The Long-Range Macroeconomic Effects of Sars-Covid-19 Pandemic in Hungary: a Conceptual Framework and Methodology – Focusing Approach

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Abstract: The COVID pandemic has caused an unprecedented socio-economic situation in the world, short-term consequences of which are well documented. At the same time, the long-term effects of the crisis are much lesser studied and quantified. The goal of the current paper is to demonstrate a potential way of analysis for quantification of economic consequences of the pandemic based on a combination of econometric, health statistics and health economic data. The direct losses in the long-range, caused by COVID related death up to the end of January 2022, compared to the predictable economic development trajectory of Hungary were estimated as 1.2-1.4 milliard USD, discounted to the current value. Results of analysis highlight the importance of health care system development in the maintenance of economic dynamism as well as health-related intervention programs.

Keywords:Cobb-Douglas function; disease burden; simulation; system dynamics modelling

1 Introduction

It is well documented that one of the biggest shocks to the modern world economy has been the pandemic, caused by the virus strain "*severe acute respiratory syndrome coronavirus 2*" [1] (SARS-CoV-19, hereinafter: COVID). Its short-term consequences are well treated on the scale of the global economy [2] [3] [4], of different countries [5] as well as in various branches (e.g. [6] [7]) and practically in all spheres of socio-economic activities [8]. At the same time, we have a rather vague concept of its long-range macroeconomic consequences. The purpose of the current paper is twofold: (1) presentation a general, simple, but transparent and relatively easily applicable conceptual model, based on a combination of macro-, demographic- and health economic data to determine the long-range consequences of the Covid crisis; (2) application of this approach to the Hungarian economy to calculate the direct, long-range consequences of deaths, caused by the pandemic.

2 Methodology

2.1. Conceptual Framework

The backbone of our approach is the application of the Solow-Swan model of economic development. This framework is a very simple model of long-run economic growth of Solow, 1956 [9] and Swan, 1956 [10], based on quantification of the mutual, dynamic relationship of production factors and value-added in a given national economy. The conceptual framework of the model is depicted in Fig. 1.

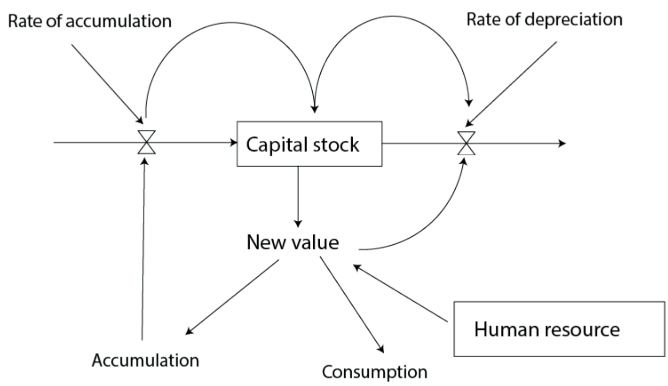

Figure 1
The conceptual model of economic development, based on the theory of Solow and Swan

Results, presented in the current paper, are based on a rather complex workflow, the basic idea of which has been originally developed for quantification of burden of chronic non-communicable diseases by the World Health Organisation (WHO) [11]. Our workflow consisted of four main steps. These were as follows:

1) In the first phase of research, we have determined the stochastic relationship between the two basic production fact///ors: capital and labour and the new value-added, approximated by the GDP. Traditionally, this relation is based on Cobb-Douglas function [12] [13] [14]. However, this method and its theoretical foundations are sometimes questioned [15], it is widely applied to describe the lows, governing economic growth [16] [17]. The classic form of this equation is a constant elasticity of substitution (CES) function:

$$y = \gamma\left(\delta x_1^{-\rho} + (1-\delta) x_2^{-\rho}\right)^{\frac{-\nu}{\rho}}$$

Where y is the value-added of the national economy, x_1 and x_2 are the production factors (in our case the capital and the labour) γ,ρ,δ,ν are parameters. The function (1) is not linear in parameters, and cannot be linearised on the base of traditional methods, that's why we had to apply different non-linear least-square optimisation algorithms. For this purpose, we have used the micEconCES r–package [18], which offers a wide range of algorithms for fitting and estimation of parameters.

The latest publications on CES functions [19] take into consideration the effects of quality changes in human resources. These approaches are mainly based on the equation, proposed by Mincer [20] to measure the economic effect of schooling. For the sake of completeness, we present the changes in quality of the living labour, but we had been focussing on quantitative changes in human resources because the inclusion of estimations on the future level of human resource qualification could make the model a rather speculative one.

Based on these pieces of information we had been able to construct a theoretical model of Hungarian economic development for the next decades, without taking into the consequences of COVID–related additional burden of disease. This model will be called hereinafter as the baseline model.

2) In the next part of the research, we have determined the additional burden, caused by the COVID pandemic. Based on the conceptual model, depicted in Fig. 1, we have assumed that the pandemic created economic losses will affect long-range, beyond the immediate economic backdrop. (1) This will be a consequence of COVID-related deaths, decreasing the human workforce; (2) The premature deaths of COVID decrease the population, and this process generates structural changes in health care costs. As a consequence of these two processes, there are changes in production factors in the national economy, which based on circular causality will lead to further changes in macroeconomic performance. This trajectory of economic development has been called as a post-COVID model. This model is a dynamic one, too, which considers the yearly changes in the number of different cohorts from year to year in a way, depicted in Fig. 2.

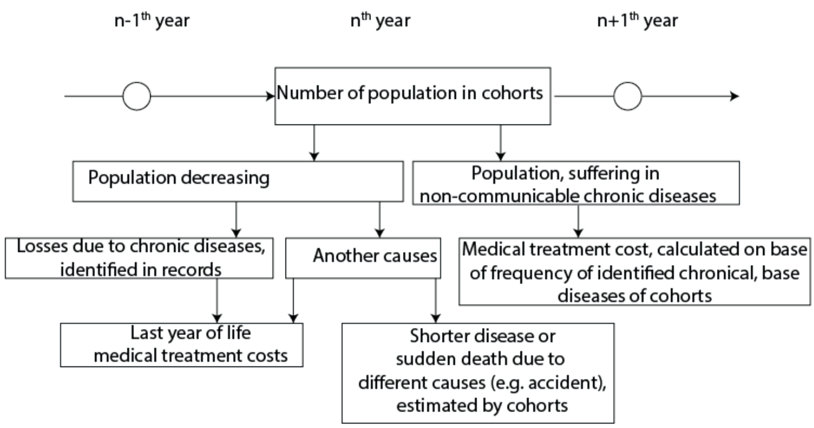

Figure 2

Model for medical cost estimation

3) The comparison of baseline and the post-COVID model offers a possibility to quantify the long-range effects of the COVID pandemic. To compare the different monetary values, we have applied the Net Present Value (NPV) concept Gaspars-Wielloch [21]. According to this approach, the present value of a future cash flow can be calculated by the formula (2).

$$NPV = \sum_{t=0}^{t=n} \frac{CF_t}{(1+i)^t}$$

where CF_t is the cash flow at the t_{th} time period and i is the discount rate.

4) The different parameters of the model are based on estimations, with a relatively high level of uncertainty. That's why we have applied simulations techniques to quantify the sensitivity of the model.

2.2. Operationalisation of the Research Plan and Data Management

2.2.1 Estimation of the Baseline Scenario

Data for the determination of Cobb-Douglas function have been downloaded from Penn World Table [22] [23]. This, internationally widely recognised and applied [24] [25] database contains a wide range of parameters, from which we have used the indices as follows: Real GDP at constant 2017 national prices, converted to 2017 USD, number of persons engaged, capital stock at constant 2017 national prices, converted to 2017 USD.

The general demographic processes in Hungary for the next decades have been determined on the basis of UN population forecast database [26]. We have supposed that the average working-age will begin at age 20 and end at the age of 65. We calculated with a 70% participation in the work of active population. This is in line with the current share. According to the data of the Central Statistical Office of Hungary [27] the average age of people, entering into a pension in 2019 has been 63 years, but in the case of younger generations, the age limit of work will be 65 years. We have calculated with this value, supposing that each person, who is capable of working is willing to labour as a full-time worker. At the same time, we have supposed, that the people in pension will not work in any form (which is – of course – a considerable simplification). We have not had enough information on the severity of different diseases, that's why we have estimated that the work intensity of individuals with diseases will be lower by20 per cent.

The average depreciation rate has been 4.5792%, determined as an average of estimations for 2015-2019 years in Penn database. The gross capital formation ratio has been estimated on the basis of the World bank Database [28]. This ratio has been 25.483% of the GDP in the average of the 2016-2020 years. We have supposed that this ratio will be standard for the next few decades.

In our calculations, we have supposed that the GDP of Hungary in 2023 will return to the level of 2019. In this way, we have not taken into consideration the short-term economic consequences of COVID.

2.2.2 Estimation of Parameters to Determine the Economic Losses

Data for the determination of prevalence and general causalities of different diseases have been downloaded from the Global Burden of Disease Collaborative Network database [29]. Currently, this database can be considered as a „gold standard" of disease-prevalence related calculations [30] [31] all over the world.

The most critical part of the study has been the determination of the health condition of people, who died in the COVID. The data collection on COVID-related mortality and morbidity data is not standardised on the international level, that's why the comparison of original (raw) data is not possible [32]. The competent Hungarian authority regularly issued the data of deceased individuals on a specific website [33], but the indication of different diseases has not been in line with any standards. The cause of death has been indicated often rather generally or according to the jargon, applied in the actual hospital. A detailed critique of this system has been written by Ferenci [34]. His heroic work [35] has been an essential contribution for data cleaning: e.g. the name of high blood pressure as a disease has been written in 24(!) variants in the original database.

The dataset, cleaned and created by Ferenci [36] has been the stepping stone for further analysis. In the next phase, we have determined the economic consequences of death due to COVID. For this purpose, by the built-in random number generator of Excel we have chosen a sample of 200 dead people from causalities of pandemic below 60 years, and different five-years age brackets from 60 to 85 years. We have analysed their health condition one by one, including two colleagues with MSc-level health-care qualifications. One of the authors and these specialists independently classified the health status of the persons in the samples and determined the most life-threatening disease, if there has been different diseases indicated.

On the basis of GBD dataset, we have estimated expected life-years with the given disease. In case of casualties, where no disease has been indicated, we have supposed a mortality rate, which has been calculated for the given cohorts, by GBD database. If there has not been given any information on the base disease of the deceased, we have projected the relative share of diagnosed diseases on this group. The deceased people, who did not have any known basic disease have been dealt with separately.

Costs of treatment of different diseases have been collected from the peer-reviewed literature, on the basis of heuristic research of Pubmed and Web of Science databases.

According to the European Cardiovascular Disease Statistics [37] the prevalence of cardiovascular diseases in Hungary has been 1.22 million people, the total cost of treatment was 1.511 milliard €, the cost per capita was 153 €/year.

In the case of cancer-related diseases, the direct economic costs of cancer treatment in Hungary has been 393 million € [38], the estimated prevalence is 225 thousand, that's why the costs were estimated as 3500 €/year.

Neural diseases cover a very wide range of diseases. From this follows that the costs of treatment are estimated on the basis of the article of Kovács et al. (2020) [39] as 1000 €/year/patient.

The most important component of the disease group is diabetes. There are different estimations of diabetes treatment costs [40], we have applied the cost review of Stegauer et al. (2020) [41]. According to their systematic review, the median of diabetes specific direct costs according to different studies is approximately 500 € annual excess cost for patients with type 2 diabetes. The chronic kidney disease costs show considerable differences as a function of the severity of the disease. The lowest costs of these treatments are in the range of 14-80 thousand USD/year.

The comparison of health care costs in different countries is an extremely difficult task. This problem is well treated in the literature [42] [43]. For simplicity, we have applied the comprehensive study of Koechline et al., 2017 [44].

Diernberger et. al [45] estimate the health treatment of last year's costs in Great Brittain as 10000 Pound Sterling. According to the calculations of [44] price relations of health care systems in Hungary and Great Brittain are in 35:110 ratio, that's why in case of Hungary we have calculated by 3100 GB Pounds cost in last year of life, which is equal to 3700 € for the last year of life.

For calculation of NPV we have applied a conservative 6% time preference (discount) rate.

3 Results and Discussion

In the first phase, we have determined the Cobb-Douglas function of the Hungarian economy on the basis of data from 1970 to 2019. If we consider the dynamics of the most important indicators, obviously there are rather contradictory tendencies (Fig. 3). The GDP had been increasing rather rapidly between 1970 and the middle of the eighties of the last century. At the end of the centrally planned economy, the GDP witnessed stagnation. The system transformation caused a considerable backdrop, but this decrease in value-added creation has been counterbalanced by rapid development, which had been fuelled by international conjuncture.

The economic performance has been considerably increasing after the years of the world economic crisis in the last years of the first decade of the new millennium. The capital stock continuously increased, however, the investment cycles remained a characteristic feature of the Hungarian economy (Fig. 4). It is worth highlighting the increase of intellectual capital. The working population considerably decreased after the system changed. In the last decade, there is a rapid increase in it.

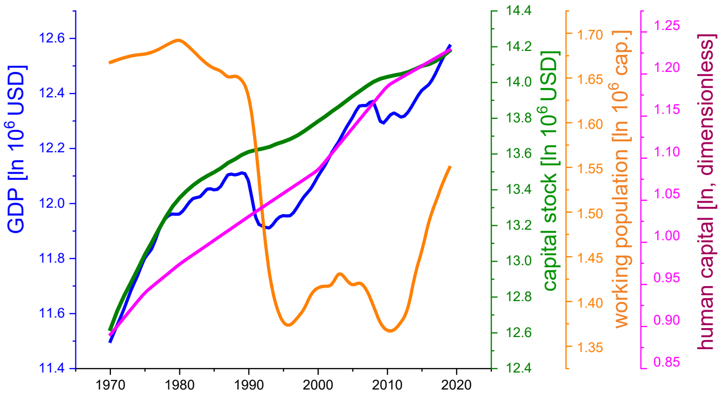

Figure 3

Changes of GDP and factors of production in Hungary, between 1970 and 2019

Source: own compilation, based on [23]

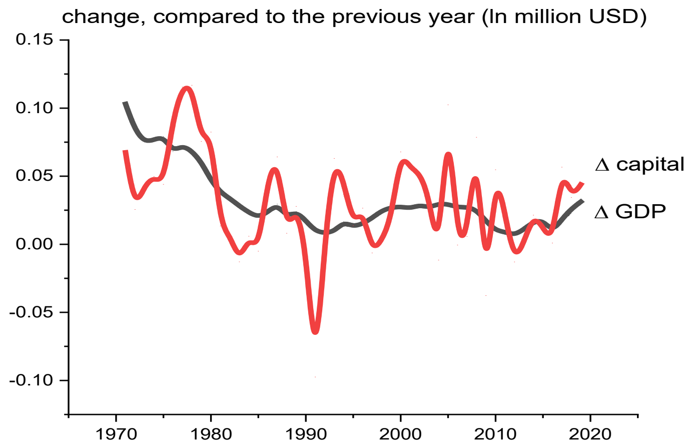

Figure 4

The roller coaster of Hungarian investment cycles

Source: own compilation, based on [23]

Analysing the results of fitting of the CES function (Table 1), it is obvious that the R squared values in some cases (e.g. Kmenta approximation, Hicks neutral technological change) are not interpretable. In the case of numerous methods, the fitting of the function is rather high, but the elasticity of substitution values show a considerable difference.

Table 1
Determination of Cobb-Douglas function parameters by different algorithms

Algorithms	γ	δ	ρ	υ	Multi. R^2	Elasticity of substitution
Kmenta approximation	5.94*	-0.89*	-0.50**	1.36**	-495.44	0.66
Conjugate gradients	0.81	0.42	-1.89	1.23**	0.98	-1.12
Conjugate gradients with increased level of tolerance	2.95	1.00**	-0.02	0.53*	0.71	1.02
Newton-type method	1.62	1.73	-0.35	0.56**	0.89	1.55
Broyden-Fletcher-Goldfarb-Shanno algorithm	2.75	0.00	-5.01	1.27**	0.99	0.05
Nelder-Mead global optimisation	1.16	0.11	-3.75	1.14**	0.98	1.79
Simulated Annealing	0.67	0.73	-1.84	1.17**	0.98	-1.17
Differntial evolution	4.95	0.99	-0.75	0.33	0.22	10.01
Byrd, Lu, Nocedal and Zhu algorithm	0.52	0.95	-0.37	1.22	28.26	1.59
Quasi-Newton Port routine	0.30**	0.84**	-1.00	1.43**	0.98	NA
Hicks neutral technological change (lambda=9.42 6E-3)	3.0E-8	6.29E-1	1.89	1.04	-3.19	0.34
Grid search algorithm	0.52	0.96**	-0.30	1.22	0.98	1.42
Two-stage grid search	0.60	0.77**	-1.21	1.23	0.985	-4.78

Legend: * significance at 95%, ** significance at 99%

We have applied the parameters, obtained by application of Newton-type method for further work. Obviously (Fig. 5), the function, which has been determined, are suitable to describe the long-range development trajectory of the Hungarian economy in the last fifty years. There is a wide choice of different functions, but the difference between the various function is marginal.

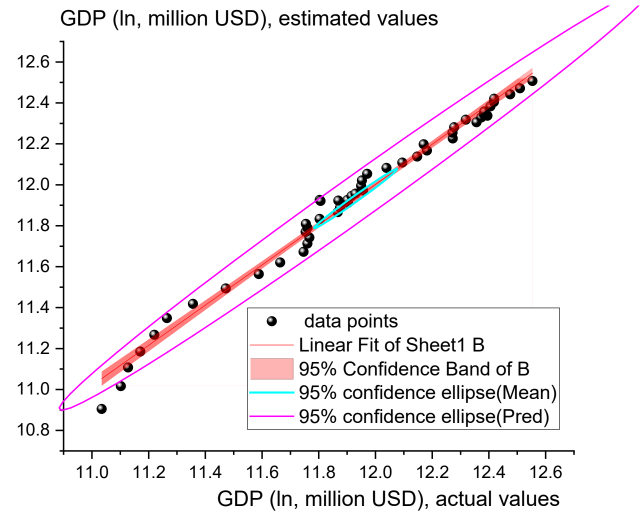

Figure 5

Fitting of the estimated CES function

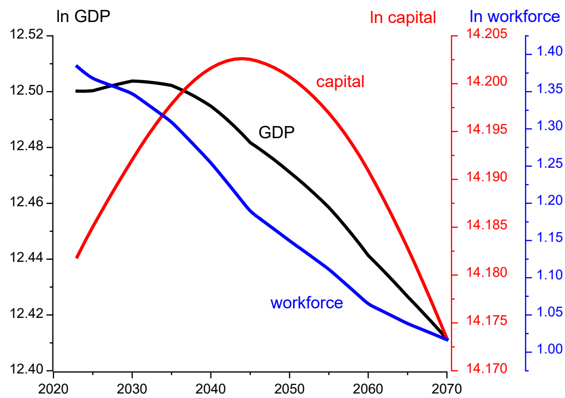

Figure 6

Characteristic parameters of the baseline model

The results of the baseline model (Fig. 6) show a relatively constant decrease in the GDP and the workforce. The relatively high level of capital accumulation rate will increase the capital stock up to the middle of forties, but later on, the demand of workforce will cause a decreased capital stock, and the superposition of decreasing of the workforce and the capital stock will cause a further decreasing of the GDP.

The analysis of the share of the relative share of different diseases in the case of deceased people shows highlights some characteristic features. Obviously (Fig. 7), the share of various diseases does not show very large differences according to cohorts. As a tendency, it can be determined the dominating role of cardiovascular diseases at all age groups. Neurological diseases play an increasing role in the case of elder age brackets.

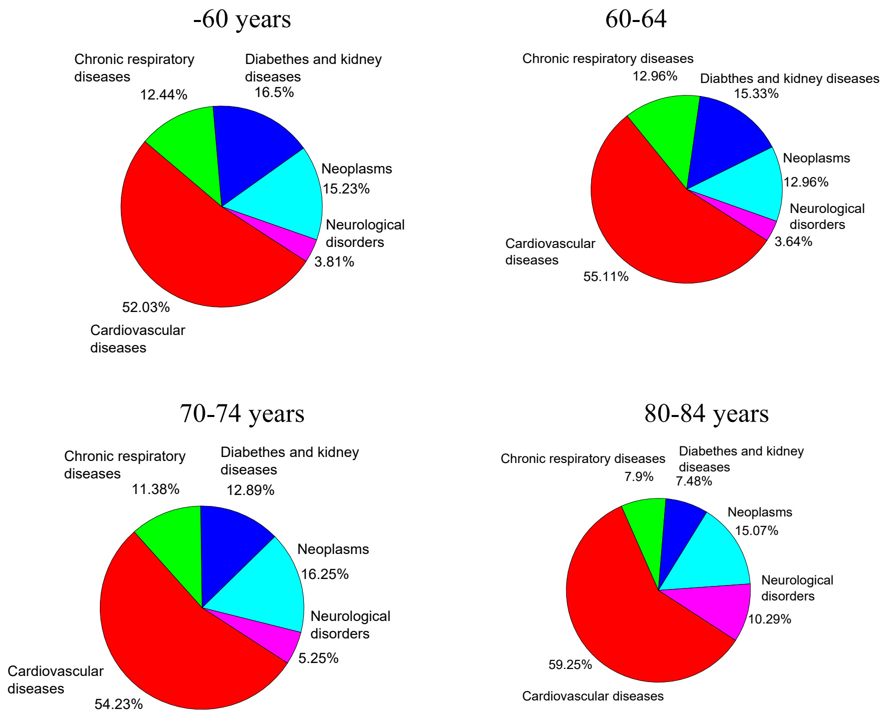

Figure 7

Distribution of known, disease groups by age-brackets

The analysis of the dynamic model to determine the long-range consequences of the pandemics offers two main lessons:

(1) the premature death of working-age members will generate long consequences, the value of which will be between 80-200 million USD in different years. This is equivalent (in current prices) with 18.9-63 milliard HUF. This former is the same order of magnitude, as the budget, allocated for the running of the Ministry of Justice in the Hungarian Budget [1.] for 2022 (19.7 milliard HUF).

(2) If we take into consideration the consequences of re-allocation of healthcare costs, the losses will be lower, especially in the next decades.

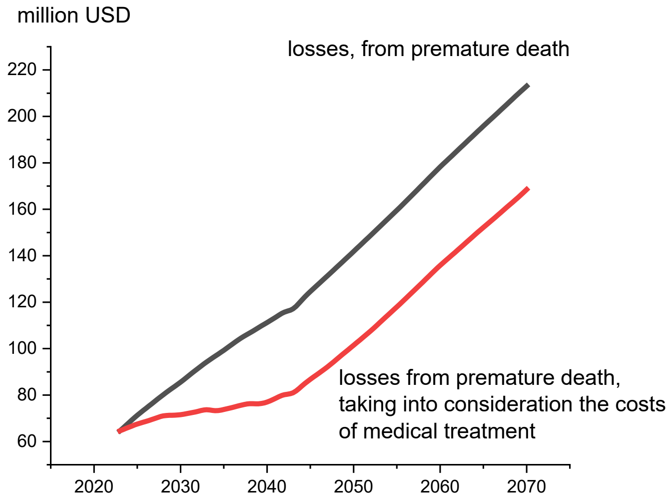

Figure 8

Losses in different years as a consequence of premature death, with and without taking into consideration the medical treatment costs

As we have emphasised earlier, there is a high-level of uncertainty in our calculations, that's why we have analysed the stability of values by simulation. Obviously (Fig. 9) results of simulation of NPV value show that the present value of losses of COVID disease will be between 1.2-1.4 milliard USD. This is double the sum, allocated for higher educational purposes in the Hungarian budget.

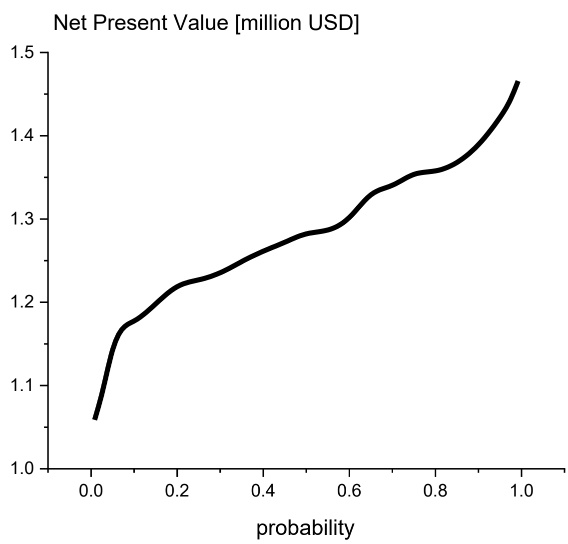

Figure 9

The cumulative distribution function of NPV value of losses, caused by the pandemics

As a summary, it can be stated that the direct, long-range economic consequences of COVID crises are considerable and their adverse effect will be felt in long-time, even if their yearly value is lesser than one tenth per cent of the Hungarian GDP, the net present value of the losses, calculated by 6% discount rate are approximately 1.2-1.6 milliard USD. This fact highlights the importance of the health care system because we have seen that even a moderate decrease of the working population can cause considerable losses. This fact does not counterbalance by lower health care costs, due to premature death of elder generations. Notwithsanding of lack of pieces of information, it can be seen, that the econometric modelling can be a suitable tool for the evaluating and forecasting of the consequences of the pandemics.

4 Limitations

This paper should be considered rather as an interim report, than a final, comprehensive summary of the economic consequences of the COVID crisis, because there is a lack of evidence on the end of COVID pandemics yet. On the approximate date of the end of pandemics, there are different, rather contradictories estimations [47].

The Cobb-Douglas function seems to be an appropriate approach to describe the long-range relation between the capital, but there is room to further sophistication of the model, including other parameters.

The current article has been focusing just on the fatal consequences of the COVID. There is an increasing quantity of proof on long-range adverse consequences of COVID [47], but the time is too short to quantify these. As a consequence of the COVID-caused overburden of the health case system, numerous screenings and not-essential medical interventions were postponed. This fact increases the long-range adverse consequences of the COVID pandemic [48] [49] as well as the adverse psychical consequences Searfini et al.

The effect of the COVID pandemic has modified practically all spheres of socio-economic life. That's why the economic consequences are much deeper and wider as we have presented.

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