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Employing of Extended Characteristic Surface Model for Forecasting of Demand in Tourism

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Employing of Extended Characteristic Surface Model for Forecasting of Demand in Tourism

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Abstract

Extended Characteristic Surface Model (eCSM) is a theoretical tool of general application designed for computing coefficients in stochastic (Monte Carlo) simulations in particular in multi equation stochastic econometric models. Econometric models are most often used for economic analysis of large enterprises as well as national economies but rarely for analysis of the small entities. The reason are very high costs of building and testing of such a large-scale models. However, presented hereby eCSM delivers not so expensive, rather intuitive and flexible method eligible for consumer sentiment analysis and forecasting as well as for "what-if" inferring suitable for entities of all sizes. In particular, it allows for analysis of demand variation resulting from messages concerning competing merchandises. The article is focused on application of eCSM for evaluation of sentiment and forecast of demand in tourism. In the work extended characteristic surface method is explained in thorough details, furthermore influence of factors such as demographic structure, prices or market size on financial outcomes is analyzed on the example of small touristic entity.

Keywords: Sentiment, Forecasting, Visualization, Machine Learning, Tourism.

JEL classification: C01, C53, D81, D91, Z32

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Introduction

For evaluation of business enterprises, complex multi-parameter econometric models are build up. As it is well known that tiny variations of input data may induce large changes on output, econometric models are employed for the analysis of the sensitivity of an entity to viable internal and external conditions often changing very abruptly. As probing input data combinations is impossible partly due to obvious danger of irreparable damages to the entity, experimenting on the mathematical model is safe and allows for reliable *what-if* analysis and forecasting.

Econometric models are sets of mutually conjuncted equations based on time series of economic categories often delayed. Such models consist generally of two elements: time series of econometric categories and set of coefficients relating them. Thus accuracy of coefficients is crucial for reliability of the model. Common methods of evaluation of coefficients are e.g. ARMA (autoregressive moving average), ARIMA (autoregressive integrated moving average), ARMAX (Auto Regressive Integrated Moving Average with eXogeneous Input) or regression based methods. Unfortunately, this gives point estimates only while due to imminent inaccuracy of learning datasets they are rather interval estimates. There are generally two attempts to overcome this limitation – Monte Carlo simulations and fuzzy number or interval arithmetic – both have pros and cons.

Fuzzy number methods despite intense research and development still suffer problems concerning computation complexity as well as convergence (Skalna et al., 2015). However, the solution may be obtained in a single computation pass (Čičak & Vašiček, 2019). Oppositely Monte Carlo based methods are presently very well explored. However, in order to produce reliable results they require multiple repetitions of every simulation pass and subsequent statistical analysis. Another problem is the need to use long and uncorrelated series of random numbers, however present day pseudorandom number generators, like Mersenne Twister (Matsumoto et al., 1998, Matsumoto, 2020), allows overcoming this limitation. The direct bonus of this procedure is obtaining empirical probability distribution estimate of output data. Furthermore, due to enormous computation power of contemporary computers considerable computation complexity of Monte Carlo based methods is no more the problem (Opita & Skalna, 2006).

In the paper hypothesis is verified that Monte Carlo based Characteristic Surface Model is useful for modelling of economic output of a single small touristic entity in the era of pandemic. Alongside numerical efficiency of the Model ability to recreate typical scenarios will be investigated as well as ability of assessment of risk level and of estimation of fluctuations level. For the case study, Croatian touristic industry was selected due to its specificity including strong influence on the State economy.

The Methodology section consists of 6 subsections. In the first specificity of tourism in Croatia is analysed. In the second one, Characteristic Surface Method, extended characteristic surface model (eCSM) is introduced as an efficient tool for determination of stochastic coefficients in econometric models. Accordingly, relevant terminology is explained. In the next section, Design of the Numerical Experiments, experimental setup is presented and explained. In the fourth section, econometric model of hypothetic private, small touristic entity is presented as a base for calculations presented in the next section. Characteristics of layers adopted in this exemplary case is presented in Layers Data subsection. In the last subsection computer program written as test tool for the case study has been described, as well as other software utilized.

In the next section, Results, attempt is made to perform numerical modelling of evolution of consumer sentiment using characteristic surface method on the

example of tourism industry in the era of SARS-Cov-2 pandemic. In particular, applicability of estimation of influence of input data, (e.g. population structure) on model output values is analysed. Computational results for four different scenarios are presented; last two examples display influence of 16% discount on final profit of the entity. Next two sections are devoted to discussion of results and conclusions.

Methodology

Specificity of Tourism in Croatia

For the case study, tourism in Croatia has been chosen due to its specificity. Economics of Croatia, as well as more than 40 other countries, depends heavily on tourism. According to some authors, share of tourism in overall economy for 2017 was about 19.6%, which is almost one third of the whole services sector – 70.1% (Obućina 2019; CIA, 2020) compared to industrial output at 26.2% and agriculture 3.6%. Other sources gives even higher figures up to 25% in y. 2019 and 383400 jobs (9.3% of population) involved in the tourism industry (Neufeld, 2020). Different figures may result from taking into account real contribution to GDP (Gross Domestic Product) accounted for 15.2 billion of US\$, (KNOEMA, 2020), while the other may include revenues (13bln US\$ in y. 2019) of touristic industry only (Neufeld, 2020). Due to analysis of Orsini and Ostojić (2018), Croatia has the highest share of tourist revenues in GDP among countries like Cyprus, Greece, Malta, Italy, and Spain. This makes Croatian economy very sensitive to even minor fluctuations.

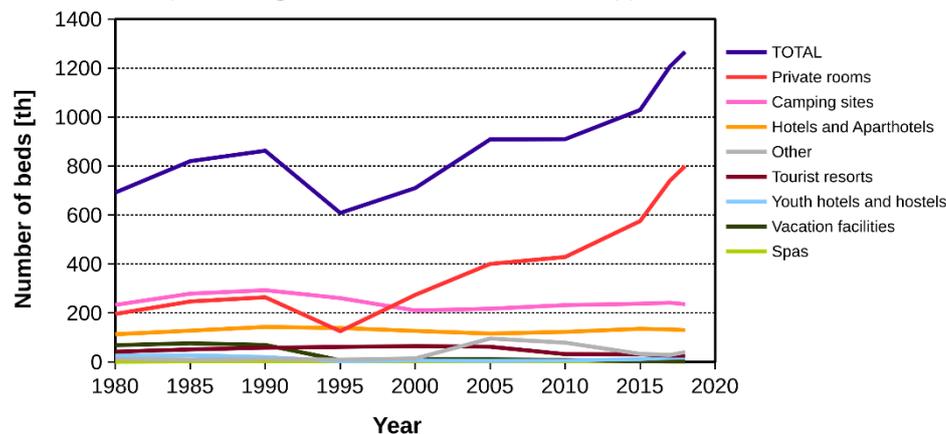
At GDP PPP accounting \$100.2 billion in 2017 Croatia was 85th country in the world, however taking into account GDP per capita (\$24100) was even higher – 82nd (Moody's Analytics, 2020). After a collapse initiated in 2008 by world financial crisis Croatia started recovery in late 2014 which culminated in 2019 at GDP growth rate at 2.9%, declining public debt (to 73.2% of GDP) (The World Bank, 2020) and notable reduction of unemployment rate to below 7% from 15% in 2015 (CIA, 2020). It is predicted that due to SARS-Cov-2 outbreak, GDP may shrink by more than 6.2% and unemployment rate may exceed 9% in 2020. While governmental emergency package (Croatia Week, 2020a) may help reducing the economy downturn, it will increase budget deficit and substantial rise of public debt even up to 84% GDP by the end of 2020. Moreover, a fiscal deficit may set a record rising close to 8% of GDP. It is expected, that economy will rebound in the second half of 2020 (The World Bank, 2020).

Characteristics of tourism in Croatia changed abruptly in 1995. Up to 1995 the share of domestic and foreign tourist was comparable, however thereafter share of domestic tourists remained on war time level, while number of foreign tourists rapidly rebounded (Ministry of Tourism of Republic of Croatia, 2019) to a record number of 21 million in 2019 (5% increase vs. 2018), (Croatia Week, 2020b). According to first readouts, this will change in 2020, as in March only drop of 75% in number of tourists was recorded year to year (Croatia Week, 2020c). Figures for the April are even more severe reaching 99% drop (Croatia Week, 2020d).

Accommodation structure is one of the most interesting factors of Croatian tourists industry (Ministry of Tourism of Republic of Croatia, 2019). While number of beds in hotels and camping sites barely grows or remains constant, number of beds in private accommodation entities more than tripled compared to year 1995 (Figure 1). This not only makes Croatian tourism unique, but also has important consequences.

Figure 1

Number of Beds Depending on Accommodation Type



Source: The author's work based on data from Ministry of Tourism of Republic of Croatia (2019)

Structure of private accommodation in Croatia is diversified. Based on data from rental agencies, offered entities range from small, one or two rooms facilities up to luxury micro hotels for say ten families. What makes them distinct from regular hotels is management - private accommodation is by rule guided by a single family or even one person only.

Average number of overnights per arrival depends on the season. In summer months, it approximates to six days/one week (July, August), 5 days in June and September and less than three days in the rest of the year. This is probably caused by policy of owners of private accommodations and camps who restricts reservations to the whole week in high season and lifts that limitation in other months (Ministry of Tourism of Republic of Croatia, 2019).

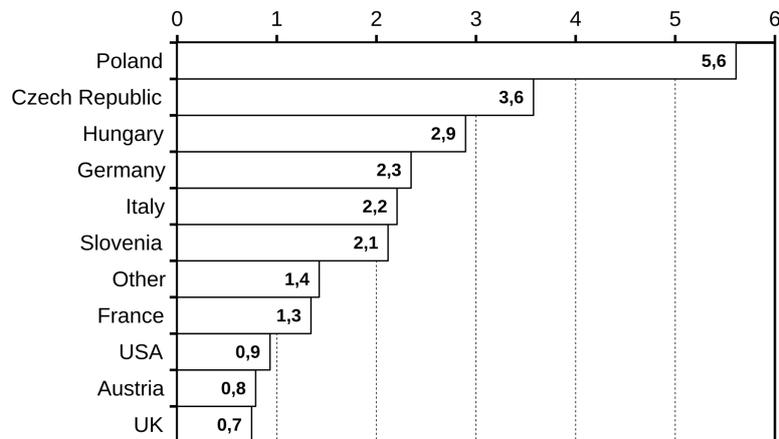
Number of overnights vary during the year and peaks in July/August far more than in other countries (Orsini & Ostojčić, 2018). Strong seasonality is another weakness of tourist industry.

Average number of overnights per arrival depends on country of origin too. While tourists from Germany, Czech Republic and Poland arrive to Croatia for one week on average (7.2, 6.8, 6.5 respectively), the other from Austria, Slovenia, Hungary, UK and Italy stays for approximately 5 days (Ministry of Tourism of Republic of Croatia, 2019). Visits from other countries are shorter than four days.

What is intriguing is that the choice of accommodation type strongly depends on the country of origin. It may be best presented as dependency of proportion of number of overnights in private accommodation and the number of overnights in hotels, on the country of origin – P/H. Four different groups may be spotted (Figure 2). The first one contains only one country – Poland ($P/H=5.6$). The second group consists of Czech Republic, Hungary, Germany, Italy and Slovenia ($2.1 < P/H < 3.6$). To the third one belongs France and other countries ($P/H \approx 1.3$). The last one consists of USA, Austria and UK ($P/H < 1.0$). While sentiment of Polish tourists toward private accommodation may be attributed to more affordable prices, the difference between Austria and Germany is more difficult to understand. Both countries are comparably wealthy and are in similar distance from Croatia. This riddle should be explained in separate research.

Figure 2

Dependency of proportion of overnights in private accommodations to hotel overnights on country of origin



Source: The author's work based on data from Ministry of Tourism of Republic of Croatia (2019)

By analysis of offers it may be stated that typical price per week/per arrival ranges from 400 up to 600 €, however prices over 1000 € per week are not uncommon. It should be stressed that as the euro is widely accepted in all payments (services, restaurants, tolls and goods), it became the semi-official currency of Croatia.

Summarizing, majority of tourists in Croatia is from abroad, spent one week per arrival most likely in private accommodation; all payments may be done in the euro. Numerical experiments presented in the next chapter are based a.o. on these observations.

Characteristic Surface Method

The method has been developed for some years. In the course of time some important and promising results has been obtained and presented in national journals (selected papers: Opita, 2005; Opita et al., 2008). However, method has not been presented yet in details at the international forum but short descriptive presentation (Opita, 2018; Opita, 2019). Thus the paper is devoted to detailed description of both theoretical background of the method and crucial details of implementation. The model is built upon specific to the model notions and assumptions defined as follows.

Population **P** consists from **I** "individuals" – exemplary it may be group of tourists, but individuals of other kind may be regarded too, namely migrating birds or deer choosing between two habitats. Many other kinds of individuals may be part of the model.

Individuals are making personal decisions choosing one of at least two options – in general **M** options. Although model allows for values of $M > 2$ usually $M = 2$ should be sufficient for majority of typical scenarios. In particular $M = 2$ allows to model financial outcome of economical entity under consideration (one option) versus their competitors (second option). However, increasing number of options beyond 2 may be sometimes necessary. So, for the sake of simplicity $M = 2$ may be assumed.

For each individual every option has an individually attributable "attractivity" A_i , $i = 1 \dots M$. Every individual selects one option according to all values of A_i , exact reason for selecting given option A_i is assumed unknown, irrelevant and it does not matter if it was selected by reason or spontaneously, however it is assumed that sentiment towards different options remains constant over time.

Act of decision may be modelled using “criterion function” $\mathbf{K}(\mathbf{A}_1, \mathbf{A}_2, \dots, \mathbf{A}_M)$ which evaluates to number 1, 2, ..., \mathbf{M} depicting which option has been selected. In order to make model computable it is further assumed that a transfer function $f()$ exists converting elusive attractivity \mathbf{A} into real number a : $a=f(\mathbf{A})$. Finally criterion function is defined as $m = \mathbf{K}(f(\mathbf{A}_1), f(\mathbf{A}_2), \dots, f(\mathbf{A}_M)) = \mathbf{K}(a_1, a_2, \dots, a_M)$, where $m=1,2, \dots, \mathbf{M}$ is the number of the option selected.

Probability of drawing of individual with set of attractiveness $\mathbf{A}=\{\mathbf{A}_1, \mathbf{A}_2, \dots, \mathbf{A}_M\}$ is governed by function \mathbf{C}_s of \mathbf{M} variables: $z=\mathbf{C}_s(a_1, a_2, \dots, a_M)$, which may be interpreted as multidimensional probability density function, PDF. This is the most important part of the model. It is assumed that shape of the function is rather constant for the given population over longer times or evolution of the function $\mathbf{C}_s(a_1, a_2, \dots, a_M)$ is predictable by direct computation, forecast or modelling. Thus, because the function $\mathbf{C}_s(a_1, a_2, \dots, a_M)$ is characteristic to the given population over some time interval it has been named Characteristic Surface (further referred as **CS**) and whole model, Characteristic Surface Model (**CSM**). While early implementations employed static characteristic surface the latter probed dynamic surfaces, i.e. changing over a time.

In order to model evolution of the characteristic surface over time and due to variety of signals (signal – a prominent event influencing behaviour of the population, e.g. epidemic) or conditions (i.e. set of parameters e.g. interests rates or mortgage loans rates), a variety of methods may be used. For example it may be mentioned: forecasting or control models, e.g. ARIMA (autoregressive integrated moving average), least squares based models GLM (General Linear Models), machine learning (ML) models, artificial intelligence (AI) trained models or formula based. The latter is very useful for performing numerical experiments while probing theoretical background of the model.

“Layer” is defined as a subset of individuals of the whole population, similarly reacting to signals. Thus splitting whole population into layers allows for individual modelling of the evolution of every single layer independently from others and as a result, modelling evolution of the completely characteristic surface. As every layer has its own shape function $\mathbf{C}_s(a_1, a_2, \dots, a_M)$, every may be modelled independently from others. One may be defined by equation the other by empirical PDF and another by AI/ML model. Furthermore, while one layer evolve the other may remain static. In that way model allows for testing many diverse scenarios.

In the paper equation, based layers were used. Author found as particularly useful use of time dependent correlated bivariate Gauss probability density distribution function $\mathbf{G}(\mu_1, \sigma_1, \mu_2, \sigma_2, \rho, t)$, where μ_1, μ_2 are means, σ_1, σ_2 standard deviations, ρ correlation coefficient and ‘t’ indicates time dependency.

In original implementation the domain of numeric attractiveness $a_i=f(A_i)$ was restricted to the unit square what was causing some troubleshoots. Current, enhanced implementation lifts this limitation so timely evolution of **CS** may be modelled in more consistent and logical way. Another possible enhancement is introduction of criterion function \mathbf{K} dependent on previous decisions of selected individual, thus allowing introduction of personal experience into the model.

Presented model does not provide procedure of evaluation of **CS**. Thus variety of methods may be applied: query, theory of the subject, historical data, Big Data analysis, Machine Learning/Artificial Intelligence and A/B testing method (Kohavi & Thomke, 2017; known also as bucket or split-run testing) or just formula – which suits the best.

Summarizing, the Characteristic Surface Model may be denoted as a set CSM consisting from Characteristic Surface, attractivity A and criterion function K: CSM =

{CS, A, K}. Obviously, CSM is the function of the number of options M , number of layers L and time t . It is assumed in the following analysis that $M=2$, there are three layers and one of them evolves with time. To stress the difference between static and dynamic formulations time dependent variant of the model was named "enhanced".

Design of the Numerical Experiments

In order to test and illustrate pros, cons and caveats of the model, hypothetical tiny tourists entity located in small destination has been selected. This is motivated by following assumptions and goals:

- small entities are more sensitive to fluctuations of incomes and expenditures than bigger,
- it is far more difficult to simulate small-scale entity than large-scale as fluctuations rapidly rise for small number of individuals/tourists,
- as the number of small tourist entities is currently very big and still grows it is important to test the tool for analysis of *what-if* scenarios for them.

Econometric model and assumed data

In the paper multi-equation stochastic econometric model of the agritourism farm, developed and tested in the past, (Opita, 2008; Opita, 2018; Opita, 2019) was adopted and enhanced. Due to the exploratory nature of this research, some simplifications were accepted. The subject of the model is small touristic entity located in small touristic destination (e.g. Soline, Silo, Lumbarda) thus $M=2$. Host offers 5 apartments on weekly basis and earns flat price over all season 20 weeks long, beginning June 1st. There is no problem with implementing more complex scenario but this is far beyond the scope of the paper. Weekly cost of the facility consists of constant part (instalments, local taxes) and variable costs depending on the number of flats rented (e.g., tourist tax, water, energy). Fixed costs per week are of course case dependent. However, they may be deduced from yearly costs recalculated per one week in the season. Although according to official statements only about 8% of loans indexed to CHF were taken for seaside rental houses (Ramotowski, 2015), such a case is taken into account in this experiment. According to the analysis performed by Tepuš (2005), on average house monthly instalments were estimated at 654 € before y. 2005. Thus, value of fixed costs has been assumed at 700 € level.

Although not very high, model takes into account cost connected with not-rented apartments. No taxes (local and other taxes are included implicitly in fixed and variable costs) are taken into account. It was assumed that whole population might be split into 3 distinct layers, defined as bivariate correlated Gaussian distribution. For the testing purposes, two were assumed static while the third one was migrating (change of μ_1 and μ_2) and changing its dispersion parameters (σ_1 and σ_2), while keeping correlation coefficient constant. Summary of data of Model are presented in the Table 1.

Layers Data

Identification of layers is the key point of the model. While sentiments are usually rather stable and inert, in response to some signals (e.g. disasters like epidemic or earthquake) may change rapidly. For example recovery of frozen economy, thereafter lockdown will take some time due to aversion to the risk especially present in the tourist industry. Obviously no rest in the presence of risk.

As stated above evaluation of layers and their sensitivity to variety of signals is not simple task, requiring not only access to raw data but trained experts and

specialized software too. Luckily, this does not need to be done frequently as once computed layers do not change rapidly or change in the predictable manner.

Table 1

Specification of the Econometric Model

Variable	Category, formula or value assumed	Remarks
t	0...20	Index; week number
R_0	3000 €	Initial resources
N_R	100	Number of repetitions
N	5	Number of apartments for rent, constant
N_D	90, 135 or 200	Number of apartments for rent in destination, constant
p_t	420 €	Price per week 't', assumed constant
F_t	700 €	Fixed costs at period 't', estimated based on (Tepuš 2005)
$D_{Tot,t}$	90	Total demand for the destination. Assumed constant.
$C_{F,t}$	10 €	Cost of "free" apartment
$C_{U,t}$	25 €	Unit cost per apartment rented at time 't'
D_t	$D_t = D(t, \dots)$	Demand in period 't', depends on many factors
$N_{s,t}$	$N_{s,t} = \min(D_t, N)$	Number of rented apartments in period 't', $N_{s,t} \leq N$
C_t	$C_t = F_t + N_{s,t} \cdot C_{U,t} + (N - N_{s,t}) \cdot C_{F,t}$	Total cost of rented apartment at 't'; variable
I_t	$I_t = p_t \cdot N_{s,t}$	Incomes for week 't'
P_t	$P_t = I_t - C_t$	Profit per week 't'
$P_{C,t}$	$P_{C,t} = P_t + P_{C,t-1}$	Cumulated profit

Note: All values are estimated or assumed.

Source: the author's work

Table 2

Attributes of Layers Used in Numerical Experiments

Layer index	μ_1	μ_2	σ_1	σ_2	ρ	S [%]
L1 (static)	0.8	1.6	0.25	0.25	-0.3	40
L2 (static)	0.0	1.3	0.25	0.25	-0.2	40
L3a (migrating)	0.1	1.0	0.25	0.25	0.5	20
L3b (migrating)	0.4	0.5	0.15	0.10	0.5	20

Source: the author's work

In order to study a numerical experiment three layers has been assumed in the try to model recovery from the lockdown. As layers are shaped according to bivariate correlated Gaussian distribution, they are fully defined by 6 parameters every: standard deviations (σ_1 and σ_2), means (μ_1 and μ_2), correlation coefficient (ρ) and share in the population (S). All are presented in the Table 2. Layer '3' migrates

steadily from initial state to the final state. As of now only uniform displacement per time step is available. Although timely dependent variable displacement of the surface may be easily implemented, it is out of scope and goal of this paper. Resulting Characteristic Surface may be denoted as $CS = L1+L2+L3(t)$.

Computer Program and Other Software Used

Model is implemented as C language console program (GCC compiler, tdm-1, v.5.1.0), source code available for research groups on demand. According to the algorithm used, computing time scales linearly with the size of the problem and number of repetitions. Use of typical laptop was sufficient for all calculations. Charts were prepared using gnuplot 5.2.8 and Inkscape 1.0, if required. Typical time of the single simulation was approximately 0.1 seconds over 20-week period; it was tested that 100 repetitions is optimal for convergence. Results are presented on hybrid charts, consisting of two rows. Top row presents shape of Characteristic Surface before and thereafter migration of the monitored surface and a lower row shows evaluated demand, number of apartments rented and cumulated profit respectively. In all three charts lines presents minimum/maximum (solid bold line), lower and upper quartile (dotted line) and median (solid line) of depicted category. Vertical scale is expressed in items ("Demand" and "Sold" chart) and in thousands of euro ("Profit" chart).

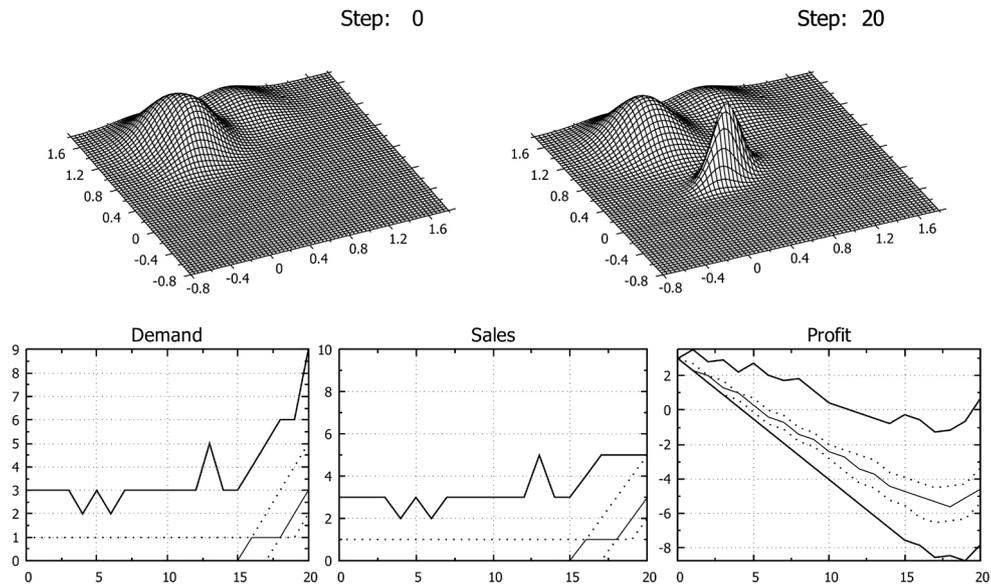
Results

From a plenty of possible and tested scenarios four were selected for the presentation of the model. Migration of the third layer from state L3a to the state L3b was assumed in all scenarios. Other attributes were defined according to the Table 1.

Results of the first experiment are presented in the Figure 3. Initially demand remains steady but beginning from week 15th maximum of demand rises above capacity of the site. However minimum value remains at zero level and upper quartile is lower than capacity most of time. Thus, there is a small probability only that the host would rent all apartments. Accordingly, cumulated profit drops until 16-17th week and then starts rising. Using layers metaphor one may ask question what to do to speed-up migration of third layer to its final position. There is no single and simple answer. The host may lower the price however until the total demand for destination is lesser than total capacity this may not suffice.

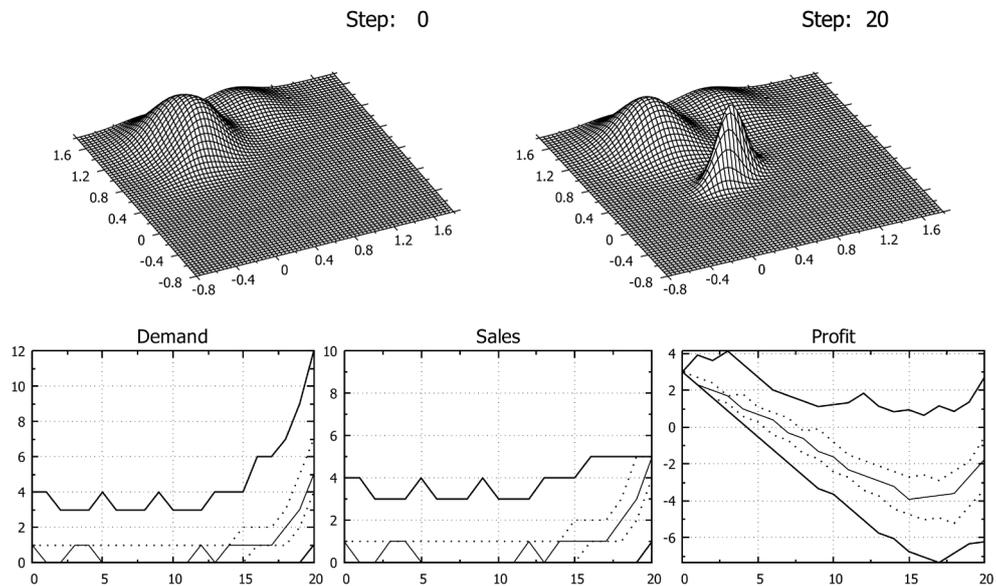
Figure 4 shows effect of increasing of total demand by 50%. While there is still 75% probability of the final loss, probability of positive output grows up to 25%. However even in this case final cumulated profit barely returns to initial value.

Figure 3
Migration of the Third Layer from State L3a to the State L3b



Source: the author's work

Figure 4
Migration of the Third Layer from State L3a to the State L3b. Total demand increased by 50%, up to 135 apartments

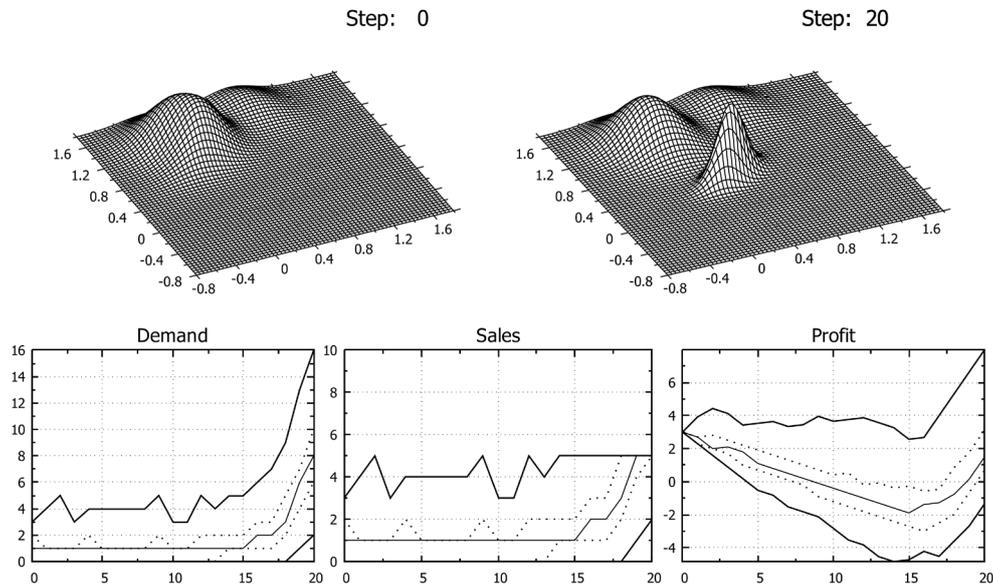


Source: the author's work

In the third example, total demand reaches value of two hundred apartments from before the incident. As shown in the Figure 5, now there is 75% probability of not ending the season in red and 25% probability of earning more money than initial resources. Moreover, positive results of recovery may be spotted started from 13th week.

Figure 5

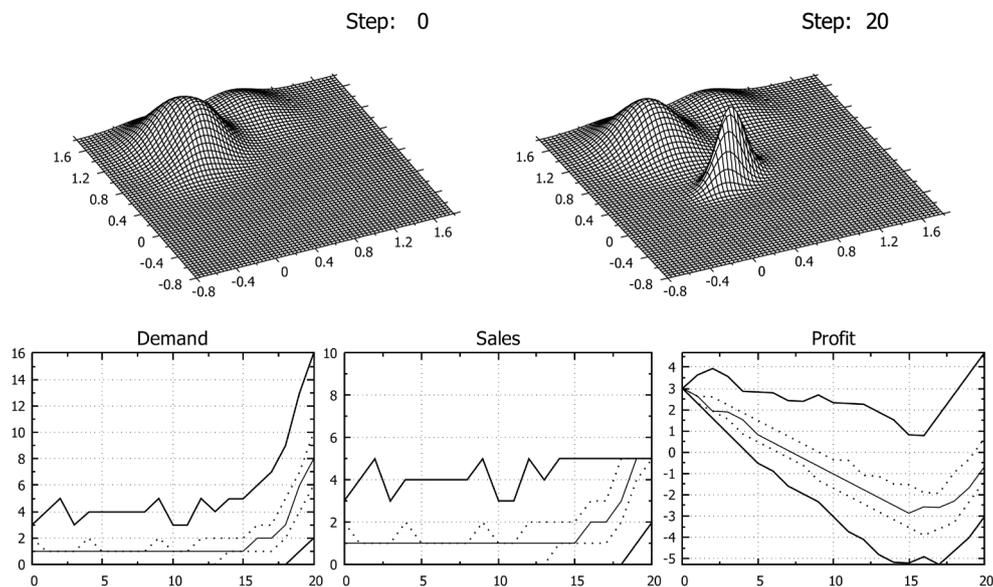
Migration of the Third Layer from State L3a to the State L3b. Total demand increased up to 200 apartments



Source: the author's work

Figure 6

Migration of the Third Layer from State L3a to the State L3b. Total demand increased up to 200 apartments, price lowered to 350 per week



Source: the author's work

As shown above encouraging tourists for coming in is crucial for recovery from the crisis. In the case of epidemic, one of possible methods is lowering price, but this reduces incomes too, which is shown in the Figure 6. Simulation was computed at total demand equal to 200 apartments and the price lowered to 350€ per week i.e. about 16% (even higher discounts up to 50% are presently observed). In this case probability of negative financial outcome rises up to 75% and probability of not increasing initial resources (3000€) exceeds approximately 85-90%.

Discussion

Results presented in the previous section suggest that Characteristic Surface model is useful for modelling of economic output of a single small touristic entity in the era of pandemic. As the Model is founded on very weak assumptions, it is very general as well, and may be easily adopted to variety of scenarios.

Numerical efficiency of the Model is satisfactory and Model itself scales linearly with number of repetitions and size of population involved. However, referential implementation of the model may still be optimised allowing for analysis of populations as numerous as 4 million of individuals and even more.

According to results presented above Model exhibits ability to recreation of typical business scenarios. Model hereby described was sensitive to even small variations of the input data in all tested scenarios. Every parameter of Model may be treated as specific "degree of freedom" of its own variability range. Even after restricting number of options to $M=2$, number of layers to $L=3$ and omitting parameters of econometric model, number of possible combinations (Cartesian product) of remaining parameters: data of Layers ($6 \cdot L$ float numbers), population size N (positive integer), criterion function definitions (numerable, infinite), transfer function definitions (numerable, greater or equal 1) is infinite.

As shown in the Results section Model allows for risk assessment for selected scenario. Furthermore, according to properties of MonteCarlo method, range of variability for computed outputs may be estimated.

For the selected case study on forecasting of recovery of Croatian tourism industry from epidemic, few conclusions can be made. As increasing rate of rented apartments is crucial for cumulated profit it may be assessed in different manner. One possibility are high social skills of the host, commonly addressed as emotional intelligence, which may help increase attractiveness of given entity over competitors. In terms of Characteristic Surface Model, this may be expressed as additional push from social skills on layer $L3$ toward higher competitiveness. Enhancement of the offer is possible as well. Markus et al. (2019) suggest that introduction of additional items like sports activities to the offer, may help increase sales. Applying discounts may increase number of rented apartments but may deteriorate profit, thus it must be precisely computed. Of course, small revenues are always better than no revenues, however discounts must be calculated as maximizing incomes.

On the state level, there are more options available. In the first place, I would mention reducing stress and fear of potential guests, as there is no holidays in the presence of critical risk. This may be obtained by several means. This may include additional, low cost health assurance, increase of number of events for tourists – festivals, concerts or charming fisherman's evenings, changing highways toll system which at present form generates horrific traffic jams every holiday weekend, safer organization of resting places along highways and support for domestic tourism. Of course, these remedies must be introduced by national agencies.

Conclusion

Presented hereby method seems to be useful for the *what-if* analysis, giving quantitative answers thus allowing for decision making at known risk. While using of the model is rather simple, fine-tuning of crucial parts of the model might not be easy and may require a lot of additional research including variety of methods from simple A/B testing up to the most complex AI/ML. In particular, layers for the specific

population may be subject of scientific research on its own. Results may be published by governmental agencies ready for use by individual entrepreneurs.

Furthermore, besides new computational method, model introduces own descriptive language suitable for discussion concerning behaviour of analysed population.

As assumptions the Model is built upon are very weak, it has almost no limitations. The main problems are proper identification and attribution of layers, determination of the response patterns (i.e. evolution of CS due to signals and time) and adoption of proper criterion function. Model easily scales with population size and may be applied to small, medium and large-scale systems.

Although shown on the example of tourist industry presented Model is universal and may be implemented for variety of scenarios, including forecasting of general elections, demand on selected goods or number of visitors in National Park at variety of weather conditions.

Possible areas of further development include methods of determination of Characteristic Surface, introduction of innovative transfer functions and development of time dependent criterion functions.

References

1. Central Intelligence Agency. (2020), "The world factbook: Croatia", available at: <https://www.cia.gov/library/publications/the-world-factbook/geos/hr.html> (20 June, 2020)
2. Čičak, J., Vašiček, D. (2019), "Determining the level of accounting conservatism through the fuzzy logic system", Business Systems Research, Vol. 10, No. 1, pp. 88-101.
3. Croatia Week. (2020a), "Croatian PM announces package to help save jobs and economy", available at: <https://www.croatiaweek.com/croatian-pm-announces-package-to-help-save-jobs-and-economy/> (20 June 2020),
4. Croatia Week. (2020b), "Record 21 million tourists visit Croatia in 2019", available at: <https://www.croatiaweek.com/record-21-million-tourists-visit-croatia-in-2019/> (accessed June 20, 2020),
5. Croatia Week. (2020c), "Record 21 million tourists visit Croatia in 2019", available at: <https://www.croatiaweek.com/record-21-million-tourists-visit-croatia-in-2019/> (accessed June 20, 2020),
6. Croatia Week. (2020d), "Croatia sees 99% fewer tourists in April than last year", available at: <https://www.croatiaweek.com/croatia-sees-99-fewer-tourists-in-april-than-last-year/> (accessed June 20, 2020)
7. KNOEMA. (2020), "Croatia - contribution of travel and tourism to GDP in constant prices of 2011", available at: <https://knoema.com/atlas/Croatia/topics/Tourism/Travel-and-Tourism-Total-Contribution-to-GDP/Real-contribution-of-travel-and-tourism-to-GDP> (11 July, 2020)
8. Kohavi, R., Thomke, S. H. (2017), "The surprising power of online experiments: getting the most out of A/B and other controlled tests", Harvard Business Review, Vol. 95, No. 5, pp. 74-82.
9. Markus, Z., Perovic, D., Pekovic, S., Popovic, S. (2019), "Assessing tourist revisit intention through the sports and recreational services offered", Business Systems Research, Vol. 10, No. 2, pp. 141-150.
10. Matsumoto M., Nishimura T. (1998), ACM Transactions on Modelling and Computer Simulations. Special Issue on Random Number Generators,
11. Matsumoto M., (2020) Mersenne Twister, computer program, Open Source - available at: <http://www.math.sci.hiroshima-u.ac.jp/~m-mat/MT/emt.html>, (June 17. 2020),
12. Ministry of Tourism of Republic of Croatia. (2019), "Tourism in figures 2018", available at: https://www.htz.hr/sites/default/files/2019-09/HTZ%20TUB%20ENG_2018.pdf (20 June, 2020)

13. Moodys Analytics. (2020), "Croatia - economic indicators", available at: <https://www.economy.com/croatia/indicators#FACTBOOK> (20 June, 2020)
14. Neufeld, D. (2020), "Visualizing the countries most reliant on tourism", available at: <https://www.visualcapitalist.com/countries-reliant-tourism/> (11 July, 2020)
15. Obućina, V. (2019), "Croatian tourism model – is it sustainable?", available at: <https://www.obserwatorfinansowy.pl/in-english/croatian-tourism-model-is-it-sustainable/> (11 July, 2020)
16. Opiła J., Skalna, I. (2006), "Pseudorandom number generators in stochastic econometric models" in Duda, J. T., Waszkielewicz, W. (Eds.), *Modern methods and techniques in management*, AGH Uczelniane Wydawnictwa Naukowo-Dydaktyczne, Cracow, pp. 200-210.
17. Opiła, J. (2005), "Analiza ewolucji nastrojów konsumenckich z wykorzystaniem metody powierzchni charakterystycznej" (An analysis of the evolution of consumer sentiment using the characteristic surface method), in Duda, J. T. (Ed.), *Systemy informatyczne i metody obliczeniowe w zarządzaniu (Information systems and computational methods in management)*, AGH Uczelniane Wydawnictwa Naukowo-Dydaktyczne, Kraków, pp. 141-148.
18. Opiła, J. (2018), "Visualization in a knowledge transfer process", in 2018 ENTRENOVA-ENTerprise REsearch InNOVation Conference, 6-8 September, Split, pp. 485-493.
19. Opiła, J. (2019), "Role of visualization in a knowledge transfer process", *Business Systems Research*, Vol. 10, No. 1, pp. 164-179.
20. Opiła, J., Opiła, C., Cichowska, J. (2008), "Prognozowanie ostrzegawcze w mikroprzedsiębiorczości z zastosowaniem rozszerzonej metody powierzchni charakterystycznej na przykładzie gospodarstwa agroturystycznego" (Emergency forecasting in microenterprise with the use of the extended surface method on the example of an agritourism farm) in 9th International scientific conference Zarządzanie przedsiębiorstwem – teoria i praktyka (Business management - theory and practice), WZ AGH, Kraków, pp. 1-10.
21. Orsini, K., Ostojic, V., (2018), "Croatia's tourism industry: beyond the Sun and Sea", available at: https://ec.europa.eu/info/publications/economy-finance/croatias-tourism-industry-beyond-sun-and-sea_en (11 July, 2020)
22. Ramotowski, J. (2015), "Frank zaraża bilanse banków nie tylko w środkowej Europie" (Frank infects bank balance sheets not only in Central Europe), available at: <https://www.obserwatorfinansowy.pl/tematyka/rynki-finansowe/bankowosc/frank-zaraza-bilanse-bankow-nie-tylko-w-srodkowej-europie/> (28 June, 2010)
23. Skalna, I., Rębiasz, B., Gaweł, B., Basiura, B., Duda, J., Opiła, J., Pełech-Pilichowski, T. (2015), *Advances in Fuzzy Decision Making: Theory and Practice*, Springer International Publishing, Cham.
24. Tepuš, M. M. (2005), "Housing finance models and standards in the republic of Croatia", available at: <http://housing-finance-networks.com/documents/doc.aspx?id=1631> (28 June, 2020)
25. The World Bank. (2020), "The World Bank in Croatia", available at: <https://www.worldbank.org/en/country/croatia/overview#3> (20 June, 2020)

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