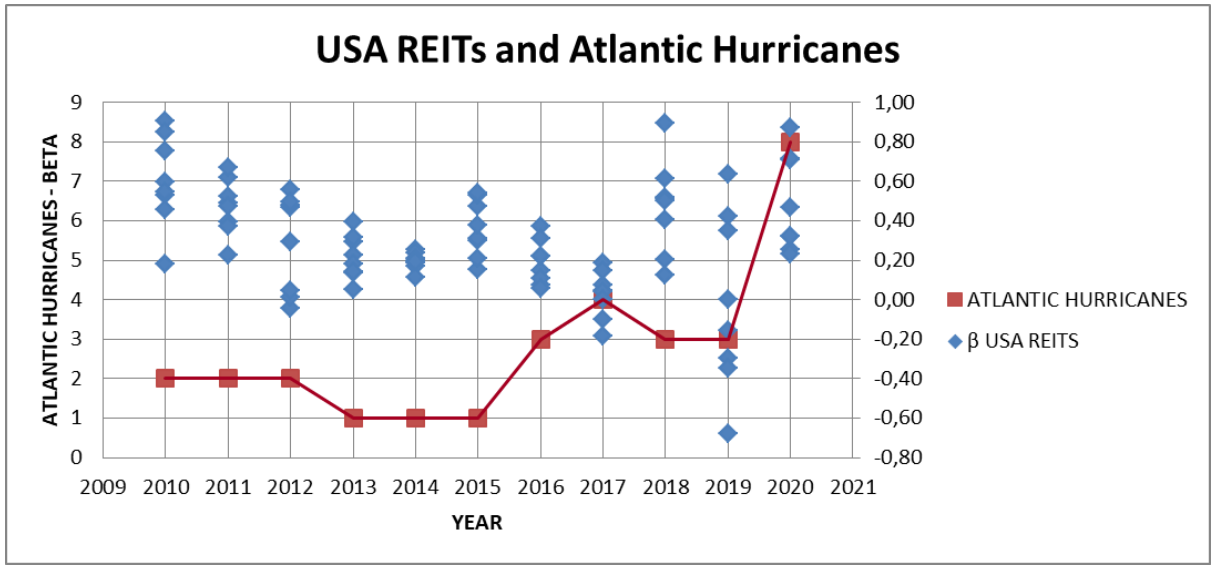

THE WHARF HOLDING
2,00
1,50
1,00
0,50
0,00
-0,50
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
β THE WHARF HOLDING
β WHARF HOLDING CHINA
Lineare (β THE WHARF HOLDING)
Lineare (β WHARF HOLDING CHINA)

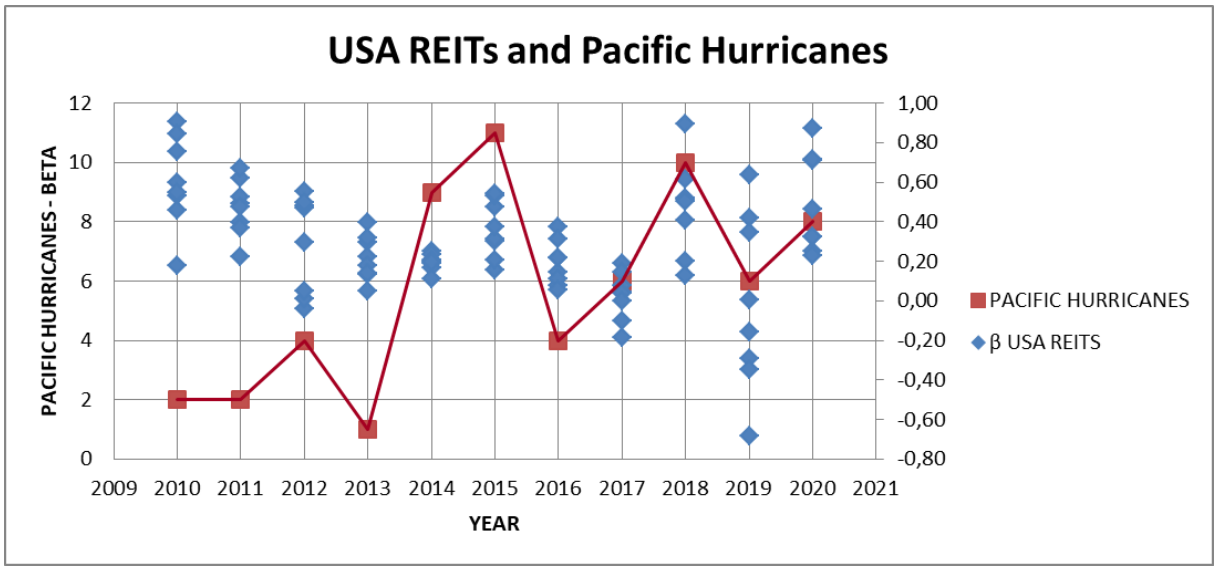

HANG LUNG PROPERTIES
2,00
1,50
1,00
0,50
0,00
-0,50
-1,00
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
β HANG LUNG PROPERTIES
β HANG LUNG PROPERTIES CHINA
Lineare (β HANG LUNG PROPERTIES)
Lineare (β HANG LUNG PROPERTIES CHINA)

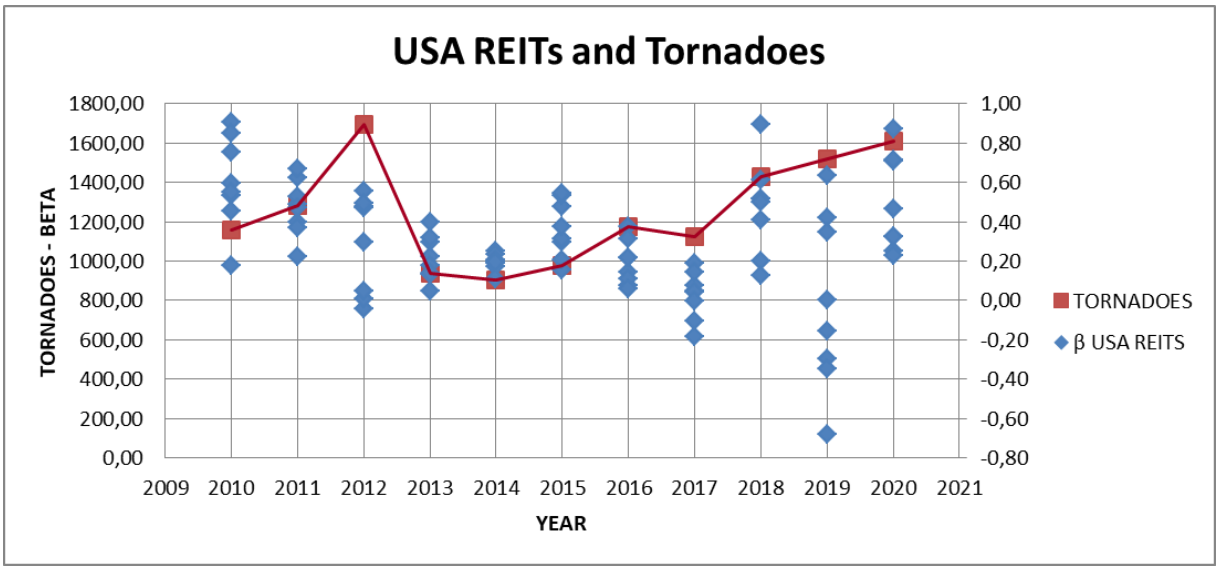
- **Scatterplots of panel analysis of USA based REITs and climate events.**



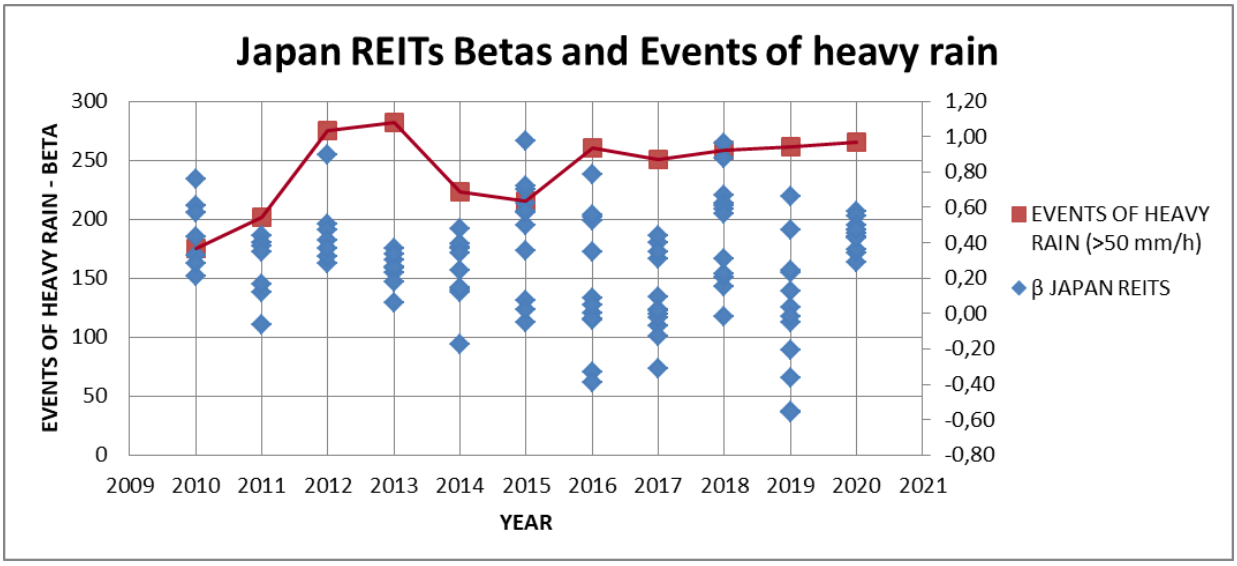


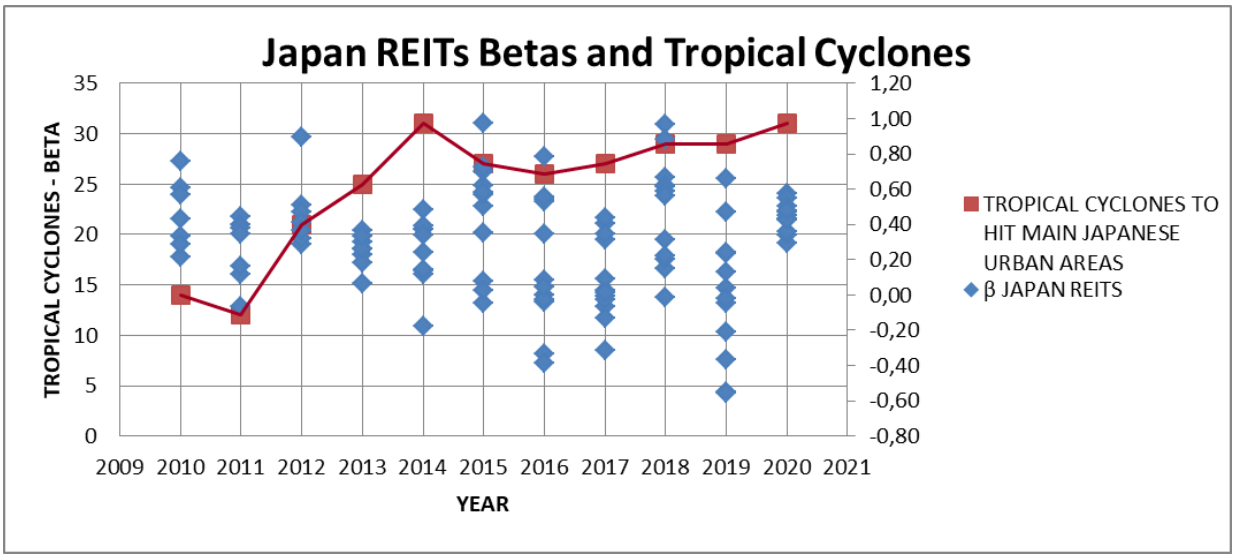


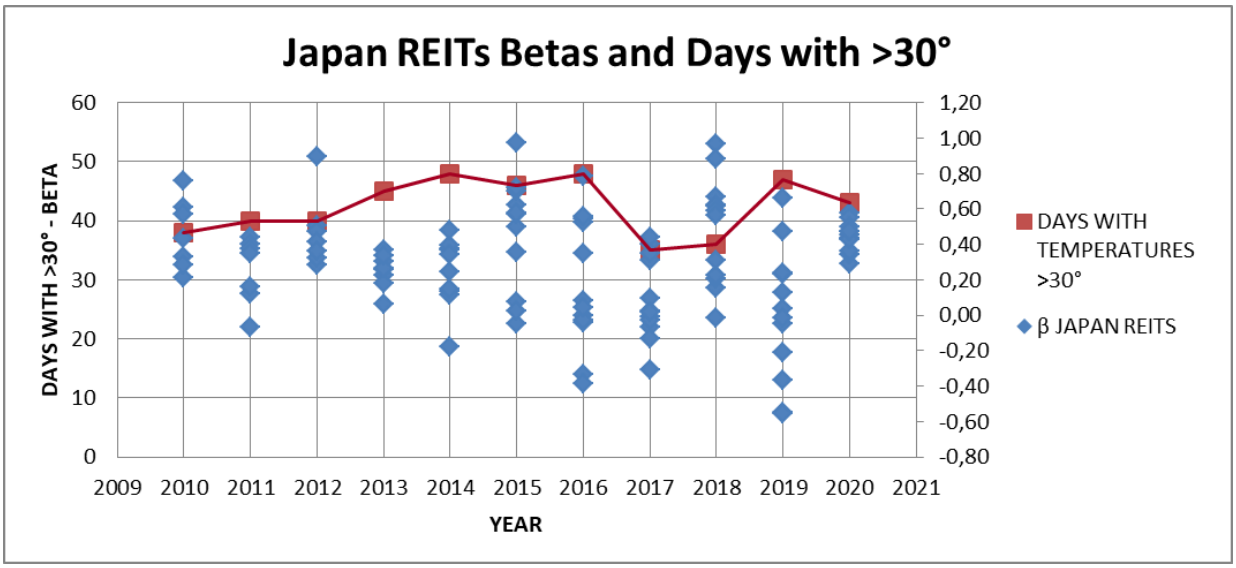

USA REITs and Pacific Hurricanes
PACIFIC HURRICANES - BETA
12
10
8
6
4
2
0
1,00
0,80
0,60
0,40
0,20
0,00
-0,20
-0,40
-0,60
-0,80
2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
YEAR
PACIFIC HURRICANES
β USA REITS

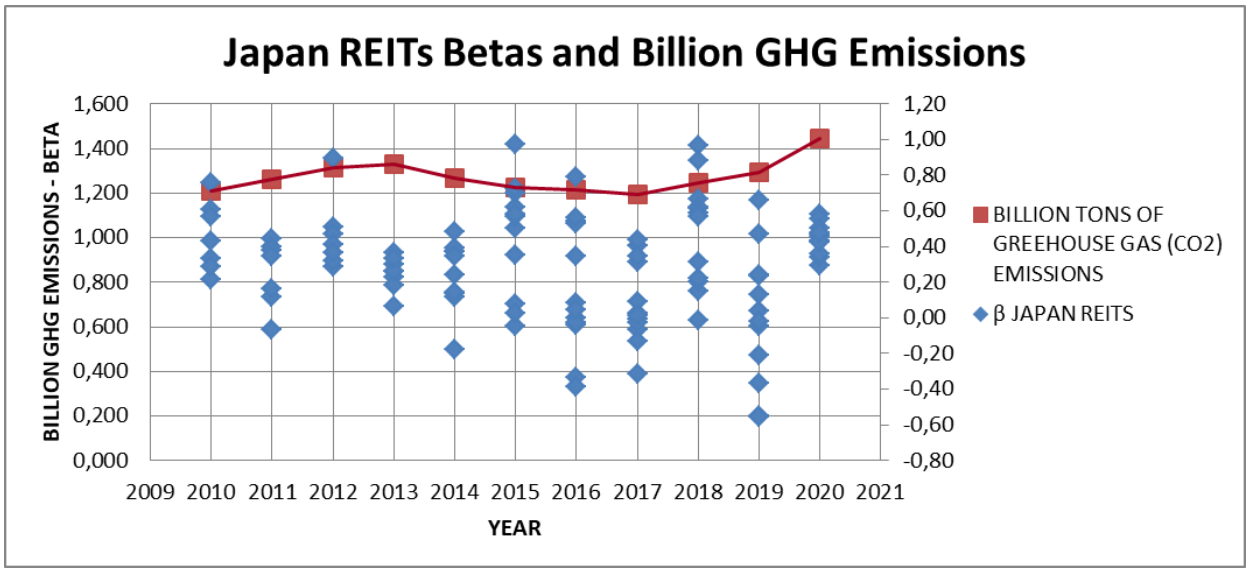

USA REITs and Tornadoes
TORNADOES - BETA
1800,00
1600,00
1400,00
1200,00
1000,00
800,00
600,00
400,00
200,00
0,00
1,00
0,80
0,60
0,40
0,20
0,00
-0,20
-0,40
-0,60
-0,80
2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
YEAR
TORNADOES
β USA REITS

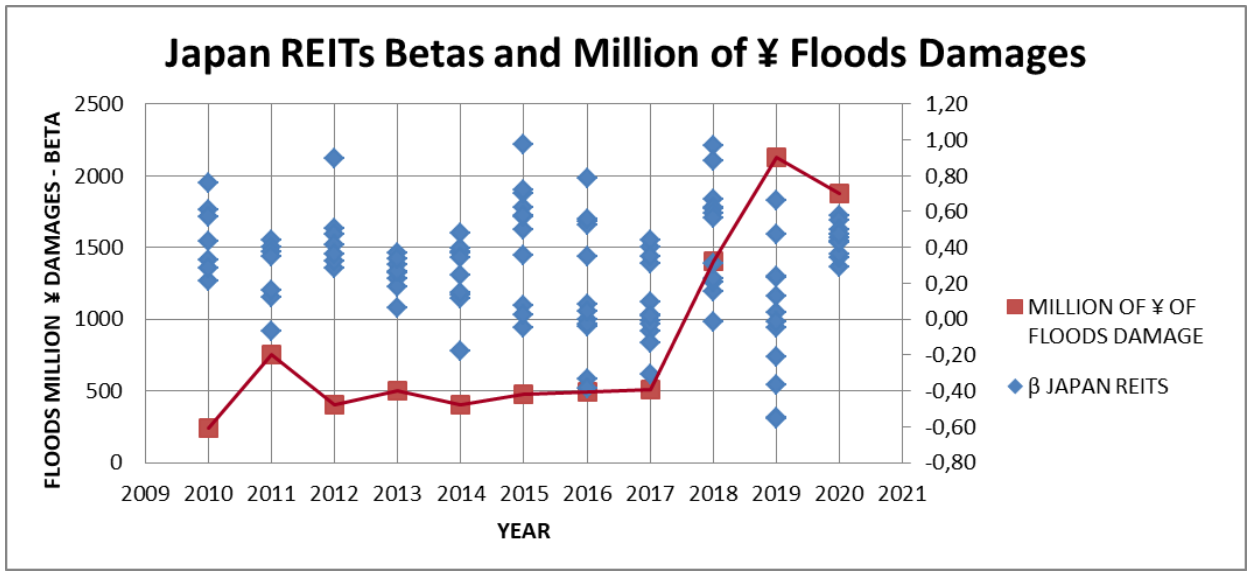
- **Scatterplots of panel analysis of Japan based REITs and climate events.**



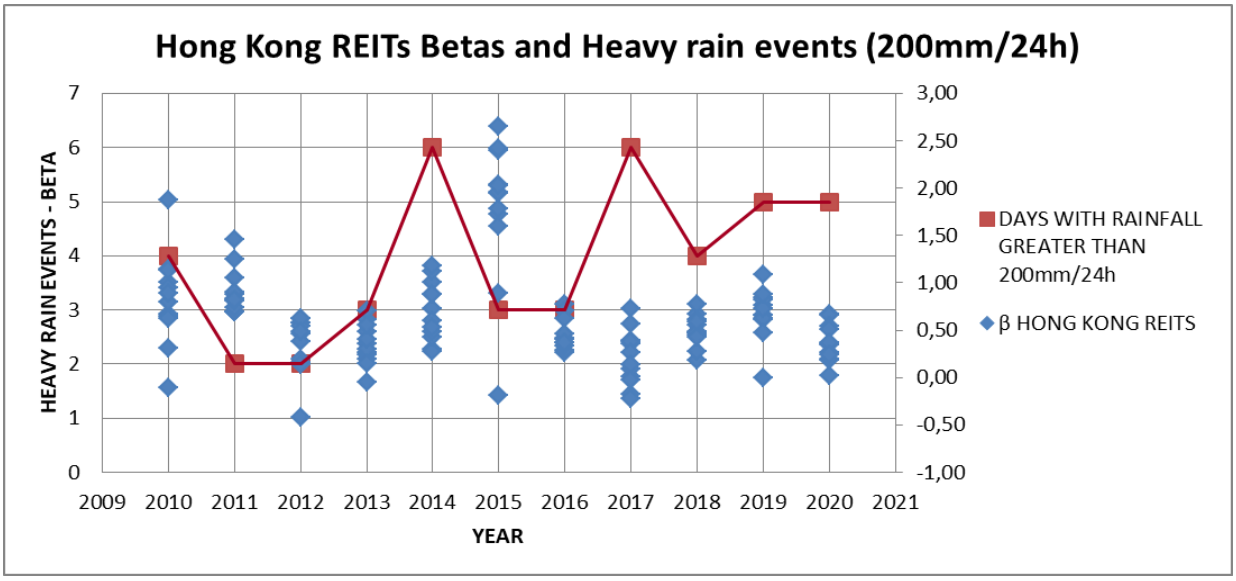


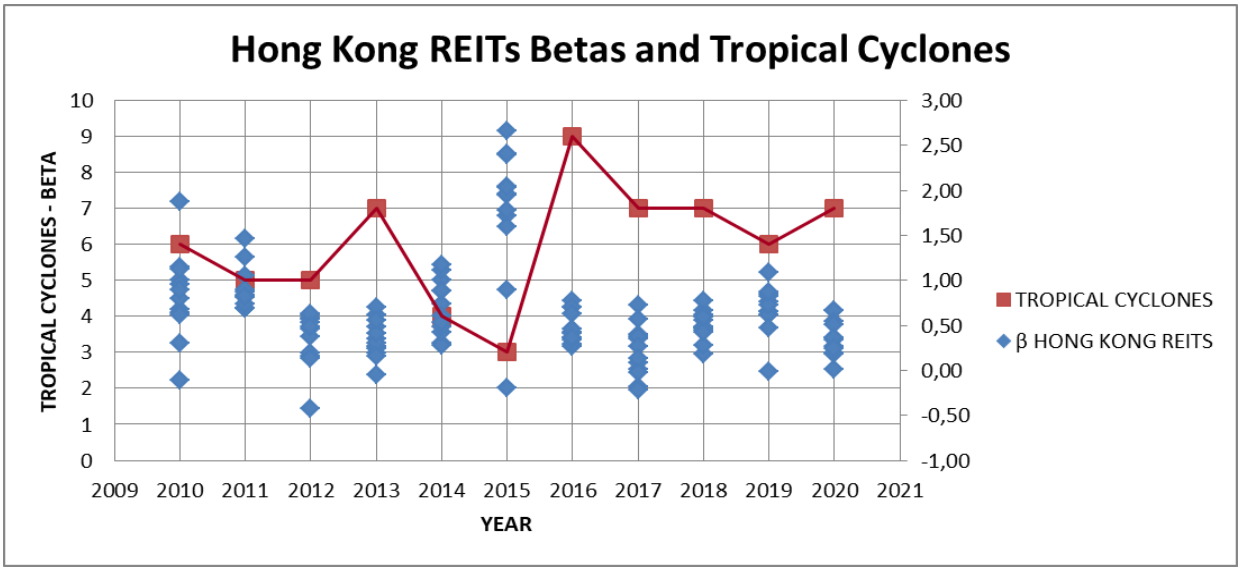


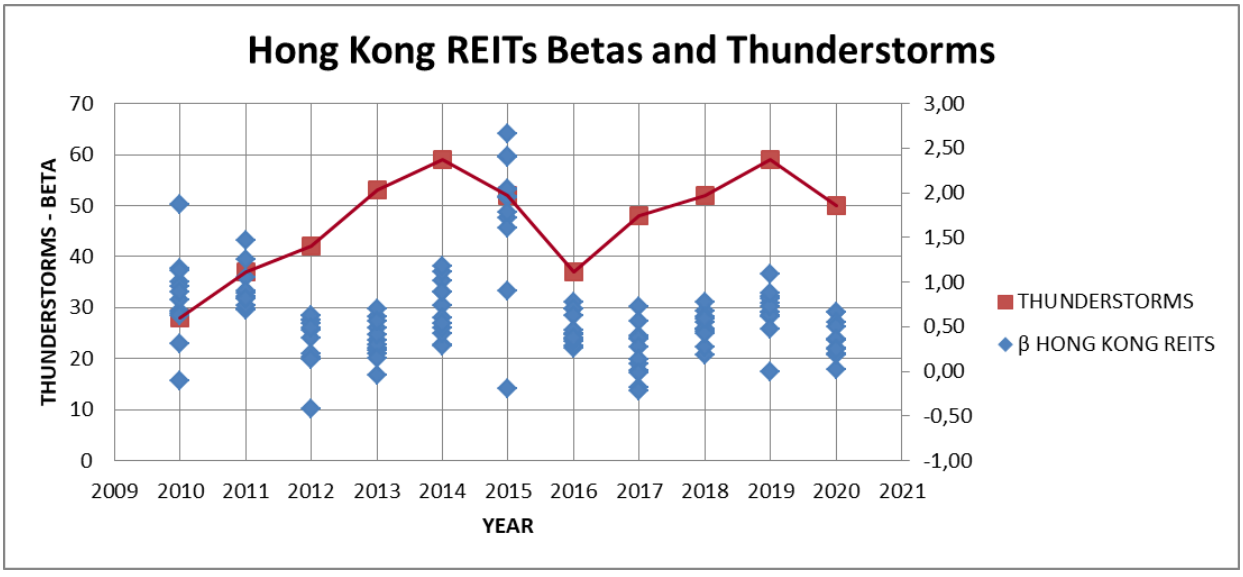

Japan REITs Betas and Billion GHG Emissions
BILLION GHG EMISSIONS - BETA
1,600
1,400
1,200
1,000
0,800
0,600
0,400
0,200
0,000
1,20
1,00
0,80
0,60
0,40
0,20
0,00
-0,20
-0,40
-0,60
-0,80
2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
YEAR
BILLION TONS OF GREEHOUSE GAS (CO2) EMISSIONS
β JAPAN REITS

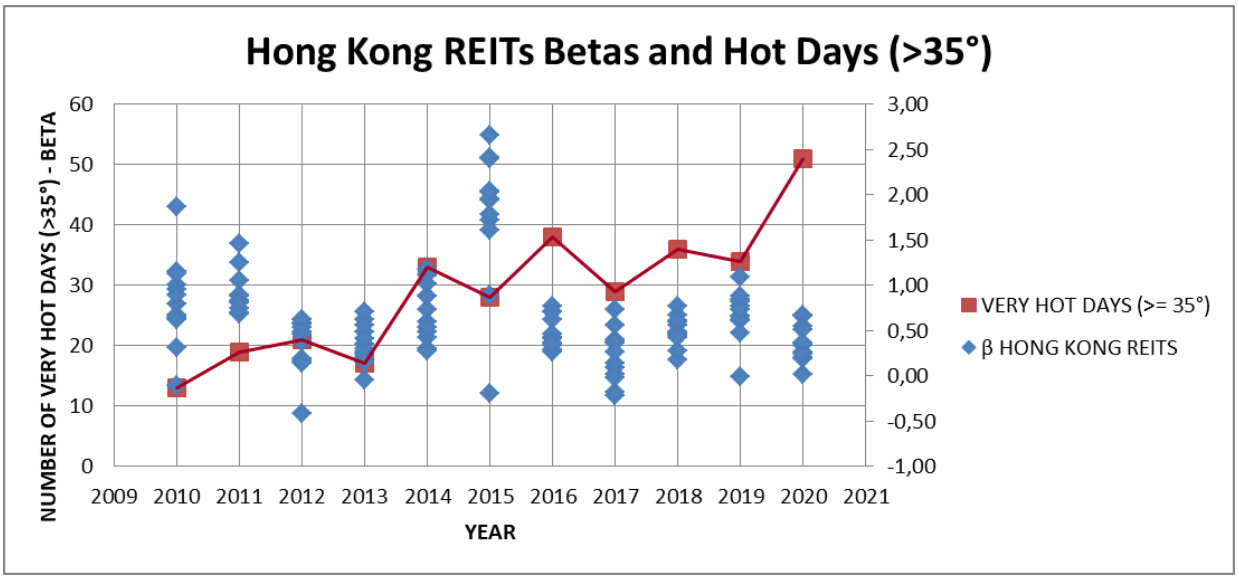

Japan REITs Betas and Million of ¥ Floods Damages
FLOODS MILLION ¥ DAMAGES - BETA
2500
2000
1500
1000
500
0
1,20
1,00
0,80
0,60
0,40
0,20
0,00
-0,20
-0,40
-0,60
-0,80
2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
YEAR
MILLION OF ¥ OF FLOODS DAMAGE
β JAPAN REITS

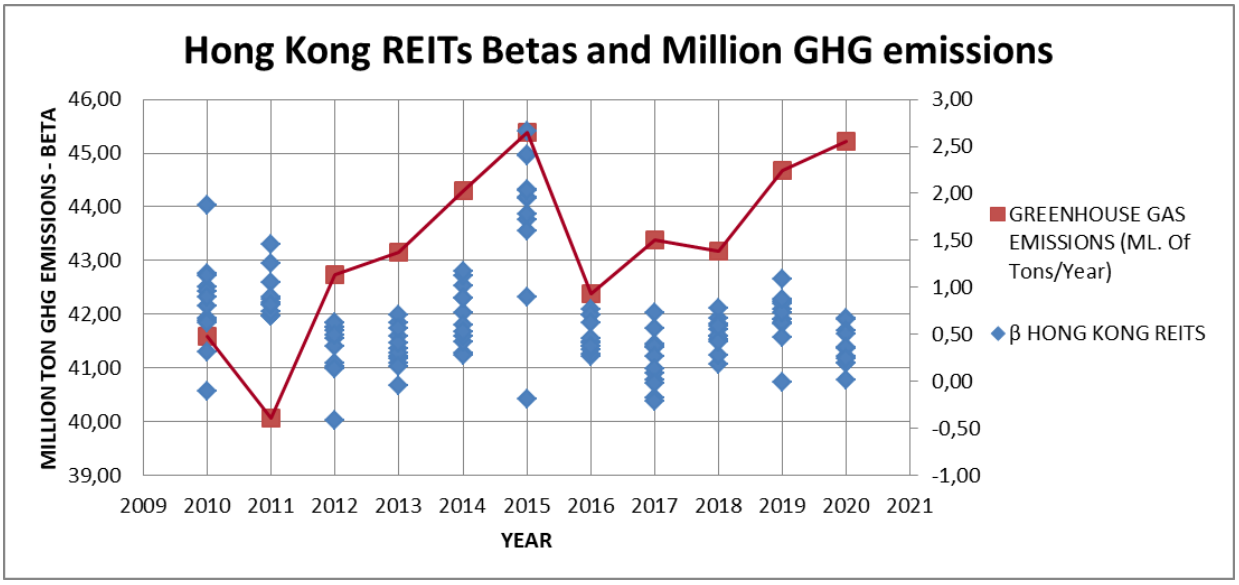
- **Scatterplots of panel analysis of Hong Kong based REITs and climate events.**








Hong Kong REITs Betas and Hot Days (>35°)
NUMBER OF VERY HOT DAYS (>35°) - BETA
60
50
40
30
20
10
0
3,00
2,50
2,00
1,50
1,00
0,50
0,00
-0,50
-1,00
2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
YEAR
VERY HOT DAYS (>= 35°)
β HONG KONG REITS


Hong Kong REITs Betas and Million GHG emissions
MILLION TON GHG EMISSIONS - BETA
46,00
45,00
44,00
43,00
42,00
41,00
40,00
39,00
3,00
2,50
2,00
1,50
1,00
0,50
0,00
-0,50
-1,00
2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
YEAR
GREENHOUSE GAS EMISSIONS (ML. Of Tons/Year)
β HONG KONG REITS