

EMPLOYING BAYESIAN NETWORKS FOR SUBJECTIVE WELL-BEING PREDICTION

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Abstract

This contribution aims at using Bayesian networks for modelling the relations between the individual subjective well-being (SWB) and the individual material situation. The material situation is approximated by subjective measures (perceived economic strain, subjective evaluation of the income relative to most people in the country and to own past) and objective measures (household's income, material deprivation, financial problems and housing defects). The suggested Bayesian network represents the relations among SWB and the variables approximating the material situation. The structure is established based on the expertise gained from literature, whereas the parameters are learnt based on empirical data from 3rd edition of European Quality of Life Study for the Czech Republic, Hungary, Poland and Slovakia conducted in 2011. Prediction accuracy of SWB is tested and compared with two benchmark models whose structures are learnt using Gbnlp software and a greedy algorithm built in Hugin software. SWB prediction accuracy of the expert model is 66,83%, which is significantly different from no information rate of 55,16%. It is slightly lower than the two machine learnt benchmark models.

1 Introduction

Throughout the last couple of decades, subjective well-being (hereinafter referred as “W”) has become an attractive field of study for sociologists, psychologists and economists. Each of these branches looks at the topic from the different perspective, whereas their models reflects mainly their own needs and understanding. For example, economists use the concept of SWB in their models as a certain approximation when investigating the utility. The empirical research of SWB and its

association with economic variables such as individual income, material situation, relative deprivation, material deprivation etc. is usually based on the use of various statistical methods. Applications of probability calculus and modelling to examine sociological concepts such as SWB seem to be rather marginal. In this contribution we tried to develop an alternative to the classical statistical approach and suggest the probability model for the description of the relationships among the individual SWB and selected proxies of the economic situation based on empirical data from four central European countries. For such an attempt Bayesian networks are used, whereas the predictive capacity of the model is discussed in terms of SWB. The broad purpose of this study is to demonstrate possible new approaches for modelling in sociology.

2 Literature

SWB can be defined uneasily and approaches to that differ quite a lot. For the purposes of this research the definition of SWB promoted in [9] is used. Based on this definition there are two components of SWB, affective and cognitive. The cognitive component can be understood as a judgement of one's life satisfaction, whereas the affective dimension is represented by emotions and moods. The surplus of positive emotions over negative ones is referred as happiness. Comprehensive overviews of the issues defining SWB are provided for example in [7] or [10]. Both outlined dimensions of SWB are reflected in the empirical analysis in this paper.

The individual material situation can be approximated by diverse variables, both objective and subjective. The term "material situation" appears in the study [4] where direct and indirect measures are discussed. Economic variables once examined were mostly limited to the income [22]. Household's income is the most obvious indirect measure, but the evidence of the relation between the income and SWB is mixed. Some authors stress the importance of the income for SWB whereas others look it rather unimportant. The reviews of the evidence are provided eg. in [7], [9] and [25]. Overall, researchers mostly suggest that money has a positive, yet diminishing effect on SWB [11, p. 97], which is in line with the widely accepted economic law of declining marginal utility.

Some studies (e.g. [9]) suggest that the relative, rather than the absolute, income matters, as people simply tend to compare one to another. Clark et al. [5] talk about the comparison to others and the comparison to oneself in the past. Diener et al. [8, p.195] summarize that the impact of the income depends on "changeable standards derived from expectancies, habituation levels, and social comparisons". It means that the additional income has no effect on SWB if the income of people in the reference group also increase [11, p. 98]. With some exemptions (e.g. [8]), the research is quite consistent in the assertion of importance not to consider the effect of income to SWB only in absolute terms.

Material deprivation measures are used in poverty research since introduced in [3] and [30]. It is commonly assumed that there is a close relationship between

the income and the material deprivation as the lack of resources caused by the low income results in the lack of something considered to be a necessity. However, the research often suggest that the discrepancies between the income and the material deprivation exist. Studies suggesting that there are low income households not experiencing deprivation as well as households not living in poverty but suffering from the deprivation (measured by non-monetary indicators) are summarized, for example, in [32]. The authors provided reasoning why the income and the material deprivation may relate loosely – the length of time the low income persists, the existence of other resources (savings etc.), a different view of what is necessary, and other social and economic processes may influence the relationship between current income and deprivation. They made analysis of the income, the deprivation and the economic strain based on data for twelve European Union countries from the first wave of the European Community Household Panel Study (ECHP) conducted in 1994 and found that the relationship of the income with the deprivation “was generally weakest in the richer countries where the level of deprivation is lowest, and strongest where it is highest” [32, p. 370] and the economic strain (the perceived ability to make ends meet) is impacted by both the income and the deprivation whereas the effect of the deprivation is stronger. The structure of the deprivation is consistent across examined EU countries. Based on European Quality of Life Survey (EQLS) data for EU25 plus 3 candidate states at that time (Romania, Bulgaria and Turkey) [33] later confirmed the earlier finding that the relationship between the income and the life style deprivation is relatively weak, whereas the income plays more important role in the poorer regions as a predictor of deprivation. The association between the deprivation and the economic strain is the strongest in 12 richest EU countries whereas in all other EU regions is just a bit weaker.

3 Data and method

Learning the structures and the parameters is based on the empirical data from European Quality of Life Study (hereinafter referred as “EQLS”) carried out by the European Foundation for the Improvement of Living and Working Conditions – Eurofound [19] covering all 27 EU member states and 7 non-EU countries. Third edition of the survey conducted in Autumn/Winter 2011 is used for this purpose. Only one interview per household was held whereas the adult household member with the next upcoming birthday was taken as the eligible respondent. The statistical population of the study covered all persons aged 18 and over whose usual place of residence was in the territory of the surveyed country. Random probability sampling procedures were used promising that every member of the statistical population have non-zero probability to be included in the sample. The sample was stratified according to NUTS2, level of urbanization and clustered geographically on Primary Sampling Units. The sample can hence be considered representative. All necessary technical details how the study was conducted are available in EQLS Technical report [18] and EQLS Sampling report [17].

Probability models presented in this contribution are learnt using only data of four post-communist central European countries (the Czech Republic, Hungary, Poland and Slovakia). This approach promises to have a sufficient sample from very similar countries in terms of culture, geography, politics, economics and modern history. Total sample size for the four countries is 5.298 (1,012 in the Czech Republic, 1.024 in Hungary, 2.262 in Poland and 1.000 in Slovakia) respondents out of whom 3.797 (722 in the Czech Republic, 687 in Hungary, 1.707 in Poland and 681 in Slovakia) complete data vectors are extracted by removing respondents not having answered the relevant questions. This selection of countries is represented by the node COUNTRY in the model.

Broad range of domains is covered by EQLS including SWB and the financial situation measures. There is no single question on SWB, there are questions on both happiness and life satisfaction instead. For the happiness respondents are asked in the following way: “Taking all things together on a scale of 1 to 10, how happy would you say you are?” Code 1 means very unhappy and 10 means very happy on the scale. The question of the overall satisfaction is: “All things considered, how satisfied would you say you are with your life these days?” Similarly to happiness the scale of 1 to 10 is given, where 1 means very dissatisfied and 10 means very satisfied. Model variable of the subjective well-being (abbreviated as “AVGSWB” in the model) is binary where one state represents SWB below the median and the other state represents SWB on or above the median. For each respondent the average of happiness and life satisfaction is computed first and then the median is calculated from this working scale. Because SWB is a two-item measure, the internal consistency was checked using Cronbach’s alpha. The value of alpha is 0.774 which is generally considered acceptable in the social research.

A set of seven variables is used for the description of the individual material situation and the deprivation in the model. Household income, material deprivation, defects in housing conditions and financial problems are the objective ones. The subjective variables comprise the subjective economic strain and the relative income approximated by the subjective evaluation of own current financial situation compared to other people in the country and by the subjective evaluation of own current financial situation compared to own past situation. People are often cautious stating their household income (total of 1.333 respondents out of the 5.298 did not declare their income). The respondents were asked to state their total net income per month from all sources of all members of the household. The household income equalized based on purchasing power parity euros is used for the analysis, such a figure is provided in the EQLS dataset. The variable of income is binary where one state covers the income up to the median (including) and the second state the income above median.

EQLS respondents were asked whether they are able to afford six items if they would like them to get. The six items include keeping your home adequately warm, paying for a week’s annual holiday away from home (not staying with relatives), replacing any worn-out furniture, having a meal with meat, chicken, fish every second day (if wanted), buying new, rather than second-hand, clothes and having

friends or family for a drink or meal at least once a month. Resulting six binary variables (able to afford / unable to afford) are transformed into a single binary variable, where one group of respondents can afford all six items and the other group cannot afford one to six items. The respondents having refused to answer the whole set of six sub-questions are excluded from the further analysis. This variable of the material deprivation is abbreviated as “WANTED” in the model.

Financial problems in the form of the ability to pay various households bills as scheduled in the past 12 months is another objective variable related to the living conditions. The question on the financial problems has five sub-questions covering payments that typical household needs to pay regularly: rent or mortgage payments for accommodation, utility bills, such as electricity, water, gas, payments related to consumer loans, including credit card overdrafts and payments related to informal loans from friends or relatives not living in the household. Four binary variable (able to pay bills as scheduled / unable to pay bills as scheduled) are transformed into a single binary variable where one state means able to afford all four items whereas the other state means unable to afford one to six items. Consistent principle is adopted for those not answering questions. Excluded are those who did not answer all the sub-questions. This variable of the financial problems is abbreviated as “UNABLEPAY” in the model. The last objective variable related to the material living conditions describes defects in housing conditions. The related EQLS question has six sub-questions on type of common deficiencies of housing: shortage of space, rot in windows, doors or floors, damp or leaks in walls or roof, lack of indoor flushing toilet, lack of bath or shower and lack of place to sit outside (e.g. garden, balcony, terrace etc.). Single binary variable is again derived from the six partial binaries (problem exists / problem does not exist) same way (one category contains only respondents having no problems with housing and the other contains respondents having one to six problems with housing, respondents having refused all six items are excluded from the dataset). This variable of the housing defects is abbreviated as “ACCOMP” in the model.

Subjective measures are based on the respondent’s subjective feeling of their own situation rather than on the objective material living conditions. Broadly speaking the relative income is the income compared with a defined standard given by other incomes as perceived by the respondent. As discussed before the income can be compared with own income in the past and the income of people in the country, region or closer neighborhood. Same for the financial situation. The EQLS question dealing with own financial situation compared with others is the following: “Could you please evaluate the financial situation of your household? In comparison to most people in your country would you say it is much worse, somewhat worse, neither worse nor better, somewhat better or much better?” For the purpose of modelling this 5-point scale is transformed into the 3-point scale (worse, the same and better financial situation). The variable is hence ternary and is abbreviated as “FINSITEVAL”. The EQLS question on comparison with own past was posed this way: “When you compare the financial situation of your household 12 months ago and now, would you say it has become better, worse or

remained the same?” The ternary variable is abbreviated as “PASTFIN” in the model.

The perceived economic strain is covered by the following EQLS question: “Thinking of your household’s total monthly income: is your household able to make ends meet very easily, easily, fairly easily, with some difficulty, with difficulty or with great difficulty?” This 6-point scale is transformed to only two categories of those able to make ends meet easily and those able to make ends meet with difficulty. The transformed variable used for modelling is abbreviated as “MEE-TENDS”.

The model in the form of Bayesian network is constructed using the above outlined data. The expertise gained from the existing literature review is used to establish the structure of the model, whereas parameters are learnt using EQLS data as described above. To evaluate the predictive accuracy of the expert model two more benchmark models are constructed using different structure learning approaches: a greedy algorithm and the optimal Gobnilp algorithm [6]. To summarize, in this empirical study, following models are considered:

- **Greedy-BIC** – structure learnt with the greedy search-and-score algorithm with the BIC scoring criterion.
- **Gobnilp-BIC** – structure learnt using the Gobnilp algorithm with the BIC scoring criterion.
- **Expert** -- structure learnt using expert knowledge.

The structural learning of the Greedy-BIC model is performed in the analytic software Hugin [23], parameters of all models are learnt in Hugin as well. Structure of the Gobnilp-BIC model is learnt using Gobnilp software [6]. Gobnilp-BIC model is optimal in terms of the BIC criterion.

4 Model and discussion

In Figure 1 we present the suggested Bayesian network which represents the relations among SWB and the variables approximating the material situation of an individual. The variable referred as COUNTRY represents the country the respondent come from. Figure 1 Bayesian network structure (expert version). The suggested model is examined from the perspective of conditional independencies and the ability to predict SWB based on the given material situation variables. Expert argumentation for the relations between the nodes is summarized with the special respect to SWB.

4.1 4.1. Variables directly linked to SWB

SWB is directly linked with the relative income expressed as both *the income relative to own past* (represented by the node PASTFIN) and *the income relative*

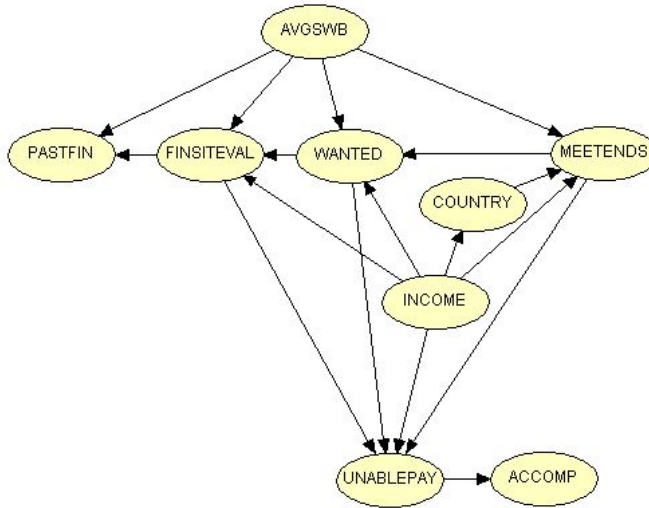


Figure 1: Bayesian network structure (expert version)

to the other people in the country (represented by the node FINSITEVAL). The two expressions of the relative income are also directly linked. As seen before, the direct link between SWB and the relative income can be traced to the literature, for example [5] and [8]. Simply said, people are unhappy and unsatisfied when feeling their material situation get worse comparing to either what was before or what others have. The measures are both subjective. SWB is also directly linked with the *material deprivation* (represented by the node WANTED). This direct link can also be supported by the literature, for example [1]. Basically SWB drops down if one hunger after something that cannot be afforded. The last variable directly linked with SWB is *perceived economic strain* (represented by the node MEETENDS). The evidence for the direct link can again be found in the literature, for example [26] and [12]. Common sense reasoning is that SWB is reduced in case a household is unable to make ends meet. The direct link between the *economic strain* and the *material deprivation* can be supported by the literature too, where [32] and [33] stand as examples. Inability to make ends meet in essence corresponds directly with the impossibility to afford things desired. Similarly, the subjective assessment of own financial situation compared to most people in the country is linked with the *material deprivation* – people are deprived as they cannot afford things they think other people in the country mostly can. To summarize, SWB is directly linked with all other subjective measures in the model (there is no other subjective measure in the model). The only objective measure directly linked with SWB is the *material deprivation*. These five interconnected variables constitutes a sort of cluster within the network.

4.2 WB and income and country

Two variables are d-separated from SWB in the model – the country and the income. It means that if we know nothing else, SWB is independent of the country and the income. It can be easily argued that the household’s income in absolute terms is linked with the country in which the household resides. It is not that apparent from the perspective of the four examined countries, but it is clear globally. Independence of SWB and the country means the level of SWB cannot simply imply the characteristics of a given country and vice versa. For example, we cannot conclude that people living in the rich countries are automatically happier and more satisfied with their lives than those living in the poor countries although the common sense might suggest otherwise.

Modern economic discussion on the relations between the level of SWB and the economic performance of a country as well as household’s level of incomes was launched by Richard Easterlin [13]. Based on the empirical evidence he proposed, that there is a noticeable positive association of the income with the happiness within a given country. But the picture is quite different from the international perspective; the reported level of happiness on average was not associated with national income per head. At least in countries, where the income per head is sufficient to cover basic needs¹. Shortly, people in a rich country are not on average happier than people in a poor country (given that basic needs are met), but within a given country the income and the reported happiness are associated. Furthermore, according to the Easterlin, there is no correlation between the increase in national product per person and the increase in the average reported happiness over the long-term. Twenty years later Easterlin [14] reacted to the criticism of his research (e.g. [31]) and refined his original conclusion. This refinement is that raising the incomes of all people in the society does not increase the happiness of all, because, so-called, “material norms” increase in the same proportion as the income of the society. When the country becomes richer, higher level of income becomes normal – although the absolute income is higher, the relative income remains the same. This Easterlin’s arguments are in essence in line with the conclusions of the importance of the relative income explored above. Once again Easterlin [16] confirmed his paradox on updated dataset and stressed that the happiness and the economic performance are not related only in long term, while short term fluctuations of the happiness and the national income are positively associated. Because of confusion the short and long term trends, some authors may suggest the positive relation of SWB and GDP in long term too. There are many studies confirming (e.g. [2]) and disputing Easterlin’s conclusion (e.g. [21], [31]) and the debate is certainly not over.

¹His conclusion was later nicknamed Easterlin paradox.

4.3 Variables intermediating SWB and income

Based on the suggested graph SWB and the country are d-connected when other information is available; information of either relative income or material deprivation or perceived economic strain. The importance of the relative income as a mediator between SWB and the economic performance of the country has just been discussed. If the relative income is known, the conclusion on the country can theoretically be drawn from the level of SWB and vice versa. Still, this conclusion can be reached rather in case of more different countries than the four examined central European ones². The perceived economic strain as well as the material deprivation could be contemplated in the same way as mediators. Both variables were examined in the EU-wide context by [20], who suggest that these measures should be employed as indicators for certain purposes rather than the income as they provide better information than pure income thresholds in situation of inequality in the income between the EU member states.

The important feature of the model is that the absolute level of the income is treated as conditionally independent of SWB and the knowledge of mediating factors is needed since SWB and the income are d-separated (given an empty set). It is a sort of the model assumption, as immense amount of studies confirming that the income and SWB of an individual are associated can be found as already discussed. Still, newer research tend to understand the income rather as indirect measure (e.g. [4]). Relative income, perceived economic strain and material deprivation are the suggested mediators between the income and SWB in the Bayesian network. If we know one of them, the link from the income to SWB is unblocked. Direct links from the income to all of the three mediating variables can be well argued.

In case of higher current level of the income the probability of the subjective evaluation of own income compared to others increases. (Absolute income is not directly linked with the relative income compared to past, the way goes through the node FINISTEVAL. It means the knowledge of the income is not necessary to conclude on the relative income compared to past). Similarly higher income can be directly associated with lower perceived economic strain (making ends meet is more probable) as well as with less material deprivation (affordability of things wanted is more probable). Same the other direction. It is assumed that the income and SWB is independent, but if we know how this income is perceived relative to other people in the community, we can conclude on SWB and vice versa. Similarly, with the knowledge of the material deprivation or the perceived economic strain we can conclude on SWB from the income. For example high income leading to the ability to afford things wanted leads us to conclude on good level of SWB. On the other hand the same level of the income can be insufficient to afford things wanted for another household which will lead to dissatisfaction as they become deprived. We must have such information to conclude on SWB from the income.

²For example, such a conclusion can be made in case of comparison the Czech Republic with Bhutan, a poor Buddhists country known for their extraordinary nation-wide approach of pursuing happiness.

This is confirmed by the literature concerning on material aspirations. Based on [15] the material aspirations increase together with the income over the life course, whereas SWB, generally, rises with the income, but inversely with the material aspirations. The rise of the income causes the rise of SWB on the one hand, but also the rise of the material aspirations on the other hand. The rise of the material aspirations affects negatively SWB and erase the positive effect of the income. People tend to want more and more throughout the life, which negatively affects their SWB (SWB would otherwise gain from the increase of the income). Similarly [29] empirically tested the effect of the income aspirations on people’s utility operationalized as reported satisfaction with life. He finds that, *ceteris paribus*, higher income aspirations reduce people’s utility measured by the satisfaction with life. The author offers two explanations for that: processes of adaptation and social comparison. Firstly, the increase of the income initially provide additional pleasure at the beginning, but the effect disappear as people get used to the new income level. Secondly, the relative income position rather than absolute level of the income matters, because people tend to compare themselves with others in the community. Stutzer talks about “socially comparative or even competitive processes in consumption” [29, p.3]. This view is in line with previously referred Easterlin paradox, because people in a rich country are adapted to their material standards and simple fact that they are richer than people in a poor country cannot make them happier. People in the poor country have their own standards they are adapted to. To conclude on the material aspirations, [28] found the negative relationship of life-satisfaction with materialism (which could be seen as individual orientation to possession and acquisition). Materialistically oriented people were less satisfied with their lives as a whole, with their standard of living, family lives and other life domains than those low in materialism.

The literature hence confirmed that it is important to know whether the income is sufficient for the ability of afford desired thing in order to conclude on SWB. Logic is the similar in case of the perceived economic strain. The income sufficient to safely make ends meet probably promotes the higher level of SWB, still, the other household may not be able to manage to make ends meet with the income in the same amount.

4.4 Other variables

Only variables examined so far and no other variables are in the Markov blanket³ of the node SWB, the two of them (income and country) are d-separated given the empty set and the rest is d-connected (given the empty set). If we know the states of them, no other information is necessary to conclude on SWB. The two other variables remains outside the Markov blanket: *financial problems* (UNABLEPAY) and *housing defects* (ACCOMP). They are both associated with SWB, but having

³The Markov blanket of a variable A is the set consisting of the parents of A, the children of A, and the variables sharing a child with A. If all variables in the Markov blanket for A are instantiated, then A is d-separated from the rest of the network [24, p. 11].

the information of either relative income or perceived economic strain or material deprivation, information of the financial problems (and the housing defects) are not necessary. If a household does not feel economically strained (or feels their situation is relatively good or can afford what they otherwise want), the SWB of that household might be good even if it has problems paying bills in arrears. On the contrary, if there are no problems paying bills, but members of the household feel deprived, economically strained and bad in terms of their situation compared to others, their SWB will probably be worsen. Still, if we have no other knowledge, information on financial problems is relevant in terms of SWB prediction.

Other links in the model can be explained in similar way and analyzed further. For example the income is directly linked with financial problems – having less income may affect the ability to pay bills if households has no savings. The last comment belongs to the node of housing defects, which seems to stay a bit apart from the heart of the network as it is linked with the rest of the network only via the node of financial problems. This variable covers, inter alia, the problems with payments of rents, mortgages, utility bills etc. It could hence be expected that the inability to pay such bills is also connected with housing defects (household has to move to a smaller apartment of a lower standard).

4.5 Prediction of SWB

We perform an evaluation of the prediction accuracy of the expert model and compare it with two learning algorithm approaches. The prediction accuracy is tested using the R software [27]. The adopted approach uses 75% of the available dataset as training data to learn the parameters of the model whereas the obtained predictions of SWB are compared with the true state of SWB on remaining 25% observations in the second step. Ten rounds of such tests were performed. The average accuracy of the expert model in predicting SWB is 66.83% (95% confidence interval 65,87% to 67,78%), which is significantly different from no information rate of 55.16%.

The prediction accuracy of the expert model is compared with the other two models presented in Figures 2 and 3. The SWB prediction accuracy of the Greedy-BIC model learnt with Hugin [23] is 67.01% (the 95% confidence interval is from 66.05% to 67.95%). In case of the Gobnilp-BIC model learnt with GOBNILP software [6] the prediction accuracy of SWB is 67.00% (the 95% confidence interval is from 66.04% to 67.94%). This third model is optimal with respect to the Bayesian Information Criterion (BIC) and it has its BIC equal to -24390.4 while Greedy-BIC model reached BIC of -24391.2. The expert model is worst out of the three suggested model with BIC equal to -24754.2. The two machine learnt models are almost identical in terms of the predictive accuracy as well as BIC, where the Gobnilp-BIC model seems to be only marginally better as suggested by both measures.

Although expert model is the weakest in terms of BIC and the predictive accuracy, it does not significantly differ from the other two models learnt from data.

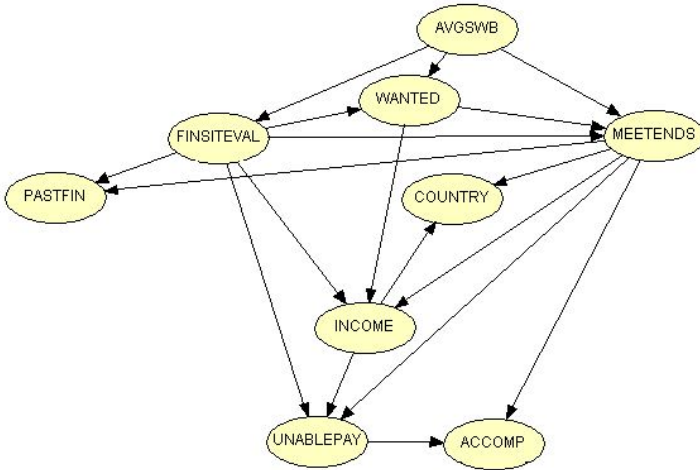


Figure 2: Bayesian network structure (Greedy-BIC version)

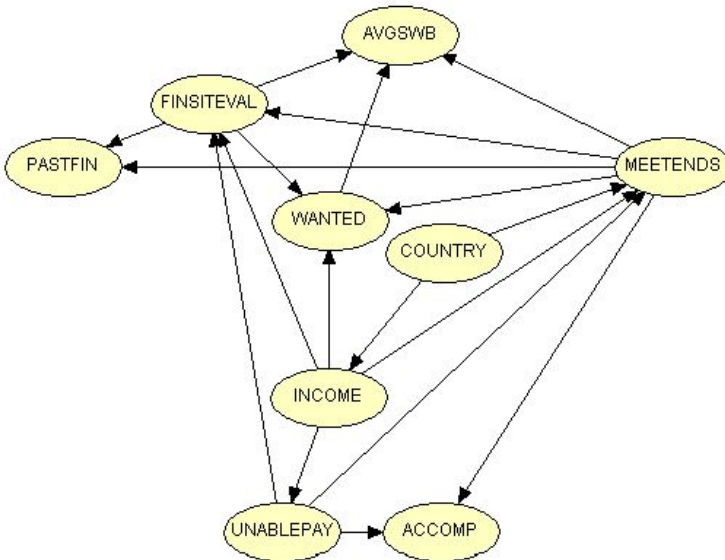


Figure 3: Bayesian network structure (Gobnilp-BIC version)

The expert version is worth considering, because it represents relations and conditional independencies of SWB and factors related to material conditions known from the social research made so far probably better than the other two models. The key difference between the expert version and the other two models is the conditional independence of the income and SWB as well as the country and SWB. The key feature of the expert version is that the income (the country) and SWB are conditionally independent (given the empty set) as explained earlier, whereas the income and SWB as well as country and SWB are d-connected in the benchmark models.

5 Concluding remarks

This contribution is an attempt to employ Bayesian networks in a research of sociological topics such as SWB. To the knowledge of the authors the Bayesian network approach has not yet been adopted in the way described in this paper. However, as such, it should be understood as a first step of a longer journey.

For the analysis, the EQLS data of four Central European countries collected in 2011 are used with the argument of the similarity of these countries from several points of view. The model hence reflects the situation in these post-communist countries and a care should be taken when using it in different context. Recently, newer data were made available⁴, there is hence a room for updating and a further exploration.

Expert model, as well as the other two models, are able to predict SWB based on material living conditions and deprivation considering that these factors constitute only a small part of the whole picture. Immense number of studies is available on SWB and how it is associated with the factors related to demography, aspirations, expectations, personality, social relations and wider environment, where personality traits seems to matter in long term, while life events play the role rather in short term. Most of the factors we examined falls into the latter category, whereas the subjective opinion of material living standards and deprivation are certainly impacted by the personality too. Other than material factors are not reflected in the suggested network as they are too tangled to be described in their complexity.

Acknowledgement

This work was supported by the Czech Science Foundation (project 17-08182S).

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