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Abstract

The growth rate of real GDP per capita is modelled and predicted at various time horizons for France, Germany, New Zealand, and the United Kingdom. The rate of growth is represented by a sum of two components – a monotonically decreasing trend and fluctuations related to the change in country-specific age population. The trend is an inverse function of real GDP per capita with constant numerator. Similar analysis was conducted for the USA and Japan.

Keywords: real GDP per capita, modelling, prediction, population

JEL classification: E1, E3, O4, O5

1. Introduction

The end of the first decade of the 21st century highlighted acute and deep problems in the conventional economics. It failed again in predicting sharp falls in real growth rate often called recessions. The irony of it is that the mainstream economists only gain strength instead of shame which usually accompanies poor description and prediction. The new motto is - the crisis allows understanding economic processes better. Seemingly, the economics profession wins again and again. This is not a fair win, however. It is an overall loss for everybody – the absence of clear understanding easily transforms into a negative emotional excitation, as one can see from the stock market behavior. The real problem with the description of economic processes is that no other science, including physics, can overcome economics despite numerous claims [1]. Without a valid quantitative theory of economic processes this hopeless situation will last forever [2]. To be valid any scientific theory must fit observations and predict new effects or future evolution. Unfortunately, the current economic paradigm denies, without any formal or empirical proof, the possibility to develop a deterministic economic theory. Such a theory does exist, however.

Three years ago we introduced a new concept describing the evolution of real Gross Domestic Product (GDP) as driven by the change in specific age population and the attained level of real GDP per capita [3-6]. According to this model, the growth in real GDP per capita (for the sake of brevity, below we often omit "per capita") in developed countries is characterized by an annual increment, as expressed in dollars per year, which is constant over time, and all fluctuations around the long-term trend defined by the increment can be explained by the change in the number of people of country-specific age population. Therefore, real GDP would be growing as a linear function of time, when no change in the population of relevant age is observed. As a rule, in Western Europe the cumulative growth in the specific age population during the last 60 years is negligible and thus the cumulative input of the population component is close to zero. In the USA, the overall increase in the specific age population is responsible for about 20% of the total growth in real GDP since 1960 [4]. The presence of constant increment implies that the rate of growth of real GDP is an inverse function of the attained level of real GDP itself.

Our model of real economic growth was first derived from data for the United States [3] and Japan [7]. Since all GDP time series are intrinsically non-stationary ones we have conducted a comprehensive statistical analysis including tests for cointegration [6]. Both the Engle-Granger and Johansen approaches confirmed the presence of a cointegrating relation between real GDP and the specific age population, which is nine years in the USA and eighteen years in Japan. In this paper, we demonstrate the possibility to predict the evolution of real GDP in France, Germany, New Zealand, and the United Kingdom. Due to shorter time series for these countries, no econometric (statistical) techniques are used to validate the concept except obvious visual fit between dynamic and cumulative time series.

The remainder of the paper consists of two Section and conclusion. Section one introduces the model. Section two summarizes principal results for the four studied countries.

1. The model and data

Real GDP per capita is a measured macroeconomic variable characterized by a long-term predictability for a large developed economy [3,7]. The evolution of GDP is driven by the change in the number of "*s*"-year-olds, where *s* is a country-specific age, on top of a trend fully defined by the attained level of GDP. Under our framework, the speed of economic growth, i.e.

the first derivative of GDP with respect to time, at any given time can be defined by a constant annual increment, as expressed by the following relationship:

$$dG(t)/dt = A \tag{1}$$

where $G(t)$ is the absolute level of the GDP at time t, A is an empirical and country-specific constant. When all population driven fluctuations around the trend are removed, A becomes a time independent constant [5], and the solution of ordinary differential equation (1) is as follows:

$$G_t(t) = At + B \tag{2}$$

where $G_t(t)$ is the trend trajectory of the GDP, $B=G_t(t_0)=G(t_0)$, t_0 is the start time of the studied period. So, the *rate* of growth of the GDP along the trend line, $g_t(t)$, is:

$$g_t(t) = dG_t/G_t{\cdot}dt = A/G \tag{3}$$

Relationship (3) implies that the (trend) rate should be asymptotically declining to zero over time.

Now, following our general approach of the two sources of real economic growth, one can write an equation for the growth rate of real GDP per capita, $g_{pc}(t)$:

$$g_{pc}(t) = dG(t)/(dt \bullet G(t)) = 0.5dN_s(t)/(dt \bullet N_s(t)) + g_t(t) \tag{4}$$

where $0.5dN_s(t)/(dt \bullet N_s(t))$ is the halved rate of growth in the number of s-year-olds (nine years in the United States) at time t. The factor of 1/2 is common for developed countries, except Japan where it is likely 2/3 [7].

When reversed, relationship (4) defines the evolution of the number of s-year-olds as a function of real economic growth:

$$d(lnN_s(t)) = 2(g_{pc} - A/G(t))dt \tag{5}$$

Equation (5) is a formal one, i.e. it should never be interpreted as if real economic growth defines the contemporary number of s-year-olds.

In quantitative terms, the start point of the evolution has to be characterized by (actual) initial specific age population. However, various population estimates (for example, post- and intercensal one) potentially require different initial values and coefficient A. Hence, there is intrinsic uncertainty in both defining parameters.

Instead of integrating (5) analytically, we use relevant annual readings for all the involved variables and rewrite (5) in a discrete form:

$$N_s(t+\Delta t) = N_s(t)[1 + 2\Delta t(g_{pc}(t) - A/G(t))] \tag{6}$$

where Δt is the time step equal to one year. Notice that instantaneous trend is $A/G(t)$, i.e. the attained level of the GDP, not the trend one - $G_t(t)$. Equation (6) uses a simple discrete representation of time derivative of the population estimates, where the derivative is approximated by its estimate at point t.

Both time series g_{pc} (or equivalently, $G(t)$) and N_s are independently measured variables. In order to obtain using (6) the best prediction of $N_s(t)$ one has to vary coefficient A and (only in the range of uncertainty of corresponding population estimates) the initial value – $N_s(t_0)$. The best-fit parameters can be obtained by some standard technique minimising the RMS difference between predicted and measured series. In this study, only visual fit between curves is used. As a result, this approach might not provide the lowermost standard deviation.

Relationship (6) can be interpreted in the following way - the deviation between the measured growth rate of GDP per capita and that defined by the long-tern trend is completely defined as a *half* of the change rate of the number of *s*-year olds. We would like to stress that the reversed statement is hardly to be correct - the number of people of some specific age can not be completely, or even in any significant part, defined by contemporary real economic growth. Specifically, the causality principle prohibits the present to influence the birth rate nine years ago. Econometrically speaking, the number of *s*-year-olds has to be a weakly exogenous variable relative to real economic growth, as shown to be valid for the US.

Availability of high quality data is a crucial condition for successful modelling. However, the quality of GDP and population estimates in developed countries is inferior to that in physics. Among many others, we would like to mention likely the main problem - numerous revisions to definitions. Essentially, GDP has been measured in randomly varying units since the very beginning. Unfortunately, there is no procedure to correct the past measurements because necessary information is missing and statistic agencies openly declare the non-compatibility of data over time. In addition, the number of *s*-year-olds is significantly biased by balancing among adjacent age groups [3].

Nevertheless, quantitative modelling of GDP is possible and demonstrates a reasonable statistical reliability [6]. In order to avoid the influence of fluctuations in exchange rates between various national currencies, we use only GDP expressed in 1990 US dollars converted at Gary-Khamis PPPs, as presented by the Conference Board [8]. Relevant population estimates have been retrieved from national statistical agencies: France – the INED (http://www.ined.fr), Germany – the SBD (http://www.destatis.de/jetspeed/portal/cms), New Zealand – SNZ (http://www.stats.govt.nz), and the UK – NSO (http://www.statistics.gov.uk).

2. Results

We start the modelling with France. This is one of the biggest developed countries providing information on population age distribution. The model of GDP growth for France has been obtained by trial-and-error method using a discrete form of (4). The empirical constant A and the defining age have been varied in order to fit the amplitude and timing of observed peaks and troughs. The best fit value is \$320 (1990 US dollars) and eighteen years. In the left panel of Figure 1, observed and predicted curves for the period between 1970 and 2009 are presented. Superficial visual inspection allows suggesting that the agreement between the curves does not contradict our concept, which was originally developed for the USA. The only principal difference between the US and France is that the defining age for France is eighteen years. This age occurred to be the defining one also for Japan [7].

There are original estimates of the number of 18-year-olds in France, which can be used for the prediction of the past GDP figures. The future GDP can be predicted only by extrapolation of younger age populations. For example, the number of 10-year-olds in 2000 can be used as a proxy to the number of 18-year-olds in 2008. Moreover, it is possible to transform an age pyramid for a given year into the distribution of 18-year-olds, with the accuracy of extrapolation decaying with the distance from the given year. In this study, the number of 5-year-olds in 2001 is the reference distribution. So, using this age we are able to estimate the evolution of GDP till 2014. A better prediction could be obtained after censuses, which usually provide a well balanced single year of age distribution. In France, the last general population census was in 1999. By itself, the accuracy of population estimates is difficult to evaluate, but many features unveil artificial character of the procedure for population age pyramid [3]. In any case, one cannot help observing very good correspondence between the slowdowns in both curves in the beginning of 1990s and 2000s.

A high-amplitude fluctuation in the first time derivative is a common feature for almost all measured macroeconomic variables. This is a direct manifestation of measurement errors associated with numerous limitations in relevant measuring procedures and inappropriately small time step. In the USA, the average annual growth in real GDP per capita during the latter 20 years is around 2% with the average uncertainty of 1 percentage point, i.e. the annual estimates are of the same order of magnitude as corresponding uncertainty. Before these problems are resolved, the time step should be larger than one year.

As an intermediate measure one can smooth all time series in order to cancel out measurement noise. There is a variety of smoothing techniques, some of them very complicated, but even a moving average is enough for the original data in Figure 1. In the right panel, the original predicted and observed curves are smoothed with a three-year moving average, MA(3). After 1985, the curves are very close. This supports the assumption that the fluctuations were chiefly induced by measurements and thus are effectively suppressed by destructive interference. Before 1985, the curves suffer a slight divergence, which can be an indication of the problems with the extrapolation over 20 years back in the past and with the reliability of GDP measurements. According to the predicted curves, France will not suffer significant recession in the next four to six years, but it is likely that a short recession period will hit France in the near future.

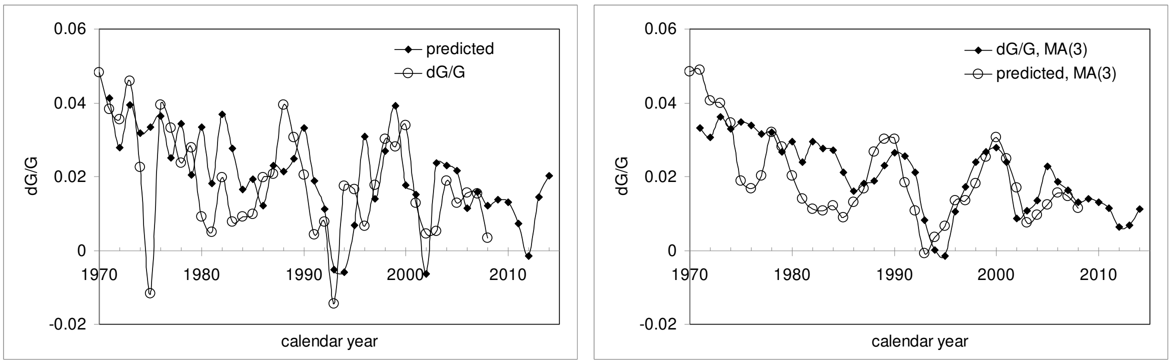

Figure 1. Observed and predicted rate of real GDP growth in France. The predicted curve is obtained from relationship (2) with A=$320 (1990 US dollars). Left panel: original curves. Right panel: the original curves smoothed with MA(3). One should not expect a recession period before 2012.

Having the annual GDP estimates, one can use (6) to calculate the number of 18-year-olds in France. Figure 2 illustrates results of the inversion between 1963 and 2009. In general, the observed and predicted curves are very close after 1985. Before 1985, the curves diverge in minor details, but both show a sharp increase in the 18-year-old population after 1960. This is a major feature which has higher importance for the model than smaller deviations. In the past, population estimates in developed countries were not too reliable.

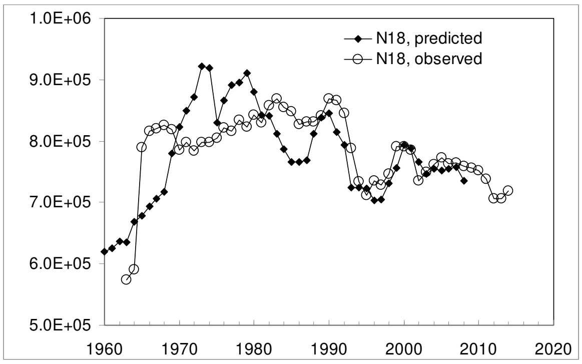

Figure 2. Observed and predicted number of 18-year-olds in France. The former variable is extrapolated from the number of 5-year-olds in 2001 with a 13-year shift, and the latter from the observed real GDP per capita.

In alphabetical order, the next country to predict the evolution of real GDP per capita is Germany. The best fit constant A=\$260 and the defining age is eighteen years. The age distribution from 2002 allows a prediction at an 18-year horizon. From Figure 3, one can expect a slow-down in 2009 and likely a recession in 2011. Here, we would like to accentuate that the prediction of the 2009 slowdown could be obtained in 2002, i.e. seven years before it happened! The estimates of population age structure are slightly noisy, however. Otherwise, the agreement between the observed and predicted curves is excellent after some years of turbulence associated with the reunification.

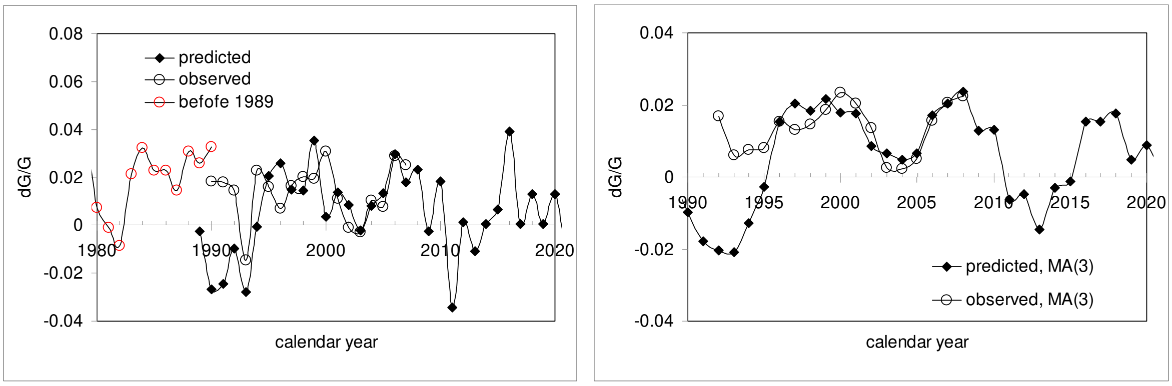

Figure 3. Observed and predicted rate of real GDP growth in Germany after the reunification. The predicted curve is obtained from relationship (2) with A=\$260 (1990 US dollars). *Left panel*: original curves. *Right panel*: the original curves smoothed with MA(3). One should not expect a recession period before 2011, but the year of 2009 is very close to a recession.

The model for New Zealand is also obtained by trial-and-error method. Empirical constant A and the specific age have been varied in order to fit amplitude and major features of the observed curve. The best fit value is A=\$220 (1990 US\$), i.e. less than in France and Germany. The specific age population in New Zealand is 14 years, which is different from that in the US, Japan, France, and Germany. The age pyramid enumerated by the 2006 census was extrapolated in the past and in the future in order to estimate the number of 14-year-olds in (4).

Figure 4 presents observed and predicted GDP for New Zealand. As for other countries, the original readings of GDP were obtained from the Conference Board. Both curves in the left panel are characterized by high-amplitude oscillations likely associated with measurement errors. Therefore, in the right panel of Figure 4, the original curves are smoothed with MA(5) and MA(3), respectively. Without prejudice to the mainstream economics, we have failed to find such a good prediction of real GDP elsewhere. Shape, amplitude, and timing of the curves are in an excellent agreement after 1980. There is no danger of a deep recession in New Zealand, but the rate of real economic growth will be very low (~0.5% per year in average) in the years to come. Before 1980, data are likely not reliable due to significant revisions to relevant definitions.

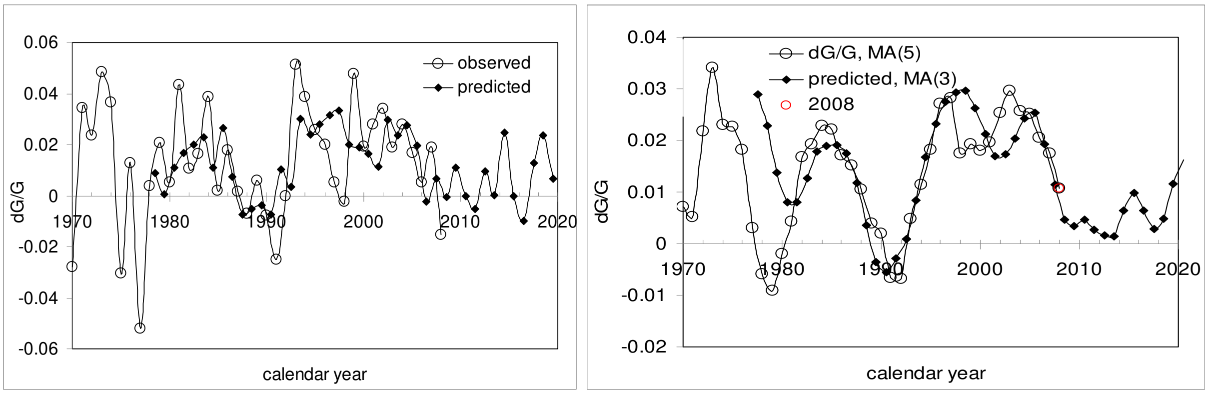

Figure 4. *Left Panel*: Observed and predicted growth rate of real GDP per capita in New Zealand. *Right panel*: The observed curve is smoothed with a 5-year moving average. The predicted rate is smoothed with MA(3). One can observe an outstanding agreement between the smoothed curves. Red circle uses the reading for 2008.

Finally, the United Kingdom presents an interesting case, where one can introduce a structural break in the model, i.e. in the predicted time series. Figure 5 displays original and smoothed curves for both observed and predicted GDP between 1972 and 2009. There is a distinct break around 1991 in both time series, which is described by a step in *A* from \$400 to \$500. The curve before 1991 is also shifted by 1 year relative to that after 1991. This implies the change in the specific age, which is nine years after 1991.

Both segments of the predicted curve explain the 1991 recession. Because of the break, the 1991 reading can not be modelled. Since 1995, the observed growth rate has been hovering around 2% per year. It is a very difficult time series to model. The absence of changes with time means that any variable constant over the same period perfectly explains the observed pattern. Even the smallest difference of 0.5% is seen as a larger deviation, as the right panel of Figure 5 shows. In any case, the rate of GDP growth in the UK will likely remain above the zero line.

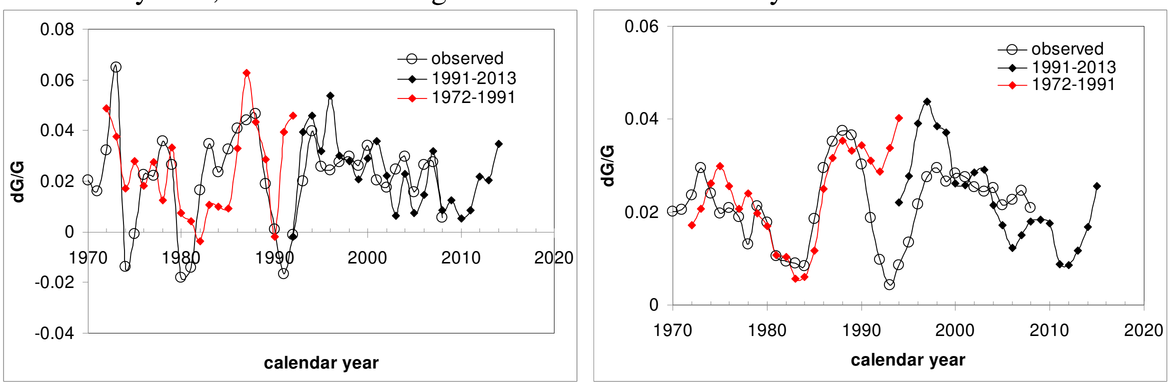

Figure 5. Observed and predicted rate of GDP growth in the United Kingdom after 1972. The predicted curve is obtained by relationship (4) with A=\$400 before 1991 and A=\$500 after 1991 (1990 US\$). *Left panel*: original curves. *Right panel*: the predicted curves are smoothed with MA(3) and the observed one with MA(5). One should not expect any recession in the UK.

Conclusion

We have developed an empirical model which defines the evolution of real GDP per capita using only two parameters – the attained level of GDP itself and the number of people of specific age. In this paper, general results of empirical modelling in four developed courtiers are presented. France, Germany, New Zealand, and the United Kingdom extend the set of successfully modelled cases to six. Three of these four countries are the biggest developed economics after the US and Japan, which were also successfully modelled. New Zealand is a smaller economy with tight economic links to Australia. Nevertheless, it demonstrates a good degree of independence on external factors.

This study is a logical step in the validation of our model for real economic growth. More countries modelled, extensions in historical time series, and improvements in data quality increase robustness and predictive power of the model. We are confident that all models, including those developed for macroeconomic variables, must fit observations, when claimed to be scientific ones.

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