Optimising Nobel Prize Laureates*

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The Nobel Prize, which has existed since 1901, is awarded to persons (and on rare occasion to institutions) who have achieved outstanding results in physics, chemistry, medicine, literature and the pursuit of peace. The history of the Nobel Prize in Economic Sciences – awarded for the first time in 1969 and officially known as the 'Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel' – shows a slightly different picture, since in the first two decades it was awarded to still living "doyens" of this branch of science (Frisch, Tinbergen, Hicks, Myrdal, Hayek, Haavelmo, Coase – just to mention a few of them). In recent years, this prize serves primarily for the recognition of research results: In 1994, 2005, 2007, 2012 and 2014 the prize was awarded to scientists excelling in various game theories, in 1996 and 2001 to experts working in the field of asymmetric information, and in 2002 to experts researching the link between psychology and economic science. In 2010 and 2016, the Nobel Prize in Economic Sciences was awarded in the field of labour market analysis and contract theory, respectively. It appears as if the Committee awarding the prize first chose a generally topical subject matter and then award the Prize to experts who are successful and produce outstanding results in that field. 2018 was no exception. Although the laudation of the two laureates – William Nordhaus and Paul Romer – mentions their excellent scientific achievement, as they received the Prize "for their work analysing the impact of climate change on global economy, and related to the endogenous growth theory", a more detailed analysis shows that here again there is a very strong link between the two scientists in terms of content and methodology, since the problem of sustainability and the application of the optimisation procedures, mentioned in the title, also connects them.

Journal of Economic Literature (JEL) codes: B22, O40, O44

Keywords: endogenous growth theory, sustainability, climate change

1. Optimisation and control

Anybody who is just a little bit familiar with the history of economic science knows that optimisation appears in this discipline as early as with Adam Smith, at the time when formalised procedures were yet unknown. In the 19th century – particularly

* The papers in this issue contain the views of the authors which are not necessarily the same as the official views of the Magyar Nemzeti Bank.

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The Hungarian manuscript was received on 13 January 2019.

DOI: http://doi.org/10.33893/FER.18.1.125141

since *Jevons* (1871) – the optimal consumption structure of households and the optimal factor utilisation of enterprises, etc. were already defined with the use of mathematical tools. However, these problems have always been examined statically, i.e. the optimal solution was determined under given and *constant* conditions. Dynamic elements appeared in the economic models relatively late.[1] In economic sciences, studies using the dynamic approach commenced in larger numbers only from the 1950s; however, these were still limited to the description of processes. The focus was on issues such as that of *Robert M. Solow* (1956), the laureate of the 1987 Nobel Prize of Economic Sciences, the goal of whose research was to find out how the growth of the revenue of an economy, which can be characterised by a given willingness to save – and in connection with this – to invest, can be modelled. In the language of mathematics: In fact, Solow and his followers set up a differential equation, which defines the temporal development of revenues or any of the variables determining that, under given parameters – constant growth rate of the population, stable saving rate and also a given depreciation rate – in an abstract way or generally, by the value of the given variable. Thus, the relation then targeted was an equation, which – assuming continuity – can be set up as follows:

$$\frac{dx(t)}{dt} = \dot{x}(t) = f\left(x(t)\right) \tag{1}$$

Naturally, with this the aforementioned economists were still very far from optimisation, since they assumed that the behaviour of the economic agents was given once and for all, instead of looking for a saving or investment behaviour – which although it varies, or rather can be varied in time, is still optimal – that in a specific period results in maximum revenue or consumption. Naturally, this condition is rather far from reality, since the propensity to save very much depends on the level of income. And yet such approaches are not surprising, since the necessary mathematical optimisation tools were not yet available at that time. The detailed elaboration of these was started in the 1950s by *Richard Bellmann* (*1954*), and it is mainly owing to *Lev Pontryagin et al.* (*1968*) that by deducing the maximum principle named after him, he published an optimisation procedure that could also be applied by economists. It was *Robert Dorfman* (*1969*) who called the attention of his colleagues to this opportunity. In Hungary, the significance of this method was first recognised by András Bródy.

Thus, economic scientists have only had a set of instruments suitable for resolving dynamic optimisation tasks since the early 1970s. In fact, this is based on the linking of two processes: one of these is the original process, consisting of state variables $x(t)$ while the other one is the $u(t)$ control process. This is determined by the controlling person or institution in such a way that it takes the extreme value of

[1] Of the early works, it is worth mentioning *Feldman* (*1967*, or the original paper: *1928*), and *Palomba* (*1939*).

an objective function depending on both $x(t)$ the process and the control process. If this occurs, then we selected the best control process of all, i.e. we applied optimal control.

Consider a simple example. A fish population, deemed fully homogenous for the sake of simplicity, has a natural increase. The rate of this obviously depends on the existing stock of fish. Thus, considering the birth and death rate of fish, the process of the natural increase of the fish population can be stated as

$$\frac{dh(t)}{dt} = \dot{h}(t) = f\left(h(t)\right) \tag{2}$$

where $h(t)$ is the stock of fish at the time t, $\dot{h}(t)$ is the change in the stock of fish also at the time t, while the $f(\ldots)$ function states the relation between them; in this example the state variable is the prevailing fish stock.

The control in this example is the fishery, i.e. $u(t)$ means the number of fish fished out at time t. With this, we influence the fish stock and thereby also the reproduction rate of the fish stock. Accordingly, the formula above needs to be supplemented:

$$\dot{h}(t) = F\left(h(t), u(t)\right) \tag{3}$$

If we strive for the maximum sustainable fish stock, we need to opt for a fishing strategy that on the one hand provides profit on fish consumption, and on the other hand does not jeopardise the fish population of the future. The $G\left(h(t), u(t)\right)$ function expresses the sustainability of the fish stock. In accordance with the foregoing, in fact we look for the maximum of $\int G\left(h(t), u(t)\right) dt$. If we can manage to determine the fishing strategy that produces this maximum, we find the optimal control for the purpose of the sustainability of the fish stock.

The work of both laureates of the 2018 Nobel Prize in Economic Sciences is characterised by the continuous application of the optimisation procedure presented above. But let us investigate this in more detail.[2]

2. William Nordhaus

William Nordhaus was born on 31 May 1941 in Albuquerque, New Mexico, the largest settlement in the state. He received his BA in 1963 and MA in 1967 from the renowned Yale University. He also defended his doctoral dissertation in 1967 at MIT, as a result of which he holds a Ph.D. His scientific career unfolded at Yale University, where he returned to after obtaining his doctorate. There he climbed

[2] In this work, the author follows Zsuzsa Bekker, who – sparing no trouble – edited an excellent book on the laureates of the Nobel Prize in Economic Sciences (*Bekker 2005*).

the teaching career ladder, and finally became professor in 1973. He still holds this position at present. Of his publications, probably the best known one is the textbook entitled Economics, written together with fellow Nobel Prize Laureate in Economic Sciences *Paul A. Samuelson*, published in several editions and languages, but even before this book he wrote studies that made his name known around the world. In one of his papers (*Nordhaus 1975a*), he dealt with the political business cycles, a topic well-known to all of us: it has been observed for decades that the value of certain economic variables moves in parallel with the election periods: in the year of parliamentary elections the income and/or budget deficit is high, while the unemployment rate becomes low.[3]

2.1. The political business cycle

An important element of Nordhaus' explanation for the cycles is the assumption that the government is not the usual "benevolent dictator" but rather a rational actor, just like all other actors. This is because the government is comprised of individuals, who are interested in remaining in office. This is referred to as an opportunist government, i.e. a machine with the goal of winning the next elections as well.

Nordhaus assumed of the *ith* voter that he makes the decision on the election date – strongly simplifying it[4] – only based on the current economic situation. He measures the latter by factors determining his own wealth – which, according to Nordhaus, includes the unemployment rate $u(t)$ and the inflation rate $\pi(t)$. Based on this, we can draw the $h_i(u(t),\pi(t))$ "election function" of the *i*th voter applicable to the *t*th period, the value of which +1 if he votes for the government, and 0 if he votes against. By aggregating these individual election functions we obtain the nationwide election function:

$$h(u(t),\pi(t))=\sum_{i=1}^{n}h_i(u(t),\pi(t)), \tag{4}$$

where n is the number of citizens eligible to vote. Since the nationwide election function contains only the number of votes for the governing parties, $\frac{1}{n}\sum_{i=1}^{n}h_i(u(t),\pi(t))$ expresses the ratio of those voting for the government. The higher (lower) this ratio is, the greater (lesser) chance the governing parties have of winning the election.

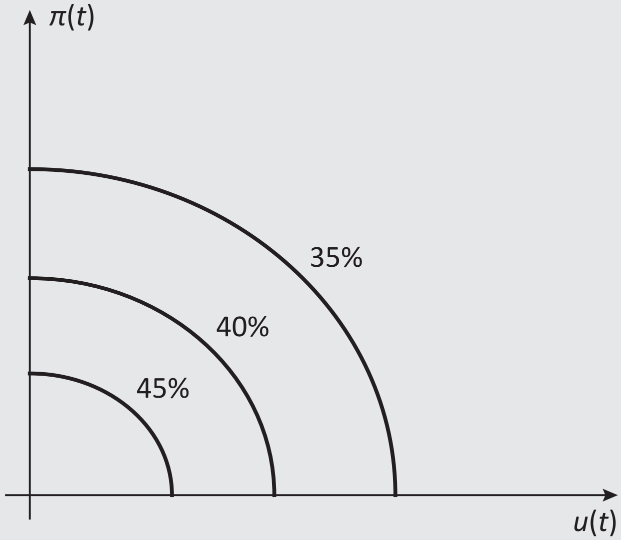
Obviously, an identical election result may be achieved by different $(u(t),\pi(t))$ pairs. Accordingly, the indifference curve of the nationwide election can be drawn as the set of points providing an identical number of election votes. This curve

[3] This phenomenon existed in Hungary as well, except that here it was budget deficit – which until 2006 was always outstandingly high in the election years – that first follows the election period rather than the change in unemployment and inflation.

[4] Factors such as the voters' party loyalty, social approach, the positive or negative judgement of the organisations running for the election, etc. are ignored.

is left-skewed, since with an increasing unemployment rate an identical election result is feasible only with an inflation rate that is lower than before. Naturally, the different number of votes represents different curves, which obviously can have no common point. Since the higher unemployment rate and higher inflation rate result in decreasing wealth, which also reduces the number of votes, the curves which are further away from the origin represent a worse election result (see *Figure 1*).

Figure 1
Indifference curves of nationwide election



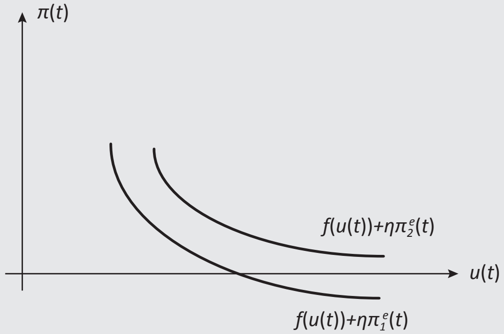
However, economic agents do not decide who to support with their votes solely on the basis of the unemployment rate and inflation rate prevailing on the election day: they also consider the period since the last election as a whole. If the date of the previous election was year 0 and the date of the current election is year *t**, the period in question is the interval [0,*t**]. The further away the date is, the less weight it has it in the current decision. Based on this, the number of votes that can be expected by the government is the weighted average of the votes belonging to each point of time of interval [0,*t**], which – taking time as a continuous variable – leads to expression $\int_0^{t^*} h(u(t),\pi(t))e^{\mu t}dt$. Thus, the government in office is interested in the maximisation of this.

The other side of the model is the restrictive condition, the *Phillips curve* – also relying on the unemployment rate and inflation rate – which, for the sake of a dynamic approach, Nordhaus supplemented with inflation expectations:

$$\pi(t) = f\left(u(t)\right) + \eta\pi^e(t)\,, \tag{5}$$

where $\pi^e(t)$ is the expected inflation rate, and $f'\left(u(t)\right) < 0$, and $0 < \eta < 1$. Equation (5) means that the higher the inflation expectations are, the higher the inflation rate will be with a constant unemployment rate, i.e. rising inflation expectations push the Phillips curve upwards (see *Figure 2*, where $\pi_2^e(t) > \pi_1^e(t)$).

Figure 2
Impact of inflation expectations on the Phillips curve



With this, the model contains three variables, $u(t)$, $\pi(t)$ and $\pi^e(t)$-t. The government is interested in pursuing an economic policy that earns the maximum number of votes, i.e. it needs to find the Phillips curve that affects the lowest lying election indifference curve. The optimal position thus determined also means that the combination of the unemployment rate and inflation rate is acceptable for the majority of voters (*Figure 3*).

Pursuant to the foregoing, the equation specifying inflation expectations is still missing from our model. In respect of this, Nordhaus assumes that it is produced in an adaptive manner, i.e.

$$\dot{\pi}^e(t) = \delta\left(\pi(t) - \pi^e(t)\right) \tag{6}$$

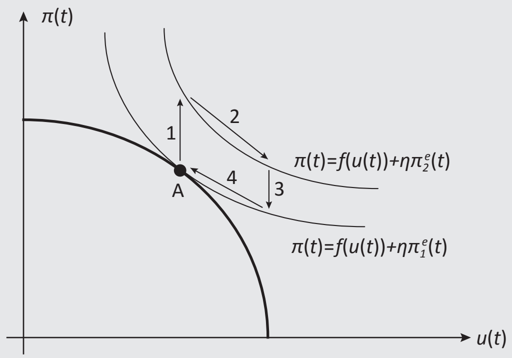
The duty of the government striving for re-election is now to maximise

$$\int_0^{t^*} h\left(u(t), \pi(t)\right) e^{\mu t} dt$$

under conditions (5) and (6).

In the model above, $\pi^e(t)$ is the state variable and $u(t)$ is the control variable. The problem can be formulated as follows: We look for the economic policy that results in an unemployment rate the development of which and the development of the related inflation expectations maximise the number of votes for the incumbent government. The mechanism for this is as follows: The government must ensure that the unemployment rate is low right before the election. According to the concept of the Phillips curve, this implies a high inflation rate (point A on *Figure 3*), which increases inflation expectations in the near future, and thus the Phillips curve shifts upwards (arrow 1). Naturally, in political terms this means a loss of votes. In its work, the government must make efforts to reduce inflation by proper financial strategy (arrow 2), as a result of which inflation expectations decline and the Phillips curve shifts downwards (arrow 3). However, the anti-inflation policy causes the unemployment rate to rise. If the government manages to reduce the latter once again before the next elections (arrow 4), it has a chance to win the elections repeatedly.

Figure 3
Mechanism of the optimal economic policy



In the Nordhaus model, unemployment and inflation rates fluctuate depending on the date of the elections. The more precisely the electoral law of a country stipulates the date of the elections (e.g. every five years, every seven years), the more regular cycle can be expected. Naturally, in the background there is the tacit assumption that the voters do not discover the trick, or – if they do anyway – they forget it by the next election...

2.2. Climate and economic growth

Nordhaus (*1975b, 1977*) also started to deal with climate issues almost simultaneously with the elaboration of the political business cycle. It was the potential control of the volume of carbon dioxide that raised his interest. He published two essays on this topic, in which he had not yet modelled, but rather wanted to present a picture of the situation based on empirical analyses. Naturally, this topic had been researched before as well, and even the first steps to curb the detrimental effects of carbon dioxide had been made, but – as noted by Nordhaus – these were mostly characterised by managing the problems locally, although it should be obvious that the world faces a global problem. Hence, it is very much possible that the carbon dioxide emission and the stronger presence of industrial heat may also generate climate changes in the future.

Nordhaus participated almost from the very beginning in the elaboration and application of the Integrated Assessment models. These are extremely complex models, which contain the models of the individual disciplines as parts, and the objective of their application is to analyse global questions, such as global warming or climate policy, as well as the causal connections, as comprehensively as possible, considering the technological, economic, political and social aspects. *Nordhaus* (*1992*) is also linked with the elaboration of DICE (Dynamic Integrated Climate-Economy) and RICE (Regional Integrated Climate-Economy), and the continuous fine tuning of these.

He also published numerous papers on the topic of economic growth and climate change. Carbon dioxide emissions increase due to the economic growth compulsion, and this causes changes in the climate. As a result of this, the economic and ecological conditions change, which leads to various climate policy measures. However, these curb economic growth. Thus, the question is: what can we do? *Nordhaus* (*1991*) and his followers looked for the answer relying on a growth model, which I present below in a very simplified form. In his model, Nordhaus considered three effects of climate change:

- Part of the otherwise realisable income cannot be generated due to climate change; arable land decreases due to floods, crops decrease due to droughts, the performance of employees decreases due to the lasting heat, etc.

- Capital goods are worn out to a larger degree; part of the real capital is damaged due to natural disasters (see Fukushima), but this also includes the increasingly frequent forest fires, which destroy a significant part of the wealth.

- A new cost factor appears: capital goods that were not necessary before must be deployed, e.g. due to the rise in the average temperature more air conditioners are needed both by industry and households, due to the drought more irrigation is necessary, etc.

The income that can be generated at the *t*th point of time before the occurrence of climate change is marked with $\hat{Y}(t)$. We define the generation of this with a Cobb–Douglas production function, i.e. $\hat{Y}(t)=AK(t)^{\alpha}L(t)^{1-\alpha}$; here *A* is the parameter representing technical progress, *K*(*t*) is the capital stock involved in production at the *t*th point in time, while *L*(*t*) is the number of people in employment at time *t*th. The α parameter is the production flexibility of the capital, while $1-\alpha$ is the production flexibility of labour; obviously $0<\alpha<1$. If as a result of climate change D_Y per cent of the potentially realisable income is not generated (first impact), then the actual income is only $(1-D_Y)\hat{Y}(t)$. However, if Λ per cent of this needs to be used for the recovery or mitigation of damages (third impact), the income[5] available for consumption and saving is only $Y(t)=(1-\Lambda)(1-D_Y)\hat{Y}(t)$, i.e.

$$Y(t)=(1-\Lambda)(1-D_Y)AK(t)^{\alpha}L(t)^{1-\alpha}\,. \tag{7}$$

Thus, the change in capital stock is the difference between the investment and the wear and tear of the capital stock, i.e. $\dot{K}(t)=dK(t)/dt=I(t)-\delta K(t)$. This relation now changes, because both the capital stock and the growth thereof decrease with the wear and tear stemming from climate change (second impact). If – as a result of climate change – the capital stock decreases by D_K per cent, the relation valid for the investment is now $(1-D_K)\dot{K}(t)=I(t)-(1-D_K)\delta K(t)$, i.e.

$$\dot{K}(t)=\frac{1}{1-D_K}I(t)-\delta K(t) \tag{8}$$

In the equilibrium assumed by Nordhaus, investment equals savings, and the latter forms part of the income, i.e. $I(t)=S(t)=sY(t)=s(1-D_Y)(1-\Lambda)Ak(t)^{\alpha}L(t)$. Some calculation returns the following (see *Appendix*) equation,

$$\dot{k}(t)=\frac{1}{1-D_K}s(1-D_Y)(1-\Lambda)Ak(t)^{\alpha}-(\delta+g_L)k(t)\,, \tag{9}$$

the equilibrium resolution of which is

$$k^{\alpha}=\frac{(\delta+g_L)(1-D_K)}{s(1-D_Y)(1-\Lambda)A}k\,. \tag{10}$$

The left side of the equation practically contains a root function ($0<\alpha<1$), while the right side is a function linear in *k*, which passes through the origin, and the steepness of which is $\left[(\delta+g_L)(1-D_K)\right]/\left[s(1-D_Y)(1-\Lambda)A\right]$. These two curves are shown in *Figure 4*.

[5] Naturally, tax should be also taken into consideration, but we ignore it in this discussion.

Figure 4
Equilibrium in the climate model

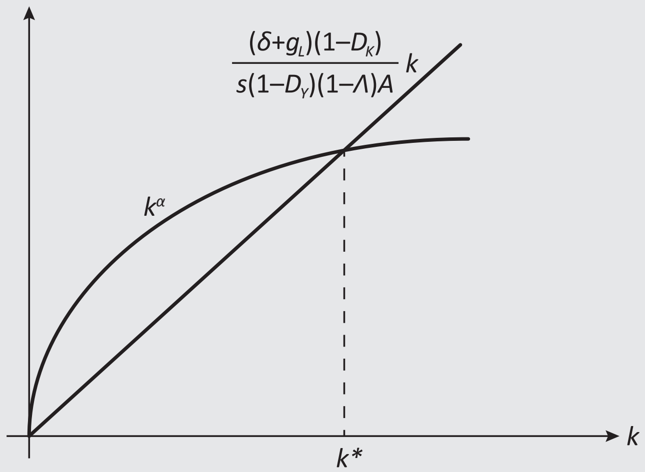


Figure 4 shows that

- if – as a result of climate change – the impact on income generation increases (D_K), the straight line will be steeper, i.e. the intersection will shift to the left, and thus the capital stock per capita decreases, thereby also decreasing the level of the equilibrium income;
- the situation is the same if the costs generated by climate change (Λ) increase: this also reduces the capital stock per capita;
- if climate change influences the capital stock negatively, the steepness of the straight line declines and the capital stock per capita increases.

The rather different impact of the first two and the third statements is attributable to the fact that in the first two cases either no supply is created at all or supply is damaged. However, in the third case the absence of capital generates demand, thereby stimulating production and income formation. Thus, it cannot be stated immediately and unambiguously that the economic impact of climate change is definitely negative; the question is much more complicated and complex than that.

The model presented reflects the work of Nordhaus in an overly simplified manner; Nordhaus made an attempt, through empirical analyses, to quantify the damages stemming from climate change and to also capture their development over time. His work legitimately makes him a leading climate economist in the field.

3. Paul Romer

Paul Michael Romer was born on 7 November 1955, in Denver, Colorado. His father, *Roy Romer*, was once Governor of Colorado. He earned a bachelor degree in mathematics in 1977 from the University of Chicago. He started to deal with economic science more deeply thereafter, first at MIT and then at Queens University, in Canada. He earned his Ph.D. from the University of Chicago in 1983. The first station in his career, between 1982 and 1988, was the University of Rochester, after which he served as professor at a number of famous universities – at the University of Chicago until 1990, at the University of California, Berkeley until 1996 and at Stanford University until 2010. At present, he is a Professor of Economics at the Stern School of Business, operating under New York University. He was chief economist of the World Bank between 2016 and 2018.

The mathematical background of *Romer* (*1986a*) can be felt mostly in his early publications. The paper, published three years after defending his dissertation, is a major mathematical contribution to mathematical economics and in a certain sense it is a starting point on the way leading to the elaboration of the endogenous growth theory.

One of the most frequent assumptions of economic science, even these days, is diminishing returns, i.e. the phenomenon according to which if we increase the production factor expenditure by one unit, output will increase, but an additional factor unit will only increase output to a lesser degree than the previous unit did. This can be supported by several examples; however, it should be noted that this criterion is extremely important in terms of modelling as well. This is because, in the language of mathematics, diminishing returns means that – staying in the above field, i.e. product manufacturing – the production function is concave, i.e. the marginal product curves belonging to it are left-skewed. Thus, it is certain that by increasing the factor expenditure, the factor price curve intersects the marginal product curve, and this intersection also determines the optimal factor utilisation. In other words, had the concavity condition been not met, the negative skewness of the marginal product curve would also not be ensured, and thus the definition of the intersection by the factor price curve, and thereby of the optimal factor utilisation, would be also at risk, or the "optimal" volume of factors would be infinite. In the aforementioned paper, Romer proved a thesis, which facilitates the usual optimisation in the case of non-concave functions as well.

Since human resource, knowledge or technological innovations are typically factors that produce non-concave functions, it is not surprising at all that *Romer* (*1986b*) published a paper back in 1986, where he applied his own results in the model that also takes technological changes into consideration.

3.1. The endogenous growth theory

The modern growth theory started with the work of *Robert M. Solow*, Laureate of the Nobel Prize in Economic Sciences (*1956*, *1957*). In his first paper, he elaborated an equilibrium and stable growth model, where investment in real capital was the driver of income growth. He chose a Cobb-Douglas relation as production function. Based on this – using the capital stock and employment time series of the USA for the period 1909–1949 – he prepared an estimate for the income values expected for the period. He compared this with the actually observed data and found that his own estimates explain only around 33 per cent of the real values. The conclusion he drew was clear: if it is not possible to describe the actual development of income only by capital and labour, there must be at least one more factor that influences production. He labelled this as “technical change” (*Solow 1957*).

In fact, he integrated this technical progress into his model by introducing a new parameter; thus, technical change simply “exists” – and hence it is an exogenous factor of economic growth. Naturally, it did not take long to come under fire; the “function of technical progress” of *Miklós Káldor* (*1957*) or the “learning by doing” concept of *Kenneth J. Arrow* (*1961*) are critiques and also attempts to manage the problem.

Romer (*1990*) also joined in the discussion on this topic. He also believes that technological change is the most important growth factor, but does not regard it as something given from outside or as a process determined by some macroeconomic regime; instead, he interprets technical progress as the result of the conscious, profit-oriented decision of micro actors, primarily enterprises, i.e. essentially some kind of product or at least a phenomenon similar to it. This means that in order to induce technological change, enterprises forego part of their consumption, and save and invest it in the same way as in the case of the other products. However, the product that carries the technological change – the idea – is a special product: it is neither private, nor public property. The utilisation of an idea does not disadvantage anybody; it can be often used without causing damages to other – i.e. there is no competition, and thus it cannot be private property. At the same time, they can prevent others by patents from applying the idea. They do so to be able to cover the – often very high – research or development costs, from the initial revenues earned on the monopolistic market created as result of the protection of the product. Others can be prevented from the use of the product, and thus it cannot be public property.

The fact that the use of the ideas may be restricted also meant that Romer overstepped the former neoclassical growth theory, since he had to break with the perfect markets approach, continuously emphasised by the advocates thereof. At this point, it is worth referring back to Romer’s aforementioned optimisation paper: on neoclassical perfect markets the marginal productivity theses are almost automatically valid, i.e. each factor of production obtains as much of the production result as it contributed to the generation thereof. Since the human resource or technical progress results in increasing yield, adhering to the marginal productivity theses would lead to the conclusion that this factor must receive an increasingly larger part of the final goods. And this would only be possible by spending less on the financing of the other factors, i.e. it would lead to the result that the marginal product of labour and capital would exceed the factor prices. And this is nonsense.

In his model, Romer differentiates three sectors:

a) the research sector, producing ideas – innovation;

b) the sector producing intermediate goods – essentially capital goods; which then

c) will be used in the sector manufacturing final goods for consumption.

In the *research sector,* part of the currently existing $H(t)$ knowledge (φ) is used, with defined efficiency (δ) for the "production" of additional knowledge:

$$\dot{H}(t)=\delta\varphi H(t). \tag{11}$$

The sector that produces final goods uses the following Cobb-Douglas technology:

$$Y(t)=\left[(1-\varphi)H(t)\right]^{\alpha}L^{\beta}(t)K^{1-\alpha-\beta}(t)\,, \tag{12}$$

where $Y(t)$ is the final good, $(1–φ)H(t)$ is the human resource used during the production of the final goods, $L(t)$ is the labour input and $K(t)$ is the capital stock.

The capital stock is augmented from savings, i.e. from the unconsumed final goods, which – if we ignore the depreciation of the capital goods – means that

$$\dot{K}(t)=Y(t)-C(t)=\left[(1-\varphi)H(t)\right]^{\alpha}L^{\beta}(t)K^{1-\alpha-\beta}(t)-C(t)\,. \tag{13}$$

Households strive to maximise their consumption, i.e.

$$\int_0^{\infty} C(t)e^{\gamma t}\,dt \rightarrow max!$$

The economic content of the problem can be formulated as follows: we look for the savings or investment strategy and human resource development strategy, based on which we obtain revenues that maximise consumption.

The statement of the problem shows that there is a very strong methodological parallel between the approaches of Nordhaus and Romer. Both of them optimise dynamic processes; Nordhaus optimises inflation expectations, while Romer optimises income developments. As anti-inflation policy was a tool for Nordhaus to ensure the re-election of the government by the proper shaping of inflation expectations changing as a result thereof, similarly, the development of proper human resources is a tool for Romer to maximise households' consumption.

3.2. The Charter City concept

In 2009, Romer came up with an idea that has been disputed ever since. His solution for the global overpopulation and impoverishment observed in certain parts of the world is to establish new large cities in the territory of developing countries. In his view, overpopulation and impoverishment are caused by the fact that investment resources, undoubtedly available in the developed countries, are not used in the areas where they would be needed the most, because these countries are usually unstable in political terms. Potential investors do not invest in developing countries, because they deem the political risk to be too high. The question is: to what extent it is possible to reinvest the profit earned there, elsewhere. To what extent does the government guarantee the inviolability of ownership rights, and what does it mean when the government guarantees it in words? How corrupt is the administration of the respective country and what additional costs does this generate later on?

Romer believes that these are the issues that first of all should be settled reassuringly, because ensuring political stability and fixing the general legal and economic conditions over the long run would encourage the inflow of capital necessary for economic development and recovery would ensue almost automatically.

Romer envisages the implementation of this by the developing countries providing the territory for the establishment of artificial cities and the developed countries would elaborate the legal system applicable to these cities – the Charter – since in this case political stability and predicable economic and legal conditions would be guaranteed. The staff of the administration – including the justice system and the armed forces – would mostly include the experienced and tried-and-true representatives of the developed countries. There would no elections; the leaders of the cities would be elected by the population of the developed countries or appointed by the boards of these countries. Under such circumstances the problems that now deter investors would practically disappear.

The Charter Cities are the combination of the developed legislation and the low costs that characterise less developed regions. Under such circumstances, the less developed regions or countries would be able to enforce their comparative advantages better. This is why Romer proposed that these artificial metropolises initially be established mostly in the coastal areas, since it is much easier to manage trade there. Hong Kong, returned by the United Kingdom to China, but the operation of which is still controlled by the British in the new situation as well, is the favourite, often cited success story of Romer.

The formulation of Romer's concept was obviously governed by his own experiences in the USA. There, if a city (has not yet) adopted its own Charter, the functioning thereof is controlled by the constitution of the respective state. It is not uncommon in the United States for the cities to opt for this solution. For example, 121 of the 478 cities in California are governed solely by the laws and regulations issued by the State – including large cities such as San Francisco and Los Angeles. According to the legislation of Texas as well, all cities without a Charter organise their life in accordance with the constitution of the federal state.

However, there is a big difference between the examples from the USA and Romer's proposal. The basis of the success story of the United States, and even of Hong Kong, is that the population of those cities accept, or even become one with the superior government level. However, the situation is completely different when the representatives of the developed states "oppress" the less developed region and thus the opinions of those cannot be simply rejected. Due to this, Romer is accused of spreading neo-colonisation ideas.

4. Brief evaluation summary

This paper presented only a small part of the wide-ranging activity of the two award-winning economists. Nevertheless, outlining the selected research topics probably still supports the opinion of this paper's author, according to which in 2018 the Nobel Prize in Economic Sciences was awarded to two experts who take a very peculiar approach not only on the economic processes, but also on the social problems to be interpreted much more broadly and who – although their views may often be disputed – have enriched economic and social science with their work.

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Appendix

The equation below follows from relation (7)

$$Y(t)=(1-\Lambda)(1-D_Y)Ak(t)^{\alpha}L(t),$$

where $k(t)=K(t)/L(t)$, i.e. the capital stock per capita.

The change in the capital stock is

$$\dot{K}(t)=\frac{1}{1-D_K}s(1-D_Y)(1-\Lambda)Ak(t)^{\alpha}L(t)-\delta K(t),$$

or

$$\frac{\dot{K}(t)}{K(t)}=\frac{1}{1-D_K}s(1-D_Y)(1-\Lambda)Ak(t)^{\alpha}\frac{L(t)}{K(t)}-\delta=$$
$$=\frac{1}{1-D_K}s(1-D_Y)(1-\Lambda)Ak(t)^{\alpha-1}-\delta$$

Growth rate of the capital stock per capita

$$\frac{\dot{k}(t)}{k(t)}=\frac{\dot{K}(t)}{K(t)}-\frac{\dot{L}(t)}{L(t)},$$

from this – taking the growth in the number of people in employment as constant $\left(\dot{L}(t)/L(t)=g_L\right)$ – we obtain

$$\frac{\dot{k}(t)}{k(t)}=\frac{1}{1-D_K}s(1-D_Y)(1-\Lambda)Ak(t)^{\alpha-1}-\delta-g_L,$$

i.e.

$$\dot{k}(t)=\frac{1}{1-D_K}s(1-D_Y)(1-\Lambda)Ak(t)^{\alpha}-(\delta+g_L)k(t).$$

Nordhaus examined the stationary status, thus $\dot{k}(t)=0$. The discussed relation (10) follows from this.