COMPLEX SPATIAL MODELLING POSSIBILITIES OF THE SOCIO-ECONOMIC CHANGES OF HUNGARY - POTENTIAL APPROACHES AND METHODS

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Abstract: *The paper overviews the possible methodological and practical approaches which can be used to create a custom-made toolset for the complex spatial modelling and forecasting of the socio-economic processes of Hungary for the 21th century. The author already participated in projects concerning land cover change and demographic modelling and gathered valuable experience in creating isolated models. In his three-year post-doctoral research programme, the author plans to take a more holistic approach with combining the elements of demography, economy and land use to create an integrated model with feedbacks between the consisting parts. The proposed methodology relies heavily on a scenario-based approach, creating a range of different forecasts from the business-as-usual ones to the highly improbable ones to explore the outer edges of future possibilities. Both local and global future assumptions will be considered during the formulation of the scenarios. An additional goal is to make the prepared modelling tool publicly available.*
KEYWORDS*: AGENT-BASED MODELLING, SPATIAL MODELLING, FORECAST, SCENARIO, HUNGARY, DEMOGRAPHY, ECONOMY, LAND COVER*

1. Introduction

In the light of the looming challenges of the 21st century, the significance of socio-economical modelling and forecasting cannot be overstated. Besides global level, this need has been recognised in Hungary as well, and different sectoral predictions were prepared (Polónyi and Timár 2002, Király 2015, Koós 2015, Tagai 2015, Vaszócsik 2017, Obádovics 2018).

I've also participated in some projects concerning land cover change modelling and demographic modelling (Long-term Socio-Economic Forecasting for Hungary – 2015, the further development of NATéR (KEHOP) – the possible effects of climate change on internal migration processes (2017-2018), and the further development of NATéR (KEHOP) – the methodological improvement of land cover modelling (2017-2018) (Farkas and Lennert 2015, 2016).During these research contributions, I've gathered valuable experience in creating isolated models, and I've also became familiar with the limitations of this approach. In my ongoing postdoctoral research project (PD 128372, from 2018.09.01 to 2021.08.31), focusing on the complex spatial modelling possibilities of the socio-economic changes of Hungary for the 21st century, I'd like to move toward a more holistic direction. The modelling toolset will constitute of three main components (demography, economy, and land use) forming an integrated model and thus provide more possibilities for feedback than the isolated ones. With heavily relying on a scenario-based approach, I want to extend the timescale of the forecast farther than before – and to explore the challenges and limits for Hungary in the 21st century. In order to achieve this, I am going to elaborate a custom modelling tool fit for my purposes. The existing professional software can be used to model the selected phenomenon (e.g. land use change) more or less universally – and I do not wish to compete with that feature. However, general applicability has a price – it cannot handle the regional/national irregularities of the investigated phenomena well, and it is hard (or impossible) to alter an existing toolset. However, if I build the modelling framework taking these regional characteristics into consideration from the beginning, I get much less generally applicable software as a result, but more fit to my purpose: the modelling of the selected socio-economic processes of Hungary. The aimed interconnectivity of the components also calls for a custom design.

Naturally, with these intentions, a marketable product cannot be prepared (the socioeconomic modelling needs of a single middle-sized country cannot be considered even as a niche market). However, I still intend to make the prepared modelling tool publicly available in the suitable platforms (a dedicated website, and/or GitHub), in the hopes that the stakeholders and professionals can freely experience with the different scenarios and their territorial consequences, and to generate further research contributions.

The research project is still in the stage of conceptualisation (with results coming in 2021), so in the next pages, I'd like to summarise my previous experiences in modelling and forecasting, and present the insights that contributed to the conceptualisation of the recent research.

2. Results and discussion

In the project of the Long-term Socio-Economic Forecasting for Hungary, I created a land cover modelling and forecast with my college, Jenő Farkas. For the procedure, the Land Change Modeler for ArcGIS software was used and the Corine Land Cover maps were served as basemaps (1990 and 2006). According to the meta-analysis of Schrojenstein and his colleges, all simulation models of land use are based on at least one of the following four principles: continuation of historical development, suitability of land, result of neighbourhood interaction and result of actor interaction.

Also, they distinguished the following methodological concepts, which can be used for land use change modelling: cellular automata, statistical analysis, Markov chains, artificial neural networks, economic based models, agent based models (Schrojenstein et. al. 2011).

For predicting the amount of future land cover transformation, the LCM relied on Markov chains and on the historical trends (represented by the two basemaps). From the possible options for locating the sites of the transformations, we selected the Multilayer Perceptron neural network method, which uses a neural network, the basemaps explanatory variables (with the same spatial dimension) to determine the probability of change between each modelled land cover category. The available variables mostly emphasised the expression of the principles of suitability of land and neighbourhood interaction. Additionally, it was also possible to declare spatial constraints and incentives for certain transitions, which helps the expression of author interaction.

With the software, two types of predictions were produced, a hard prediction showing the land cover for 2030 and a soft prediction depicting the probability of change, which can be considered valid for a longer period. The results indicate an increase in the share of forests, artificial surfaces and vineyards and fruit cultivations, and a decrease in the area of arable land, grasslands and complex agricultural surfaces. According to the soft prediction, the probable transition hotspots include the rural-urban fringe of Budapest, and also the diverse but environmentally vulnerable landscapes of Kiskunság and Nyírség.

During the execution of the research, we could identify several limitations. In its default setting, the volume of future change is exclusively based on the rate of change between the two uploaded basemaps, and possible changes in the driving forces are dismissed. Also, without a feedback between the determination of the transition locations and the total amount of change, suitability does not necessarily translate to viability. In case of a shortage from a certain land use category, transitions will occur even in the highly improbable locations (except if absolute constraints had been declared). Generally, the Land Change Modeller software produces the best results in case long-term changes with few well identifiable location factors (like tropical deforestation and urban sprawl).

The planned recent research will take these limitations into consideration. The integrated execution with the demographic and economic component will make it possible to follow a more supply and demand based approach instead on relying on historical trends. And while the previous research experiences proved that Corine Land Cover is a good starting point for creating a basemap for modelling, but because of the presence of some unique features in Hungary (e.g. scattered farms and garden zones), some of the categories need revision (e.g. complex cultivation patterns).

In case of the preceding demographic modelling research (the further development of NATéR – the possible effects of climate change on internal migration processes), I used a self-developed modelling toolset coded in Python. The model integrates a lot of different theoretical-practical approaches of demographic modelling (e.g. cohort-component method, Lee's push-pull theory, neoclassical theories, value-expectancy model, life course approach of migration, Enyedi's urbanisation stages), but from methodological viewpoint, it can be considered as an agent-based model, which handles each inhabitant as an individual decision making agent. During each five-year modelling cycle, every person undergoes a multiple-step decision tree with seven possible outcomes (passes away, gives birth, participates in university student migration, participates in labour migration, participates in suburbanisation, participates in amenity migration, remains in his/her former location without taking part in any of the former ones). The attractiveness of the areas are defined independently for each migration type, and probability for the actors to take part in either of the natural or migration movement depends on the age, sex and the socioeconomic status of the inhabitant. The model gives stochastic results.

During the research 33 scenarios were prepared, which differ from each other in three aspects: their fertility and mortality assumptions, the integrated climatic scenarios, and in their socioeconomic assumptions about transport, commuting, and the prevalence of atypical work.

The results indicate that (further) natural decrease of the population of Hungary seems unavoidable, but the scenarios vary between moderate to drastic loss. Due to the current age structure, an increase in life expectancy can play a more significant role in reducing population loss than an increase in fertility. As a consequence, higher projected population number means a less favourable old-age dependency ratio.

The results also point out, that the predicted changes will further increase the spatial differences of Hungary. While the agglomeration ring of Budapest will continue to grow, the larger part of Hungary faces significant to severe depopulation. The rate of decrease is average in the urban, below average in the commutable rural, and higher than average in the remote rural areas.

The different introduced climate scenarios only had minimal effect on the predicted migration patterns, while the differences in the socio-economic path caused more substantial alterations. The results also indicate that the effect of climate change on the internal migration patterns will depend more on the share of population who is able and willing to take the climactic parameters into account when changing residence than on the exact changes in the climatic parameters.

The created custom modelling tool provides a good starting point for the current modelling procedure. However, it still has three important shortcomings of which I plan to address this time.

The first concerns the agents: while they were created together with individual age and gender data from the population census of the starting year, municipality level data was used to describe their socioeconomic status – which affects their migration preferences and probabilities. This decision was a necessity stemming from the lack suitable data. While it provided acceptable results, it hindered the expression of the life-course approach. Also, the presence of different social strata within the same settlement is an important driving factor for some migration types (e.g. involuntary economic migration). These migration types could not be included without individually declared economic situation before, but the current project will remedy this. As the 0^{th} step of the project, a more detailed database connected to agents will be assembled with the inclusion of socioeconomic data (the lack of suitable database still persists, so in some cases, I will have to rely on estimations based on cross-sectioned data).

The partial overlook of the meso-theories of migration shows a somewhat opposite shortcoming. While the previous one focused on the improvement of individual agents, the meso-theories emphasise the role of social connections in the migration decisions, especially family ties. In order to comply with this approach, the agents has to be formulated together with their respective relationship network (with the help of census data), and in some cases, migration decisions have to be taken in family level.

The importance of feedback was already emphasized between components. Within the demographic component, the changes of housing prices will also provide an important (usually negative) feedback, making migration from the depressed areas less probable. In the previous research, this phenomenon was taken into account using the settlement development level, but this time I aim for a more dynamic implementation. This will also help the inclusion of involuntary economic migration subtype to the model. To achieve this, a dynamic housing database has to be assembled, and joined to the agents. Also, the economic component has to take the housing market into consideration.

Without previous research experience, the elaboration of the economic component is the least certain. Economic actors (currently existing and potential fictional) determining the changes of the labour market (and thus the migration flows) surely have to be declared. The most important economic actor of Hungary is naturally the central government. It will be elaborated as a half-autonomous agent, with predefined preferences and condition-action rules which depend on the selected scenario.

3. Conclusion

The project aims to create projections till the end of the century. While it is a daunting aspiration, the previous research experiments pointed out its necessity. If we want the introduced socio-economic paradigm shifts to play out in their full scale and create significant divergences from the business-as-usual scenarios, we have to consider a longer modelling period then a few decades. Naturally, it is increases the uncertainty of the projections. However, as the previous research results have pointed out, uncertainty appears in a spatially uneven pattern. While some settlements and regions face with a rather undetermined future, the fate of other areas seems to be more certain due to their path-dependency. Even without providing unquestionable predictions, the mapping of uncertainty is a valuable result in itself.

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