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Models to evaluate the quantitative effects of climate change on real estate markets

- A first look at approaches and effects -

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Abstract

Purpose – This paper seeks to critically review the existing literature and models on climate change with regard to the effects on real estate markets and examines ways to quantify the impacts within the property industry. By focusing on selected parts of different real estate markets changes in value which are due to the change of climate are disclosed.

Design/methodology/approach – The research is based on hedonic pricing models as well as the results of the general research on climate change in order to identify an improved method for the real estate industry which could serve as a basis for further research concerning the quantified impact of climate change.

Findings – The authors identified that research activity concerning the impact of climate change on real estate markets has to be improved, since climate change has a very strong impact on property markets however until today this field of research has been just about untouched.

Practical implications – The impact of climate change on real estate is very strong. Still practitioners do not react proactively since the effects have not been researched in detail. Especially very fragile regions seem to be very intensely affected.

Originality/value – This Paper indicates one first step towards a new research field which deals with the quantifications of the impact of climate change on real estate markets. Therefore, the quantitative impacts of different scenarios are illustrated and possible methods of quantification are discussed in this paper.

Keywords – Climate Change, Real Estate, Market Value, Multiple-Regression, Welfare loss, Hedonic-Pricing

Introduction & Background

Due to the changes of the global climate, our civilization is confronted with profound transformation which will affect all areas of our lives. In scientific circles it is now generally accepted that a significant portion of the climatic changes is due to human activity (IPCC, 2007). While climate change is better understood we also find a wider range of activities concerning the profound quantitative assessment of risks by ecologists and other research groups. The link between financial markets, the general economy and climate change is very important since climate change can be seen as the biggest "Market Failure" (Stern, 2006, pp. 24 ff) ever – climate change is a result of the negative external effects associated with emissions. Those who created the emissions did not pay for all the costs associated with the usage of the good. The "remaining costs" must be paid by the whole population or maybe even future generations. Therefore all activities to quantify the impact are a strong guidance to economists as well as politicians for decision making. The Stern Report (Stern, 2006) concludes that without further activity against climate change the average temperature change will be similar to the temperature difference between the last ice age and the present. Moreover, recent publications demonstrate increasingly gloomy pictures: While the IPCC-Report of 2001 predicts an increase in temperature of 5,8% until the end of this century, the IPCC-Report of 2007 goes even further and calculates an increase of 6,4% if no counteractions are taken (IPCC, 2007). Such a serious change of the physical geography of the earth will inevitably lead to a change of the human geography, i.e. where people live and how they live.

The costs of extreme weather conditions are already rising due to the increase of natural disasters such as floods, droughts, storms/ hurricanes, hail, mudslides etc. From 1995 to 2005 three times as many natural disasters occurred as in the 1960s. (Source: Münchner Rück). But also the gradual change due to changes in the rainfall patterns and the rising of the global mean surface temperature, as well as water pollution and acid rain are affecting our lives to a great extend.

A high quality of the environment and especially also of the soil, its sustainable usability for agricultural and economic purposes, its bearing capacity etc. are vital location factors. An impairment of the real estate markets is contra-productive for the entire economy. If you take into account that real estate valuation is based on the premise that real estate is valued according to its "highest and best use", it becomes clear that a loss of the utilization method which determines the highest-and-best-use-value leads to welfare loss. This is also true for losses which are due to climate change. Based on this it is surprising that real estate related research has not dealt with this field yet. In general the economic follow-up costs of pollution clearly exceed the annual costs for the protection of the environment (see Brügenmeier, 2006). The follow-up costs of this pollution have not yet been quantified for the real estate market. Very often the quantification of the costs caused has only been carried out insufficiently and/or has not been carried out at all as it is the case for the ground rent and the resulting land value. This is very surprising as land together with labor and capital represents one of the three major production factors according to the production functions of Gutenberg. These introductory considerations already illustrate that climate change will have a strong impact on the construction- and real estate industry. Consequently, market participants are forced to asses risks that have to be reflected in prices, deal with the effects on the land values and adjust their business models according to this new situation.

Present State of Research

Actually, the global climate change is one of the favorite topics of media and the awareness as well as the sensibility of the broad public is growing. Economists nowadays recognize that they have to deal with this topic, particularly since the Stern-Report has quantified the negative consequences of climate change in monetary measures.

Climate change has a number of characteristics which are unique (see in detail Stern, 2006):

- It is global in its causes and consequences;
- The impacts of climate change are long-term and persistent;
- Uncertainties and risks in the economic impacts are pervasive.
- There is a serious risk of major, irreversible change with non-marginal economic effects.
- Originator and persons concerned are usually not identical;
- Negative external effects caused climate change;
- Climate Change is a very complex field and until today not very well understood;
- There is an interaction with other aspects of market-failure;
- Aspects concerning ethics, justice and freedom are also relevant;
- The problem of climate change is inter-generational.

The challenges that arise out of this situation are manifold and turn it into a challenge to convert climate change into a financial figure. In future, there will be a focus on aspects like cause/effect relationships, temporal components of the changes, questions about regional consternation as well as strategies to internalize negative external effects or neutralize developments that are already (possibly) irreversible. Of equal importance is the answer to the question of how every individual can adapt to the changes. All around the world thousands of biologists, meteorologists, statisticians and other experts from various disciplines are working on the above mentioned research questions. For economic analysis aspects like the special restriction of effects, the definition of adequately long time horizons, the implementation of the uncertainty in terms of the input variables and the model structure itself, the consideration of ethics in economic-models etc. must carefully be looked at. It is obvious that a lot of the analytical tools and models used in economics today are likely to fail when it comes to the quantification of the welfare loss and general economic impact of climate change (for further details see Stern, 2006). For example a main reason why probabilities based on historical results must fail is because due to climate change the developed models are constantly changing. Therefore it is not possible to derive probabilities by using statistical data series since these results can be used as an estimator for future volatility of the distribution. All present approaches have in common that the analysis does not focus on the individual economic subject or land but rather on the entire economic costs and welfare loss.

Especially since 2005 a lot of publications and research work have focused on the financial implications and costs of climate change driven by the rising damages, which had to be covered to a great extend by insurance companies like Swiss Re and Munich Re. Since the companies focus on their profit and the needed premiums of the insured climate change has eventually become a more financial figure. The German Max-Planck-Institute expects rising costs of 27 billion € annually in Germany until 2050. Major investors and insurance companies therefore legitimately ask

companies to develop climate strategies in order to secure their assets in the long run (see Bergius, 2006).

Stern, 2006, was the first economist who in depth started to quantify the impact and cost of climate change on a global basis. But also geo-engineering experts like Crutzen (see Schürmann, 2006) start to quantify the costs of climate change or more exactly the costs of reversing the development to more than 50 billion € p.a. worldwide.[1]

Research Structure and Objectives for Real Estate

Land is one of the three elementary production factors and the most significant subject in real estate economics. A large part of the capital in the economy is tied up in real estate, which is why both the function of its pricing processes and the forecasts for pricing trends have always been the most intensively studied fields. The objective of this paper and of the real estate industry in general must be to clarify the relationship between climatic transformations and the resulting changes in land values. For this reason it is necessary to first isolate the effect of the climate on land values and the yield rate generated by the use of land. In order to determine the price changes for real estate, concrete points have to be found that can be transferred into an impact on the prices or indirectly on the expected yield rates generated by the use of land and other input variables for the appraisal process.

Until today climate change has not been a field of research in real estate

The "market value“ of any real estate is the "the estimated amount for which a property should exchange on the date of valuation between a willing buyer and a willing seller in an arm’s length transaction after proper marketing wherein the parties had each acted knowledgeably, prudently and without compulsion.” (RICS, 2003). In the end today's value of land is always the current value of future profit potentials which can result thereof. If this future profit is restricted due to climate change, it has to be considered in today's value. Investment or income methods for real estate appraisal show this relation most clearly since these methods discount future cash-flows to calculate their net-present-value which represents the market value.

Looking at the discount rates which should be used reveals another challenge. A long-lasting, healthy environment has its pay-off in the future instead of the consumption of all the benefits of nature, climate and the entire environment today. Therefore a relatively high discount rate of the future cash-flows will more likely lead to a capital value of the benefits which is smaller than the costs today to achieve the course of events which is in favor from the standpoint of future generations. In other words: if you do not care about your children choose a high discount rate. On the other hand every real estate appraiser knows that choosing a relatively high discount rate expresses also that the investment cash-flows are somehow uncertain, especially when the horizon is very long like in the case of climate change. So even finding the “right” discount rate is difficult but at the same time crucial for the results (see also Stern, 2006).

[1] see Stern, 2006 for further discussion of a more detailed framework concerning intertemporal appraisal, uncertainty, changing population, inequality within generations, market imperfections , etc.

Until now, researchers (e.g. Christaller and von Thünen) have mainly published studies illuminating the influence of demographic and socio-economic aspects on values. Two spheres that have not yet been analyzed scientifically are the influence of climatic conditions on the value of land in depth and the effects of climate change on future real estate values. More exactly, the essential research field that deals with the issue of the effects of climate change on land values has been left almost completely untouched. Neither real estate economists nor climate researchers have drawn definitive conclusions for this particular field. Some universities already deal with the topic of climate change and accelerate the critical examination of complex future implications. In Germany for example the real estate faculties of the Bergische University of Wuppertal as well as the University of Regensburg have started activities in this field of research. A further institution driving research in this field is RICS e.g. with the "Green Value" report (RICS, 2005), which deals with the purpose of ecological investments. It is also particularly noticeable that topics like sustainability of buildings or energy building efficiency are widely discussed, while the topic of this paper did not attract much interest so far.

First the available results of the general climatic research must be scrutinized to determine their relevance for the real estate economy from a qualitative perspective. Hereby one must distinguish between natural disasters caused by climate change (such as storms, hail, flooding, droughts, acid rain, and water pollution) and creeping transformations (such as global temperature increases). Using the comparison method a lot of the value drivers used in this method are directly related to the climate and therefore also exposed to climate change:

- **Defined macro and micro location:** climatic conditions, especially illumination, sun, wind, emissions (noise, smoke, dust);
- **Soil conditions of the location:** surface formation, natural cover, bearing capacity, ground water conditions, mud slide areas, exposure to dangerous areas (flooding, avalanches, torrents).

Even a very superficial review reveals that the impact on the use of land and the connected yields generated is very powerful:

- **Migration:** E.g. about 200 million people of coastal regions will not be able to enjoy their familiar quality of living and will therefore move inland.
- **Destruction:** Vast regions of Africa and the Mediterranean will be destroyed by decreasing precipitation and will not be economically usable anymore, e.g. Holiday destinations could lose much of their appeal, hotels must expect smaller occupancy rates and the demand for vacation homes could decrease which would lead to sharply falling prices.
- **Increasing operating expenses:** Buildings need to be equipped with air condition, which will lead to higher construction costs al well as higher operating costs. Moreover, the high demand for electric power during the summer is likely to overload power supply systems and lead to a growing number of collapses.

- **Decreasing crop yields:** Certain regions will have to face decreasing crop yields

- **Melting of the glaciers:** As mountain glaciers disappear the potential threat to water supplies in several areas rises and during the transformation mud slides are likely to happen.
- **Change of water distribution worldwide**: Significant changes in water availability will lead to increasing expenses for the distribution and/or migration will be encouraged
- **Rising sea level:** Reduces the habitat which can be used by human beings and leads to flooding etc.
- **Fragile ecosystems collapse:** A large fraction of (especially more fragile) ecosystems will be unable to continue at existing forms (rainforests, Alps, Coral reef etc.)
- **Protection costs** for extreme weather events will rise (like for storms, forest fires, droughts, flooding and heat waves etc.), e.g. the increasing number of heat waves could badly affect streets and other infrastructure.
- **Change of construction methods and operating costs:** Rising operating costs e.g. for cooling. For example the unequal distribution of precipitation will more frequently lead to torrential rain with its respective requirements on infrastructure.

Specific examples of places that have already experienced irreversible changes concerning the environment and therefore also land value include the following: Austria in areas where high-risk zones because of floods or other climate change related risks were extended after the deluges; in Greece in the regions afflicted by forest fires; and in Florida where there has been an increase in the damage caused by hurricanes.

In the following sections three new approaches are drafted, which are the basis for a further quantification for the monetary implications of climate change on the value of real estates. These approaches will be starting points for future investigations in this field of research.

Approach I: Using (rising) insurance premiums as a proxy

One possibility to deal with the negative consequences of climate change is focus on insurances. Due to the fact that every insurance company calculates risks according to the combination of probability of occurrence (1) and amount of loss in the case of occurrence (2), the amount and trend of insurance premiums enable us to identify the effect of climate change. Therefore the premiums of insurance companies are on the one hand modeled by the loss amounts an insurance company has to expect and on the other hand by the return periods of natural hazards. As already mentioned, the number of extreme weather events due to climate change will increase. As a result the insurance industry will be obliged to adjust their premiums for property insurance and so the running costs of exposed buildings will increase. In the future buildings which are actually not directly affected by natural hazards could get jeopardized. The cost of insurance cover reduces the net revenue of the building and therefore the value of the subject property when using income approaches to convert future benefit into a present value.

In that approach the regional risks are also included because the insurance companies differentiate the rates because of factors and questions like:

- Frequency of climate environmental disasters (e.g number of floods, hurricanes, forest fires)
- Structural measures against that influences (e.g. bulkhead against water)
- Security instruments (e.g. distance to the next fire brigade).

On of the extreme weather events that could be covered by insurance are floods. Especially in the Alps the risk from river flooding and flash floods will increase significantly. In general the insurance industry defines flooding as a temporary covering of land so that surface waters escape from their normal confines. Flooding could also be the result of heavy precipitations in a special region. Three main types of flood can be distinguished:

- **Storm surges** along the coasts of seas and big lakes have the highest loss potential of water-related natural events concerning the human loss and the loss of property
- **River floods** are the result of intense and/or persistent rain for several days. The area affected can be very large in case of flat valleys as a result of wide flood plains. At narrow valleys the damage is restricted to a small strip along the river but the water depths are great and flow velocities tend to become high so the mechanical forces and sediment transport play a major role as a cause of damage
- **Flash floods** following an intense rainfall over a small area with a sudden onset will create a surge running down the valley. Propagating very quickly the floodwave can reach locations that are far away where the rainstorm was not even noticeable. Flash floods occur in a relatively small area and last only a few hours but have an incredible potential for destruction.

The basic principle of insurance is that the sum of premiums should cover the sum of loss, both over a certain time. For example a potential loss of 400.000 Euro which is expected to occur once in 100 years has to be balanced by a technical annual premium of approx. 4.000 Euro – leaving aside aspects of discounting. This very simple paradigm shows us the coherence between premiums and the probability of occurrence. Another very important criterion for the calculation of premiums is the concentration of values in areas of high population density.

For the modeling of natural hazards insurance companies use hazard maps for the loss potential estimation. The main principle of risk can be described as a function of hazard (internal and external scientific input), vulnerability (loss experience of the insurance company, analysis of historic natural hazards) and the exposed values (individual exposure of the insurance company). With a set of scenarios and statistics the individual risk curve can be modeled (expected loss / loss occurance probability).

As *Bin et al.* have shown, the effects of exposures to natural hazards can influence property prices in different ways. The study for the state of North Carolina examined that the impacts of coastal flood events on residential property prices can vary strongly. As expected researchers discovered that locations within a floodplain lowers the property prices between 5% and 10%. Interestingly locations exposed to hazards from wave action increases property values. It seams that the substantial amenity values of property with direct access to the beach are very high. A relatively high flood insurance premium in coastal areas seems inconsequential in determining property values. An explanation for this could be that the current flood insurance program only covers the

building and the contents but not the land. But the coastal erosion due to the rise of sea level and coastal storms could lead to loss of capital assets in coastal communities.

In their study about the impacts of the flood zone status on housing prices *Harrison et al.* discovered that the price differential is less than present value of future flood insurance premiums. It seams that the relative importance of flood zone location appears to be increasing over the time.

The main problem of that approach is that assurances cover just damages for the insured object and cannot cover damages on the whole economics. The most common insurance contracts cover just damages on buildings, but not the value decrease of the land, of crops or losses on tourism. A very simple example shows that the later ones can be huge in value and are in most cases very long-lasting. A good example for the “non-insured” monetary consequences on land prices is Greece. The huge forest fires in 2007 destroyed approx 5 Mio. Olive trees, which represents approx. 5 % of the total amount. Taking into account that the Greece Olive-market has a total value of about 9 Bio. € the reduction caused by climate change amounts to approx. 450 Mio. €.

Approach II: Using multiple regression and hedonic pricing models

Hedonic pricing models attempt to decompose the given housing prices into their value drivers by using multiple regression models. However, until now these analyses have focused on the influences of infrastructure, population density and other socio-economic aspects within the framework of hedonic pricing models. Some environmental factors like crime, neighborhood, earthquake risk, air pollution and climate where also analyzed (see Gyourko, Kahn and Tracy (1999)). Leaving other variables constant, how much lower would the market values be in a city with a mild climate compared to hot climate? Hedonic pricing models are useful to disclose the marginal consumer’s preference for different value drivers which together are the market value. Levitt (2004), Costa and Kahn (2003) and others estimated how the hedonic price of a non-market good like "climate" can be estimated and how it has evolved as well as how hedonic valuation might be affected by shocks like new laws. This field of research can be called "cross-city hedonic quality of life literature". It has existed for approx. 25 years and its results and hypotheses are a very useful foundation for further research on climate change and its impact on real estate markets.

There are some reasons why the use of hedonic pricing models to estimate the cost and the impact of climate change have been an untouched research field until today. This is mainly because (1) hedonic pricing models analyze historical data and climate change is a dynamical process with a lot of the results only visible in the future and (2) because climate change is a complex topic with a lot of variables interacting and (3) because uncertainty is inherent when talking about climate change. Still hedonic pricing models can help a lot. Since they can disclose the value of “clean air” in one city and “dirty air” in another, there are possibilities to come up with a price for an aspect of climate. Given the models for climate change with the projection of future events both aspects together enable to calculate the impact of further air pollution on the housing market in the location being appraised today. However the problems of interaction, uncertainty, time-preference and changing consumer preference still need to be addressed. The uncertainty of floods for example could be captured by using existing concepts like the probability of occurrence and the expected amount of loss to evaluate the results.

Approach III: Using experts' views and proxies to calculate the impact on real estate related variables

Expert interviews and surveys provide information on how the input variables for the valuation of real estate (markets) will change. It is worth considering the functional chains, i.e. responding to the question of how the climate will influence e.g. macroeconomic values and how they are linked with the real estate industry. However, it is problematic that the functional chains have not been researched in depth. As the first results concerning the expected revolution (see Stern, 2006) already exist on the macroeconomic level, it is possible to make rough estimates already now. We will come back to this aspect when dealing with a simple case study for Tyrol.

It is also helpful to continually observe various variables prior to real estate values as they are exposed to visible changes already now due to climate change. Among these points are the prices of renewable resources (e.g. oranges or nutmeg), price quotes for climate certificates, the development of insurance premiums, changes in the GDP dynamics of affected regions, increasing preventative costs related to construction measures and other measures for containing forest fires.

Questions beyond today's research activities

Concerning real estate markets the quantification of the impact of climate change has just reached its starting point. A lot of research questions that have not been discussed in detail until present have to be addressed:

- What can the real estate industry contribute to the internalization of negative externalities and to what extent can irreversible damages be avoided?
- What is the advice real estate researchers can communicate to real estate investors in order to build up their (long-term) investment plans and strategies which incorporate climate related aspects?
- Are there also opportunities for the real estate industry or do we just face threats? Is it possible to reveal real estate markets that present themselves as "windows of opportunity" which could profit from environmental change and would otherwise have escaped the focus of investors?
- Is there a possibility to come up with a more detailed quantification of the costs and maybe benefits of climate change for different regions?
- How do decision makers process information with regard to real estate investments and what is the influence of uncertain future events like climate change? Is the information processing of the players sufficient or is climate change not yet considered sufficiently in the current land values?[2]

In this respect, it would be exemplary to answer the question of why the real estate prices in Spain have risen exorbitantly in the past few years, even if the market participants must be fully aware of the long-term forecasts for the Iberian peninsula (here it will be important to separate climate from the other components in the pricing processes).

Based on these results, an "Ecological Change Impact Index on Real Estate Markets (ECIREM)" should be developed in the middle term. This index must include a feature that makes it possible to continuously enter and update data automatically collected from the various existing climate models. It would probably be sensible to differentiate the index, so that the impact within different timeframes (e.g. 10, 20, 50 yeas) would become more transparent. The Index would cover a global database, whereby Europe will be studied more closely.

However, besides the negative effects addressed in previous sections, climate change also will provide new opportunities: A moderate increase of mean temperature will, according to the Stern-Report, lead to higher crop yields, lower death rates in winter, lower demand of heating energy as well as a to positive effects for tourism. Thus, land prices in parts of Russia, Canada or Scandinavia are likely to grow.

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[2] Remark: There is strong evidence that the relevance of the climate change is still underestimated – in fact also by professional participants of the market like e.g. property insurers (Lansch, 2006).

Of course, real estate derivatives are in fledgling stages at present, but they offer a good chance to initiate a connection to climate data, comparable to weather derivatives which are already established in market. Successful placements of products which deal with topics like “Global Warming” or renewable energy show that such “climate matters” are recognized as “stories” on stock exchange. Investors successfully integrating climate issues by considering related economical long term trends – nowadays known as “Global Macro” Strategies – currently benefit form their assets.

Parts of agriculture will also benefit from a growing demand of renewable fuels like canola, bio-ethanol etc. For example, in the state of Iowa 21 bio-ethanol facilities already exist, further are in planning stage. While Iowa used to be an exporter of crop, this state will become a net importer in the near future. Generally, it is not clear at this point of time to what extend the growing demand of renewable materials will exceed the negative effects of climate change. In Czech Republic e.g. 50% of forest stand are marred by the higher temperature, lower rainfall and more windbreaks. Climate change also leads to an increasing incidence of bark beetles which e.g. also jeopardize the Austrian forest stand. The market participants of forestry also call into question, if they can provide sustainable materials to a sufficient extend in future.

From a project developer’s and real estate marketing point of view, it was a substantial deficit that demand did not response sufficiently to supply in the past, by not paying attention on sustainability of buildings. In this context it should be mentioned that actually a change in public opinion is recognizable. Real estate market participants all across the European Union pay more and more attention to energy efficiency of commercial buildings. One reason for this trend is the introduction of the energy certification for buildings according to directive 2002/91/EC of the European Parliament and the Council of 16 December 2002 (EPD, 2002). Consequently, large building projects as e.g. the Generali-Tower and the La Phare in France are being developed on basis of an forward-looking and sustainable concept. Moreover in England a group of market leaders in construction- and real estate industry has established a program which tries to identify strategies to reduce CO2 emission of new buildings.

Quantification of the climate impact on the Austrian lodging industry

a) General overview

In this first step the paper only focuses on areas which require further and more intense analysis. Therefore the first step does not yet try to fully connect the econometrics of the real estate markets with the current climate models or to show an entire presentation of the monetary effects of the real estate markets based on the occurrence probability of climate scenarios.

In this first analysis we focus only on negative market impacts that can already be “measured”. We use a ceteris paribus model and also leave out the possibility that positive changes might occur (like an increase in the corps production at higher altitudes, higher price for clean power production etc.). In this example we derive the climate change from expert statements and empirical studies representing the current doctrine as well as the state-of-the-art of climate experts. So based on these scenarios of climate change the current real estate values have to be transferred into their expected value in order to quantify the effects of climate change. In this context it is of major importance that the current real estate values did not yet consider the effects of climate change because in this case redundancies would jeopardize the significance of the result. At this point two

alternatives can be chosen. The first alternative are hedonic pricing models. Value drivers which are calculated within multiple regressions are the link between the situation for climate A and the situation for a new climate B. For this purpose it has to be proven empirically how much more a piece of land at location C with the feature "180 days of complete snow cover p.a." costs compared to a similar piece of land with the feature "170 days of complete snow cover p.a.". Of course, the expected difference in value has to be discounted in order to represent the current value of welfare loss. However, it is easier – and this is our choice for this example – to use e.g. an average investment value of the past x-years which means largely without climatic elements. Based on the climate models certain real estate input parameters are again changed. However in this case the change only relies on expert assumptions which are supported by climate data and conclusions about chains of cause and effect. Even if the latter method can be questioned concerning the chains of cause and effect which are only verbally substantiated, a first impression of the quantitative welfare loss for the purpose of an awareness analysis can be gained.

This study seeks to examine an especially fragile ecosystem like the Alpine region, taking Tyrol – a region in Austria - as an example. In Tyrol the following effects relating to land value relevant aspects of climate change can be observed:

- **Melting glaciers and shorter winters:** As mountain glaciers disappear the potential threat to water supplies in several areas rises and during this transformation mud slides are likely to happen.
- **Change of water distribution:** Significant changes in water availability will lead to increasing expenses for the distribution and/or migration is encouraged.
- **Fragile eco systems collapse:** A large fraction of (especially more fragile) ecosystems will be unable to continue at existing forms (rainforests, Alps, Coral reef etc.)
- **Protections costs increase** for extreme weather events will rise (like for storms, forest fire droughts, flooding and heat waves etc.). In Tyrol especially high costs for protective measures concerning avalanches, mud slides, early warning systems, flooding etc. have to be taken into account.
- **Expansion of the security zones:** The non-constructible areas due to increasing natural hazards have lately been expanded considerably in Alpine regions. These areas are not at all (red zones) or only partly constructible (yellow zones). Compared to land without these restrictions significant value losses can be stated due to the expansion of these areas.
- **Change of construction and operating costs:** Rising operating costs e.g. for cooling. Or for example the unequal distribution of precipitation will more frequently lead to torrential rain with its respective requirements on infrastructure.
- **Decreasing income potentials:** Due to shorter winters and rising snow lines Tyrol's most important source of income – winter tourism – will be impaired in a sustainable way. Cable car owners currently have a turnover of approx. 40 million € and the accommodation industry of approximately 1.1-1.2 billion € in the winter season only.

For Tyrol the year 2006 was the hottest period in 1.300 years (ZAMAK, 2006). The effects of climate change are more severe in the Alps than in less fragile regions.

b) Example: Impact on the lodging market

We are only focusing on winter tourism which represents 60% of all overnight stays. The turnover share of the winter tourism amounts to approx. 70%, especially because per-capita expenses and occupancy rates are higher in winter than in summer. Tyrol is the province with the biggest share of Austria's winter tourism with 42.4% of overnight stays (Source: Landesstatistik Tirol).

Different research projects show that winter tourism in the Alps will be severely affected by the forthcoming changes that are already irrevocable. It is already accepted that the closing of ski resorts which are at an altitude of less than 2.000m is a probable scenario since the snow line will rise by approx. 400m. Tyrol offers approximately 7,200 hectares of ski slopes with approx. 1,200 lifts and cable cars which achieve an annual turnover of approx. 400 billion € (2001). The annual investment amounts to approx. 180 million €, 23 million € of which are used for the production of snow in 2001 – an upward trend (Chamber of Commerce Tyrol). While the share of artificially snowed slopes was 45% in 2001, it has risen to 80% in 2006 (Gasser). In 2001 86 Tyrolean lifts were closed due to inefficiency, but the construction of new lifts at higher reaches compensated for this again (Ludescher, 2001). About a third of the 70 Tyrolean ski resorts are below an altitude of 2,000m and will therefore be concerned most by the effects of climate change. During the winter season 2006/2007 ski resorts which are situated at lower altitudes have experienced a reduction of turnover and frequency of up to 80% due to lack of snow (Chamber of Commerce Tyrol, Section Cable Cars). A considerable move towards ski resorts at higher reaches with slopes that are well maintained and up to now in perfect snow condition can be observed. As the current climate predictions assume also the melting of very high glaciers it is disputable whether intensified investment in these areas is really profitable. Already today the winter season starts approx. 3 days later and stops again 3 days earlier which means that it is gradually becoming shorter. And so far the operators of ski facilities are all reacting the same way: they buy more snow machines, e.g. SkiWelt, one of the biggest ski resorts with an annual turnover of 43 million €, operates 400 snow machines.

During the past 10 years the average overnight stays amounted to 23,120,000 p.a. in winter. For this period the average number of beds was approx. 307,000. The winter season starts on 1 November of the previous year and ends on 30 April of the indicated year and thus comprises 181 days. This leads to an average occupancy rate of beds for all types of accommodation of approx. 42%. The turnover per overnight stay in a bed and breakfast in Tyrol amounts to approx. 50,- €. If you deduct the costs of the breakfast of approx. 5,- €, the share of accommodation (without taxes) amounts to approx. 45,- € per overnight stay (Source: Landesstatistik Tirol).

	Gross Revenue (Turnover)
-	Gross Expenditures
=	Gross Profit
-	Tenant's Expenditures
-	Tenant's Share
=	Ratable Value (Rental Revenue)

- Other Operating Expenses
= Net Operating Income to Owner

It is assumed that approx. 25% of the turnover remains with the owner of the real estate as ratable value or rental revenue. After deducting the approx. 15 % of the operating expenses the remaining cash flow must be discounted to appraise the property. The capitalization rate for hotel valuations is approx. 6,75 %. In agreement with the theories according to international approaches of valuation this revenue is considered to be perpetual rent.

Example Part I.: Direct capitalization of one stabilized year	
Scenario I.: Average Capital Stock based on historical data	
Number of Beds	307.000
Stabilized Occupancy in %	0,4158
Stabilized Revenue per Night (incl. Breakfast) in €	50
Breakfast portion in €	5
Stabilized Revenue per Night (excl. Breakfast) in €	45
Days of Operation in the Winter Season	181
Stabilized Total Revenue in the Winter Season in €	1.039.714.137
Rental Revenue in %	0,25
Rental Revenue in €	259.928.534
Operation Expenses in %	0,15
Net Operating Income to Owner in the Winter Season in €	220.939.254
All Risk Yield (Discount Rate)	0,0675
YP in perpetuity (Year's Purchase)	14,81
Net Income × Year's Purchase = **Capital Value Contribution of the Winter Season** in €	**3.273.174.135**
Value contribution per Bed	10.662
Value contribution per Room (with two Beds per Room)	21.324

Table 1: Using *Direct capitalization* to appraise the Capital Value Contribution (this strongly simplified example illustrates the issue)

This results in a capital stock contribution based on the NOI-Contribution of the average winter season of approx. 3.3 billion € based on the above mentioned theories and without influence of climate change.

Against the background of climate change the input data for the valuation of the capital stock are changed accordingly. This first, simple example is primarily used to show how the change of climatic variables influences the input parameters of the real estate market. The changing variables are the operation days, the occupancy rate, the average revenues as well as the risk of the investment. All aspects can be quantified. It is a realistic scenario that e.g. the operation days are shortened due to the late start and early end of the winter season. The chosen duration of a total of 5 days represents the lower end of the predicted future development.

Example Part II.: Direct capitalization of one stabilized year	
Scenario II.: Increasing Average Temperature of 2 °C	
Number of Beds	307.000
Negative Impact on Occupancy in %	-0,05
Adjusted Stabilized Occupancy in %	0,39501
Negative Impact on Revenue in %	-0,05
Adjusted Stabilized Revenue per Night (incl. Breakfast) in €	47,5
Breakfast portion in €	5
Stabilized Revenue per Night (excl. Breakfast) in €	42,5
Negative Impact on Days of Operation	-5
Adjusted Days of Operation in the Winter Season	176
Stabilized Total Revenue in the Winter Season in €	907.085.164
Rental Revenue in %	0,25
Rental Revenue in €	226.771.291
Operation Expenses in %	0,15
Net Operating Income to Owner in the Winter Season in €	192.755.597
Negative Impact on Discount Rate	0,0025
Adjusted All Risk Yield (Discount Rate)	0,07
YP in perpetuity (Year's Purchase)	14,29
Net Income × Year's Purchase = **Capital Value Contribution of the Winter Season** in €	**2.753.651.390**
Value contribution per Bed	8.970
Value contribution per Room (with two Beds per Room)	17.939

Net Capital Loss in %	0,16
Net Capital Loss in €	**519.522.746**

Table 2: Appraising the Loss of Capital Value due to Climate Change
(this strongly simplified example illustrates the issue)

Of course this calculation is far from being perfect. On the one hand one could argue that e.g. the winter season is shortened, but that the problem can be solved with the aid of snow machines. However, this leads to enormous costs which would have to be taken into account in in-depth analyses. On the other hand it is legitimate to ask why the risk of investment – represented by the increase of the discount rate – is increased in this way. Indeed this field has to be analyzed critically and furthermore the actual increase must be examined scientifically and empirically. Income effects which concern the 33,000 employees of the tourism industry as well as the approx. 6,000 employees of the cable car operators are not yet taken into account either although they have a (negative) influence on the real estate market and lead to an aggravation of the mentioned changes. Revenues resulting from the clothing industry (winter sports goods) and gastronomy are not considered etc.

Nevertheless the first interpretation of the result is of major interest. Obviously the effect on the real estate capital stock of society with its 500 million € is highly remarkable. This welfare loss becomes reality already when the above mentioned minor changes of the input parameters provable by

realistic climate scenarios occur. As only a minor fraction of the concerned areas of the entire Tyrolean real estate market could be dealt with in this analysis, there is a serious need for further research in this field.

Resume

With this paper a contribution has been made to opening the climate discussion also to a larger audience in the real estate economy, and to showing a number of ways how to approach the calculation of the forthcoming changes.

So far neither national nor international researchers have succeeded in uncoupling the economic growth from the use of non-regenerative resources. The quantification of all follow-up costs and value losses which are due to climate change is a fundamental prerequisite for the long-term enforcement of resource prices taking into account also the negative external effects. It is recommended that the real estate industry more actively focuses also on the long-term development of assets in their investment appraisal methods. This also includes the signals – considered to be weak by some real estate experts – of the climate scientists. It is problematic that currently the structural change due to climate change is not sufficiently perceived as a sustainable change yet. Fahrholz (2006) showed that many winter sports resorts meet this change rather passively and with obsolete strategies instead of facing the issue proactively. For this reason the negative effects of climate change will hit these regions especially hard.

The real estate industry can obviously contribute a reasonable as well as considerable part to the current "climate debate". Especially when considering the big share of real estate bound assets of the national economy this aspect is highly important. In order to solve the challenges due to negative external effects only an internationally coordinated approach makes sense. Results of the real estate research may provide decision makers with the necessary input in this context.

However, this topic has only become part of public conscience in terms of a problem of the state or large industrial corporations and has not lead to a change in the actual behavior of economic agents so far. Exemplarily, this becomes clear if you consider that 93% of German inhabitants have not changed their attitude towards long-distance trips despite possible effects on climate change. This pattern of behavior is especially noticeable in real estate economics: a recently published study by the real estate company *Donaldson* assessed that still the best yields can be achieved from commercial real estate that comply least to sustainable requirements. This is yet one more indication that the discussion about climate change has not yet reached the individual’s consciousness.

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