



FROM MY PERSPECTIVE

Logistic growth of the global economy and competitiveness of nations

Witold Kwasnicki

Institute of Economic Sciences, University of Wrocław, Wrocław, Poland

ARTICLE INFO

Article history:

Received 5 January 2011

Received in revised form 9 July 2012

Accepted 12 July 2012

Available online 9 August 2012

Keywords:

Logistic growth

Logistic curve

S-curve

Logistic substitution

Globalization

Global growth

Competitiveness index

ABSTRACT

In the first part of the paper we are dealing with the possibility of predicting long-term development on the basis of logistic/exponential curves. We have selected three characteristics of global development, namely the change of population size in the world, the volume of world output (measured by the value of global GDP) and global welfare (GDP per capita). The important feature of the proposed approach is that we propose to examine the impact of different identification criterion on the obtained predictions. It turns out that the assumed criterion of parameters' identification could essentially influence the obtained predictions.

In the second part of the paper, the extension of the logistic curve into the substitution–diffusion model is proposed. This allows us to evaluate the future share of national/regional economies in the global GDP and to estimate the competitiveness of these economies. It turns out that the competitiveness of nations/regions is far from being constant. A proposal of building the competitiveness ranking of nations/regions is presented. In the final section a possible scenario of development of the five countries/regions (namely the USA, the E12, Japan, China, India) is presented.

© 2012 Elsevier Inc. All rights reserved.

1. Introduction

The main goal of this paper is to present alternative predictions of global demographic and economic development using a trend analysis based on well-known logistic/exponential curves and to propose a method of prediction of the structure of economic growth (in terms of shares of different nations/regions in the global GDP) based on the evolutionary model of the substitution–diffusion model. A new concept of competitiveness of national and regional economies is presented. This approach allows us to generate ranking of the states according to diminishing competitiveness and to estimate tendencies of the evolution of national competitiveness.

Using trend analysis is a kind of classical approach, but frequently this approach is made in a routinized, let us say, 'mechanical' way, namely: on the basis of historical data the estimation (fitting to the real data; parameters' identification) of the logistic/exponential functions are made (usually applying standardised statistical packages) and the following extrapolations (predictions) of future values is done. We would like to point out that this kind of extrapolation ought to be done in a more cautious way. One of the questions stated in the paper, and to our knowledge, not discussed in the relevant literature is: to what extent the extrapolations (predictions) depend on the assumed criterion of the parameters' identification?

A growth with saturation (with upper limit) is frequently observed in real processes. From an economic point of view this is a natural phenomenon: limited resources (limited growth factors) are the usual condition of socio-economic development. Therefore so-called logistic curves (S-shaped, sigmoid curves) are very frequently used to describe the evolution of those processes. Logistic curves have been successfully used in such fields as demographics, biology, economics, engineering, and many others. The application of the logistic curve, e.g. to describe the evolution of population (in biology and demographics) or the diffusion of new technologies

E-mail address: kwasnicki@prawo.uni.wroc.pl.

URL: <http://kwasnicki.prawo.uni.wroc.pl>.

and products, as well as, in general, economic growth, is very illustrative and appealing (mainly due to nice graphic representation). The popularity of the logistic curve in the description of the variety of real phenomena dates from the middle of the 20th century, and the relevant literature is enormous.¹

It is worth mentioning two researchers who have laid the ground for the steadily growing popularity of logistic curve application in numerous areas, namely Cesare Marchetti and Theodore Modis. A large number of their publications related to logistic growth is available to download from their websites: <http://cesaremarchetti.org/index.html> and <http://www.growth-dynamics.com/>, respectively.

For decades, *Technological Forecasting and Social Change* has been a good and friendly platform to present recent advancement in research on logistic growth. It is not possible to list all the relevant papers published in *TF&SCh* in recent decades, but some of them published in the last few years have spurred on this author to write this paper, among them are refs. [1–5], and especially ref. [6].

The logistic curve is often used to describe and to predict the development of social and economic processes. In a natural way, it is suitable to describe the development of the so-called Limited world.

If we denote by y a measure of development (e.g. population size or national income) then the logistic growth (often called sigmoid, S-type growth, a growth with saturation) can be described by the difference Eq. (1), in the case of discrete measures such as population, or by the corresponding differential Eq. (2), in the case of continuous measurements, such as national income:

$$y_{t+1} = y_t + \text{round}\left(r y_t \left(1 - \frac{y_t}{K}\right)\right) \quad (1)$$

$$\frac{dy}{dt} = r y \left(1 - \frac{y}{K}\right) \quad (2)$$

where:

K saturation level (sometimes called the capacity of the environment),
 r maximum growth rate.

Properties (especially related to the fluctuation behaviour) of the discrete logistic curve are discussed by Phillips and Kim [7]. We will use the logistic equation in continuous form. This choice is motivated by the need to compare our results with the results obtained by other authors who use the logistic curve in the continuous form (e.g. [6]).

The solution of Eq. (2) is the logistic function:

$$y = \frac{K}{1 + ae^{-bt}} \quad (3)$$

The logistic function has three parameters (K , a , b), which are associated with three parameters in the logistic Eq. (2) – environmental capacity (K), the maximum growth rate (r) and the initial value of the variable y (y_0).

To make the logistic function parameters more intuitive, this function is often presented in the following form (e.g. [8]):

$$y = \frac{K}{1 + e^{-\frac{\ln(81)}{\Delta t}(t-t_m)}} \quad (4)$$

Δt is the time needed for y to increase from 10% to 90% of the maximum value of K (so-called characteristic duration).
 t_m is the so-called midpoint, i.e. the time t in which the value characteristics of the development y is equal to 50% of the saturation K .

When the size of the saturation of the environment tends to infinity, the logistic growth becomes exponential one (γ – the growth rate), i.e.

$$\lim_{K \rightarrow \infty} y = \lim_{K \rightarrow \infty} \frac{K}{1 + ae^{-bt}} = Ae^{\gamma t} \quad (5)$$

Fig. 1 illustrates the logistics growth in a qualitative way.

Modis [1] proposed the seasons' metaphor to describe in a friendlier manner the differences and special attributes of successive periods of growth, saturation, and decline in a logistic development. Boretos [6, p. 318] suggests a slight variation of the Modis metaphor and divides the period of growth of y from 1% to 99% of the value of K into five equal periods called *Winter*,

¹ Probably for the first time the logistics curve (logistic equation) was used in 1838 by Pierre-François Verhulst to describe growth of human population (it was probably inspired by Thomas Malthus' *An Essay on the Principle of Population*). The equation was rediscovered in the 1920s by Raymond Pearl, Lowell Reed and Alfred J. Lotka (who in 1925 proposed to call it the *law of population growth*). Applications of the logistic equation to describe other processes beside population growth were spurred on by B. Ryan, N. Gross who published in 1943 the paper on "The diffusion of hybrid seed corn in two Iowa communities". Selected bibliography for the Logistic Curve can be found at: http://math.fullerton.edu/mathews/n2003/logisticcurve/LogisticEquationBib/Links/LogisticEquationBib_Ink_3.html

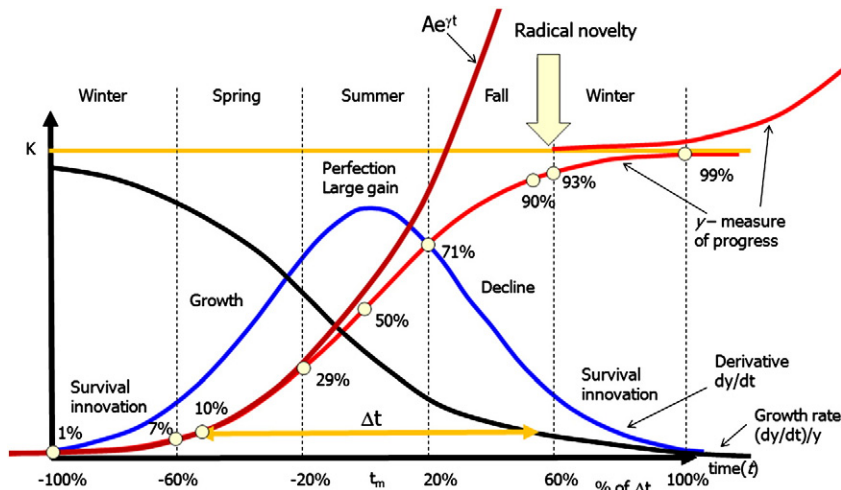


Fig. 1. Qualitative characteristics of the logistic growth.

Spring, Summer, Autumn and again Winter. Such a seasonal metaphor allows for distinguishing specific phases of development associated with the emergence of successive radical innovations. It suggests a relatively rapid growth associated with the spread of a radical innovation (in the Spring), the maturity of development (during the Summer), the exhausting of potential for further growth based on a particular radical innovation (Autumn). The next Winter is related to the emergence of another radical innovation and entering the next phase of logistic growth with a higher capacity of the environment (K). Analysis of many processes of development suggests that during the slowdown of economic growth (Autumn) we can observe an increase of the intensity of the search for breakthrough innovation. Usually, as an effect of this intensive exploration, another radical innovation emerges (mostly in late Autumn/Winter) which enables further growth along a qualitatively different trajectory of development (along a different logistic curve). The full cycle (i.e. an increase in the value y from about 1% of the saturation K to about 99% of K) is equal to $2\Delta t$. The parameter Δt informs us also about the length of the cycle. It is worth noting that the sum of periods of growth from 1% to 10% and from 90% to 99% is the same as the period of growth from 10% to 90% of the saturation K .

Our task seems to be typical, namely, having historical data describing the changes of the characteristics of development y in a period from t_0 to t_{\max} , we ought to identify the values of the three parameters (K , Δt , t_m) of the logistic function in such a way that this function fits the historical process in the best way. We have selected three characteristics of global development, namely the change of population size in the world, the volume of world output (measured by the value of global GDP) and the global GDP per capita. The historical data of these three characteristics are available on *The Conference Board Total Economy Database* website.² The data was downloaded on 19th November 2009. The available data covered the period from 1950 to 2008 in the case of world population, and from 1950 to 2006 in the case of global GDP and GDP per capita.³

We have adopted the two most widely used identification criteria, namely the mean square error (this criterion will be denoted by Q_1) and the relative mean square error (this criterion will be denoted by Q_2).⁴ Thus by fitting the logistic curves to the historical data we will try to state the values of K , Δt , and t_m to minimize one of the following criteria:

$$Q_1 = \sqrt{\frac{1}{t_{\max} - t_0 + 1} \sum_{t=t_0}^{t_{\max}} (y^r(t) - y^m(t))^2} \quad (6)$$

$$Q_2 = \sqrt{\frac{1}{t_{\max} - t_0 + 1} \sum_{t=t_0}^{t_{\max}} \left(\frac{y^r(t) - y^m(t)}{y^m(t)} \right)^2} \quad (7)$$

where:

t_0 and t_{\max} the initial and the final years of historical data used for identification of the logistic curve parameters, respectively.
 $y^r(t)$ and $y^m(t)$ the historical (real) data and the logistic curve (model) values at time t .

² <http://www.conference-board.org/data/economydatabase/>

³ The global GDP is expressed in constant purchasing power dollar terms in 1990, called Geary–Khamis PPPs. This methodology is widely accepted (including the World Bank and the International Monetary Fund), as was proposed in 1958 by Roy C. Geary and modified by Salem Hanna Khamis in the early 1970s.

⁴ This choice is motivated by a desire to examine the impact of the selected identification criterion on the obtained predictions. The problem would require further, systematic research, as it is possible to choose other metrics (e.g. the absolute distance, the Manhattan metric). It would be interesting to investigate the influence not only of the relative and absolute criteria, but also the different metrics (not only the mean square metric).

Table 1

The World population growth. The parameters values of the logistic and exponential curves. Historical data for identification: 1950–2008.

| Curve/criterion | $K [\times 10^9]$ | Δt | t_m | Identification error |
|-------------------|---------------------------------------|------------|-------------|----------------------|
| Logistic Q_1 | 11.856990 | 159.6778 | 1998.589 | 26903.66 |
| Logistic Q_2 | 12.959189 | 168.4098 | 2005.108 | 0.00673835 |
| | $A \rightarrow y(1950) [\times 10^9]$ | | γ | Identification error |
| Exponential Q_1 | 2.6426809 | | 0.016581239 | 101118.6711 |
| Exponential Q_2 | 2.5859190 | | 0.017194096 | 0.02091690034 |

There are no analytical methods for identifying the parameters of the nonlinear logistic function (as, for example, in the case of calculating linear regression models). Nor is there any method of the transformation of the logistic model into the linear model. Therefore, the only method of identification of the logistic function parameters is to use one of the known optimization methods. A very effective means of nonlinear optimization methods is based on genetic algorithms. In this work we used a computer program (*GeneticFinder*) developed by Mariusz Sobczak in 2008 (then a student of Wrocław University of Technology). The program allows to define any parameterized function and to identify its parameters on the basis of historical data (given as a CSV file.) The results of optimization obtained using *GeneticFinder* seem trustworthy. This program has been tested in numerous test functions, moreover, the results of many test functions as well as selected results presented in this article were compared with the results obtained using *Wolfram Mathematica*.

In some cases the identification of the parameters of the logistic function is insensitive to the saturation value K , i.e. very often large fluctuations in the value of K result in minor changes of the value criterion for identification. Therefore, for many experiments of the identification of the logistic function parameters identification, the parameters of the exponential function are added (i.e. the logistic function when K tends to infinity, see Eq. (5)).

2. The world population growth

Let us start with the identification of the parameters of the logistic function and the exponential function assuming that for the parameters' identification we use all the available data on global population growth, i.e. in the period 1950–2008. The parameter values that minimize both criteria and the values of the criteria are presented in Table 1. The corresponding approximating curves and historical data are presented in Fig. 2. As we can see, for both criteria the identification error is much smaller for the logistic function (Fig. 2, Table 1). Thus, it is appropriate to use the logistic function to forecast population growth. The prediction is presented in Fig. 3, and as we can see in spite of the quite similar quality of approximation for both criterion (Q_1 and Q_2), the values of the identified parameters (Table 1) are significantly different. For example, the saturation level K in the case of the mean square relative error (Q_2) is over one billion larger than for the absolute mean square error (Q_1).

Differences in these parameters cause significant differences in the estimated world population, especially when approaching the end of the 21st century. Although by 2040 the differences are relatively small, however in the second half of the twenty-first

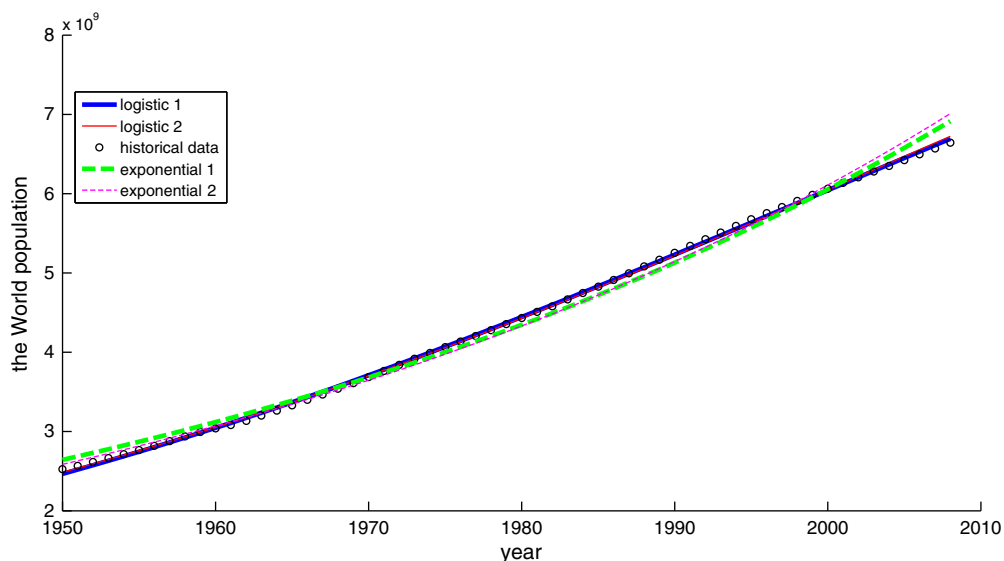


Fig. 2. The world population in 1950–2008. Approximation of real data by logistic and exponential curves.

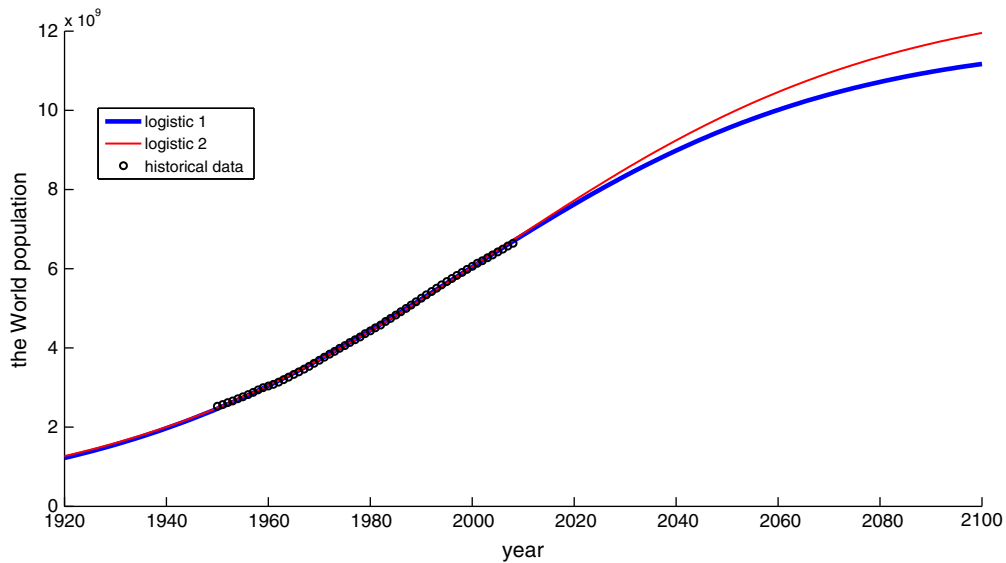


Fig. 3. Forecast of the World population by the end of the 21st century (logistic function parameter identification based on historical data from the years 1950 to 2008).

Table 2

Global GDP growth. The parameters values of the logistic and exponential curves. Historical data for identification: 1950–2006.

| Curve/Criterion | $K [\times 10^{13} \text{ US dol.}]$ | Δt | t_m | Identification error |
|-------------------|--|------------|-------------|----------------------|
| Logistic Q_1 | 15.903705 | 107.8116 | 2028.9320 | 817670.5046 |
| Logistic Q_2 | 7.417883 | 86.85134 | 2000.2162 | 0.033703579 |
| | $A \rightarrow y(1950) [*10^{13} \text{ US dol.}]$ | | γ | Identification error |
| Exponential Q_1 | 0.66738338 | | 0.034468590 | 907728.54560 |
| Exponential Q_2 | 0.59569569 | | 0.037459243 | 0.063252585 |

century they are clearly visible. According to these predictions, in the mid twenty-first century the global population will be approximately 9.5 billion but by the end of the twenty-first century the world population will be somewhere between 11.9 billion and 12.9 billion.

This and many other experiments (the results of some of them will be presented in this paper) suggest that the selection criterion for identification may have a significant impact on the forecasted development. Another question to which there is no unequivocal answer is ‘Which criterion is better?’⁵

3. Global economic growth

The available statistics on global GDP in the years 1950–2006 allow us to identify the parameters of logistic and exponential functions and to estimate the error of approximation. The results of these experiments are presented in Table 2 and Fig. 4. As in the case of the approximation of global population growth, a better fit is obtained in the case of logistic functions. The fluctuations of GDP are much larger than the changes of the world population, which leads to much larger errors of estimation (approximation).

Thus it is reasonable to select the logistic function to predict the world GDP growth in the twenty-first century. However, while the differences in growth projections of world population for both criteria might be considered as relatively small, it is not true in the case of the global GDP forecasts. The saturation level for the mean square criterion (Q_1) is over twice the saturation level for the relative mean square error (Q_2). Similar large differences in optimal values are for the two remaining parameters of the logistic function (see Table 2).

⁵ The problem of the proper selection of criterion for identifying from the viewpoint of the quality of forecasts will not be discussed in this work, but it is worth undertaking this and probably we will embark on that project in the future. In such a project it would necessary to increase the number of identification criteria, not limit it to only the two ones presented here.

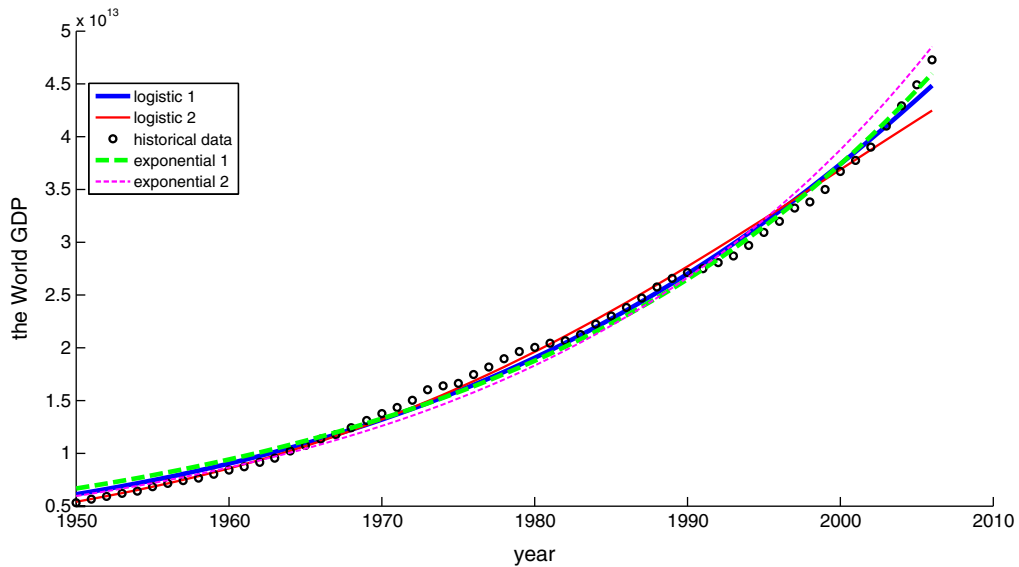


Fig. 4. Global GDP in 1950–2006. Approximation of real data by logistic and exponential curves.

Large differences in the global GDP growth forecasts are clearly seen in Fig. 5. As early as 2020 there is almost a 10% difference in the projections made by the two logistic functions:

$$y_1 = \frac{15.903705 \cdot 10^{13}}{1 + e^{-\frac{\ln(81)}{107.8116}(t-2028.982)}}, \text{ for the mean square criterion } (Q_1),$$

$$y_2 = \frac{7.417883 \cdot 10^{13}}{1 + e^{-\frac{\ln(81)}{86.85134}(t-2000.2162)}}, \text{ for the relative mean square error } (Q_2).$$

In the course of time the gap is widening, up to almost 100% at the end of the twenty-first century (Fig. 5).

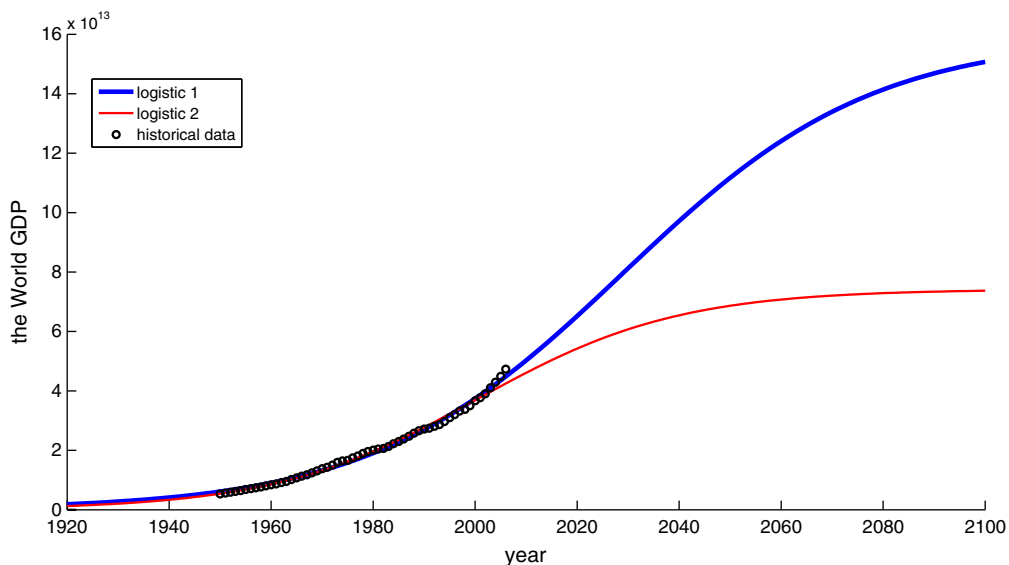


Fig. 5. The global GDP forecast (logistic function parameter identification based on historical data from the years 1950 to 2006).

Table 3

The global GDP per capita growth. The parameters values of the logistic and exponential curves. Historical data for identification: 1950–2006.

| Krzywa/kryterium | K [US dol.] | Δt | t_m | Identification error |
|-------------------|-----------------------------------|------------|-------------|----------------------|
| Logistic Q_1 | 12387.948 | 147.21609 | 2000.3777 | 552.593688 |
| Logistic Q_2 | 8956.403 | 115.55678 | 1980.4634 | 0.033352293 |
| | $A \rightarrow y(1950)$ [US dol.] | | γ | Identification error |
| Exponential Q_1 | 2422.1271 | | 0.018829270 | 622.0300316 |
| Exponential Q_2 | 2318.2722 | | 0.020025927 | 0.051156468 |

4. GDP per capita

The projection of GDP per capita can be done in two ways, either through the identification of parameters based on historical data on GDP per capita, or by the use of earlier forecasts of GDP growth and the global population growth (i.e. by dividing these values).

The first method is similar to that used in the previous two cases, compiled statistics for the period 1950–2006 allow us to identify the parameters of logistic and exponential functions using both criteria for identification (see Table 3 and Fig. 6). Again, the logistic curve fits are clearly better than the exponential curve fits (see the errors of identification in Table 3). This is a strong argument for the use of logistic curves to make predictions. Once more we can observe large differences in the optimum values of parameters of logistic functions (Table 3). The saturation value for the mean square criterion is about 30% higher than in the case of the relative mean square error. The relevant logistic functions used to predict GDP per capita are the following:

$$y_1 = \frac{12387.948}{1 + e^{-\frac{\ln(81)}{147.21609}(t-2000.3777)}}, \text{ for the mean square criterion } (Q_1),$$

$$y_2 = \frac{8956.403}{1 + e^{-\frac{\ln}{115.55678}(t-1980.4634)}}, \text{ for the relative mean square criterion } (Q_2).$$

Looking at the forecasts of GDP per capita (Fig. 7), we notice large differences between these two projections. What is interesting is that there is a discrepancy between the identified trends and the trend observed in historical data in the last 10 years, i.e. in 1996–2006. Namely we can observe very fast real GDP growth per capita since the mid-1990s and the slowdown of growth in the last ten years in both the forecasted long-term trends. Naturally, this is caused by the significantly different nature of the change in the second half of the twentieth century (from 1950 to the mid-1990s.). This issue will be discussed later in this paper.

We get radically different predictions when we make them by dividing the values obtained from the forecasts of GDP growth (Fig. 5) and the values of the forecast of the world population (Fig. 3). The results of this experiment are shown in Fig. 8. Firstly, the value of GDP per capita calculated using the two forecasts based on the mean square error criterion (Q_1) is above the both

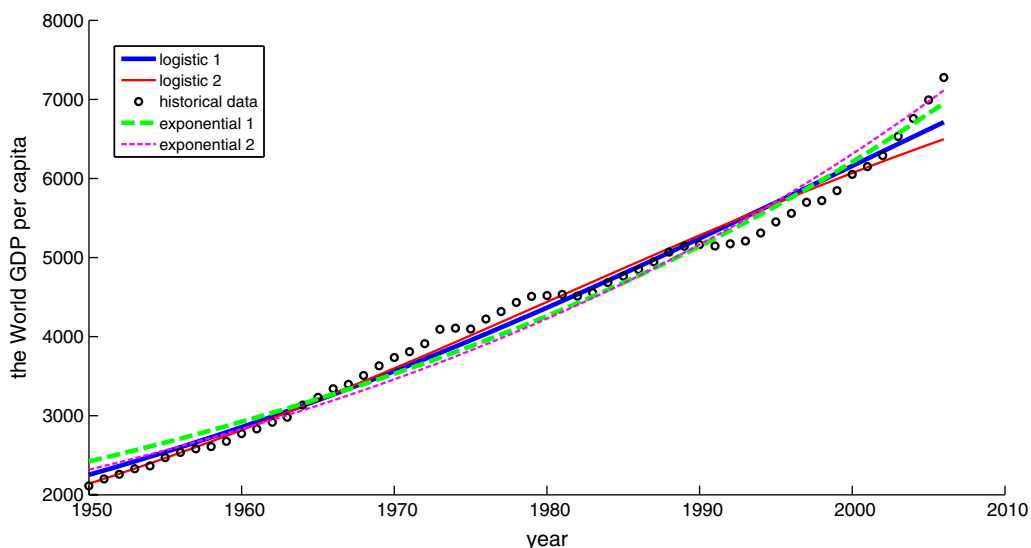


Fig. 6. Global GDP per capita in 1950–2006. Approximation of historical data by logistic and exponential curves.

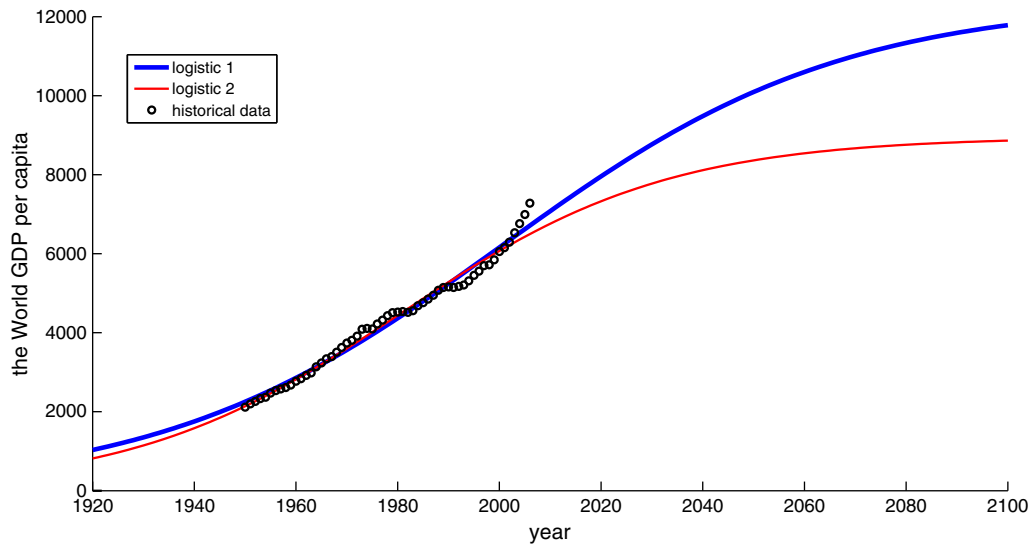


Fig. 7. Forecast of the global GDP per capita growth by the end of the 21st age (logistic function parameter identification based on historical data from the years 1950 to 2006).

extrapolative forecasts (Fig. 7). Secondly, the calculation of GDP per capita by division of the global GDP by the global population obtained for the mean square relative error (Q_2) generate in the first decades of the forecast (up to around 2025) a small rise of GDP per capita and then, up to the end of the twenty-first century, a slow decline (the lower curve in Fig. 8). To compare the results of these two approaches, all four forecasts are presented in Fig. 9. It is seen that the extrapolative forecasts are between the two projections calculated by dividing the global GDP and the population of the world. It is also worth noting that all four trends fit quite well to the real data from the period 1950–2006, but long-term extrapolations give significantly different projections. It can be said that the future of global welfare is really uncertain and open to great variability.

5. So far so good?

It seems that at this stage our work could be considered as completed – the relevant forecasts have been done. But all the time we ought to be sceptical in relation to the obtained results. The presented forecasts show the great potential of the logistic function in forecasting, although significant differences in the forecasts made applying different criteria to identify the parameters

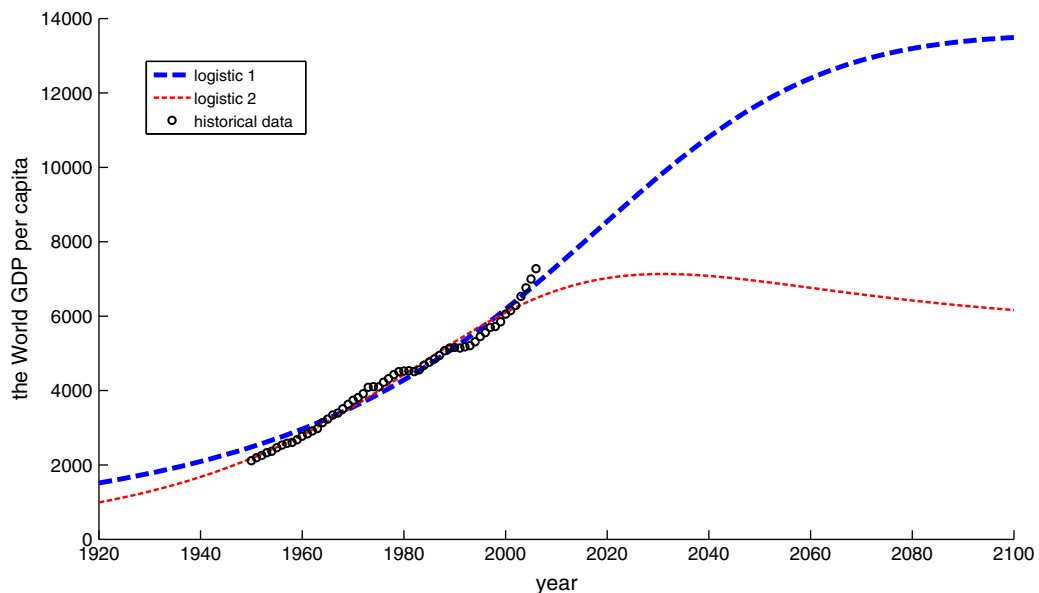


Fig. 8. The forecasts of the global GDP per capita growth by the end of the 21st age calculated from the partial projections of global GDP growth and increase the World population.

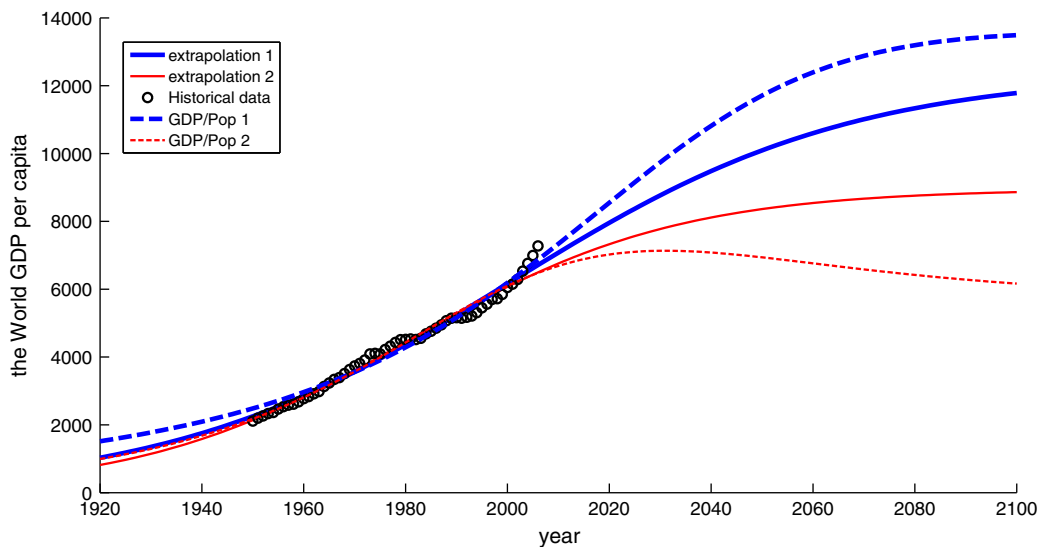


Fig. 9. Comparison of the four forecasts of the global GDP per capita by the end of the 21st century (Two made by extrapolating the trends from the years 1950–2006 (continuous lines) and two calculated from the partial projections of global GDP growth and increase the world population (dashed lines).

of the logistic function may cause a certain anxiety. It turns out that the selection of other periods to identify the parameters can generate essentially different results, not only in quantitative but also in qualitative terms.

5.1. Global GDP growth analysis

Up to now we were using all the available historical data (from 1950 to 2006) to identify trends on which the predictions have been made. To test to what extent shorter identification periods produce similar results we use the historical data from two sub-periods, namely 1950–1971 and 1980–2006 to identify the parameters of logistic and exponential functions. The period 1950–1971 allows us to compare the forecast with real development in years 1972–2006.

It turns out that in that case of the period 1980–2006 the best fit is obtained for the exponential function (see Table 4). Table 4 shows also a few results of logistic identification using a criterion of the average square error (Q_1). As the volume of saturation (K) is growing, the identification error is decreasing, but it is worth noting that very large differences in the values of K (e.g. a hundredfold) have resulted in a slight diminishing of the identification error (the differences at the 6th LSD). The higher the K the better fit, so one could suspect that the best alignment occurs for the exponential function (i.e. when K goes to infinity), and indeed that is the case. However, depending on the fitting criterion we obtained slightly different values of optimal parameters, e.g. for the mean square error criterion the optimal growth rate (γ) is equal to 3.29%, while for the mean square relative error (Q_2) optimal growth rate is equal to 3.19%. These differences are minor ones, but in the long-term they result in reasonably different predictions (see Fig. 10).

More interestingly, while we use the data from the period 1950–1971 to identify the parameters of the logistic and the exponential functions we obtain similar results – better fitting to the historical data is the one for exponential growth (see Table 5). A comparison of exponential growth in the period 1950–1971 with exponential growth in the period 1980–2006 shows a much higher rate of growth in the post-war period (approximately 4.7% compared to 3.2% in the period 1980–2006). The

Table 4

Global GDP growth. The parameters values of the logistic and exponential curves. Historical data for identification: 1980–2006.

| Curve/criterion | K [10^{14} US dol.] | Δt | t_m | Identification error |
|-------------------|--|------------|-------------|----------------------|
| Logistic Q_1 | 0.99997717 | 132.9904 | 2169.188 | 712551.0880 |
| Logistic Q_1 | 97.68471900 | 133.3967 | 2308.901 | 710387.6721 |
| Logistic Q_1 | 998.55000000 | 133.4024 | 2379.482 | 710367.5573 |
| Logistic Q_1 | 95917.25000000 | 133.4024 | 2518.060 | 710365.3992 |
| Logistic Q_1 | 9718381.00000000 | 133.4023 | 2658.257 | 710365.3768 |
| Logistic Q_1 | 59807200.00000000 | 133.4025 | 2713.420 | 710365.3766 |
| | $A \rightarrow y(1950)$ [10^{13} US dol.] | | γ | Identification error |
| Exponential Q_1 | 1.9243691 | | 0.032941280 | 710365.3765 |
| Exponential Q_2 | 1.9516935 | | 0.031941294 | 0.02033412209 |

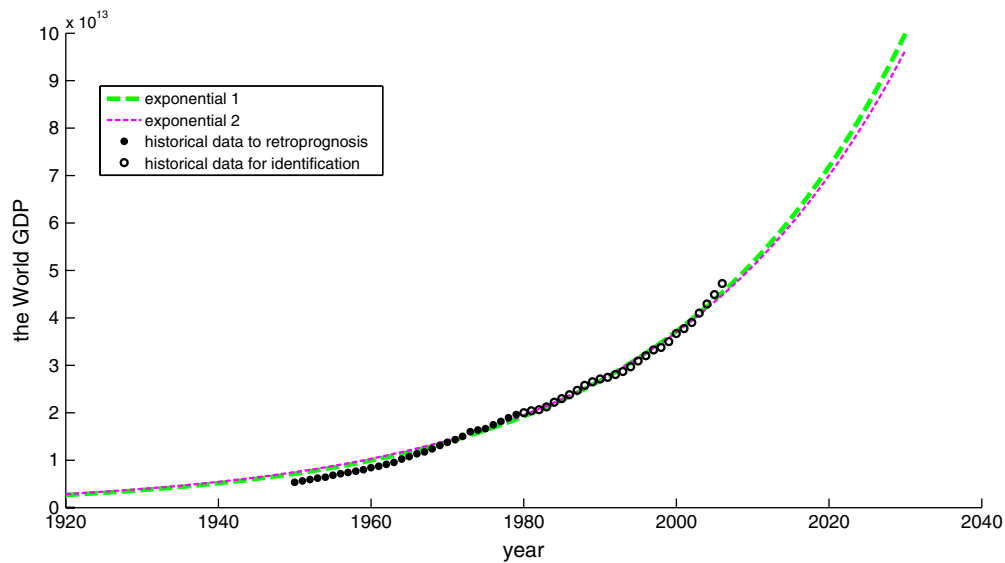


Fig. 10. The global GDP forecast (exponential function parameter identification based on historical data from the years 1980 to 2006).

Table 5

Global GDP growth. The parameters values of the logistic and exponential curves. Historical data for identification: 1950–1971.

| Curve/Criterion | K [10^{15} US dol.] | Δt | t_m | Identification error |
|-------------------|--|------------|-------------|----------------------|
| Logistic Q_1 | 7.8277065 | 92.9378 | 2201.748 | 108823.5452 |
| Logistic Q_1 | 99.9828330 | 92.9386 | 2255.624 | 108820.9534 |
| Logistic Q_1 | 776.2378700 | 92.9384 | 2347.665 | 108820.7356 |
| | $A \rightarrow y(1950)$ [10^{13} US dol.] | | γ | Identification error |
| Exponential Q_1 | 5.2962144 | | 0.047283458 | 108820.7328 |
| Exponential Q_2 | 5.3408785 | | 0.046580132 | 0.01219099369 |

differences in the forecasts of exponential growth for the two criteria are small but clearly visible (see Fig. 11). It should be noted that comparing these predictions with the available historical data for 1972–2006 shows shortages in their effectiveness. Error estimates for 1980 are relatively small, but after 1980 they are more and more significant, in 2006 this error is around 40%.

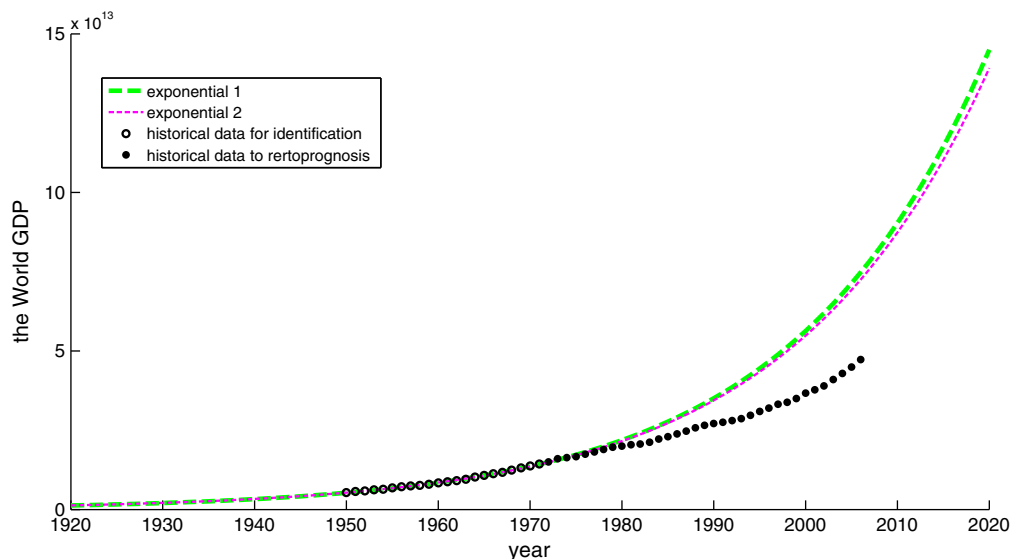


Fig. 11. The global GDP forecast (exponential function parameter identification based on historical data from the years 1950 to 1971).

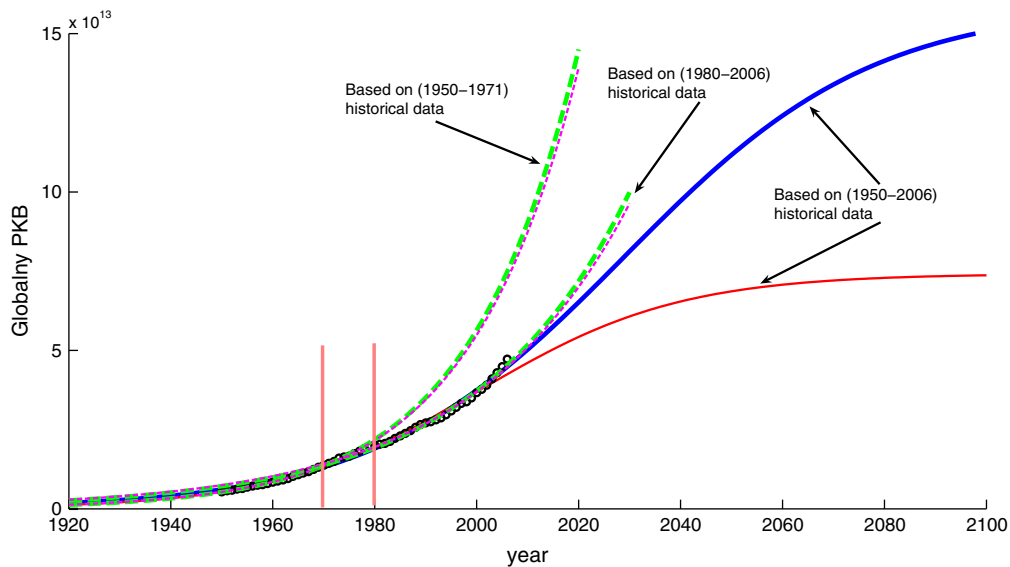


Fig. 12. Comparison of the global GDP growth forecasts based on extrapolation of exponential growth in the years (1950–1971) and (1980–2006) and the logistic growth in (1950–2006).

Fig. 12 shows the comparison of all our predictions of global GDP growth. It is hard to say which of these predictions is more likely. However, it appears that the forecasts made using the logistic function are more plausible (although the dispersion between the two logistic predictions is very large).

The most intriguing however, is that the inclusion in the identification of a relatively short period of oil shocks (i.e. the period 1972–1979, marked in Fig. 12 by the two vertical lines) so radically changes the nature of exponential growth (observed in the periods 1950–1971 and 1980–2006) into the logistic one (based on the whole historical data from 1950 to 2006).

5.2. Demographic growth analysis

Making similar experiments with global population growth we also obtain qualitatively different results. As we will show, in 1950–1971 the world population growth is better described by the exponential function, while in the period 1980–2008 we observe a slowdown in the growth of world population and the logistic function fits better to that trend. The values of error identification for several values of the logistic function are presented in Table 6. It is seen that in the post-war period 1950–1971, the higher saturation value K , the better fit to the logistic curve. This suggests that the exponential curve fits better to the historical data, and that is the case. It is worth noting that for both criteria the identified population growth rate is nearly the same, namely approximately 1.89% per annum. It is true that the exponential trend fits well to the historical data in the period 1950–1971, but a forecast based on the extrapolation of that exponential trend (Fig. 13) is relatively good only for the next 20 years (until 1990), at the end of the 20th century and beginning of the 21st century we observe significant deviations of that trend from the historical data.

If we use historical data from the period 1980–2008 to identify the logistic and exponential curves parameters, we clearly see that a better fit to historical data is obtained for the logistic function (Table 7). In contrast to the earlier identification based on historical data from the years 1950–2008 (see Table 1 and Fig. 3), in this experiment, the value of the identified parameters of the logistic function for both the identification criteria are very similar, in particular saturation K is roughly equal to 9.2 billion (Table 7 and Fig. 14). The value of this saturation is about 30% smaller than the saturation value obtained for identification based

Table 6

The growth of the World population. The parameters' values of logistic and exponential curves. Historical data (1950–1971).

| Curve/Criterion | K [10^9 US dol.] | Δt | t_m | Identification error |
|-------------------|---|------------|-------------|----------------------|
| Logistic Q_1 | 20.515148 | 197.2791 | 2038.442 | 13635920.27 |
| Logistic Q_1 | 6287.348200 | 232.3073 | 2363.559 | 11028257.11 |
| Logistic Q_1 | 38717522.000000 | 232.4238 | 2825.282 | 11021606.83 |
| | $A \rightarrow y(1950)$ [10^9 US dol.] | | γ | Identification error |
| Exponential Q_1 | 2.5163250 | | 0.018907043 | 11021605.77 |
| Exponential Q_2 | 2.5184137 | | 0.018831309 | 0.00339091178 |

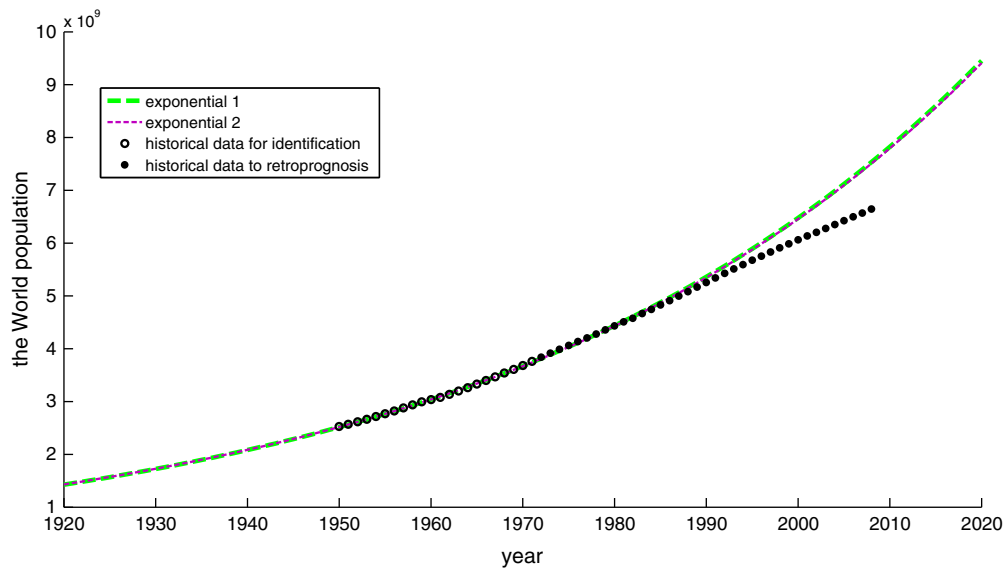


Fig. 13. The global population growth extrapolation (exponential parameter identification based on historical data from the years 1950 to 1971).

Table 7

The growth of the World population. The parameters' values of logistic and exponential curves. Historical data (1980–2008).

| Curve/Criterion | K [10^9 US dol.] | Δt | t_m | Identification error |
|-------------------|---|------------|-------------|----------------------|
| Logistic Q_1 | 9.206758 | 119.2270 | 1982.23 | 7028676 |
| Logistic Q_2 | 9.266125 | 120.4273 | 1982.57 | 0.001387531253 |
| | $A \rightarrow y(1950)$ [10^9 US dol.] | | γ | Identification error |
| Exponential Q_1 | 4.5238956 | | 0.014286828 | 55615848.68 |
| Exponential Q_2 | 4.5057450 | | 0.014541383 | 0.01002837651 |

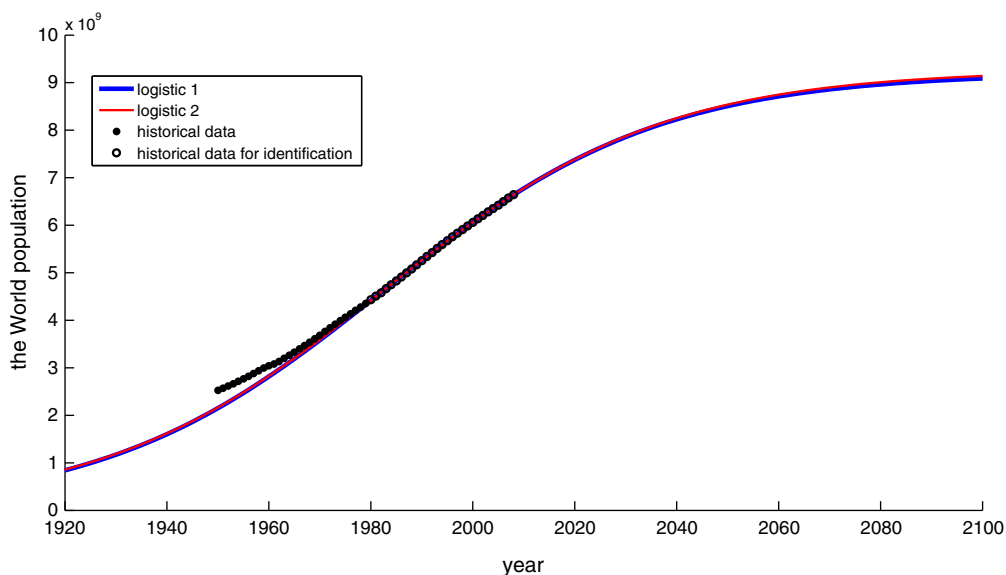


Fig. 14. Forecast of the World population by the end of the 21st century (logistic function parameter identification based on historical data from the years 1980 to 2008).

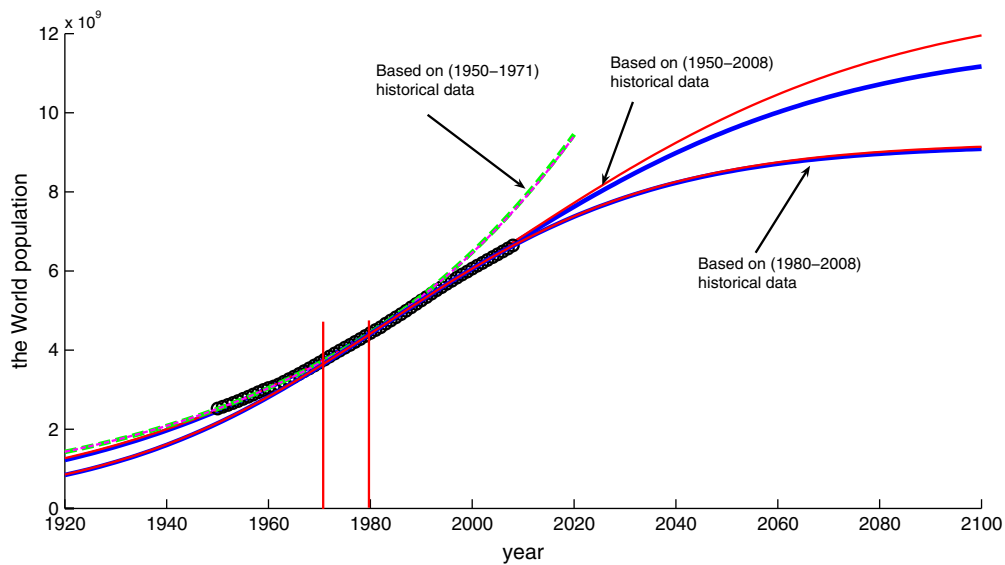


Fig. 15. Comparison of the global population growth forecasts based on extrapolation of exponential growth in the years (1950–1971) and the logistic growth in (1980–2006) and (1950–2008).

on data for 1950–2008. A comparison of the three experiments (predictions) is shown in Fig. 15 (vertical lines indicate the period 1972 to 1979; the oil crises). It seems that for the world population growth, the logistics trend seems more probable and the expected maximum number of people living on the Earth might be between 9 and 12 billion.

The presented results allow us to understand (and to some extent to justify) the incorrect population projections presented in the First Report for the Club of Rome *The Limits to Growth*, published in 1972. The demographic development up to the 1970s suggested a very rapid, exponential (some even have claimed hyperbolic) trend of world population growth. The authors of *The Limits to Growth* have not taken into account the limits to population growth in their world model, caused by some natural mechanisms (mainly the market ones), which usually contribute to slowing down population growth in the course of increasing population density and growing welfare (this slowdown, as we can see, is observed in the last decades of the twentieth and the first decade of the twenty-first centuries).

5.3. GDP per capita analysis

A trend analysis of changes of global welfare (measured by the volume of GDP per capita) in the periods 1950–1971 and 1980–2006 shows that, as in the case of global GDP, the development is dominated by an exponential trend. Thus once again we can see that the inclusion of the oil crises (1972–1979) radically changes the nature of the trend (as was shown earlier in Section 3, the 1950–2006 identified trend was a logistic one).

Table 8 presents the results of the identification of GDP per capita growth based on historical data from the years 1950–1971. The identification error is diminishing for the increasing values of the saturation K ; this suggests that a better fit is obtained for the exponential function. The rate of growth of GDP per capita in the years 1950–1971 is similar for both identification criteria. It was indeed a period of rapid growth of prosperity; GDP per capita was growing during this period by approximately 2.8% annually. It should be emphasized that the gap between the forecast and the actual values after 1980 is significant and is widening in subsequent decades, in 2006, the difference is roughly 30% (Fig. 16).

Table 8

GDP per capita. The parameters' values of logistic and exponential curves. Historical data (1950–1971).

| Curves/Criterion | K [US dol.] | Δt | t_m | Identification error |
|-------------------|-----------------------------------|------------|-------------|----------------------|
| Logistic Q_1 | 899999.82 | 156.201 | 2165.102 | 94.34445365 |
| Logistic Q_1 | 8999908.40 | 156.6601 | 2247.892 | 94.13893579 |
| Logistic Q_1 | 38710930.00 | 156.6988 | 2299.994 | 94.12151201 |
| | $A \rightarrow y(1950)$ [US dol.] | | γ | Identification error |
| Exponential Q_1 | 2114.0825 | | 0.028041745 | 94.11623718 |
| Exponential Q_2 | 2120.7042 | | 0.027753573 | 0.01059338021 |

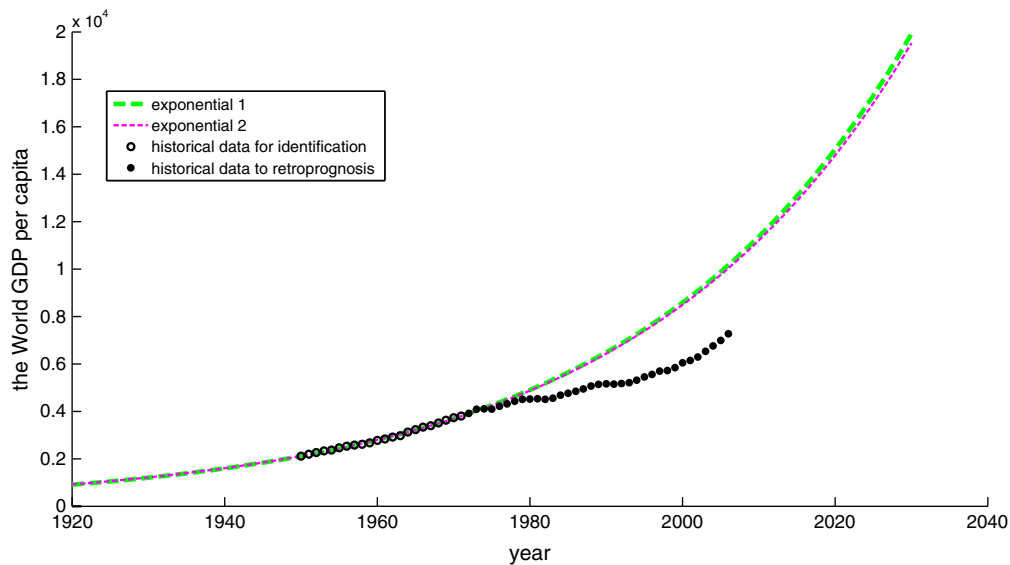


Fig. 16. GDP per capita (identification period 1950–1971).

The identification of the parameters of logistic and exponential functions using historical data from the years 1980–2006 gives qualitatively similar results. The best fit is for exponential growth, but the growth rate during this period is much smaller than in the post-war period, namely approximately 1.7% (Table 9, Fig. 17).

Fig. 18 shows a comparison of these three extrapolative forecasts of GDP per capita. The fastest exponential growth (2.8% per annum) is observed in 1950–1971, and a slower exponential growth (a growth rate of around 1.7%) in the years 1980–2006. Once again the inclusion of the data for the years 1972–1979 in the process of parameters' identification (i.e. for the identification period 1950–2006) makes the logistic growth fit better. The saturation level of the logistic curves is different for different criteria, namely roughly \$12,000 for the mean square criterion and \$9000 for the relative mean square error.

An alternative approach to welfare forecasting is to use partial forecasts of global GDP and global population growth and divide the relevant values. It turns out that when we calculate GDP per capita by division of the global GDP by the global population obtained on the basis of historical data from the period 1950–1971 (when, as we remember, the best fit either in terms of GDP and the global population were for the exponential trends) the results are almost the same as for a simple extrapolation of GDP per capita. A comparison of these predictions is presented in Fig. 19. As we can see, the differences between these forecasts are negligible, but (as is mentioned in the discussion of Fig. 16) they are very unreliable – after a few years (since the early 1980s) the differences between the forecasts and the actual data are significant, and in the course of time become larger and larger.

Fig. 20 shows a similar comparison of the forecasts on the assumption that the identification is based on historical data from the years 1980–2006. As we remember during this period, the best fit for GDP growth occurred for the exponential curve and for the population growth for the logistic curve. The calculation of GDP per capita by dividing these values produces the trend similar to the 'exponential growth' (there is no tendency to saturation). As we can see in Fig. 20, there are significant differences between these forecasts. Naturally it is difficult to say which forecast is better because we have no comparative data (as is the case of identification on the basis of the years 1950 to 1971).

Table 9

GDP per capita. The parameters' values of logistic and exponential curves. Historical data (1980–2006).

| Curve/Criterion | K [US dol.] | Δt | t_m | Identification error |
|-------------------|-----------------------------------|------------|-------------|----------------------|
| Logistic Q_1 | 18.975492 | 238.3667 | 2184.235 | 538.7584161 |
| Logistic Q_1 | 9989.583600 | 245.2912 | 2541.190 | 511.3574212 |
| Logistic Q_1 | 827547.000000 | 245.3055 | 2787.785 | 511.3353354 |
| Logistic Q_1 | 8005822.300000 | 245.3055 | 2914.470 | 511.3352584 |
| | $A \rightarrow y(1980)$ [US dol.] | | γ | Identification error |
| Exponential Q_1 | 4297.3220 | | 0.017914200 | 511.3352495 |
| Exponential Q_2 | 4342.7828 | | 0.017054013 | 0.02713080275 |

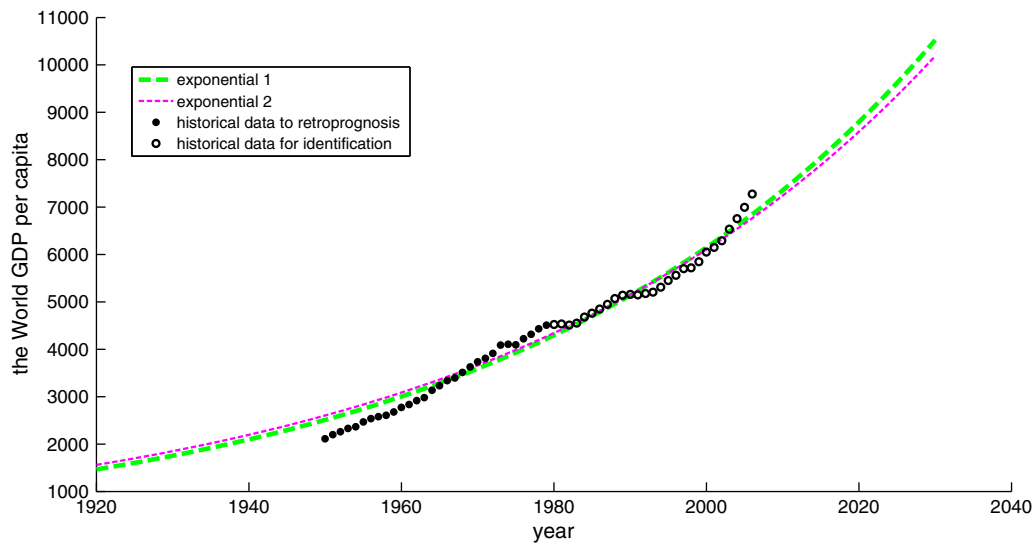


Fig. 17. GDP per capita (identification period 1980–2006).

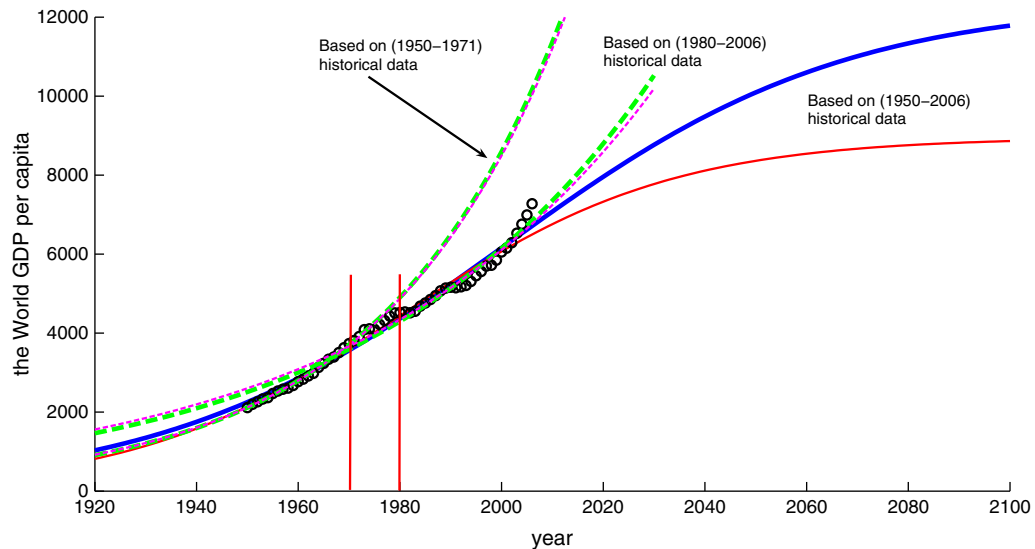


Fig. 18. Comparison of the three extrapolative forecast of the global welfare.

6. Competition and competitiveness of nations

Boretos [6] uses the Logistic Substitution⁶ fit of actual GDP contribution for the Western countries, China, and the rest of the world.⁷ He concludes that “currently China is at an emerging phase, the West at a decline phase, and the rest of the World is substituting”. According to his prediction “[if] the current trend continues, the West will follow a slow declining pace reaching 36% at 2050. The rest of the World is expected to fall gradually to 28% at 2025, while entering the decline phase at almost the same time. China is expected to grow even more in the following years reaching 32% contribution at 2025, and 51% at 2050. China’s economy is expected to surpass Western countries’ combined economies by 2034, and even earlier at 2023 the rest of the World region.”

⁶ Logistic Substitution Model II Copyright © 2004–2006, International Institute for Applied System Analysis, Transitions to New Technologies Program; <http://www.iiasa.ac.at/Research/TNT/WEB/Software/LSM2/lsm2-index.html>

⁷ the Western countries include: Austria, Belgium, Cyprus, Denmark, Finland, France, Germany (West Germany from 1950 to 1988, united Germany from 1989 onwards), Greece, Iceland, Ireland, Italy, Luxembourg, Malta, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, Canada, the United States, Australia, New Zealand, China consists of the People’s Republic of China and Hong Kong.

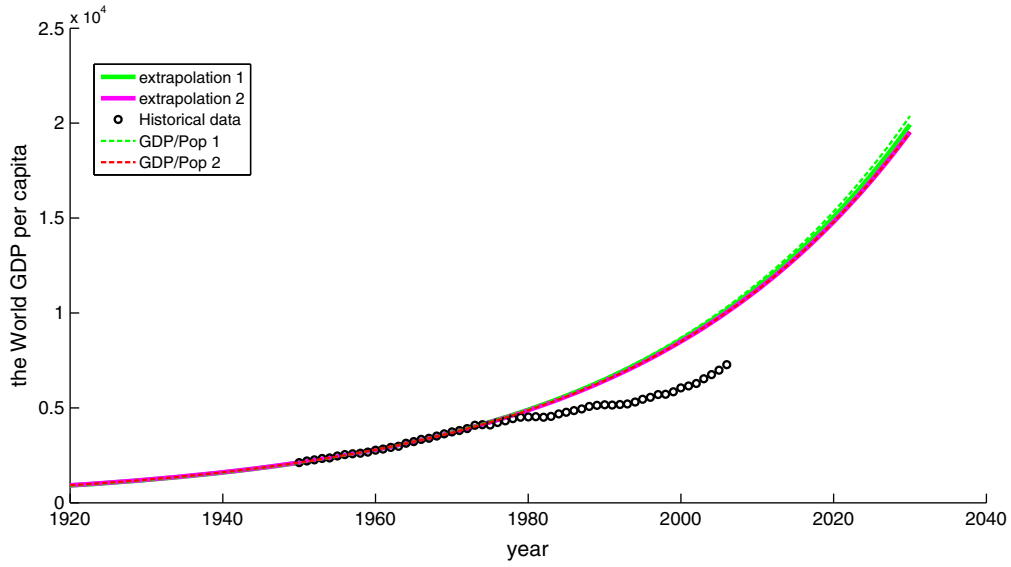


Fig. 19. Comparison of the GDP per capita forecasts: extrapolative and calculated on the basis of the global GDP and the global population (historical data 1950–1971).

In the middle of the 1990s we have proposed the evolutionary model of substitution–diffusion processes which can be used to make similar prediction as was done by George Boretos. The model and the procedure of its parameters identification is presented in ref. [9], here we will confine ourselves to describing only the model's basic characteristics.

Let us assume that we have n competing nations (or regions). The dynamics of the share $f_i(t)$ of a nation (region) i in the global GDP in year t can be described by the so-called replicator equation (selection equation):

$$f_i(t) = f_i(t-1) \frac{c_i(t)}{\bar{c}}(t) \quad (8)$$

where

$c_i(t)$ competitiveness of the nation (region) i at time t .
 $\bar{c}(t)$ the average competitiveness at time t :

$$\bar{c}(t) = \sum_{i=1}^n c_i(t) f_i(t-1) \quad (9)$$

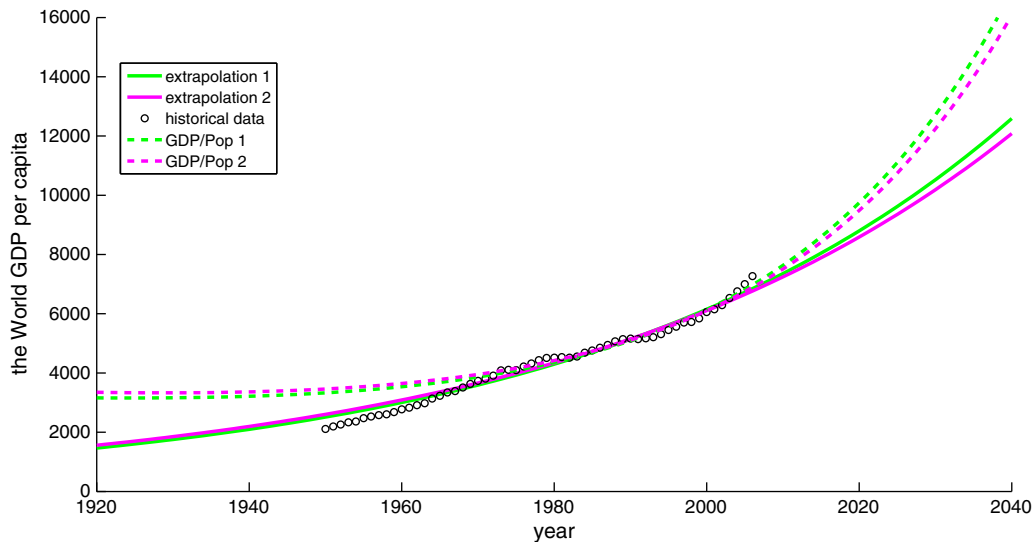
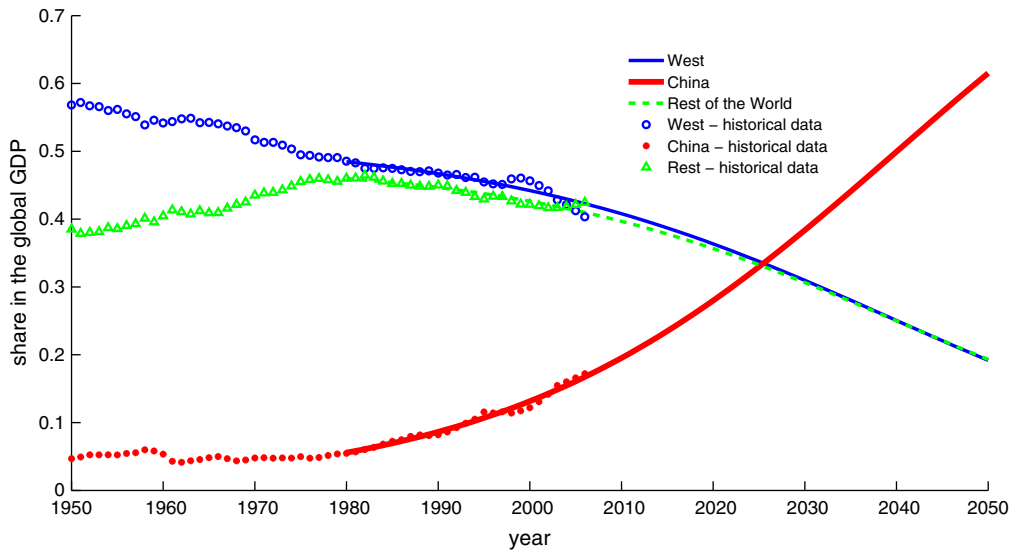


Fig. 20. Comparison of the GDP per capita forecasts: extrapolative and calculated on the basis of the global GDP and the global population (historical data 1980–2006).

Table 10

Values of the model's parameters: China, West and the Rest of the World – the identification period 1980–2006.

| | Competitiveness (c_i) | Initial share $f_i(t_0)$ in 1979 |
|-------------------|---------------------------|----------------------------------|
| West | 0.999152 | 0.486100 |
| China | 1.047807 | 0.053287 |
| Rest of the world | 1.000000 | 0.460613 |

**Fig. 21.** Evolution of the GDP shares of the three regions: China, West and the Rest of the World (the identification period 1980–2006).

As we can see from the replicator equation, the share of nation (region) i is growing if the competitiveness of that nation is greater than the average competitiveness and is declining for the competitiveness smaller than the average competitiveness.

Let us assume that we identify the replicator equations parameters on the basis of historical data from 1980 to 2006.⁸ This will allow us to compare our results with that of George Boretos. The identified competitiveness for the three considered regions and the initial shares are presented in Table 10. We can see that China's competitiveness is much higher than the competitiveness of the West as well as of the Rest of the World. The model fits quite well to the historical data (see Fig. 21). Our predictions are slightly different than those made by Boretos. According to our extrapolations, in 2050 the West and the Rest will have roughly the same shares in global GDP (equal to 19%), and the share of China will be around 60%. China will surpass the West as well as the Rest at around 2025. This scenario seems to be rather doubtful (as unlikely as is also the scenario proposed by Boretos⁹) and therefore the discussion of reliability of these predictions will be presented in the following part of the paper.

We obtain slightly different results if we use the whole available historical data of the period 1950–2006 for the parameters' identification. The overall competitiveness of China is much lower (see Table 11) and in the middle of the 21st century the share of China in global GDP is almost the same as the share of the West (roughly 29%; see Fig. 22). The share of the Rest is equal to 42%. Naturally we may complain that the fitting of the model to historical data is not good (Fig. 22). This is understandable because the structure of the Chinese economy of the post-war period up to the end of the 1970s was significantly different than that of the post 1980 one.

We may expect that the competitiveness of the regions is far from being constant and fluctuates in the course of time. Our model allows identifying dynamics of these fluctuations. Namely we are able to assume a much smaller identification period

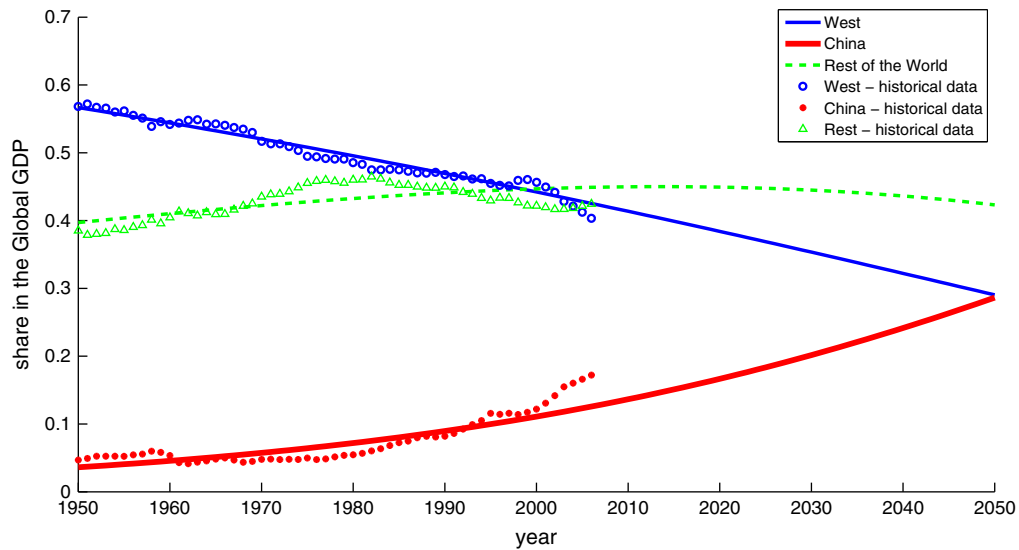
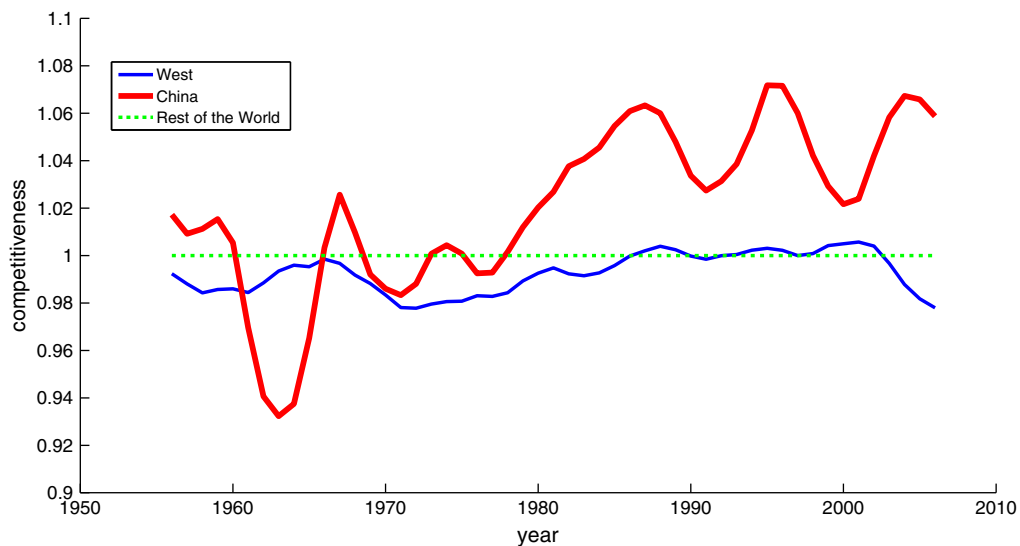
⁸ In 1977 Deng Xiaoping became the new leader of China (after Mao Zedong's death) and initiated pro free market economic reforms (based also on the economic policy encouraging foreign trade and foreign investments).

⁹ He writes: "It is evident that in the following years China will probably become the largest economy of the World, surpassing even the leading U.S. economy. By the year 2024 though it will enter the substitution phase, as our world will most likely experience the emergence of a new "superpower" that will take its place, and once more will change the international landscape as we know it today. One of the best candidates to be that superpower is India which currently accounts for 6% of World GDP and has one of the largest growth rates around the globe (7% CAGR for 2000–2005). If this does happen then our forecast will most likely overestimate China's relative power during 2025–2050, and underestimate the rest of the World and eventually India's contribution for the same period." [6, p. 324].

Table 11

Values of the model's parameters: China, West and the Rest of the World — the identification period 1950–2006.

| | Competitiveness (c_i) | Initial share $f_i(t_0)$ in 1949 |
|-------------------|---------------------------|----------------------------------|
| West | 0.992706 | 0.568897 |
| China | 1.020249 | 0.035354 |
| Rest of the World | 1.000000 | 0.395749 |

**Fig. 22.** Evolution of the GDP shares of the three regions: China, West and the Rest of the World (the identification period 1980–2006).**Fig. 23.** Dynamics of the competitiveness: China, West and the Rest of the World (identification is based on the 7 years moving window of historical data).

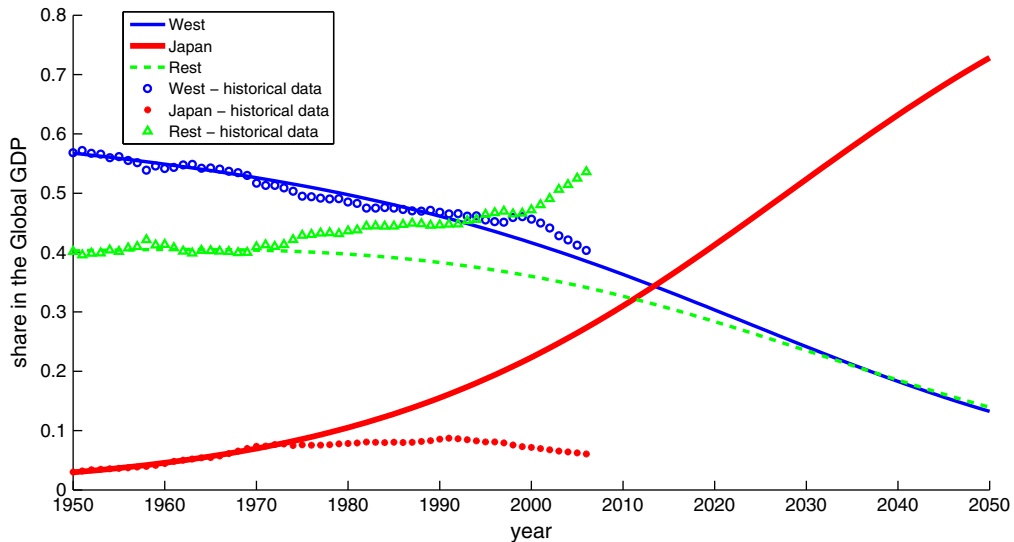
(e.g., a 7 year window) and make the identification of the competitiveness starting from the period 1950–1956 and move the 7 year window up to the last year, i.e. to the period 2000–2006.¹⁰ In such a case we obtain a kind of a 'moving competitiveness'. The result of this experiment is presented in Fig. 23.

¹⁰ this procedure is described in details in ref. [9].

Table 12

Values of the model's parameters: Japan, West and the Rest of the World – the identification period 1950–1970.

| | Competitiveness (c_i) | Initial share $f_i(t_0)$ in 1949 |
|-------------------|---------------------------|----------------------------------|
| West | 0.996064 | 0.569261 |
| Japan | 1.043551 | 0.028382 |
| Rest of the World | 1.000000 | 0.402356 |

**Fig. 24.** Evolution of the GDP shares of the three regions: Japan, West and the Rest of the World (the identification period 1950–1970).

As can be seen (Fig. 23) the competitiveness is far from being constant. Up to the end of the 1980s the competitiveness of the West was below the competitiveness of the Rest of the World and usually slightly below China's competitiveness. The West's economies were more competitive from the end of the 1980s, but after the dot.com crisis the West's competitiveness has been declining. It is clearly visible that China's competitiveness started to rise after the Deng Xiaoping reforms and (although fluctuating) was much higher than the West and the Rest's competitiveness. It is difficult to predict the future of the Chinese economy's competitiveness but we may expect that in the near future the advance of China will be sustained. The lesson of Japan may give us a hint as to what may happen in the longer perspective.

As is known, Japan's economy was treated as the model for growth in the post-war period up to the beginning of the 1970s. The identified competitiveness of the Japanese economy, based on the historical data from 1950 to 1970, is roughly similar to China's competitiveness for the period 1980–2006 (see Table 12) – the competitiveness was roughly 4% higher than the West and the Rest's competitiveness. The share of Japan's GDP in global production more than doubled in the period 1950–1970 (similar as in the period 1980–2000 for China).

The prediction of the shares in global GDP of Japan and the two other regions are shown in Fig. 24. We can see that since the middle of the 1970s the discrepancy between the prediction and the real development has been growing. The prediction based on the trend observed in 1950–1980 suggested that in 2030 the share of Japan's economy will be above 50% (as in the case of China in 2050). According to that prediction we might expect that the share of Japan in the global production in 2006 ought to be 27%, in reality it declined to 6% (see Fig. 24).

The results suggest that it would be good to look at the dynamics of changes of Japan's competitiveness. The results of a similar experiment with moving the 7 year identification window (as in the case of China) are presented in Fig. 25. We can see that the pattern of changes of Japan's competitiveness in 1950–1970 is more or less similar to the pattern of the changes of China's competitiveness in 1980–2000 (compare Figs. 25 and 23), we can see the enormous superiority of Japan's and China's economies in the relevant periods. As we can notice (Fig. 25) the sharp decline of Japan's competitiveness was observed in the 1970s, the almost constant level of competitiveness in the 1980s and the beginning of the 1990s, and once more the sharp decline at the turn of the 20th and the 21st centuries. We do not claim that a similar pattern will be observed in the case of China's economy in the next few decades, but we would like to point out that we ought to be very cautious in our evaluations of the future of the Chinese economy.

Our model allows us to investigate the evolution of a larger number of countries/regions. As the first experiment in that series, let us assume that the world is divided into six countries/regions, namely: the USA, the E12,¹¹ Japan, China, India and the Rest of

¹¹ E12 consists of the twelve European countries, namely: Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom.

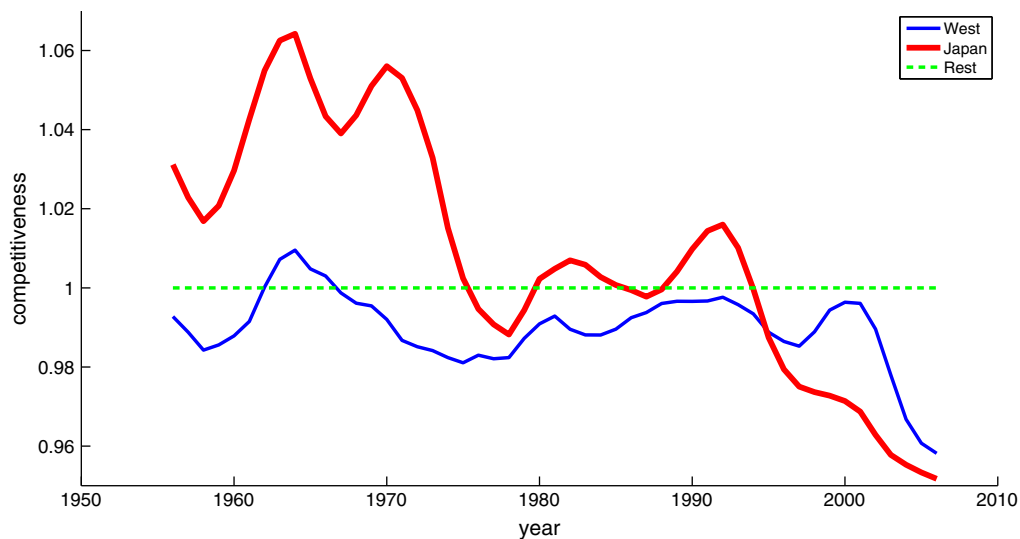


Fig. 25. Dynamics of the competitiveness: Japan, West and the Rest of the World (identification is based on the 7 years moving window of historical data).

Table 13

Values of the model's parameters: USA, E12, Japan, China, India and the Rest of the World — the identification period 1950–2006.

| | Competitiveness (c_i) | Initial share $f_i(t_0)$ in 1949 |
|-------------------|---------------------------|----------------------------------|
| USA | 0.995710 | 0.253936 |
| E12 | 0.992412 | 0.261623 |
| Japan | 1.014378 | 0.041473 |
| China | 1.022661 | 0.035302 |
| India | 1.006745 | 0.032042 |
| Rest of the World | 1.000000 | 0.375624 |

the World. The overall competitiveness of those six countries/regions in the post-war period is presented in Table 13. We can see that either the USA or the E12 economies lose their positions in the post-war period: their competitiveness is smaller than the competitiveness of all the other countries/regions. The fit of the model (see Fig. 26) is rather poor and is clearly unsatisfactory. Significant differences between the model and the historical data are seen in almost all the countries/regions, but are especially visible in the case of China, Japan, and the Rest of the World. This is caused by significant differences in the mood of development of the World's economy before and after 1980. This is clearly seen when we look at the dynamics of competitiveness in the post-war period (Fig. 27). To identify the moving competitiveness we use the 14 year identification window.¹² It is clearly visible that for all the competitiveness the mood of changes up to 1980 is significantly different than that after 1980. The competitiveness of India's economy in the last three decades is only slightly smaller than China's competitiveness; the USA's competitiveness, although smaller than China's and India's, is significantly greater than that of the E12.

Therefore let us look more closely at the development of the world economy in the last three decades. The average competitiveness in the period 1980–2006 is presented in Table 14, and we can see that it confirms the general impression flowing from Fig. 27; Japan and the E12 economies lose their position, but the USA economy tries to compete with China and India. Fig. 28 shows the prognosis based on the trends observed in the period 1980–2006. It confirms the suggestions concerning the expected future of the Chinese economy presented in Fig. 21 (the share of China's GDP will be around 60% of global GDP). According to that prediction, currently we ought to observe the catching up of the USA by the Chinese economy (in GDP terms). India's economy will exceed the E12's around 2030 and will be at the same level as the USA's in the middle of the 21st century.¹³

¹² It is necessary to identify $2n-1$ parameters in our model (n is the number of countries/regions; namely $n-1$ competitiveness and n initial shares), therefore the number of historical data ought to be greater than $2n-1$ (in our case greater than 11, therefore we select the 14 year identification window).

¹³ A more plausible scenario is presented in our working paper on *China, India and the future of the global economy* (available at http://mpr.ub.uni-muenchen.de/32558/1/MPRA_paper_32558.pdf), pp. 23–25. According to that scenario “the Chinese economy will overcome the US in 2011 (with a roughly 20% share of global GDP by both economies) and will still grow to reach the maximum share equal to 28% in 2027, in the next two decades (still being the largest global economy) its share will be dropping to reach 24.5% in 2050. The second largest economy will be the US, but its share will still decline to reach the minimum 18.3% in 2027. From that year the share of the US economy will rise to reach 22% in 2050 (roughly the same as China). The share of the Indian economy will grow steadily to reach almost 16% in 2050 (and being a 3rd world economy). The total share of the twelve European countries (E12) will keep the past tendency to decline, but, due to the reform initiated in the 2030s, in the middle of the century will reach a plateau with a share equal to 10%. The same pattern of development will be experienced by Japan, but the plateau (roughly a 5% share) is reached by the Japanese economy in the beginning of the 2030s.”

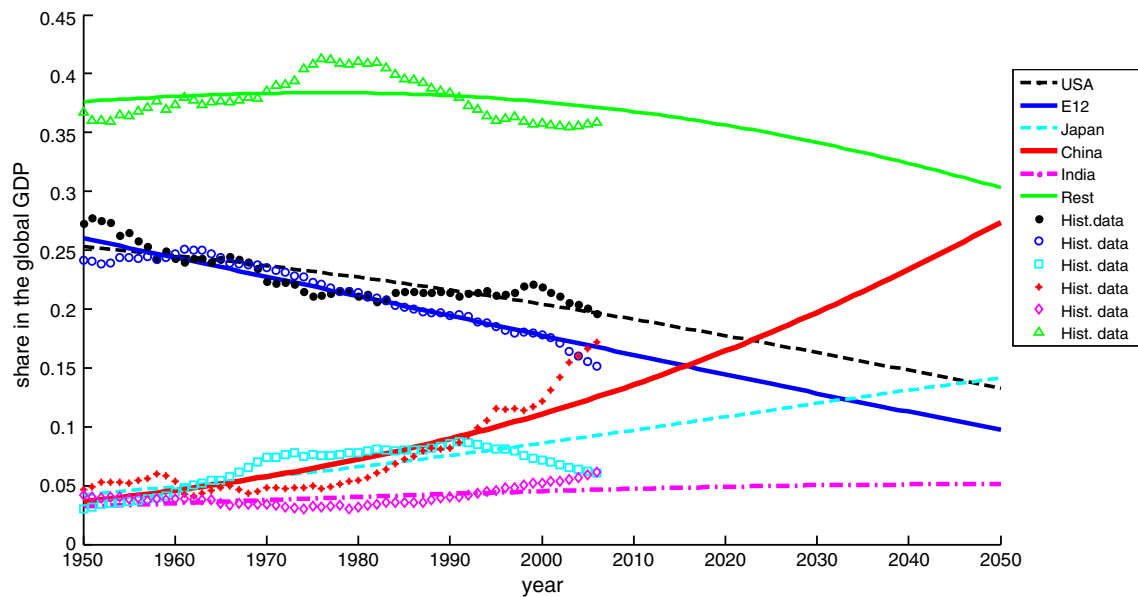


Fig. 26. Evolution of the GDP shares of the six regions/countries: USA, E12, Japan, China, India and the Rest of the World (the identification period 1950–2006).

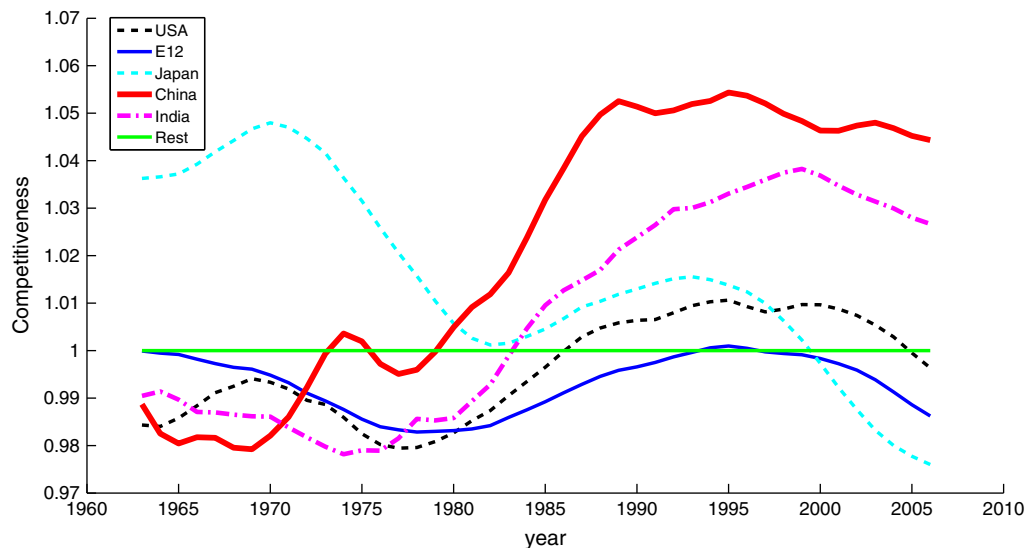


Fig. 27. Dynamics of the competitiveness: USA, E12, Japan, China, India and the Rest of the World (identification is based on the 14 years moving window of historical data).

The idea of ranking the national economies according to their competitiveness index came to us during working on this paper. The problem is that if we would like to consider, let us say 100 nations, and calculate their competitiveness using our model we ought to have historical data on their GDP for roughly 200 years. Naturally it is not possible to collect such long historical data; therefore we propose a simplified approach. Let us assume that we consider each country separately as competing with the Rest of the World. To identify the competitiveness of that country (against the competitiveness of the Rest, all the time assumed as equal to one¹⁴) we ought to have historical data on at least four years (usually we assume a longer period, e.g. 7 years for two types (countries)). Just to investigate the relevance of this approach we calculated moving the competitiveness for the five considered countries/regions by making five simulation experiments: each country competes with the rest of the World. The results of these experiments are presented in Fig. 29. The general tendency of the competitiveness changes is more or less similar

¹⁴ As we explain in ref. [9] one country (type) ought to be treated as the reference country (type) and it is necessary to assume the reference value of the competitiveness of that country (type).

Table 14

Values of the model's parameters: USA, E12, Japan, China, India and the Rest of the World – the identification period 1980–2006.

| | Competitiveness (c_i) | Initial share $f_i(t_0)$ in 1949 |
|-------------------|---------------------------|----------------------------------|
| USA | 1.005344 | 0.211215 |
| E12 | 0.994965 | 0.215214 |
| Japan | 0.996753 | 0.086284 |
| China | 1.049823 | 0.053095 |
| India | 1.031486 | 0.030351 |
| Rest of the World | 1.000000 | 0.403841 |

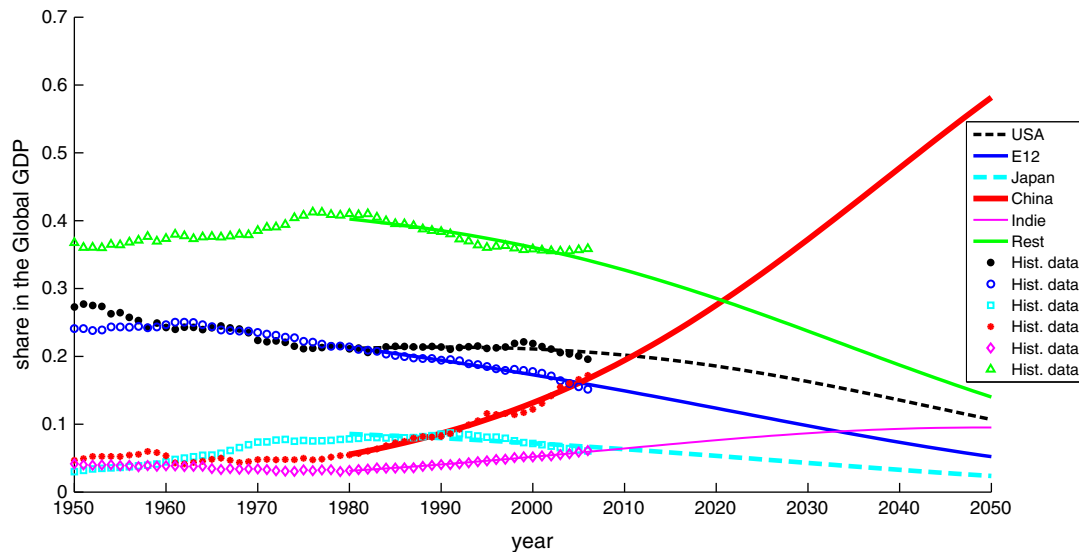


Fig. 28. Evolution of the GDP shares of the six regions/countries: USA, E12, Japan, China, India and the Rest of the World (the identification period 1980–2006).

to that observed in the experiment where all countries/nations competed altogether (see Fig. 27). Just to show the level of the differences, Figs. 27 and 29 are collectively presented in Fig. 30 (for all six countries/regions competing (solid lines) and calculated separately for each country competing with the Rest of The World (dashed lines)). The differences are visible, although

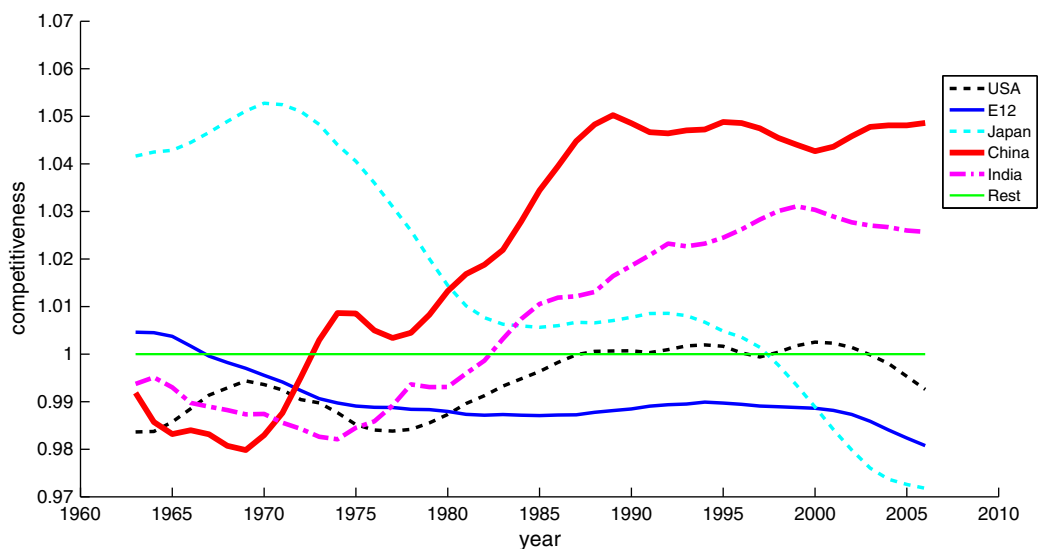


Fig. 29. Dynamics of the competitiveness: USA, E12, Japan, China, India and the Rest of the World, calculated separately for each country competing with the Rest of The World (identification is based on the 14 years moving window of historical data).

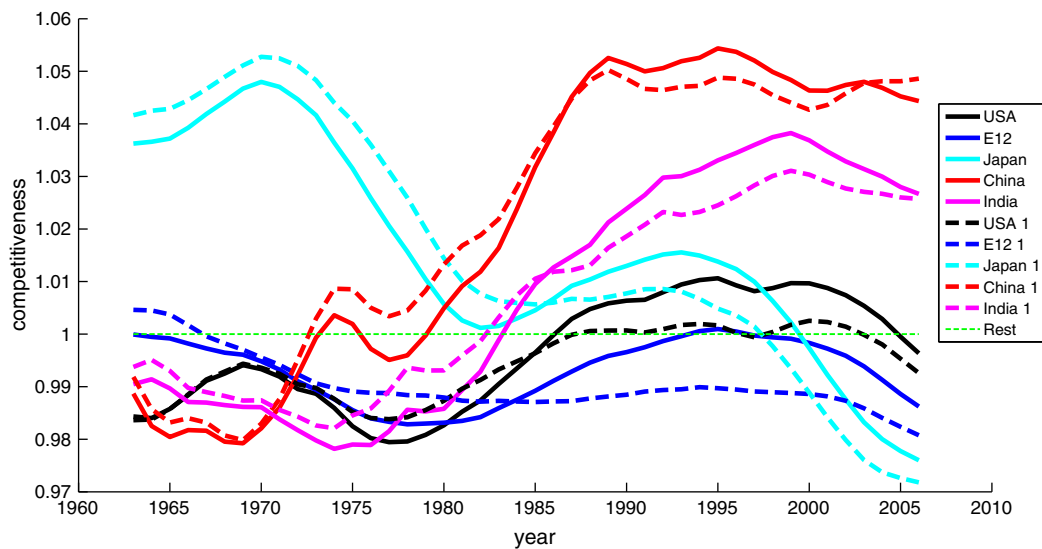


Fig. 30. Comparison of the dynamics of the competitiveness: USA, E12, Japan, China, India and the Rest of the World, for all six countries/regions competing (solid lines) and calculated separately for each country competing with the Rest of The World (dashed lines); (identification is based on the 14 years moving window of historical data).

there is general agreement concerning the observed tendencies and the far reaching similarities in the competitiveness rankings. In Table 15 the rankings of these five countries/regions for 1970, 1980, 1990, and 2000 are presented. The compatibility of rankings obtained for these two approaches is astonishingly good. The only difference is for 1970 where the USA and the E12 interchange their positions (but as we see in Fig. 30 their competitiveness are very similar).

There is no room to present the rankings of the competitiveness of all the countries in the World but we plan to undertake such a project in the near future. Here, as the first step towards that project we present an experiment for twenty-nine selected countries and the E12 (distinguished as a region competing especially with the USA and China). The dynamics of the competitiveness of the ten selected countries are presented in Fig. 31 (for a larger number of countries the figure would be unreadable). Once more we can see the great variability of the competitiveness for almost all the countries since the middle of the 20th century. In Table 16 we present the rankings of the 30 countries/region for selected years. We start from the middle 1950s, and as we can see, Israel, Germany and Japan were the most competitive countries at that time. Due to the market oriented reforms initiated in 1948 by Ludwig Erhard, the German economy was one of the most competitive in the 1950s, but in the course of time Germany has become more and more a welfare state and less and less competitive, in 1980 Germany was ranked 19th, in 1990 25th, and in the last few years was placed at the bottom of the ranking. The same tendency of losing competitiveness is observed for all of the twelve European countries (E12). The growing competitiveness in the last 20–30 years is observed for such economies as: Chile, Ireland, India, and China. Poland, and to some extent also Hungary, are good examples of competitiveness advance due to market oriented transformations. Hungary and Poland in 1990 were at the bottom of the ranking and now, after 20 years of transformation, are placed in the top ten.

In the last column of Table 16 the competitiveness indices for the latest available historical data (2006) are presented. It is worth noting the strong superiority of China and India over all the advanced economies. The index for China is roughly 10% higher than that of the USA, France, Japan and Germany. Even small differences in the values of the competitive indices result in an enormous advantage/disadvantage of the economy in the long term. For example, there is nearly a 3% difference between the competitiveness of China and the West in the period 1950–2006 (see Table 11), which resulted in an increase of China's share in global GDP from 11% in 2000 to 28% in 2050 and a decrease of the share of the West from 44% to 29% (see Fig. 22).

Table 15

Rankings of competitiveness of different countries/regions for two approaches 'altogether competition' and 'separate competition'.

| | 1970 | | 1980 | | 1990 | | 2000 | |
|-------|------------------------|----------------------|------------------------|----------------------|------------------------|----------------------|------------------------|----------------------|
| | Altogether competition | Separate competition | Altogether competition | Separate competition | Altogether competition | Separate competition | Altogether competition | Separate competition |
| USA | 3 | 2 | 4 | 4 | 4 | 4 | 3 | 3 |
| E12 | 2 | 3 | 4 | 4 | 5 | 5 | 4 | 4 |
| Japan | 1 | 1 | 1 | 1 | 3 | 3 | 4 | 4 |
| China | 5 | 5 | 1 | 1 | 1 | 1 | 1 | 1 |
| India | 4 | 4 | 3 | 2 | 2 | 2 | 2 | 2 |

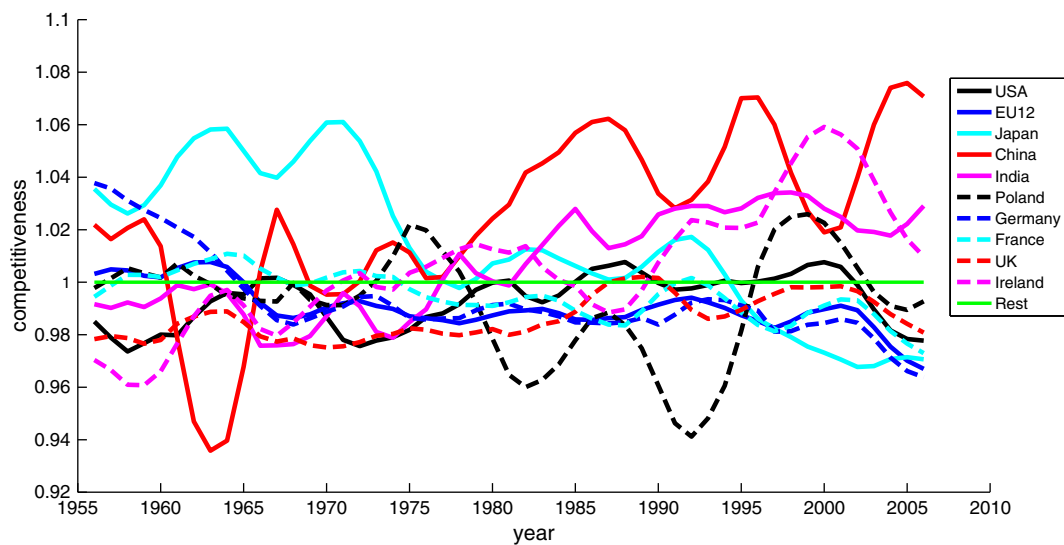


Fig. 31. Dynamics of the competitiveness of nine countries and E12; calculated separately for each country competing with the Rest of The World (identification is based on the 7 years moving window of historical data).

6.1. Possible scenario of development

The extrapolation of the future development of structure of global GDP, as presented in Fig. 28, seems to be rather improbable, mainly because it is hardly possible that the competitiveness of the selected six countries/regions will be constant over the next 40 years. Let us make an experiment and assume the future development of competitiveness of these six regions. The initial competitiveness of those six regions are as presented in Table 14 (i.e. based on the identification period 1980–2006). Future competitiveness (up to 2050) is assumed to change as follows (as illustrated in Fig. 32): the USA's competitiveness will be stable

Table 16

Ranking of the competitiveness of selected economies (30 countries and regions).

| Ranking | 1956 | 1960 | 1970 | 1980 | 1990 | 1995 | 2000 | 2006 | 2006 |
|---------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|--------|
| 1 | Israel | Israel | Singapore | Hong Kong | South Korea | China | Ireland | China | 1.0707 |
| 2 | Germany | Japan | Japan | South Korea | Hong Kong | India | Singapore | India | 1.0291 |
| 3 | Japan | Hong Kong | South Korea | Singapore | Singapore | Chile | Singapore | Ireland | 1.0098 |
| 4 | South Korea | Brazil | Israel | Brazil | China | South Korea | Poland | Hong Kong | 1.0053 |
| 5 | Hong Kong | Germany | Spain | Mexico | Chile | Israel | China | Singapore | 1.0029 |
| 6 | China | Mexico | Brazil | China | India | Hong Kong | Finland | South Korea | 1.0015 |
| 7 | Austria | Austria | Mexico | Chile | Japan | India | Chile | Chile | 1.0011 |
| 8 | Italy | China | Hong Kong | Ireland | Spain | Ireland | South Korea | Hungary | 0.9992 |
| 9 | Singapore | Italy | Italy | Norway | Ireland | Norway | Israel | Poland | 0.9927 |
| 10 | Mexico | France | Australia | Japan | Israel | Australia | Netherlands | Spain | 0.9893 |
| 11 | Spain | E12 | Netherlands | India | Australia | N. Zealand | Australia | N. Zealand | 0.9893 |
| 12 | Netherlands | Poland | France | Italy | Finland | Mexico | USA | Australia | 0.9881 |
| 13 | Brazil | Hungary | Canada | USA | UK | USA | Mexico | Israel | 0.9860 |
| 14 | E12 | Canada | Austria | Canada | USA | Austria | Canada | Sweden | 0.9853 |
| 15 | Canada | South Korea | Ireland | Israel | Canada | Netherlands | Spain | Finland | 0.9847 |
| 16 | Switzerland | Finland | China | Spain | France | Brazil | Hungary | Canada | 0.9830 |
| 17 | Finland | Australia | Finland | Australia | Italy | Denmark | Norway | UK | 0.9808 |
| 18 | Poland | Singapore | Chile | Austria | Brazil | Japan | Sweden | Brazil | 0.9799 |
| 19 | N. Zealand | Switzerland | Poland | Germany | Netherlands | Spain | UK | Norway | 0.9793 |
| 20 | France | Denmark | Norway | France | Austria | Germany | Denmark | Mexico | 0.9790 |
| 21 | Norway | N. Zealand | E12 | Netherlands | Switzerland | Canada | Hong Kong | USA | 0.9777 |
| 22 | India | Chile | Denmark | E12 | E12 | UK | Austria | Austria | 0.9742 |
| 23 | Australia | India | Switzerland | Finland | Sweden | France | N. Zealand | Denmark | 0.9733 |
| 24 | Hungary | Netherlands | Sweden | Denmark | Norway | E12 | France | France | 0.9730 |
| 25 | USA | Spain | Germany | Hungary | Germany | Italy | Brazil | Switzerland | 0.9719 |
| 26 | Chile | Norway | India | UK | Denmark | Poland | E12 | Netherlands | 0.9707 |
| 27 | Sweden | Sweden | USA | Poland | Mexico | Switzerland | Italy | Japan | 0.9707 |
| 28 | UK | USA | Hungary | Sweden | N. Zealand | Sweden | Switzerland | E12 | 0.9670 |
| 29 | Denmark | UK | UK | Switzerland | Hungary | Finland | Germany | Italy | 0.9648 |
| 30 | Ireland | Ireland | N. Zealand | N. Zealand | Poland | Hungary | Japan | Germany | 0.9638 |

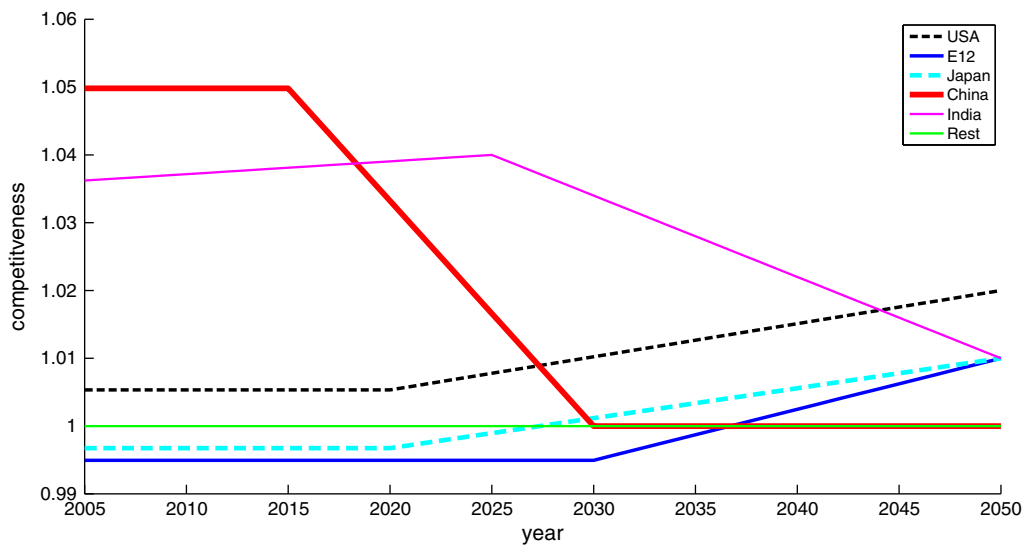


Fig. 32. Assumed evolution of the competitiveness of the six countries/regions in the proposed scenario.

(and equal to 1.005344) up to 2020 and from that year will grow steadily (in a linear form) over the next 30 years, to reach 1.02 in 2050; the E12 competitiveness will remain constant (and equal to 0.994965) up to 2030, from that year it will grow steadily to reach 1.01 in 2050; the same pattern is assumed for Japan, although it is assumed that the reform will start earlier than in Europe, and the steady growth of Japan's economy's competitiveness will start in 2020, to reach the same value 1.01 in 2050; China's economy's competitiveness will be the highest (and equal to 1.49823) up to 2015, and then will drop significantly to reach 1.0 in 2030, from that year it will be constant and equal 1.0 (so it is assumed that the pattern is similar to that of Japan in the 1970s and 1980s); India's competitiveness will grow from the initial 1.031486 to 1.04 in 2025 and from that year will diminish steadily to 1.01 in 2050; the competitiveness of the rest of the world as the reference competitiveness is assumed to be constant for the whole period, and equal to 1.0.

In short, we assume that the US economy will be able to recover in the next ten years and will return to its relatively high competitiveness after 2020, the European countries (mainly due to the bureaucratic burden of the EU) will start the necessary reforms ten years later and will slowly revive after 2030. Japan will follow the same pattern of reforms as the US, although their results will be not so impressive (therefore the final competitiveness in 2050 of Japan is slightly lower than the US in 2050). China will be able to become the most competitive economy in the next decade, but mainly due to the lack of the political reform the economy will lose its vigorousness after 2020. Thanks to the democratic system and openness of the Indian economy, India will be the most competitive economy from 2019 to 2044.

In Fig. 33 the evolution of the structure of global GDP (under the above assumptions) is presented. The Chinese economy should overtake the US in 2011 (with roughly a 20% share of global GDP by both economies) and will still grow to reach the maximum share equal to 28% in 2027, in the next two decades (still being the largest global economy) its share will be dropping to reach 24.5% in 2050. The second largest economy will be the US, but its share will still decline to reach the minimum 18.3% in 2027. From that year the share of the US economy will rise to reach 22% in 2050 (roughly the same as China's). The share of the Indian economy will grow steadily to reach almost 16% in 2050 (becoming the third economy in the world). The total share of the twelve European countries (E12) will keep the past tendency to decline, but, due to the reform initiated in 2030s, in the middle of the century will reach a plateau with a share equal to 10%. The same pattern of development will be experienced by Japan, but the plateau (roughly a 5% share) will be reached by the Japanese economy in the beginning of the 2030s.

7. Summary

One of the goals of this paper was to add new insight into the frequently mentioned (e.g. by Joseph P. Martino) far reaching skepticism in using trend analysis in the forecasting of socio-economic processes. The problem of the quality of statistical (historical) data and its impact on the accuracy of forecasts were not discussed in this paper. Instead, we have pointed out two important aspects, namely:

- selection of the identification period for a model calibration may highly influence the generated forecasts (not only in quantitative terms but, what is more important, in qualitative terms).
- the selected identification criterion (i.e. a measure of trend fitting to the historical data) has an essential influence on the quality of the generated forecast.

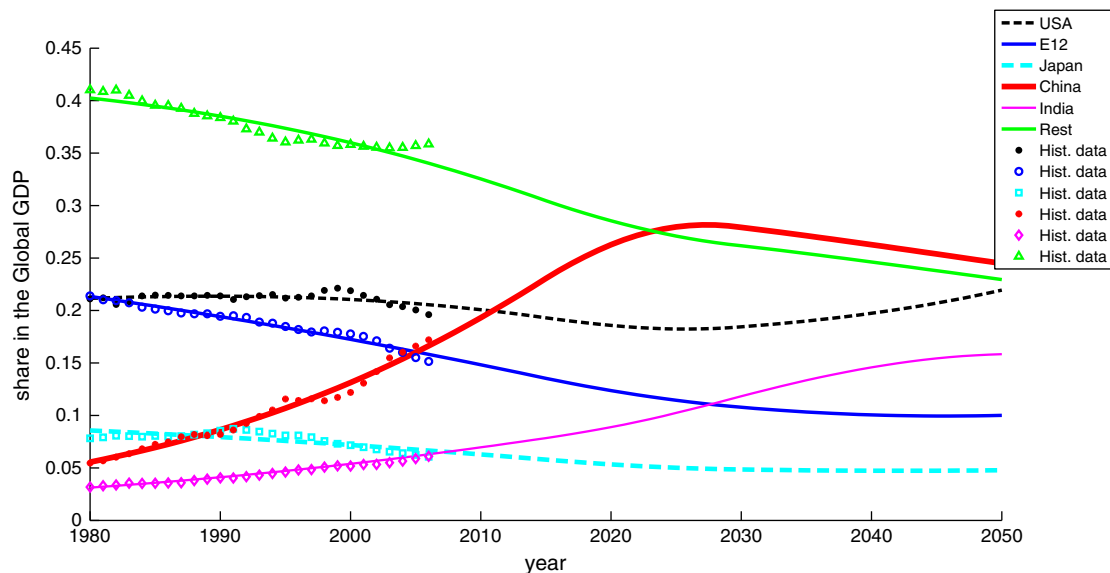


Fig. 33. Scenario of development of future structure of global GDP – the six regions/countries: USA, E12, Japan, China, India and the Rest of the World.

The prognoses of global economic development (in terms of global GDP) and demographic prognoses (in terms of the world's human population) presented in the first section has been generated on the basis of a relatively long time series of historical data (from 1950 to 2006–2008). Someone may suppose that such a long historical period will result in a much more reliable prognoses, but as is shown in the paper, it is hard to decide which period, e.g. shorter or longer, allows the generation of more reliable forecasts.

The extension of the logistic curve into the substitution–diffusion model allows to evaluate the future share of national/regional economies in global GDP and to estimate the competitiveness of these economies. It turns out that the competitiveness of nations/regions is far from being constant.

An interesting question stated in the article concerns the possible way of development of the Chinese economy. To what extent the history of the Japanese economy in the post-war period may suit us as a metaphor/analogy for the future development of China?

The proposition of building competitiveness ranking is presented. The problem not stated in the paper (due to the limited space of the regular article) is to what extent the proposed ranking is compatible with the well-known Doing Business ranking,¹⁵ The Global Competitiveness Report,¹⁶ The World Competitiveness Yearbook,¹⁷ or Index of Economic Freedom rankings¹⁸ and Economic Freedom of the World.¹⁹ This problem will be undertaken in future studies.

In the final section a possible scenario of the development of the five countries/regions (namely the USA, the E12, Japan, China, India) is presented. The future development of the competitiveness of the six regions was assumed. Naturally it is fully subjective estimation, but we evaluate it as highly probable.

References

- [1] T. Modis, *Conquering Uncertainty*, McGraw-Hill, New York, 1998.
- [2] T. Modis, Strengths and weaknesses of S-curves, *Technol. Forecast. Soc. Change* 74 (2007) 866–872.
- [3] F. Phillips, On S-curves and tipping points, *Technol. Forecast. Soc. Change* 74 (2007) 715–730.
- [4] T. Devezas, Crises, depressions, and expansions: Global analysis and secular trends, *Technol. Forecast. Soc. Change* 77 (2010) 739–761.
- [5] L.C.M. Miranda, C.A.S. Lima, On the logistic modeling and forecasting of evolutionary processes: application to human population dynamics, *Technol. Forecast. Soc. Change* 77 (2010) 699–711.
- [6] G.P. Boretos, The future of the global economy, *Technol. Forecast. Soc. Change* 76 (2009) 316–326.
- [7] F. Phillips, N. Kim, Implications of chaos research for new product forecasting, *Technol. Forecast. Soc. Change* 53 (3) (1996) 239–261.
- [8] P.S. Meyer, J.W. Yung, J.H. Ausubel, A primer on logistic growth and substitution: the mathematics of the Loglet Lab Software, *Technol. Forecast. Soc. Change* 61 (3) (1999) 247–271.
- [9] W. Kwasnicki, H. Kwasnicka, Long-term diffusion factors of technological development: an evolutionary model and case study, *Technol. Forecast. Soc. Change* 52 (1996) 31–57.

¹⁵ <http://www.doingbusiness.org/>

¹⁶ <http://www.weforum.org/en/initiatives/gcp/Global%20Competitiveness%20Report/index.htm>

¹⁷ <http://www.imd.org/research/publications/wcy/index.cfm>

¹⁸ <http://www.heritage.org/index/>

¹⁹ <http://www.cato.org/pubs/efw/> or <http://www.freetheworld.com/index.html>

Witold Kwasnicki is Professor of Economics at the Institute of Economic Sciences, Wroclaw University, Poland. His specific attitude to economic analysis is highly shaped by his former engineering education, he became M.Sc. and Engineer in 1976 at the Institute of Engineering Cybernetics; in 1980 he defended a Ph.D. thesis in computer science at Wroclaw University of Technology. Formal degree in economics (DSc, so-called habilitation) he got from the University of Economics, Wroclaw in 1995. His scientific and educational interests are focused on problems of economic development perceived as an evolutionary process. Focal areas of his research are evolutionary economics, innovation processes, liberalism and the Austrian Economics. He tries to find general mechanisms of evolutionary development which are common to, and are present in, biological (natural) evolution as well as in socioeconomic evolution (such as economic evolution, knowledge evolution, language evolution, etc.). He is an author of three books on *Knowledge, Innovation, and Economy. An Evolutionary Exploration*, Edward Elgar Publishing Ltd., 1996 (Chinese translation, 1999), *History of Liberal Thought. Liberty, Property and Responsibility*, Warszawa: PWE, 2000, *The Principles of Market Economics*, Wroclaw, 2001, and numerous papers and articles (see for details his website at <http://kwasnicki.prawo.uni.wroc.pl/>).