Title: Quantitative technique for pricing and managing risk, with applications in finance and tourism

Brief introduction

Nowadays the information technology (IT) allows for the use of pricing models that are financial market consistent, so that firms can adjust prices by exploiting the functionality of the stock markets, which has led to the so-called "financification" of the strategic pricing function in the firm (Kauffman and Lee, 2010). In the "big-data era" - the Internet provides a unique technological context for performing micro-level analyses of price-setting behaviors and strategies in those productive sectors that have moved a large part of their selling activity online. Tourism is certainly one of these. In fact, modern approaches to dynamic pricing have become more and more sophisticated, with stochastic demand forecasting being the core of the algorithms that are employed for jointly optimizing assortment and prices (Li and Talluri 2020).

In parallel, the recent financial crises have brought the issues of option pricing, hedging and portfolio risk management to the fore of the financial literature (Mostafa et al., 2017). The field of risk management has developed rapidly, also in response to both the increasing complexity of financial instruments and regulation of the financial service industry. New structured and controlled approaches to risk evaluation are developed and we believe that there is room to study how strategies and analytical techniques for managing pure financial risk (aiming at optimizing the trade-off between expected profit and risk) can be translated and adapted to enterprise risk management (aiming at creating competitive advantages for enterprises), making the risk management practice more multidisciplinary.

Background and statement of the problem

The main objective of this research project is to develop new quantitative methods to forecast and handle corporate risks, with the purpose of protecting the operators' profitability under adverse changes in the operative setting. The effect of these changes can manifest in either the short, the medium or the long term.

Regarding the long-term operational risk, the activity will focus on compound climate events (events that result from the combination of multiple drivers and/or hazards, which collectively lead to a socioeconomic and/or environmental risk – see Zscheischler et al. 2018), pointing out the role of non-linear and non-parametric modelling to obtain a realistic representation of the true data-generating process for the climatic risk. That way, we will be able to suggest hedging strategies for protection of tourist resorts' profitability against adverse climate conditions, identifying the best-performing hedge portfolios with periodic reset of climate options.

Concerning the mid-term operational risk, the COVID-19 pandemic forces Governments to periodically introduce/revoke mandates of social distancing. This is determining new seasonal patterns while tourists themselves tend to travel short distance (Gössling et al., 2020). The

reshaping of both the destinations' source markets and seasonality do to the pandemic, translates into a new risk factor that change the balance between benefits of agglomeration and damage of spatial competition. This calls for new tools to measure the risk of failure/temporary shutdown of tourism enterprises.

Regarding the short-term operational risk, we observe that travel meta search systems (e.g. Trivago) have almost cleared the search/information costs, increasing the size of the segment of "strategic gamblers" (Masiero et al. 2020), i.e., consumers that choose free cancellation rates with the expectation to find a lower price at a shorter advance booking. Symmetrically from – the firms' perspective – they have soured the price competition along the advance booking with a pronounced focus on both inter-firm (Kim et al. 2020) and intra-firm price comparison, as a firm can competes with itself due to price fairness issue (Guizzardi et al. 2017). Thus, the advance booking-based price competition has become one of the main risks affecting profitability, turning on the spotlights on the methodologies by using which hotels determine the sequence of prices in the booking window.

As a final remark, we will pay a special effort to use both the real time information (crawled from the Internet) and auxiliary models for climatological forecasting (thanks to an international partnership that will be established with the Centre National de la Recherche Scientifique – France).

Research questions, aim, objectives and deliveries

The research will go along the following three directions, which are intimately connected among themselves by the goal to move the practice of risk management from finance to the tourism sector.

1) Can the economic consequences of climatic risk be predicted and hedged with financial instruments?

To answer this question, we will split the analysis into three broad steps. The first step consists of determining whether the historical/future climatic condition were/will be suitable for the tourism activity. It is mainly focussed on correctly describing compound hydrometeorological leveraging a novel bias correction approach (Messori et. alt. 2021) that combines breakpoint search algorithms with cubic spline logit-linear regression outputs, allowing for the reconstruction of climatic events (e.g., snowfall) without requiring multivariate or conditional bias corrections, or stochastic generations of unobserved events. In the second phase, past and future arrival patterns (or revenues) will be estimated based on the climatic analysis carried out in the previous step, and economic implications will be inferred from these patterns, with particular emphasis on differentiating spatial consequences (Guizzardi and Stacchini 2017). In the third phase, suitable hedging strategies will be developed that employ weather derivatives and appropriate mathematical techniques for option pricing based on copulas and the discounted expectation approach Bressan and Romagnoli (2021). In a nutshell, we expect to build a data driven analytical procedure to efficiently price and manage the climate risk.

2) Can the risk of failure/temporary shutdown of accommodation enterprises (due to COVID-19) be assessed/managed?

We propose an innovative application of the financial techniques for modelling credit rating migrations for the accommodation sector. In doing so, we leverage public data regarding the intertemporal pricing strategies of accommodation enterprises, to measure their activity level at different days. We point to estimate the Markov transition matrices by row-wise multinomial models (Möstel et al. 2020), conditioning to the hotels' time-varying (e.g., reviews) and time-invariant characteristics (e.g., location). Moreover, we derive confidence regions for multinomial proportions, comparing different techniques and establishing how well-suited these approaches are in the context of intertemporal pricing. That way, we expect to be able to measure the firms' performance risk, linking it to their features, and ultimately, to assess the firms' resiliency to the periodic introduction/revoking mandates of social distancing during the COVID-19 pandemic.

3) Can advance booking-based pricing strategies be used to advise managers about how to reduce the risk of bad last-minute rate forecasting?

Nowadays, a growing number of hotels compete on a local scale with revenue management systems that allow them to modify, almost in real time, the posted prices depending on the forecasting of the booking curve, i.e. the process that originates from the hotelier expectation about the stochastic demand at different arrival days (Croes and Smerad, 2012). We propose to model the difference between expected and realized fares with stochastic models that are widely applied in finance, due to their robustness to the issues of high kurtosis and asymmetry. In particular, we will implement suitable pricing strategies based on demand predictions provided by a neural network model likewise in Ballestra et al. (2019). That way, we expect to reduce the pricing risk and, ultimately, to find an optimal trade-off solution between selling a high number of rooms at a discount rate versus selling fewer rooms at a higher price.

Participants in the study (and role they play)

In addition to a continuous interaction with the proponent, the postdoctoral researcher will also have intradepartmental and international collaborations, as detailed below.

Intradepartmental collaboration: the project will also involve **Prof. Luca Vincenzo Ballestra**, who has a strong expertise in the mathematics of financial markets. He will provide valuable suggestions on how to develop the quantitative methods described above, and will contribute to the understanding of all the results obtained. His belonging to a scientific-disciplinary sector other than that of the proposer is a further guarantee of his innovative contribution to this research project.

Interdepartmental collaboration: Prof. Marcello Maria Mariani (DiSA) will supervise the research output and will contribute to the researcher's training regarding managerial aspects.

International collaboration: the research will also benefit from the collaboration of **Dr. Flavio Pons**, Ph.D., who is currently research fellow at the The Centre National de la Recherche Scientifique (the most prominent French public research institution) - Laboratoire des Sciences du Climat et de l'Environnement – Paris. Dr. Flavio Pons is an expert of compound climate events; he has a strong expertise in developing statistical and mathematical models to evaluate and predict the consequences

of climate changes on socioeconomic and/or environmental risk. Thus, he will contribute to the process of generating and assessing long-term scenarios regarding compound extremes.

Activity Plan

In the first 6 month the postdoctoral researcher will acquire an in-depth knowledge of the main mathematical and statistical models for risk management and forecasting. She/he will also learn how to apply these models in R (or Matlab) and how to use output for hedging and managing risk.

The last 6 months will focus on the dissemination of results. The research work will be presented at international conferences and will be submitted for the publication in highly qualified journals.

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