**Czech University of Life Sciences Prague**

**Faculty of Economics and Management**

**Department of Economics**

**Bachelor Thesis**

# Economic analysis of global climate change in the Alps

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Faculty of Economics and Management

# BACHELOR THESIS ASSIGNMENT

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Thesis title

**Economic analysis of global climate change in the Alps**

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**Objectives of thesis**

This work aims to outline the consequences of global climate change in the European Alps. The study is based on the assumption that with a growing population, tourism also grows, which results in an adverse impact on the environment. The results' derivation is based on appropriate statistical analysis of several possible climate impacts due to carbon emissions. For a more accurate comparison, the study deals with the winter and summer periods during the 40 years between 1979 and 2009. The target area is mainly the central Alps, i.e. the Swiss, Austrian and Italian regions.

**Methodology**

The thesis methodology is based on document studies, literature, scientific articles and historical datasets all together with practical part, which will be provided by applying statistical methods of simple regression and correlation analyses between one dependent and two independent variables. The data output analyses are done by Null hypothesis, which is tested by p-value and t-test to confirm the results and further analyse a coefficient of correlation and determination that provide information about the relationship and possibility using the data to predict the evaluation of the dependent variable.

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global climate change, weather, tourism, co2, economic analysis, alps, winter, summer, regression analysis, correlation

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BENISTON, Martin and Markus STOFFEL. Rain-on-snow events, floods and climate change in the Alps: Events may increase with warming up to 4 °C and decrease thereafter. Science of the Total Environment [online]. 2016, 571, 228–236 [accessed. 2021-02-12]. ISSN 18791026. Available at: doi:10.1016/j.scitotenv.2016.07.146

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**Declaration**

I declare that I have worked on my bachelor thesis titled "Economic analysis of global climate change in the Alps" by myself, and I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break the copyrights of any third person.

In Prague on 15th March 2021

Alexandra Chrzanowská

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# Economic analysis of global climate change in the Alps


**Abstract**

The bachelor thesis deals with the impact of global climate change on the Alpine environment over the years. It was investigated whether tourism could have some impact on the Alpine environment or the economy. For more accurate observation and a better outline of the result, data from the summer and winter seasons were processed separately. The main hypothesis was that with the growing world population, tourism and carbon emissions should grow too, and thus the associated environmental impacts, such as rising temperatures.

Average monthly temperatures from meteorological stations from 5 different Alpine areas between 1979-2019 were used for observation. Tourism data were processed as the number of nights spent in hotels and tourist accommodation. These data were different for each area due to the lack of available data, and the areas were divided into the Italian, Swiss and Austrian parts of the Alps. The last data source used would be the annual $CO_2$ data, again in 1979-2019.

The above data were processed by statistical methods of regression and correlation analysis.

It was found that the Alpine regions showed no relationship between tourism and temperature, and even though there might be some reaction of tourism to temperature changes, the impact is not significant yet. In the analysis of changes in CO2 and temperature, there was no relationship, and thus the correlation is very weak. The lag variable was also investigated in this analysis due to the possible delayed temperature response to CO2, but this did not manifest itself, and therefore a more detailed study is needed to address other factors that may affect the temperature.



**Keywords:** global climate change, weather, tourism, co2, economic analysis, alps, winter, summer, regression analysis, correlation

# Ekonomická analýza globální změny klimatu v Alpách


**Abstrakt**

Bakalářská práce se zabývá dopadem globálních klimatických změn na Alpské prostředí, během let. Zkoumalo se, zda turismus může mít určitý vliv na Alpské životní prostředí nebo ekonomiku. Pro přesnější pozorování a lepší nastínění výsledku, byly zpracovány data zvlášť z letní a zimní sezóny. Hlavní hypotézou bylo, že s rostoucí světovou populací by zároveň měl růst turismus a uhlíkové emise a tím pádem i dopady s tím spojené na životní prostředí jako je rostoucí teplota.

K pozorování byly použity průměrné měsíční teploty z meteorologických stanic z 5 různých Alpských oblastí mezi lety 1979-2019. Údaje cestovního ruchu byly zpracovány jako počet strávených nocí v hotelech a turistických ubytováních. Tyto údaje byly pro každou oblast jiné, kvůli nedostatku dostupných dat. Oblasti byly rozdělené jako, Italská, Švýcarská a Rakouská část Alp. Posledním použitým zdrojem dat by roční údaj o $CO_2$, opět v letech 1979-2019.

Výše uvedená data byla zpracována statistickými metodami regresní a korelační analýzy.

Bylo zjištěno, že Alpské oblastí nevykázaly žádný vztah mezí cestovním ruchem a teplotou, přestože se může vyskytovat velmi malá rekce cestovního ruchu na změnu klimatu, není tato příčina zatím dostatečně signifikantní. V analýze změn $CO_2$ a teploty, se žádný vztah neprojevil a tím pádem se zde vyskytla i velmi slabá korelace. V této analýze byla také zkoumána proměnná zpoždění, kvůli možné zpožděné reakci teploty na $CO_2$, tento faktor se ale také neprojevil, a proto je za potřebí podrobnější studie zabývající se dalšími faktory, které mohou mít vliv na změnu teploty.



**Klíčová slova:** globální změna klimatu, počasí, cestovní ruch, co2, ekonomická analýza, alpy, zima, léto, regresní analýza, korelace

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# 1 Introduction

The topic of global warming has been sparking discussions around the world for several years; at one side, some people are trying to prove its existence and draw attention to the dangerous consequences associated with it, and on the other side are people saying that it is only a natural process that has been cyclical for hundreds of millennia.

A look at history shows such cyclical phenomena manifested themselves and alternating cold and warm periods as the planet earth regulated its circulation of gases in the Earth's atmosphere. However, $CO_2$ in the post-industrial period, which has multiplied several times, is not to blame on nature but instead on humans. Theories suggest that this is due to human intervention in nature; for example, rainforests or cold oceans have always helped absorb $CO_2$ and thus regulate the planet's temperature, but as forests shrink and warming up, oceans can no longer absorb $CO_2$, and it remains in the Earth's atmosphere. The result of such an amount of $CO_2$ is accelerated warming, to which nature does not have time to adapt.

Global warming is not only a risk to nature. In recent years it is possible to observe increasing natural disasters, starting with the more frequent hurricanes and other intense storms, massive fires in dry areas or floods. Another climatic threat to humanity is rapidly rising sea levels; melting glaciers in the Arctic and Antarctic regions threaten coastal housing, including European housing such as Venice or much of the Netherlands, which is below sea level. Inland glaciers are an irreplaceable freshwater source, and their accelerated melting threatens even dry mountain areas such as Tibet.

Last but not least, it is the economy that can be affected by global warming; for example, tourism, which is the subject of this thesis, accounts for a large share of income of many countries whose favourite destinations may be affected by the effects of climate change.

Therefore, this work aims to determine whether temperature changes have a specific relationship in the visitors' number to the Alpine region. Another reason for writing this thesis is contributing and bringing awareness and risks associated with the global climate change topic to other people.

# 2 Objectives and Methodology

### 2.1.1 Objectives

This work aims to outline the consequences of global climate change in the European Alps. The study assumes that with a growing population, tourism also grows, which results in an adverse impact on the environment. The results' derivation is based on appropriate statistical analysis of several possible climate impacts due to carbon emissions. For a more accurate comparison, the study deals with the winter and summer periods during the 40 years between 1979 and 2009. The target area is mainly the central Alps, i.e., the Swiss, Austrian, and Italian regions.

### 2.1.2 Methodology

The thesis methodology is based on document studies, literature, scientific articles, and historical datasets, all together with practical part, which will be provided by applying statistical methods of simple regression and correlation analyses between dependent and independent variables. The analyses are divided into two parts. The first is to compare the dependent variable (tourism) with the independent (temperature) and the second part deals with comparing dependent (temperature) and (independent) $CO_2$. The data output analyses are done by Null hypothesis, which is tested by p-value and t-test to confirm the results and further analyse a coefficient of correlation and determination that provide information about the relationship and possibility using the data to predict the evaluation of the dependent variable.

Collected data for temperature from five Alpine weather station represents one average temperature variable, only separated for summer and winter season, or in the case of $CO_2$ for the whole year. Tourism data are collected as over-night stays during a specific season, and the target areas are Austria, Switzerland, and Italy, from which the data are added together from choosing single Alpine regions. Finally, $CO_2$ was collected as a global year average.

# 3 Literature Review

## 3.1 Global Climate Change

Today, global warming is a massive risk to the whole world, the planet is warming up, and more and more extreme weather is the cause of all the damage shown by human activity, i.e., population growth, deforestation, ocean fishing, production and activity, and agriculture. All the events are happening at such a rate that planet Earth can no longer repair artificial damage. Even though it is proven that the planet Earth has its cyclical period where it cools down and warms up, the last 2-3 centuries show us the results that are primarily influenced by human activity, the so-called greenhouse effect. Fumes from the combustion of coal, oil, or natural gas, as well as means of transport, release carbon dioxide and other harmful greenhouse gasses into the air, increasing the human population resulting in increased demand for natural resources, housing, and food lead to growth in industrial production, and thus even more pollution leaking to the atmosphere, resulting in the greenhouse effect. The planet Earth is adapted to absorb carbon dioxide. However, only to a certain extent, the forests that represent this activity disappear faster than they have a chance to recover, as well as forest fires caused by longer dry seasons, oceans that cool down the planet and cover about 71% of the planet's surface, no longer have the capacity to do so and are starting to warm up, creating an environment unsuitable for maintainable biodiversity. Nevertheless, it is not only nature that is affected by the greenhouse effect. Rising sea levels due to melting glaciers result in floods in coastal cities and cause damage to agriculture and thus people themselves, but it is not just cities but, for example, the Netherlands itself, most of which is located only a few meters above the sea level. Research shows an increase in the level by 0.3 - 1 meter by the end of the 21$^{st}$ century. Given today's conditions and human activity, it can be predicted that temperatures will rise by 6°C during the 21$^{st}$ century. [1]

One study outlined possible future results, assuming rising temperatures and greenhouse gases on global streamflow extremes. Results have shown that at high altitudes such as northern Eurasia, northern Canada, Alaska, the Tibetan plateau, southern India, or the central Alps may face increased flood catastrophes in the future, the probability of long-term dry periods. Simultaneously, as the abundance of water in the streams, the levels begin to rise, and the oceans' temperatures, especially the Arctic Ocean, change. [2]

Another study divides global warming trends into two types, an external trend that is caused naturally, regardless of human activity, and an internal movement that, in turn, deals with human activity and its impact on the global climate. External trends include a combined activity that sends solar plasma into the Earth's atmosphere, creating more clouds on the Earth with a higher probability of precipitation, which continues to be to blame for floods, hurricanes or other severe storms, sunlight or increasing the risk of volcanic activity. Another external trend is rising sea levels. These processes occur in certain rhythms that coincide with tectonoseismic activity due to melting Greenland glaciers or deep geological processes. The rhythm itself is associated with the cosmos year when the solar system completes the galaxy's orbit. The last of these trends is volcanic activity, its frequency and strength. Internal trends, i.e., trends caused by human activity, are, for example, climate warming itself, which is a reaction to the release of greenhouse gases into the air causing, for example, inconvenient conditions for many crops which are also impacted by numbers of natural disasters such as droughts, severe storms, or rapidly alternating waves of heat and cold during single periods. Other factors are increased human migration or human health risks such as lack of food or the body's ability to adapt to the new climatic conditions, thus increasing mortality and diseases. The last factor that must not be overlooked is the reduction of biodiversity, either due to rapid climate change, which species do not have to adapt to or due to increasing human-wildlife conflicts resulting in a decrease in natural habitats where the wildlife occurs and can move freely. Scientists predict the next temperature drop in the second decade of the 21$^{st}$ century, which will last approximately 50-70 years with subsequent warming at the beginning 22$^{nd}$ century. It also mentions the so-called Kyoto Protocol, an international agreement that is based on reducing carbon emissions. [3]

### 3.1.1 Kyoto Protocol and Paris Agreement

The Kyoto Protocol, signed in 1997 in Kyoto, Japan, aimed to reduce the world's greenhouse gases. The most significant participant is, which accounted for more than 62% of total greenhouse gases at the beginning of the 21$^{st}$ century. Records show that carbon emissions increased by 40% between 1990 and 2009. The protocol divided the share of greenhouse gases between developing countries and industrialised countries between 53% and 44%. Part of the protocol was to reduce emissions by 2012 in industrialised countries by 5.2% than in 1990; this was related to one of the conditions at least 55 countries that generate at least 55% of emissions. [4]

The study states that the problem was that the protocol did not consider developing countries, as rich developed countries were allowed to support emission reduction projects in developing countries, which gave rich countries credit and reduced mitigation costs but ultimately risked the prolongation of time for a change in their emissions production. For several reasons that did not fulfil the Kyoto Protocol's purpose and the newest climate change act is called the Paris Agreement, introduced in 2015. [5]

The agreement's purpose is to limit the possible temperature increase to 2°C, with the ideal prospect of a maximum rise of 1.5°C, without setting a clear time target but achieving these results in the long term. A study that analyses whether -2°C is safe further mentions that this increment in temperature could still be very harmful in some areas, but an additional 0.5°C could make the difference. [6]

## 3.2 Population and $CO_2$ emissions

As a study of climate change and population growth mentions, the growing population has brought with it factors such as greater demand for food, clothing, and natural resources. Satisfying these demands requires the production of greenhouse gases that are associated with the production and supply of products, various fertilisers and chemicals used to grow and treat agricultural production. The study further states that the current state of the population assumes an increase of 30% by 2050, and under these conditions, it is possible to imagine the rise in the greenhouse effect. [1]

One study on global climate change reveals greenhouse effect data, which have an enormous impact on the Earth's climate. The study states that the most significant leap in emissions occurred during the industrial revolution until the 21st century. Between 1750 and 2011, greenhouse gases increased as follows, methane by 150% and nitrous oxide by 20%. In 2011, the amount of $CO_2$ was reported at 390.5 parts per million, not only its increased b by 40% since 1990, and this data is no longer relevant as the data from May 2018 show another giant leap, at 408 parts per million. This number is considered to be the most significant amount in the last 800,000 years. [7]

Particular research deals with the importance of fertility in economic growth and reducing carbon emissions. The study suggests that the introduction of various policies to regulate fertility may not positively impact reducing emissions as expected. These regulations would make the most sense, for example, in developing countries, where their implementation would be the simplest. However, it must be considered that it is not only policies to reduce the birth rate itself that would help, but above all, better available medical services and products that are lagging in these countries and are the reason for greater fertility. Simultaneously, the study results do not say that the policies are only one of many steps that must be taken to achieve the necessary conditions. Examples are rich countries such as Russia and China, which are relatively low on the population growth ladder but still have high carbon emissions. [8]

On the other hand, another study argues that the high $CO_2$ footprint is not caused by overpopulation but rather by individual countries' environmental policies and economic and social activities. The author further argues that humans do not cause environmental problems such as killing The Great Barrier Reef or the Amazon rain forest's felling to create space for a new household or growing cities but rather for farming industrial corporations. It turned out that overpopulation is not due to higher birth rates but, on the contrary, the longer average life expectancy of a person who in today's conditions has a chance of longer life due to better health and nutrition, 1950 the average mortality age was around 47 years, now (2020) the average age is approximately 73.3 years. In conclusion, the study states that the problem is not the population's frequency but precisely life in capitalism, balancing competition rather than sustainable development and lower emissions. [9]

## 3.3 The Alps

The Alpine region is divided into three part through various European countries. The western Alps begins at France coastal area, leading north through the Rhone-Alps to Switzerland, from east of Mont Blanc, continuing along north Italy borders, where the central Alps can be found with its notorious peaks as Matterhorn, reaching the above 4000 metres above the sea. From there, the eastern part of the mountain pass is leading from the Italian Dolomites and Bavaria Alps in Germany, where mountain altitude still reaches highs of 3000 metres AMSL, to northern Slovenia and reaching the far shore of the western Balkan peninsula in Croatia where the highest peaks reach slightly to 2900 metres AMSL. [10]

Overall Alpine region can be measured as a 1000km long and 250 km wide mountain chain, narrowest in the west where its highest peaks can be found, which formed 65 million years ago. [11]

In Europe, the mountain area claims about 40 % of land and is home to 20 % of the total population. Even though only about 17% of the Alps have suitable conditions for settlements or recreational areas. [12]

### 3.3.1 Ice and Glaciers in the Alps

Alpine glaciers cover an area of around 2092 km$^2$ which makes the area of glaciers the second largest in Europe after Scandinavia (approximately 2949 km$^2$). [13]

A recent study covers glacier reserves in the last few years, as previous studies were based on data in the first ten years of the 21$^{st}$ century and needed to be updated, and new images and research on the extent of the Alpine glaciers were made in 2015-2017. The study divides the Alpine glaciers into several types, cirque, mountain, and valley type, including the largest Alpine glacier Aletsch Glacier, which covers an area of approximately 80 km$^2$ and Gorner glacier with an area of 60 km$^2$. The study further states that most glaciers are located at an altitude of 3000 meters above the sea level, but there are exceptions due to soil deposits from the surrounding rocks, which by covering the glaciers prevent rapid melting and allow them to descend to a lower altitude of about 1300 meters above sea level. The study provides results with new information and the extent of the ice surface in the Alps, 4395 glaciers larger than 0.01 km$^2$ were found, with a total covered area of up to 1805.9 km$^2$. Most of these ice sheets can be found in the Swiss Alps, whose peaks cover up to 49.4%, followed by 20% of the Austrian, 18% of the Italian Alps and 12.6% of the French Alps. However, 62.5% of these glaciers are smaller than 0.1km2 and make up approximately 5.5% of the frozen area, while glaciers larger than 5km$^{2,}$ such as the largest Aletsch glacier, are only 1.6% but cover up to 40% of the total ice surface. Further states that glaciers smaller than 1km$^2$ tend to occur at all possible heights, compared to larger glaciers which indicate a clear altitude range around an average of 3000 meters above sea level. The highest located glacier on Mont Blanc at 3140m which has an area of 10km$^2$ and is not by far the largest but not the smallest and thus indicates a trend that with increasing altitude range, the size of the glacier adapts. Regarding the change in the glacier area's size, from previous data from 2003 until this research in 2015/2016, the total area of 2060km$^2$ decreased to 1783km$^2$. [14]

One study attempted to measure the susceptibility of smaller glaciers to global warming in the Swiss Alps. The study considers the size of remote glaciers to be less than 0.5 km$^2$. More than 80% of these glaciers are located in mountainous areas. In the last two decades, the melting of these glaciers has also been a relevant subject in the topic of sea-level-rise. Small glaciers are primarily found in eclipses on the mountain slope and are strongly influenced by wind and partly by avalanches. Since 1970, they lost 70% of their original area, which testifies their susceptibility to temperature rise, which has risen by 1°C since the 80s. An interesting finding was that the internal temperature of glaciers, around 0 °C, occurred in areas of accumulation zones, which are typically located at higher altitudes. In contrast, the temperature of glaciers that occurred in the ablation zone was measured from -1°C to -2°C. Future studies predict that the internal temperature of glaciers will also rise slowly. Regarding the outflow of water from small glaciers, it is assumed that it will be only more minor in the future. Remote glaciers recorded an enormous volume of discharge from 1997 to 2004. The study concludes with a forecast of complete disappearance of these glaciers less than 0.005km$^2$, 73% by 2030, the next 30 years, the glaciers are expected to disappear almost completely, up to 97%. As for glaciers measuring 0.1m$^2$ to 0.5 km$^2$, it is assumed that only 11% will disappear by 2030, but by 2060 their melting is significantly more remarkable, and up to 88% of small glaciers will disappear. [15]

### 3.3.2 Climate Conditions in the Alps

Located in central Europe, the Alpine climate is being impacted from the west by the Atlantic Ocean, from the south by the Mediterranean Sea and from the east by the European part of the Urals. All of that creates an atmospheric circulation affected by meteorological phenomena typical for mountain areas that are very sensitive to climate change, such as precipitation, glaciers retreat, unpredictable temperature differences, change in seasonality, and snow cover depth river flow. The Atlantic affects precipitation from the north-west and continuing to the east, where it slowly decreases. Temperatures mainly depend on elevation, warmer in valleys and colder at mountain peaks. Some of the prediction show us if the temperature increases by 3°C, the Alpine glacier will shorten by 80%, and another adds up to 5°C would melt the rest of the glacier cover in the Alps. [16]

One study considers the future increased precipitation during the winter and the reduction of rainfall during the summer; these factors may affect Alpine biodiversity and the affected countries' economies. As mentioned in the previous source, the local range of precipitation and temperature is strongly influenced by the mountain variation and the Alps' independent location. Studies have shown that the most significant increase in rainfall in the $20^{th}$ century occurred in Switzerland and generally increased significantly in autumn and winter, with a further decrease in the Alps' humidity over the summer, while only reducing winter in humidity is indicated. In history, the mean temperature from the late $19^{th}$ century to the end of the $20^{th}$ century has increased by 2°C and only keep rising, the expected changes by 1.5°C in the first half of the $21^{st}$ century, by the end of the century, the temperature rise is expected even to speed up and reach 3.3°C of total change. [17]

### 3.3.3 Water Scarcity in the Alps

The Alps and the glaciers themselves are called the water tower of Europe because they hold vast freshwater supplies. Their melting supplies water everywhere in the Alpine regions. There is a threat in the name of global warming, which significantly accelerates the melting of glaciers, snow cover, permafrost, which shrink and endanger the lives of the Alps, fauna, and flora, not only in terms of water loss but other natural hazards such as landslides or debris flow. in the presence of an excessive volume of water in the soil. [18]

One of the Swiss studies deals with the current and future water supplies situation and offers the possibility of water supplies sustainability. The study states that water supplies occur mainly in the summer months, but these supplies, especially in the form of snow and ice, are endangered with the warming of the climate. Other threats to water scarcity that the study include is insufficiently high river levels for water transport, the necessary restrictions in households and tourism, and last but not least, there is a change in water temperature, which can cause problems for aquatic animals. The study introduces several solutions to deal with water shortages, such as water reservoirs, which in most areas are used only to produce electricity for the winter when the electricity demand is most significant. Therefore, there is an opportunity to improve this energy pumping and include in production things beyond the framework, such as irrigation, flood protection, water supply or recreational activities. Furthermore, it turned out that the highest water consumption has ecological flow requirements and hydropower production, slightly less irrigation, drinking water, industry sector, tourism, and the lowest in demand for water for artificial snow. The reservoir is the potential solution to the lack of water in certain seasons when the water would be stored in the reservoir and discharged if necessary. The study concludes that it is possible to cover water demand in current conditions, stocks from lakes and reservoirs. However, in future deteriorating climatic conditions, it is doubtful, as the most affected areas are unlikely to have enough water resources to build up supplies for the dry season, and so water would need to be transported from other regions. [19]

### 3.3.4 Natural Hazards

Climate change is leading to a higher incidence of natural hazards in Alpine areas. Further increasing of temperature will lead to a decrease of snow covers and retreating of glaciers, creating glacial lakes, which over time can rupture or spill-over their moraine this also with more precipitation during winters results in floods. With the retreat of glacier and melting of permafrost, more frequent rockfalls and landslides are expected. All of this will also impact Alpine biodiversity, for plants and their time required to grow will shorten with warmer winters and the same for many animals. [17]

### 3.3.5 Floods

One of the first consequences of the impact of global warming on climate conditions in the Alps is floods; these catastrophic events have the most extended history in Switzerland, where the most recorded data come from. Due to the lack of data, studies cannot rely too much on historical records older than the last 15 years from other Alpine countries and regions. Floods have a tremendous financial impact on the economy, thanks to concreted riverbeds that prevent rivers from spilling into the landscape and soaking up excess water, resulting in a loss of flora that lacks nutrients. The forecast in the northern Alps shows an increase in floods in the winter and spring seasons and decreased frequency during the summer. In contrast, in the southern part of the Alps, floods are to occur regularly in all seasons except summer. [17]

Another study on natural hazards describes mountain floods as an increase in the level of watercourses that result in exceeding the capacity of hydrological systems and the damage associated with it. Mountain floods are all the more dangerous because they involve other risks such as landslides or moving dangerous debris in watercourses. The study again mentions only areas in Switzerland due to the already mentioned shortcomings of data in the previous literature. In Switzerland, the typical flood period is considered to be the end of summer and early autumn; it is stated that one of the reasons for floods is the so-called rain-on-snow when the resulting melting snow is added to warmer rainwater from the air and results in excessive water. In snowy areas. It is these events that resulted in the most significant floods in Switzerland in 1999, 2011. The study further analyses the events on the Swiss river Sitter, which in 1960 - 2015 recorded four major flood events, 3 of which are referred to as rain-on-snow, states here also that although higher temperatures help reduce snow reserves at lower altitudes, it also increases the risk of rainy conditions at higher levels, the study concludes that the riskiest temperatures are 4°C or 5°C, with higher temperatures the flood risk caused by rain-on-snow is significantly reduced. [20]

### 3.3.6 Droughts

Drought is another dangerous factor for the Alpine region, with faster-melting and shrinking glaciers releasing less and less water each year, which is necessary for agriculture or electricity generation. At the same time, the melting of permafrost leads to the release of rocks and landslides. The study has shown that it is more difficult for the Alpine region to outline exact figures for the future due to other climate developments, despite this fact, but it has been clearly shown that the length of the drought will increase in the future. [17]

### 3.3.7 Debris Flow, Rockfall and Landslides

A study covering landslides, rockfalls and debris flow around the Alps states that with larger participation and warmer temperature for a long time, the frozen ground can lose its stability, and with a warming climate, these events can occur more and more in the future. On the other hand, it also disguises that with warmer temperature, the vegetation can grow in higher elevation, which provides more stability to the ground. The study states that the causes of a debris flow can be several, such as rain-on-snow events, the release of water from the glacier or rapid melting of snow, but it is often short but heavy, conversely, light but long-lasting rains. The cause of stone falls, in most cases, a fault of melting glaciers, and massive landslides are caused by water over logging of the soil or, in some cases, by any disability of the mountain. [21]

### 3.3.8 Snow

The snow that falls in winter is an essential water source for Alpine vegetation and human use during spring and summer. Its decrease, related to the already mentioned, a smaller amount of precipitation, will affect both these sectors. Although the snow cover varies with altitude, hill slope orientation, or other location, one of the leading "rules" that can be applied to the average snow altitude is that approximately 150 meters of snow line are shifted per degree Celsius. For the second half of the 21st century, this predicts a shift of 300-600m. This prediction is, however, wildly inaccurate due to many factors that are not considered. In one study, they tried to outline a forecast for winters in the second half of the 21st century, during which snow would fall above average, mainly due to smaller alternations of hot and cold days. This prediction was compared with the results in the years 1961-1990, where such a winter appeared eight times, and it turned out that a winter that would bring more snow than usual could manifest only 1 in 30 years. [17]

One study attempts to provide evidence of receding snow. The study showed a significant jump in snow water equivalent at the end of the '80s, mainly due to the development of the temperature situation, evaluating it as one of the findings that climate change may not be escalating in the long run but instead that it can also occur suddenly. The results also showed that water supplies had decreased significantly over the last 60 years, regardless of the height at which they are, because changes have been observed throughout. Furthermore, the most significant decrease in snow water equivalent was observed most in April; trends show that there are losses of up to 80% at lower altitudes, but in contrast, at high altitudes, the loss is measured at only 10%. However, they note these losses are not as drastic due to the Alps' location and that this mountainous area does not suffer from drought during the summer as in California. Nevertheless, the study concludes that there will be a significant reduction in water resources, with consequences for the Alps' inhabitants. [22]

### 3.3.9 Biodiversity in the Alps

Nearly two-thirds of Earth's freshwater is being held in glaciers and snow. Still untouched at some points by a human, the Alps are a rich home for vegetation and wildlife. Today's natural diversity and the Alps' shape are the results of historical climate work and human impact on its lands and nature. Alpine vegetation varies according to altitude; the higher the elevation, the lower is the number of survivable plants. Another factor is also the mountain conditions. Exposed peaks and ridges are typical for the slight richness of vegetation, mainly due to the wind, which even in winter reveals the vegetation from the snow. Alpine fauna is the basis for a functioning food chain, not only among vertebrates but also invertebrates are an important factor. Unexpected climate change can damage their hiding places and can subsequently become extinct, leading to irreversible damage to biodiversity. [23]

On the other hand, a particular study showed that many scientific articles on Europe's climate and species extinction in the Alps did not consider so-called microrefugia, which was described in [24] as following *"Microrefugia are sites that support populations of species when their ranges contract during unfavourable climate episodes ".*

Thanks to this factor, the study has shown that, as in the past, endemic species are not significantly threatened by accelerated global warming, as the local environment is more resilient to rapid climate change, dampening its impact and protecting endemics. [25]

Another study focused on the distribution of species in the Alps, and their response to rising temperatures showed that most species remained unaffected by this factor, while species that live at higher altitudes and their natural habitat is very limited, are more susceptible to change, which comes with global warming. Endemic species have also been found to be less prone because most of them do not have a problem with changes in temperature or altitude. For example, birds in this study saw an increase in the number of individuals, but spiders and butterflies responded much worse. Their numbers began to decrease with increasing temperature. [26]

## 3.4 Tourism and Climate Change

Climatic conditions play a considerable role in tourism. The weather and climate significantly influence tourist destination choice. The most endangered destinations are coastal and mountain destinations, one of the studies states that solutions have been proposed in recent years. For example, in Greece, coastal barriers for rising sea level have been proposed. In mountain areas conditions, it uses artificial snow. However, artificial snow needs a climate-adapted to it, and not all ski resorts meet this requirement. It is not just the destinations at risk, but especially the limited natural resources such as water or forests, on which the development and maintenance of tourism depend. However, non-climatic factors such as agricultural capacity, longevity, endangered species, or quality of life indicators must also be taken into account. In conclusion, the study shows that while various alternatives are offered to sustain tourism, these alternatives will not be enough to cope with climate change in the long run. At the same time, solutions such as reducing greenhouse gases reduce the vulnerability of various destinations and the development and sustainability of tourism. [27]

Another study discusses the relationship between tourism, $CO_2$ emissions and economic growth. It presents data from 2016 when the share of tourism in global GDP was 10.2% and employed 9.6% of total employment. The study states that proof of growing tourism are data forecasts that predict an increase to 20 billion tourists by 2030, while also mentioning that tourism plays an essential role as a tool for controlling economic growth. However, the development of tourism also means an increase in $CO_2$ emissions, which are associated with the journey to destinations, accommodation, and surrounding services. By 2035, $CO_2$ emissions should rise to 135% in comparison with 2005. The study concludes that in the future, it can be assumed that tourism will continue to grow as it has so far and that managing $CO_2$ emission depends on policymakers' and destinations cooperation at the same time, their visitors while ensuring the improvement of technology and services that significantly lower the environment. [28]

### 3.4.1 Tourism in the Alps

Visitors to the Alps are mainly driven by the winter seasons and local resorts, while ski resorts are not the only attractive tourist destination. Due to its natural and vegetation variation, there are many national parks or protected landscapes in the Alps. Even though the human population is growing, in the Alpine areas we can observe a decrease within the local people because the younger generations move to work in larger cities, the only places where this is often not the case are ski resorts, on the contrary, we can observe an increase in visitors and locals. [29]

Farming is another factor under which we can observe a depopulation of some areas; these do not have conditions accessible for agriculture, but also its nature stays untouched. [30]

They suffer on lack of people to cover regular services, one of the options in which governments and tourism professionals hope is the supply of tourists to these areas, not only during the winter but also in the summer. This would improve the economy and support regional development, but the sustainability of local nature and its biodiversity and closer to humans remains an essential factor. For the Alpine regions, summer tourism and stays in national nature parks account for a significant state budget share. Other research has shown that such an economic impact does not depend directly on the type of park or the degree of protection, but rather on the local nature, landscape, or marketing success. [29]

### 3.4.2 Tourism in the Protected Areas

There are over 1000 protected areas in the Alps, which together cover an area of more than 100ha, which is about 25% of the Alps. Both national parks and biosphere reserves aim primarily to protect nature, thus achieving their degree of protection, which is usually the strictest in the inner parts of parks, differing only in their external protection measures when in biosphere reserves the safety, is not as severe as in national parks. In contrast, nature parks are more focused on the experience of tourists and their encounter with nature. Measures similar to those in national parks and biosphere reserves still apply here, but they are not that strict. Thanks to these factors, nature parks are a vital source of tourism; biosphere reserves also focus on regional development, but not so much on tourism and reaction, which it supports only exceptionally. On the other hand, National Parks attracts the most tourist in the Alps then also its age or size. It is quite common that many tourists do not even know about the existence of biosphere reserves. The study of tourism in the Alps divides the tourists into three main segments according to their goal destinations and activities, the so-called traditional tourist, who travels more for nature than for cities with a rich offer of various events. It turned out that in this group, 56% of people move to the age of 50, and it remains interesting that even though they are looking for nature, on the contrary, they are not looking for recommended protected areas. The second group of tourists ranks the studies as sports and socially oriented. They are most attracted to national parks and tend to focus on various cultural events or sports experiences of natural destinations. The third and smallest group of tourists cannot be defined too much, on the basis that they are not much influenced by cultural life, and meeting nature is welcome, on the other hand, it is not even the primary goal of their travel. A deeper study further showed that tourists who were already in the Alps tend to return and explore other nature reserves, while tourists who visit the Alps for the first time are looking for more sports activities or social events. However, both groups seek and will welcome any new and unique experiences they may find in the Alps rather than searching for the particular protected area, so in the future, to attract tourists, the Alpine regions should focus more on this. [29]

### 3.4.3 Winter Tourism in the Alps

With its 100 million visitors a year, the Alps are among the world's most visited tourist destinations. Thanks to the constant improvement of services and technology on the slopes and resorts, visitors have a vast selection of activities despite the winter, which has become the primary annual season in the Alps over the last few years. Not only during the summer but also in the winter, it belongs to the most represented generation of visitors to ski resorts, people over 60 who, but with increasing age, stop visiting the Alps, and the younger generation, even though they are numerous, do not have the same preferences. [31]

As for the winter season in Austria itself, the winter season accounts for half of the tourism income. It is mainly the Austrian Tyrol, Salzburg, Vorarlberg and the Swiss Graubünden and Valais, which itself account for two-thirds of the income of winter tourism. With decreasing snow conditions, future sustainable winter tourism depends on non-snow related activities, but this is not easy to replace, especially to the same extent as in Austria or Switzerland. As already mentioned, one solution is to become artificial snow and improve the technology of artificial snow, which, despite its durability, still needs certain temperature conditions, not to mention how demanding the production of artificial snow is on energy and water. Hence, it is not a sustainable solution for the future. [32]

One study on winter tourism states that Austria offers 1.1 million beds in its 62,200 accommodation facilities, which is a considerable share compared to the Austrian population of 8,859 million in 2019. in summer, they are around 160 euros per day, and in winter, they climb to 184 euros per day. Even though Austria recorded approximately 73 million overnight stays during the winter season in 2018/2019, 66% of this figure comes from the ski resorts themselves; year-on-year growth has slowed to 1.5% over the last ten years compared to 3.1% annual growth in the 1980s. The study agrees with a previous survey of winter tourism in that Austrian ski resorts are experiencing a decline in the number of skiers and an increase in the average age of visitors. On the other hand, a new potential source market has occurred. Winter hiking recorded a rise in its share of winter tourism as more and more people find it more and more attractive. [33]

### 3.4.4 Climate Change and its effect on winter tourism in the Alps

As already discussed, rising temperatures during the 20th century, continuing into the 21st century and forecasts until the end of the 21st century, will lead to shorter and warmer winters with a loss of snow cover at lower altitudes. [17]

With a shift in snow depth above 1200m and the possibility of artificial snow, only 85% of Swiss resorts could function reliably in this way, provided that the temperature rises by only 0.3°C. In the worst case, when the temperature rises by 2°C, there is a risk that the snow line will be located around 1500m with an impact on resorts where only 63% can be operational. [34]

However, these facts are based on an older study from 1997 [34], so the results of a more recent study from 2014 are more accurate, when, as already mentioned, the expected increase in temperature for the first half of the 21st century is 1.5°C. [17]

Despite the increase in temperatures, Swiss resorts should be the least affected of the Alpine resorts, thanks to the high altitude, the impact is not so significant for them, but what must be taken as an essential factor is the higher concentration of tourists in one place, with declining ski slopes. This would affect, for example, water resources, sewers and, of course, the Alpine biosphere. If the temperature exceeded the increase by 4°C, it would mean shortening the snow cover period by about 50-60 days, even at an altitude of 2000-2500m, for altitudes lower than 1000m, it would mean shortening the days by 110-130. Italian resorts behave similarly to the Swiss one because they are also mainly located at high altitudes in the case from Austria, most ski resorts are not located at high altitudes like Switzerland or Italy and are therefore increasingly dependent on artificial snow, which also needs its conditions, an increase in temperature by 2°C and more would result in a reduction of days which are optimal for the production of artificial snow by up to 33%. However, with an increase in temperature, snow is also necessary due to unsatisfactory conditions on natural snow; with a change in temperature by 2°C would 50% of ski resorts increase artificial snow by 100-199%. [34]

A study on Austria shows that climate change will lead to the intervention of the lower and upper Austria areas earlier than the western regions of Vorarlberg, Tyrol, located at higher altitudes. However, it must not be forgotten that the west of regions would lead to actual losses in tourism and northern Italy and south-eastern Switzerland the most visited places in the Alps. As already mentioned, artificial snow is one of the ways to keep ski resorts running until the end of the 21st century, provided there is sufficient funding for energy and water, but with increasing costs, it is expected, for example, to increase ski ticket prices. It is assumed that tourists' reaction to snow conditions will be sudden rather than gradual, thanks to the possibility of easy and quick change, for example, in the choice of accommodation, destinations, or winter activities. The research shows that tourists' reaction to worse snow conditions is shallow only in areas below 2000m above sea level; there was a smaller attendance difference. In Italy, the theory of adapting tourists to the need for artificial snow was confirmed, the reaction of domestic tourists to worse winter conditions was changed, but compared to foreign tourists who, on the contrary, did not notice an increased response, the reaction of domestic tourists is minimal. In Austria, the warmer December between 2012 and 2016 had almost no effect on tourism, which does not apply to the permanently warm winter season, as in 2006/2007, during which areas below 1500m recorded losses. As for the ski seasons on glaciers, it is almost impossible in the summer because the conditions for year-round skiing allow only one glacier out of eight. [33]

### 3.4.5 Winter Tourism and its effect on Climate Change

As already mentioned, artificial snow is one possible solution to deal with the lack of snow in adverse conditions during the season, but the production itself consumes a vast amount of energy. As far as skiing itself is concerned, Austrian statistics indicate an increase in the number of areas with artificial snow and at the same time an increase in new areas, and thus an increase in emissions, but both facts must be taken into account sceptically as artificial snow-making technologies and cable cars use slightly less energy than at the beginning of the 21st century. The overall view of artificial snow is somewhat sceptical, the fact remains that snow leads to cooling and part of the consumed water returns to the soil, but there is still a part that either evaporates, sublimes, or is simply blown off the slope and is behind needs further production. The largest losses were recorded by snow lances, approximately 15-40%, while snow cannons recorded a loss of only 5-15%. Thus, many areas have begun to adapt to limited water resources and build their water reservoirs on the slopes to provide artificial snow-making supplies. [33]

### 3.4.6 Transport

Alpine transport accounts for the largest share of road transport, accounting for around 76%, aircraft that have seen their share increase since 2012 and which leave the most significant emission footprint are represented by only 13%, and train traffic remains at 7%. The high share in road transport shows the possibility that can be fulfilled by improving public transport because many tourists use the car every day as the transport to lifts and cable cars, which not only causes congestion but also increases the share of $CO_2$ in the air, just better cooperation with public transport, price adjustment could increase the attractiveness of public transportation, and the whole situation could improve. [33]

# 4 Analysis

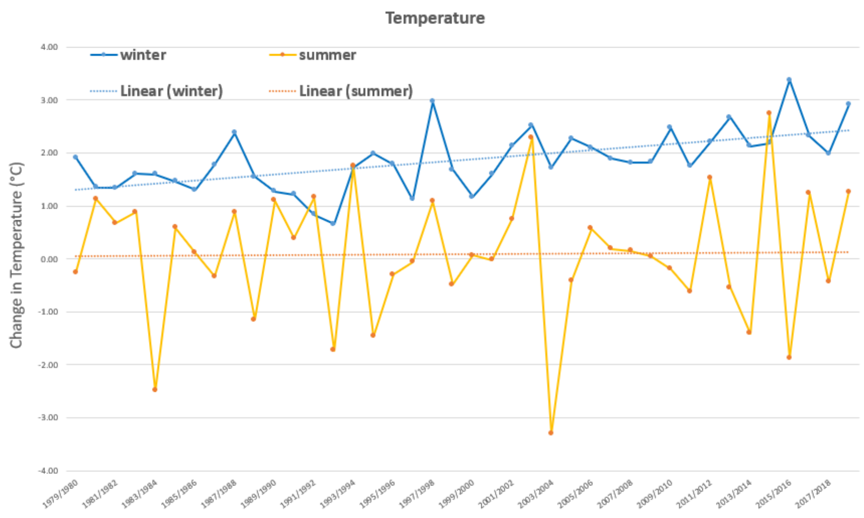
The following practical part of the thesis is focused primarily on data analysis through statistical methods, more accurately, simple linear regression with a coefficient of determination and correlation. The first step in the analysis is to set up a null hypothesis that can be rejected or accepted based on the results. After testing the null hypothesis, the analysis proceeds to test the t-test, which confirms the null hypothesis test results. Finally, at the end of each analysis, the coefficients are to proceed. The coefficient of determination results from how the dependent and independent variables affect each other in the sense of future predictions and the coefficient of correlation is used to estimate how strong the relationship is.

## 4.1 Monitored Variables

### 4.1.1 Temperature

This thesis analyses three variables. The first one is the change in average month temperature over 40 years, from 1979 to 2019. The data was collected from five weather station in the Alps, Paganella, Innsbruck, Saentis, Sonnblick and Zugspitze, during the winter and summer months separately to better understand tourism fluctuation during the single season. As observed from the graph below, the winter temperature is more sensitive to its change than summer temperature.

*Graph 1: Change in Temperature during winter and summer*

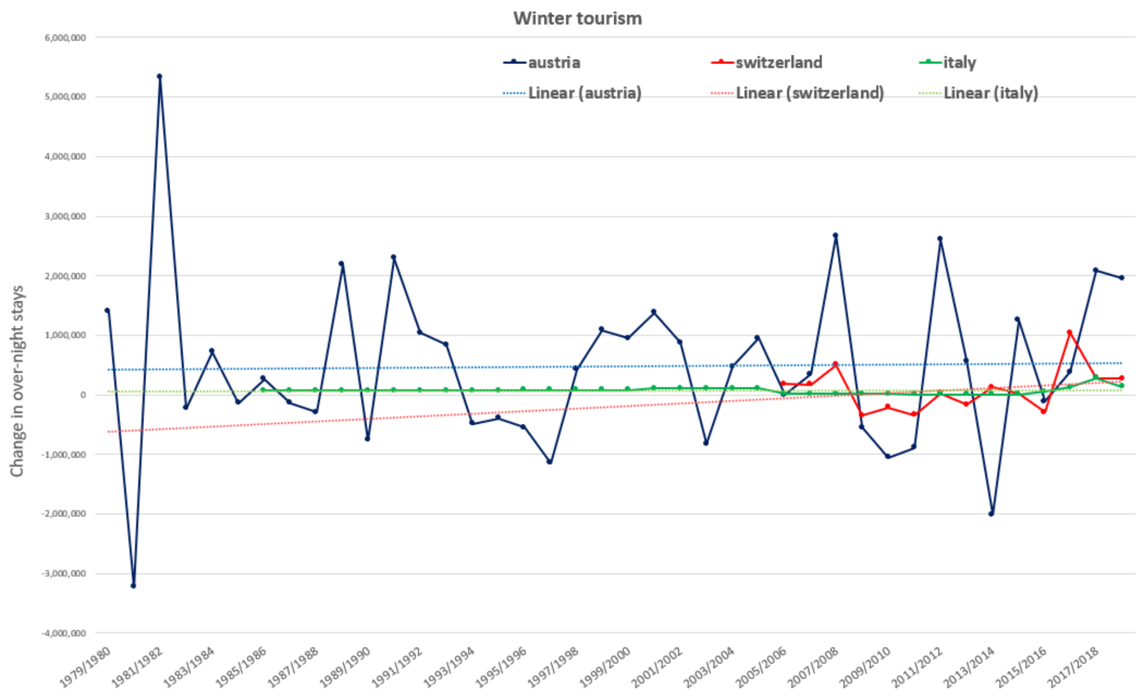



Source: National Centres for Environmental Information (NOAA)

### 4.1.2 Tourism

The research takes place in selected areas of three Alpine countries, the areas are following; Bundesland Carinthia, Salzburg, Styria, Tyrol, and Vorarlberg in Austria then, Graubünden, Eastern Switzerland, Lucerne, Bern Region, Berner Oberland, Vaud, Valais, Ticino, and Fribourg Region in Switzerland and finally in Italy, the only one province that sufficiently covers Alpine region is Trento. For winter Austria and Italy, the changes overall changes are not that significant. Switzerland might be more sensitive to the changes, but this result comes from the last 14 years, and it is tough to estimate how the graph would react with complete data.

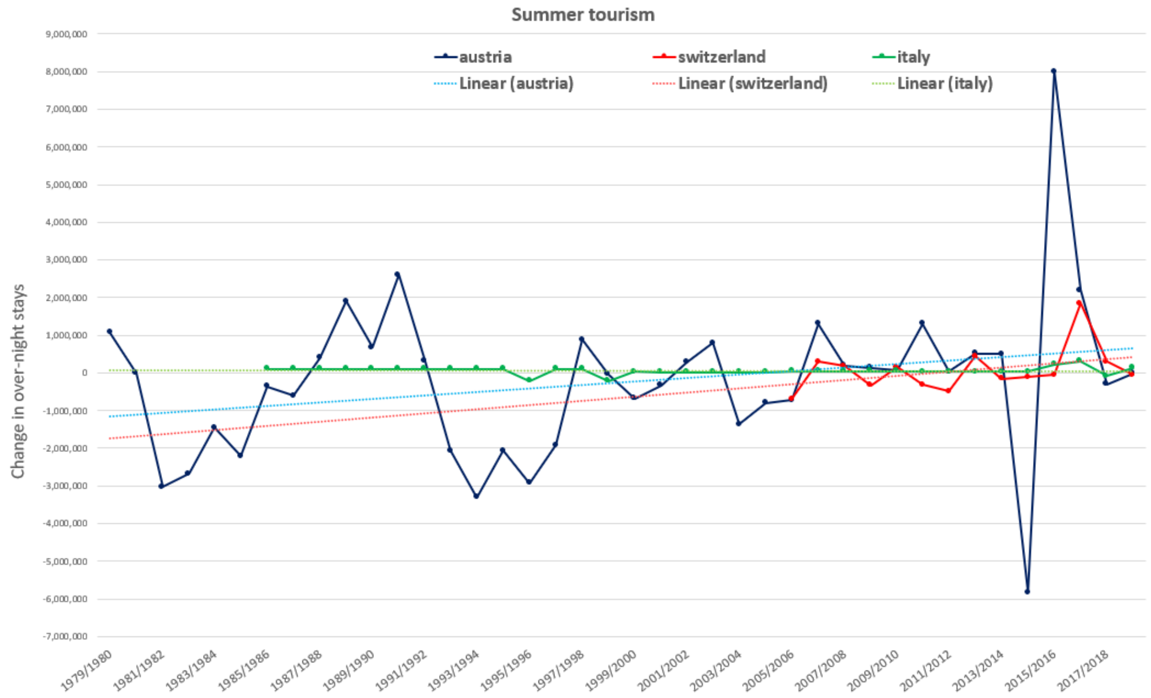
*Graph 2: Change in Winter tourism*




Source: Statistik Austria, Swiss Federal Statistical Office, Provincia autonoma di Trento

The summer analysis observes Italy, where the changes are again not that significant, but Switzerland and Austria show some sensitivity and increasing trend during summer.

*Graph 3: Change in Summer tourism*

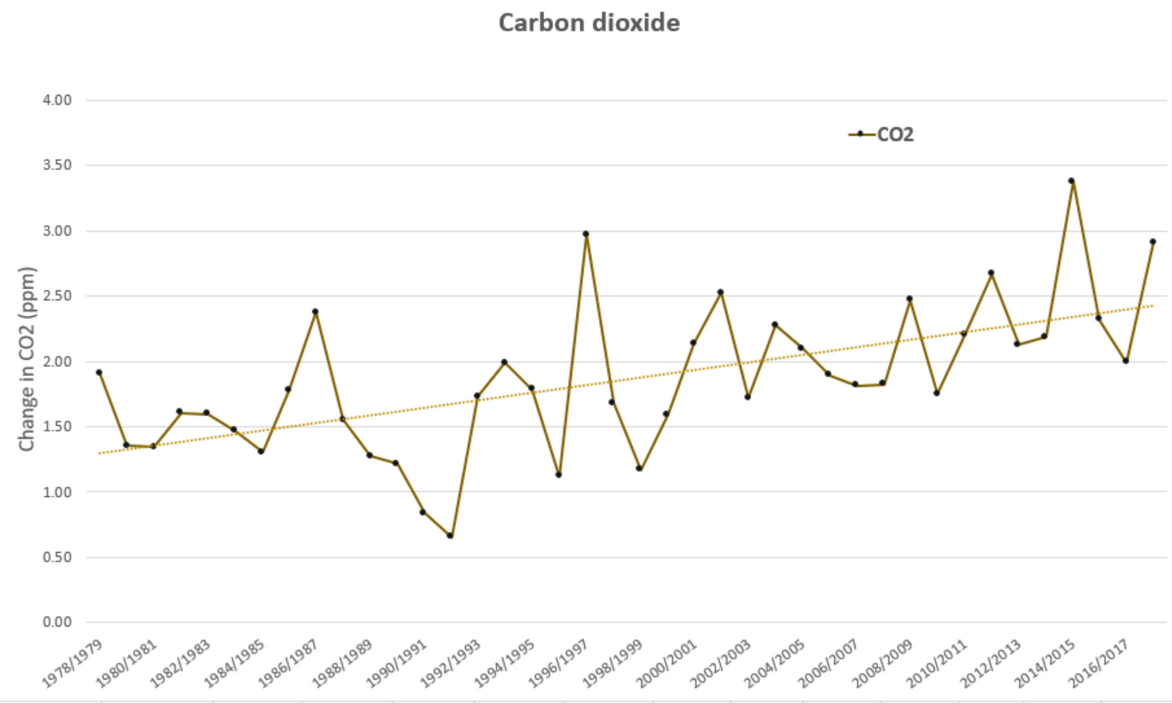



Source: Statistik Austria, Swiss Federal Statistical Office, Provincia autonoma di Trento

#### 4.1.3 Carbon dioxide

The third variable which ought to be analysed is $CO_2$. In the past, $CO_2$ showed a very similar trend in the past corresponding to temperature, and so this part is focused on the relationship between temperature and $CO_2$. The data for $CO_2$ was collected as parts per million over the whole years, so the temperature had to be adjusted, and only a year average was taken for comparison. The graph shows an increasing trend which corresponds to the theories of industrial impact on $CO_2$. It is also important to mention the difference between concentration and emission of pollutants, the concentration can differ from the emissions as this is the present amount in the atmosphere and therefore is also more suitable to analyze, in the case of $CO_2$; parts per million. Emission is measured as the amount from a specific source which is not a very reliable factor to make assumptions on.

*Graph 4: Change in CO2*




Source: Global Monitoring Laboratory (NOAA)

Another thing that needs to be considered within a $CO_2$ data analysis is a lag variable. One NASA article discusses the topic of lagging and whether temperature lags $CO_2$ or another way around. The article mentions that when the temperature went up in the pre-industrial age, the $CO_2$ went up right after; however, in the post-industrial age, the roles have changed, and the $CO_2$ is now leading the temperature. [35]

## 4.2 Spurious Relationship

Before analysing the regression output, there needs to be mentioned an essential factor. A basic theory of spurious relationship is that when two variables' outcome shows no relationship in correlation analysis, a very high possibility of a third variable might have a much more significant impact on the observed variable. With this information, the overall results can be further proceeded.

## 4.3 Results of analysis

The Null Hypothesis in these cases states that there is no relationship between the dependent and stated as follows, $H_0$: b=0, on the other side, is the alternative hypothesis which states that there is a possible relationship between the variables, therefore; $H_1$: $b \neq 0$

### 4.3.1 Winter – Austria

| SUMMARY OUTPUT | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| *Regression Statistics* | | | | | |
| Multiple R | 0.171923037 | | | | |
| R Square | 0.029557531 | | | | |
| Adjusted R Square | 0.004019571 | | | | |
| Standard Error | 1463030.42 | | | | |
| Observations | 40 | | | | |
| | | | | | |
| ANOVA | | | | | |
| | *df* | *SS* | *MS* | *F* | *Significance F* |
| Regression | 1 | 2.48E+12 | 2.47736E+12 | 1.157395931 | 0.288789537 |
| Residual | 38 | 8.13E+13 | 2.14046E+12 | | |
| Total | 39 | 8.38E+13 | | | |
| | | | | | |
| | *Coefficients* | *andard Err* | *t Stat* | *P-value* | |
| Intercept | 475581.0825 | 231379.1 | 2.055419263 | 0.046757956 | |
| X Variable 1 | 140494.1267 | 130592.2 | 1.075823373 | 0.288789537 | |

*Picture 1: Output (Winter – Austria)*

1. **The Null Hypothesis**

In the Austrian case during winter, the p-value is estimated to be approximately **0.29**, compared to α (0.05), p-value > α, the p-value is larger than α, so we can accept the null hypothesis, stating that there is no relationship between the variables.

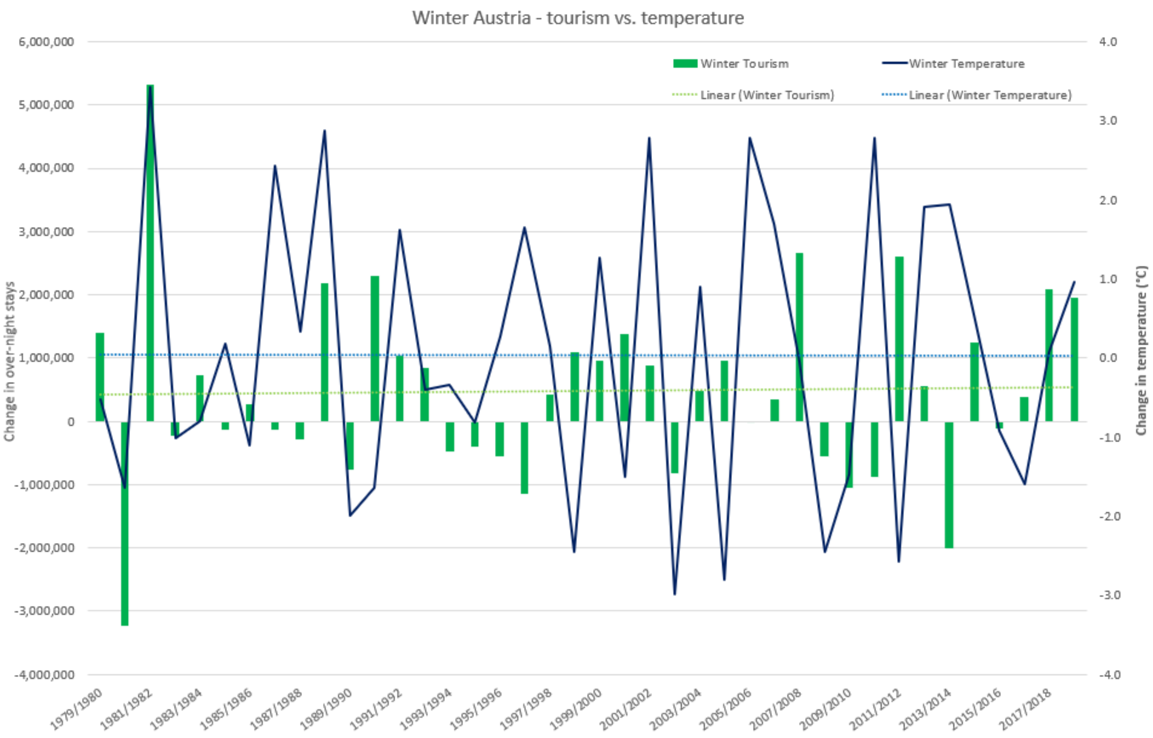
For support of these findings, the t-test can be furthermore also tested. From statistical tables (see Appendix 1) can be selected a number by degrees of freedom and α. The ANOVA results state 39 degrees of freedom which is not present in the tables, so the following lowest number of degrees of freedom can be chosen; in this case, it is 38. To compare the t-test, it is therefore used the number of **1.076** from the regression analysis output and 2.024 from the tables, resulting in $|t| < t_{\alpha(n-1)}$ the $H_0$ can be again accepted $\Rightarrow$ **1.076 < 2.024 and as such, we can proceed with the acceptation of $H_0$.**

## 2. Y and X relationship

**Coefficient of determination = R Square ($R^2$) = 0,0296**. It means that approximately 2.96% of the variability of Y (dependent variable = Over-night stays in Austria during winter) can be explained by the linear relationship between the X (independent variable = Average Winter Temperature) and Y. (In other words: 2.96% of the total sum of squares can be explained by using the estimated regression equation to predict the Over-night stays in Austria during winter).

**Coefficient of Correlation = (r) = 0.172**. This means that there is a very weak direct relationship –between X and Y. The linear sense close to 0, therefore indicates that there is no relationship at all.

*Graph 5: Tourism and Temperature in Austria (winter)*




Source: National Centres for Environmental Information (NOAA), Statistik Austria.

### 4.3.2 Winter – Switzerland

| | | | | | |
|---|---|---|---|---|---|
| *Regression Statistics* | | | | | |
| Multiple R | 0.06396777 | | | | |
| R Square | 0.00409188 | | | | |
| Adjusted R Square | -0.07890047 | | | | |
| Standard Error | 391709.835 | | | | |
| Observations | 14 | | | | |
| | | | | | |
| ANOVA | | | | | |
| | *df* | *SS* | *MS* | *F* | *Significance F* |
| Regression | 1 | 7565076237 | 7565076237 | 0.04930425 | 0.82801241 |
| Residual | 12 | 1.84124E+12 | 1.5344E+11 | | |
| Total | 13 | 1.8488E+12 | | | |
| | | | | | |
| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | |
| Intercept | 91534.5069 | 105804.6519 | 0.86512743 | 0.40393262 | |
| X Variable 1 | -13064.2859 | 58836.0487 | -0.2220456 | 0.82801241 | |

*Picture 2: Output (Winter – Switzerland)*

1. **The Null Hypothesis**

In the Swiss case during winter, the p-value is estimated to be approximately **0.83** compared to α (0.05), p-value > α, the p-value is much larger, and so we can accept the null hypothesis, stating that there is no relationship between the variables.

For support of these findings, the t-test can be furthermore also tested. From statistical tables (see Appendix 1) can be selected a number by degrees of freedom and α. The ANOVA results state 13 degrees of freedom which is not present in the tables (appendix), so the next lowest number of degrees of freedom can be chosen; in this case, it is 13. To compare the t-test, it is therefore used the number of **-0.222** from the regression analysis output and 2.160 from the tables, resulting in $|\mathbf{t}| < t_{\alpha(n-1)}$ the $H_0$ can be again accepted

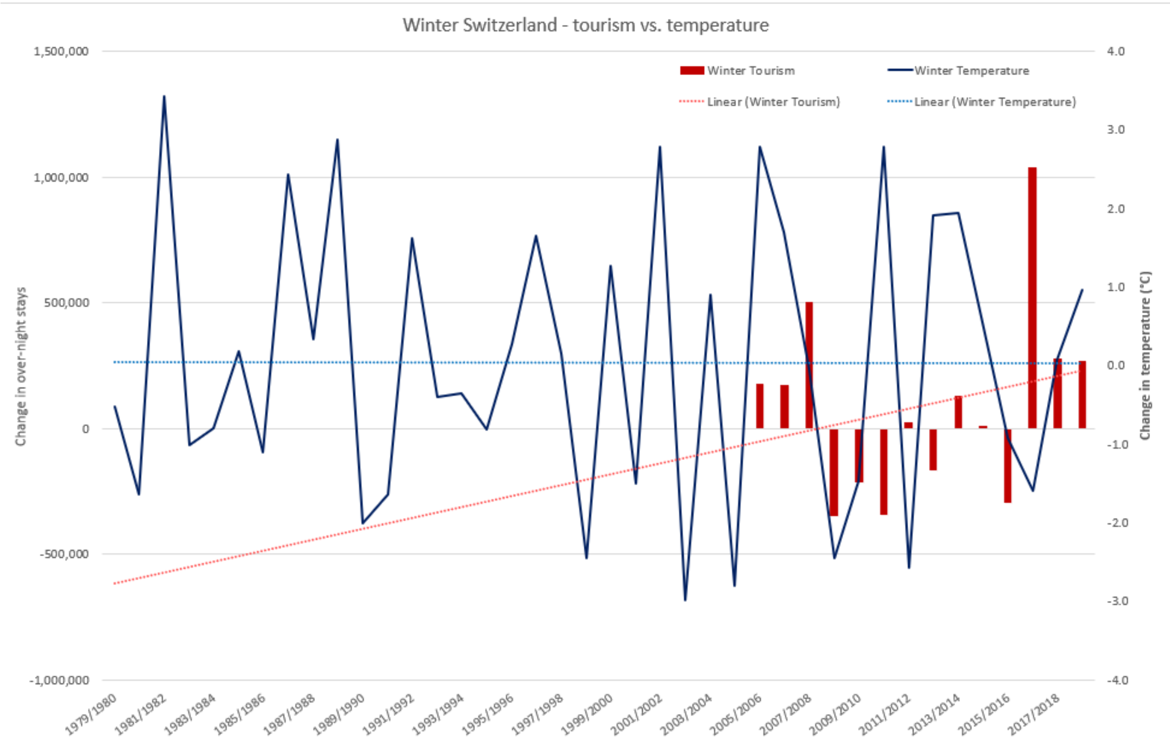
**⇒ -0.222 < 2.160 and as such, we can proceed with the acceptation of $H_0$.**

## 2. Y and X relationship

**Coefficient of determination = R Square ($R^2$) = 0,0041**. It means that approximately 0.41% of the variability of Y (dependent variable = Over-night stays in Switzerland during winter) can be explained by the linear relationship between the X (independent variable = Average Winter Temperature) and Y. (In other words: 0.41% of the total sum of squares can be explained by using the estimated regression equation to predict the Over-night stays in Switzerland during winter).

**Coefficient of Correlation = Multiple R (r) = 0.063**. This means that there is a very weak direct relationship –between X and Y. The linear sense close to 0, therefore indicates that there is no relationship at all.

*Graph 6: Tourism and Temperature in Switzerland (winter)*




Source: National Centres for Environmental Information (NOAA), Swiss Federal Statistical Office.

### 4.3.3 Winter – Italy

| | | | | | |
|---|---|---|---|---|---|
| SUMMARY OUTPUT | | | | | |
| | | | | | |
| *Regression Statistics* | | | | | |
| Multiple R | 0.140505822 | | | | |
| R Square | 0.019741886 | | | | |
| Adjusted R Square | -0.01089118 | | | | |
| Standard Error | 52095.62206 | | | | |
| Observations | 34 | | | | |
| | | | | | |
| ANOVA | | | | | |
| | *df* | *SS* | *MS* | *F* | *Significance F* |
| Regression | 1 | 1749043569 | 1.75E+09 | 0.644463271 | 0.428021671 |
| Residual | 32 | 86846522798 | 2.71E+09 | | |
| Total | 33 | 88595566366 | | | |
| | | | | | |
| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | |
| Intercept | 68591.25232 | 8938.584453 | 7.673615 | 9.55193E-09 | |
| X Variable 1 | -4005.626993 | 4989.665351 | -0.80278 | 0.428021671 | |

*Picture 3: Output (Winter – Italy)*

1. **The Null Hypothesis**

In the Italian case during winter, the p-value is estimated to be approximately **0.43**, compared to α (0.05), p-value > α, the p-value is much larger, and so we can accept the null hypothesis, stating that there is no relationship between the variables.

For support of these findings, the t-test can be furthermore also tested. From statistical tables (see Appendix 1) can be selected a number by degrees of freedom and α. The ANOVA results state 33 degrees of freedom which is not present in the tables (appendix), so the next lowest number of degrees of freedom can be chosen; in this case, it is 33, but again this number of df is not available in the table is the number of 32 df is used instead. To compare the t-test, it is therefore used the number of **-0.803** from the regression analysis output and 2.037 from the tables, resulting in $|\mathbf{t}| < t_{\alpha(n-1)}$ the $H_0$ can be again accepted

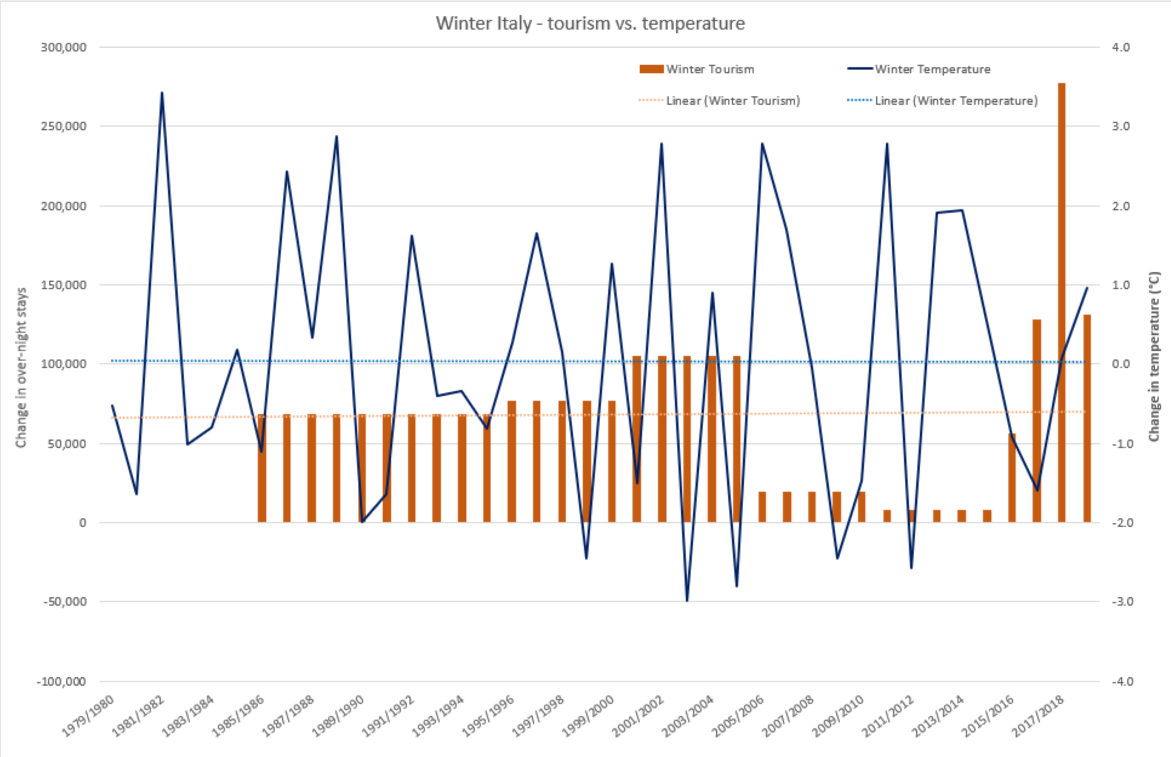
⇒ **-0.803 < 2.037 and as such, we can proceed with the acceptation of $H_0$.**

## 2. Y and X relationship:

**Coefficient of determination = R Square ($R^2$) = 0.0197**. It means that approximately 1.97% of the variability of Y (dependent variable = Over-night stays in Italy during winter) can be explained by the linear relationship between the X (independent variable = Average Winter Temperature)) and Y. (In other words: 1.97% of the total sum of squares can be explained by using the estimated regression equation to predict the Over-night stays in Italy during winter).

**Coefficient of Correlation = Multiple R (r) = 0.014**. This means that there is a very weak direct relationship between X and Y. The linear sense close to 0, therefore indicates that there is no relationship at all.

*Graph 7: Tourism and Temperature in Italy (winter)*




Source: National Centres for Environmental Information (NOAA), Provincia autonoma di Trento.

### 4.3.4 Summer – Austria

| SUMMARY OUTPUT | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| *Regression Statistics* | | | | | |
| Multiple R | 0.207586346 | | | | |
| R Square | 0.043092091 | | | | |
| Adjusted R Square | 0.017910304 | | | | |
| Standard Error | 2113618.276 | | | | |
| Observations | 40 | | | | |
| | | | | | |
| ANOVA | | | | | |
| | *df* | *SS* | *MS* | *F* | *Significance F* |
| Regression | 1 | 7.64476E+12 | 7.64476E+12 | 1.71124 | 0.198682575 |
| Residual | 38 | 1.69761E+14 | 4.46738E+12 | | |
| Total | 39 | 1.77405E+14 | | | |
| | | | | | |
| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | |
| Intercept | -206878.9808 | 335049.5404 | -0.617457886 | 0.54062 | |
| X Variable 1 | -356981.1343 | 272891.3406 | -1.30814387 | 0.19868 | |

*Picture 4: Output (Summer – Austria)*

1. **The Null Hypothesis**

In the Austrian case during summer, the p-value is estimated to be approximately **0.199** compared to α (0.05), p-value > α, the p-value is larger than α, so we can accept the null hypothesis, stating that there is no relationship between the variables.

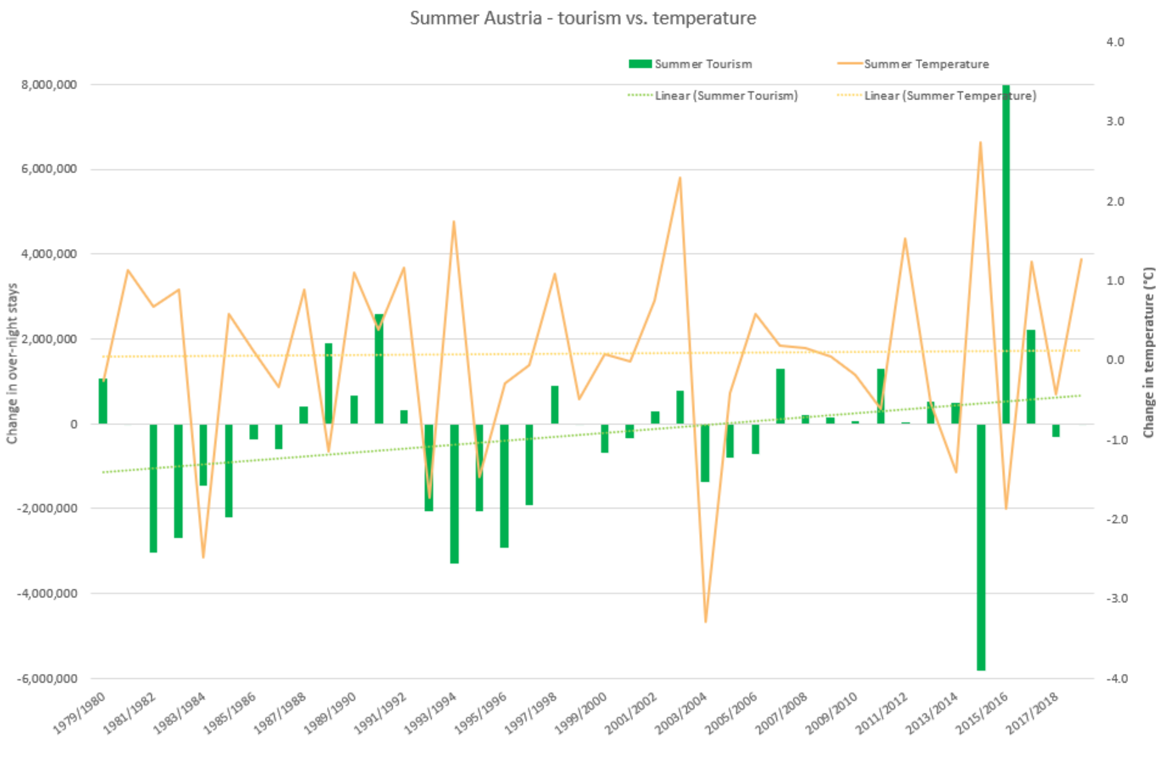
For support of these findings, the t-test can be furthermore also tested. From statistical tables (see Appendix 1) can be selected a number by degrees of freedom and α. The ANOVA results state 39 degrees of freedom which is not present in the tables, so the next lowest number of degrees of freedom can be chosen; in this case, it is 38. To compare the t-test, it is therefore used the number of **-1.308** from the regression analysis output and 2.024 from the tables, resulting in $|t| < t_{\alpha(n-1)}$ the $H_0$ can be again accepted ⇒ **-1.308 < 2.024 and as such, we can proceed with the acceptation of $H_0$.**

## 2. Y and X relationship:

**Coefficient of determination = R Square ($R^2$) = 0,043**. It means that approximately 4.3% of the variability of Y (dependent variable = Over-night stays in Austria during summer) can be explained by the linear relationship between the X (independent variable = Average Summer Temperature) and Y. (In other words: 4.3% of the total sum of squares can be explained by using the estimated regression equation to predict the Over-night stays in Austria during summer).

**Coefficient of Correlation = Multiple R (r) = 0.208**. This means that there is a very weak direct relationship –between X and Y. The linear sense close to 0, therefore indicates that there is no relationship at all.

*Graph 8: Tourism and Temperature in Austria (summer)*




Source: National Centres for Environmental Information (NOAA), Statistik Austria.

### 4.3.5 Summer – Switzerland

| SUMMARY OUTPUT | |
|---|---|
| | |
| *Regression Statistics* | |
| Multiple R | 0.075963747 |
| R Square | 0.005770491 |
| Adjusted R Square | -0.07708197 |
| Standard Error | 625932.4411 |
| Observations | 14 |

| ANOVA | | | | | |
|---|---|---|---|---|---|
| | *df* | *SS* | *MS* | *F* | *Significance F* |
| Regression | 1 | 27287407455 | 2.7287E+10 | 0.06964779 | 0.796327828 |
| Residual | 12 | 4.7015E+12 | 3.9179E+11 | | |
| Total | 13 | 4.72878E+12 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | 64964.05855 | 169493.9826 | 0.38328239 | 0.70821401 |
| X Variable 1 | 37712.7485 | 142900.7499 | 0.26390868 | 0.79632783 |

*Picture 5: Output (Summer – Switzerland)*

1. **The Null Hypothesis**

In the Swiss case during summer, the p-value is estimated to be approximately **0.796**, compared to α (0.05), p-value > α, the p-value is larger than α, and so we can accept the null hypothesis, stating that there is no relationship between the variables.

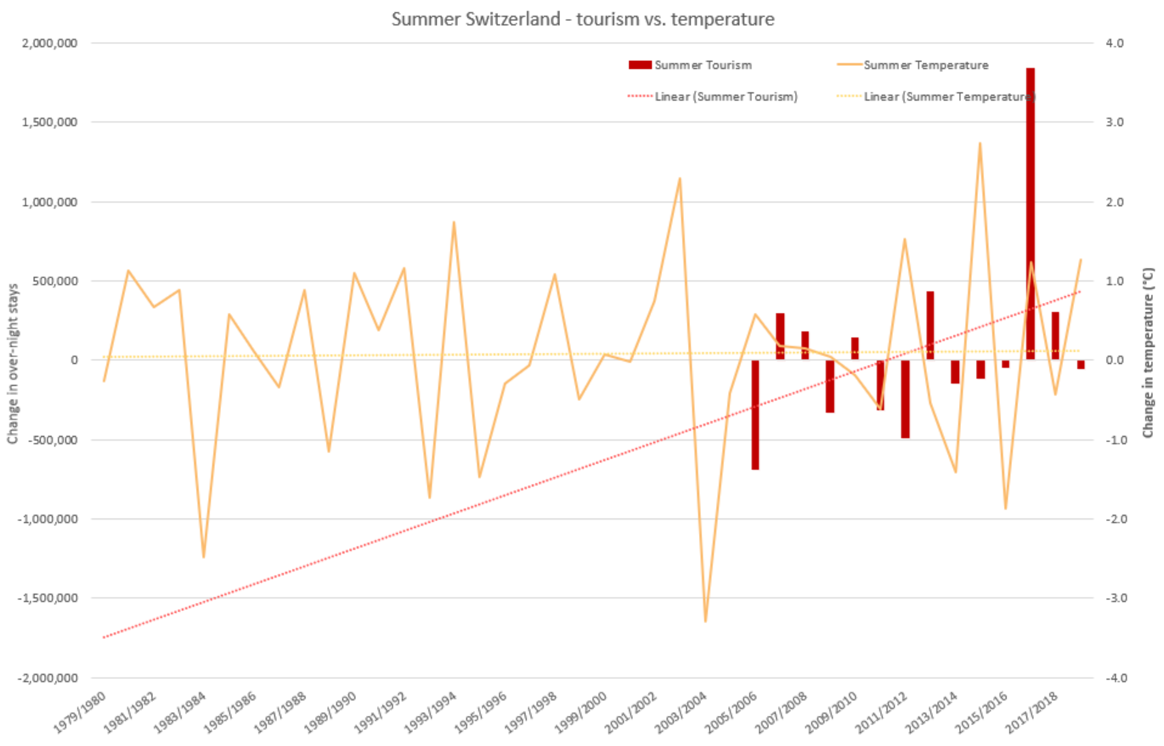
For support of these findings, the t-test can be furthermore also tested. From statistical tables (see Appendix 1) can be selected a number by degrees of freedom and α. The ANOVA results state 13 degrees of freedom which is not present in the tables (appendix), so the next lowest number of degrees of freedom can be chosen; in this case, it is 13. To analyse the t-test, it is therefore used the number of **0.264** from the regression analysis output and 2.160 from the tables, resulting in $|t| < t_{\alpha(n-1)}$ the $H_0$ can be again accepted ⇒ **0.264** < **2.160 and as such, we can proceed with the acceptation of $H_0$**.

2. **Y and X relationship:**

**Coefficient of determination = R Square ($R^2$) = 0.0058**. It means that approximately 0.58% of the variability of Y (dependent variable = Over-night stays in Switzerland during summer) can be explained by the linear relationship between the X (independent variable = Average Summer Temperature) and Y. (In other words: 0.58% of the total sum of squares can be explained by using the estimated regression equation to predict the Over-night stays in Switzerland during summer).

**Coefficient of Correlation = Multiple R (r) = 0.076**. This means that there is a weak direct relationship between X and Y. The linear sense close to 0, therefore indicates that there is no relationship at all.

*Graph 9: Tourism and Temperature in Switzerland (summer)*




Source: National Centres for Environmental Information (NOAA), Swiss Federal Statistical Office.

### 4.3.6 Summer – Italy

| SUMMARY OUTPUT | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| *Regression Statistics* | | | | | |
| Multiple R | 0.110647119 | | | | |
| R Square | 0.012242785 | | | | |
| Adjusted R Square | -0.01862463 | | | | |
| Standard Error | 96125.05877 | | | | |
| Observations | 34 | | | | |
| | | | | | |
| ANOVA | | | | | |
| | *df* | *SS* | *MS* | *F* | *Significance F* |
| Regression | 1 | 3664824829 | 3664824829 | 0.39662491 | 0.53330876 |
| Residual | 32 | 2.95681E+11 | 9240026923 | | |
| Total | 33 | 2.99346E+11 | | | |
| | | | | | |
| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | |
| Intercept | 57140.9618 | 16527.82143 | 3.45725914 | 0.00156301 | |
| X Variable 1 | 8481.82087 | 13467.87584 | 0.62978164 | 0.53330876 | |

*Picture 6: Output (Summer – Italy)*

1. **The Null Hypothesis**

In the Italian case during summer, the p-value is estimated to be approximately **0.53** compared to α (0.05), p-value < α, the p-value is smaller than α, and so we can accept the null hypothesis, stating that there is no relationship between the variables.

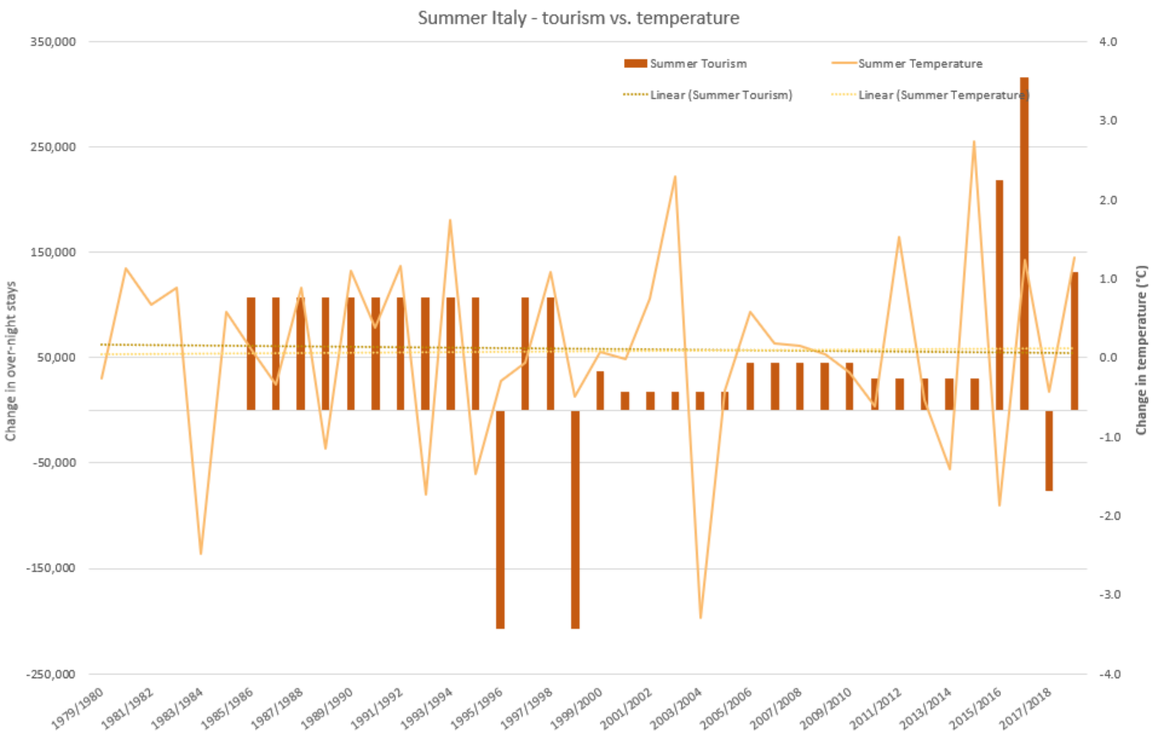
For support of these findings, the t-test can be furthermore also tested. From statistical tables (see Appendix 1) can be selected a number by degrees of freedom and α. The ANOVA results state 33 degrees of freedom which is not present in the tables (appendix), so the next lowest number of degrees of freedom can be chosen; in this case, it is 33, but again this number of df is not available in the table is the number of 32 df is used instead. To compare the t-test, it is therefore used the number of **0.63** from the regression analysis output and 2.037 from the tables, resulting in |**t**| < $t_{\alpha(n-1)}$ the $H_0$ can be again accepted ⇒ **0.63 < 2.037 and as such, we can proceed with the acceptation of $H_0$.**

2. **Y and X relationship:**

**Coefficient of determination = R Square ($R^2$) = 0.012**. It means that approximately 1.2% of the variability of Y (dependent variable = Over-night stays in Italy during winter) can be explained by the linear relationship between the X (independent variable = Average Summer Temperature) and Y. (In other words: 1.2% of the total sum of squares can be explained by using the estimated regression equation to predict the Over-night stays in Italy during winter).

**Coefficient of Correlation = Multiple R (r) = 0.111**. This means that there is a moderate direct relationship between X and Y. The linear sense close to 1, therefore, indicates that there is a strong positive relationship.

*Graph 10: Tourism and Temperature in Italy (summer)*




Source: National Centres for Environmental Information (NOAA), Provincia autonoma di Trento

### 4.3.7 Temperature – $CO_2$

| SUMMARY OUTPUT | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| *Regression Statistics* | | | | | |
| Multiple R | 0.020216375 | | | | |
| R Square | 0.000408702 | | | | |
| Adjusted R Square | -0.025896332 | | | | |
| Standard Error | 1.029409875 | | | | |
| Observations | 40 | | | | |
| | | | | | |
| ANOVA | | | | | |
| | *df* | *SS* | *MS* | *F* | *Significance F* |
| Regression | 1 | 0.016464342 | 0.016464 | 0.015537 | 0.901459624 |
| Residual | 38 | 40.26801828 | 1.059685 | | |
| Total | 39 | 40.28448262 | | | |
| | | | | | |
| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | |
| Intercept | 0.129677442 | 0.559397811 | 0.231816 | 0.817925 | |
| X Variable 1 | -0.035775447 | 0.287012767 | -0.12465 | 0.90146 | |

*Picture 7: Output (Temperature – CO2)*

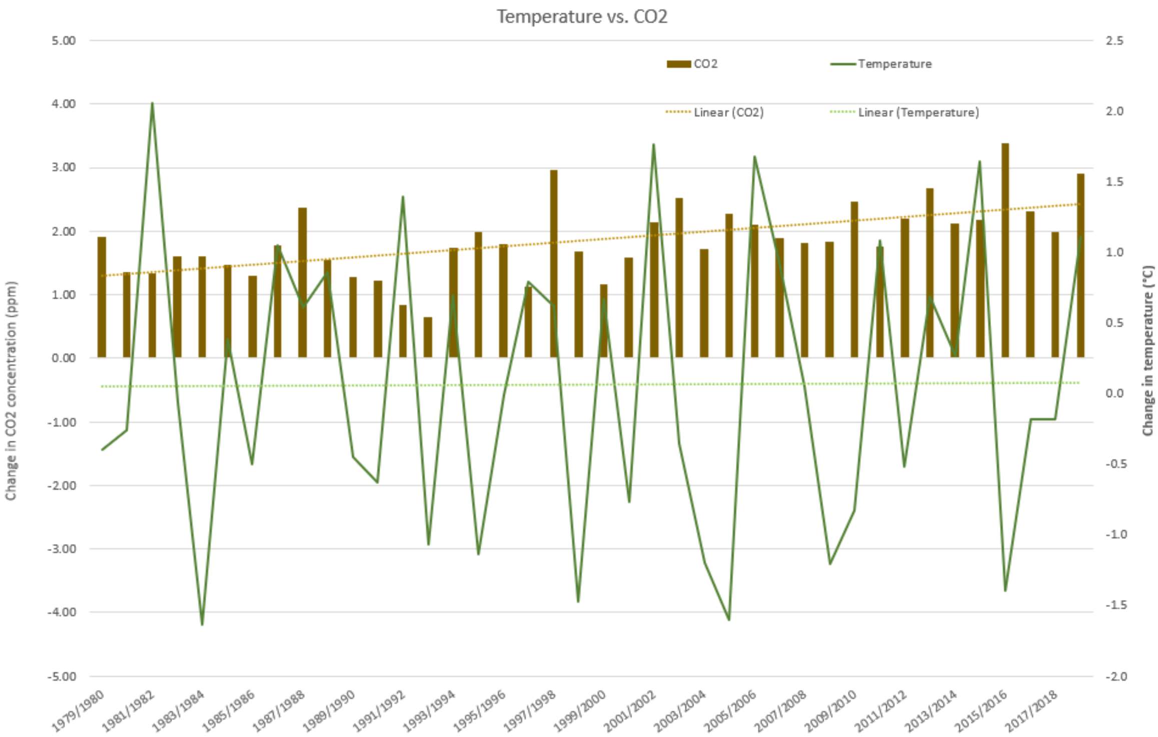
A Regression analysis output provided for the exact same years shows that p-value **0.901** is much larger than α (0.05), so the null hypothesis can be accepted the same for t-test the comparing the output value **-0.125** to table value 2.024, confirms the null hypothesis accept and therefore rejecting the possibility of the existing relationship between the variables.

Further results of the existing relationship are done by Coefficients.

**R Square:** **0.0004** estimates that approximately 0.04% of the variability of Y (dependent variable = Temperature) can be explained by the linear relationship between the X (independent variable = $CO_2$) and Y. (In other words: 0.04% of the total sum of squares can be explained by using the estimated regression equation to predict the temperature).

**Multiple R**; **0.0202**. This means that there is a weak direct relationship between X and Y. The linear sense close to 0, therefore indicates that there is no relationship at all.

*Graph 11: Temperature and CO2*




Source: National Centres for Environmental Information (NOAA), Global Monitoring Laboratory (NOAA)

# 5 Results and Discussion

## 5.1 Temperature and Tourism

| | Winter | | | Summer | | |
|---|---|---|---|---|---|---|
| Region | Austria | Switzerland | Italy | Austria | Switzerland | Italy |
| P-value | 0.29 | 0.83 | 0.43 | 0.2 | 0.8 | 0.53 |
| Hypothesis result | **no relationship** | **no relationship** | **no relationship** | **no relationship** | **no relationship** | **no relationship** |
| Correlation | 0.03 | 0.004 | 0.02 | 0.04 | 0.006 | 0.01 |
| Relationship result | **none** | **none** | **none** | **none** | **none** | **none** |

*Table 1: Overview of Temperature - Tourism Results*

The results of the statistical outputs showed that the observed areas reported no correlation in the case of the relationship between temperature and tourism. For the winter season, the no relationship output means and support theories mentioned in the literature review, and that is, that no matter what the temperature of the current year is, the tourists will visit the Alpine region, they might choose a different destination, but the overall result stays the same. What is interesting about summer and winter results is that the literature review suggests a threat of ageing target market, affecting the economy, but the results instead show an increase in tourism number. Thus, there is a couple of suggestion of what is happening; either a new target market has occurred with different desires or, which is more probably the reason is increasing population. The spurious relationship theory might support this because even though the temperature and tourism results did not show any relationship, it does not have to mean that there is no other relationship between climate change and tourism. The relationship might cause some troubles in the future and should be considered very seriously. For further investigations, more variables can be taken into accounts, such as depth of snow or precipitation to represent climate change or represent tourism; there can be population numbers and HDP and other indicators of improving the economy.

## 5.2 Temperature and $CO_2$

| | CO2 |
|---|---|
| Time | Result |
| P-value | 0.9 |
| Hypothesis result | **no relationship** |
| Correlation | 0.0004 |
| Relationship result | **none** |

*Table 2: Overview of Temperature - $CO_2$ Results*

In the case of $CO_2$ and temperature, the result shows no relationship, and the correlation is fragile. There was also tested a lag between the CO2 and temperature, but no relationship was found. The theory explains that $CO_2$ have an immediate impact, as it enters the Earth's atmosphere, and it takes approximately 30 years before disappearing completely, but the overall $CO_2$ concentration in the air is getting only higher since there are more and more emissions. To answer the problem of the non-existing relationship between $CO_2$ and temperature might be somewhat tricky; one of the first things that have to be considered is that carbon dioxide is not the only greenhouse gas in the atmosphere. The earth atmosphere is also affected by volcanic and solar activity, which most likely do not have an anthropogenic source.

Another significant thing is the natural ups and downs of temperature in history, as this information comes from a literature review in which has been mentioned that the Earth itself does naturally cool down and warm up, but to see this factor, the analysation would need to consider the more extensive insight of data from the past and not just 40 years. Of course, this information or thesis result does not mean that there should be no worries about rising temperature or $CO_2$, the greenhouse gases and other factors are still present, and their concentration is only getting bigger, which impacts the global climate. The Alpine areas are still threatened by massive car movement, which is the primary way of transport in the Alps in all seasons; this can be solved by improving more frequent bus or train transport.

The thesis covers the years from 1979 to 2019; these results might be accurate only before the year 2020. The following study should consider the Covid-19 pandemic situation, which significantly affected the economies and markets worldwide and might positively affect the concentration of emission produced by industry or tourism.

# 6 Conclusion

The work's main goal was to examine the relationship between climate change and tourism and $CO_2$. In conclusion, it is found that there is no steady relationship between rising temperatures and rising traffic, and both examples showed rising streaks both in winter and summer. Thus, the theory of a fluctuating market caused by climate change was refused. On the contrary, the number of tourists is increasing, which might be due to the growing population and improving economic conditions in the 21st century. Regardless of the weather, tourists still show great interest in the Alpine environment in winter and summer. The problem, however, is that in winter, there may be a higher concentration of tourists in destinations with better snow conditions, i.e., at higher altitudes during the warmer winter, which may result in disturbance of Alpine biodiversity and increased local emissions, $CO_2$ transport is also associated with tourist transport.

$CO_2$ itself was compared with Alpine temperatures and did not show a relationship either. Emissions from tourism are a significant part of the problem, such as high air traffic and especially car traffic, where tourists are used to using a car for any movement in the Alps, not only because of their convenient location in central Europe, which is accessible to all who own a car. The temperature does not have to directly adapt to $CO_2$ as there are many more variables to be considered, and therefore further investigation including these factors should be done to confirm this theory on the Alpine case.

The results of rising tourism and temperature say a lot about today's society and its relationship to climate change, and that people tend to avoid the topic. Simultaneously, it cannot be refused entirely that society would not be willing to undergo various regulations to protect the Alpine glaciers and nature in the future. More detailed studies and research are needed for such a determination.

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# 8 Appendixes

*Appendix 1: Statistical table for t-test*

STATISTICAL TABLES 2

**TABLE A.2**

***t* Distribution: Critical Values of *t***

| | | *Significance level* | | | | | |
|---|---|---|---|---|---|---|---|
| *Degrees of freedom* | *Two-tailed test:* | 10% | 5% | 2% | 1% | 0.2% | 0.1% |
| | *One-tailed test:* | 5% | 2.5% | 1% | 0.5% | 0.1% | 0.05% |
| **1** | | 6.314 | 12.706 | 31.821 | 63.657 | 318.309 | 636.619 |
| **2** | | 2.920 | 4.303 | 6.965 | 9.925 | 22.327 | 31.599 |
| **3** | | 2.353 | 3.182 | 4.541 | 5.841 | 10.215 | 12.924 |
| **4** | | 2.132 | 2.776 | 3.747 | 4.604 | 7.173 | 8.610 |
| **5** | | 2.015 | 2.571 | 3.365 | 4.032 | 5.893 | 6.869 |
| **6** | | 1.943 | 2.447 | 3.143 | 3.707 | 5.208 | 5.959 |
| **7** | | 1.894 | 2.365 | 2.998 | 3.499 | 4.785 | 5.408 |
| **8** | | 1.860 | 2.306 | 2.896 | 3.355 | 4.501 | 5.041 |
| **9** | | 1.833 | 2.262 | 2.821 | 3.250 | 4.297 | 4.781 |
| **10** | | 1.812 | 2.228 | 2.764 | 3.169 | 4.144 | 4.587 |
| **11** | | 1.796 | 2.201 | 2.718 | 3.106 | 4.025 | 4.437 |
| **12** | | 1.782 | 2.179 | 2.681 | 3.055 | 3.930 | 4.318 |
| **13** | | 1.771 | 2.160 | 2.650 | 3.012 | 3.852 | 4.221 |
| **14** | | 1.761 | 2.145 | 2.624 | 2.977 | 3.787 | 4.140 |
| **15** | | 1.753 | 2.131 | 2.602 | 2.947 | 3.733 | 4.073 |
| **16** | | 1.746 | 2.120 | 2.583 | 2.921 | 3.686 | 4.015 |
| **17** | | 1.740 | 2.110 | 2.567 | 2.898 | 3.646 | 3.965 |
| **18** | | 1.734 | 2.101 | 2.552 | 2.878 | 3.610 | 3.922 |
| **19** | | 1.729 | 2.093 | 2.539 | 2.861 | 3.579 | 3.883 |
| **20** | | 1.725 | 2.086 | 2.528 | 2.845 | 3.552 | 3.850 |
| **21** | | 1.721 | 2.080 | 2.518 | 2.831 | 3.527 | 3.819 |
| **22** | | 1.717 | 2.074 | 2.508 | 2.819 | 3.505 | 3.792 |
| **23** | | 1.714 | 2.069 | 2.500 | 2.807 | 3.485 | 3.768 |
| **24** | | 1.711 | 2.064 | 2.492 | 2.797 | 3.467 | 3.745 |
| **25** | | 1.708 | 2.060 | 2.485 | 2.787 | 3.450 | 3.725 |
| **26** | | 1.706 | 2.056 | 2.479 | 2.779 | 3.435 | 3.707 |
| **27** | | 1.703 | 2.052 | 2.473 | 2.771 | 3.421 | 3.690 |
| **28** | | 1.701 | 2.048 | 2.467 | 2.763 | 3.408 | 3.674 |
| **29** | | 1.699 | 2.045 | 2.462 | 2.756 | 3.396 | 3.659 |
| **30** | | 1.697 | 2.042 | 2.457 | 2.750 | 3.385 | 3.646 |
| **32** | | 1.694 | 2.037 | 2.449 | 2.738 | 3.365 | 3.622 |
| **34** | | 1.691 | 2.032 | 2.441 | 2.728 | 3.348 | 3.601 |
| **36** | | 1.688 | 2.028 | 2.434 | 2.719 | 3.333 | 3.582 |
| **38** | | 1.686 | 2.024 | 2.429 | 2.712 | 3.319 | 3.566 |
| **40** | | 1.684 | 2.021 | 2.423 | 2.704 | 3.307 | 3.551 |