Stanisław Gomułka[1]

The Global Economy in the 21st Century: Will the Trends of the 20th Century Continue?

Abstract: This paper compares three lists of basic 'stylized facts' of global economic growth and proposes a list of five 'stylized trends' that describe the main developments of the global economy in the 20th century. The author's main purpose is to answer the question whether, in the light of the contemporary growth theory and demographic forecasts, these trends are likely to continue in the 21st century. Considering this theory, it is argued that the global economy rate of growth of the per capita gross domestic product (GDP) is likely to continue to be high in the first half of the current century, but decline significantly in the second half. This paper offers forecasts for the average growth rates during this century, and the levels by its end, of the per capita GDP for the technology frontier area (TFA) of the world, and for the countries outside the TFA. According to these forecasts, the strong divergence trend of the 19th and 20th centuries will be replaced by a strong convergence between the TFA and the other countries during the 21st century.

1 Introduction

Angus Maddison's *Contours of the World Economy, I-2030 AD* (2007) is perhaps the best world economic history work. Steve Hanke summarized it as the history of three "distinct epochs of economic growth: the Middle Ages 1000–1500, when the world *per capita* GDP rose by 0.05% per year; the protocapitalistic epoch, 1500–1820, when it grew by 0.07% a year; and the capitalist epoch, 1820–2000, when the rate of growth was 17 times higher than it was in the preceding epoch" (Hanke 2008, x).

The neoclassical theory of economic growth, dominant in the economic literature until the 1960s and 1970s, treated investment in fixed assets and employment as crucial growth determining factors. Growth models were empirically tested mostly on 20th century data for developed economies. However, the last few decades have witnessed a big change in economic growth theory. There are some important reasons behind this change.

First, the following two assumptions about production functions at the national economy level are now seen as realistic:
1. Whilst the elasticity of substitution between capital and labour may differ widely across sectors and specific production outlets, the technological progress and other qualitative changes are generally labour-augmenting.
2. Returns to scale are (nearly) constant.

These assumptions imply that, in the long run, the growth rate of GDP per working hour is determined by qualitative changes. To see this, let Y stand for the GDP, L for labour hours, K for fixed capital and Q for the index of quality of K and L. By assumption (1), the relationship between Y and inputs K and L would have the form: Y=F(K, QL), and this by assumption (2) can be written as:

Y = QL * F(K/QL, 1) = QL * F((K/Y)*(Y/QL),1).

Solving for Y/QL, we get that

Y/QL = f(K/Y).

In the long run, assuming that the investment/GDP ratio remains fixed, the K/Y ratio would be constant, so Y/L would indeed be proportional to Q. The growth rate of GDP per working hour is therefore a good proxy for the pace of these qualitative changes, which I shall call the innovation rate. These changes are determined directly by technological progress and improvements in human capital, and indirectly by economic policies and institutional changes. In initial neoclassical models, both technological progress and institutional changes were exogenously given.

Secondly, empirical studies have recently been extended to practically all countries of the world and over the last millennium. These studies have resulted in a near consensus that the two types of changes, technological and institutional, are the key determinants of systematic economic growth, with institutional changes being particularly fundamental in situations when they affect, ease or hamper technological changes.

Thirdly, the mechanisms of technological progress in the most developed countries, forming the *technology frontier area* (TFA), are quite different than in non-TFA countries, including the catching-up countries, known also as *emerging economies*.

Before attempting to answer the question asked in the title of the paper, I shall first note and briefly discuss

the basic stylized facts about economic growth worldwide, as proposed by Easterly and Levine (2001), Jones and Romer (2009), and in my own work (Gomulka 1971, 1990, 2009).

2 Basic stylized facts

The statistical data on economic growth have certain fundamental characteristics, termed "stylized facts", which the growth theory must explain first and foremost. Formulations relating to these facts have undergone an important evolution.

2.1 The facts according to Easterly and Levine (2001)

Their facts are as follows:

1. **It is not differences in capital accumulation (physical or human), but differences in the productivity growth of these two kinds of capital (total factor productivity – TFP) that explain almost completely the differences in the growth rate of GDP per capita.**

This formulation assumes **implicitly** that capital accumulation and TFP are independent factors. In my interpretation of growth mechanisms, such an assumption is justified only in relation to TFA countries. In non-TFA countries, however, the import and absorption of technology from outside is usually correlated with physical and human capital accumulation.

2. **There are huge and growing differences in GDP per capita; divergence – not conditional convergence – is the big story.**

Such an approach is a polemic against the traditional Solow–Swan growth model, in which qualitative changes are given by assumption. Fact (2) is compatible with a description that emphasizes a high increase in the degree of duality of the world economy over most of the past 200 years, but is at variance with data for the last 30−40 years.

3. **Growth is not persistent over time, but capital accumulation is.**

By this formulation, the authors probably want to stress the large role in economic growth, especially in the short term, played by factors other than capital accumulation.

4. **All factors of production flow to the same places, suggesting important positive externalities.**

The observed significant variation in the level of development between places within the same countries is an indication of a substantial role of concentration, and sometimes also of climate and geography. However, such factors do not influence the trend (long-term) growth rate of *per capita* GDP.

5. **National policies influence long-term growth.**

The influence of economic policy on long-term growth is relatively limited in TFA countries, but large in non-TFA countries. The decision by Easterly and Levine is not to differentiate between these two groups of countries.

2.2 The 'new Kaldor' facts according to Jones and Romer (2009)

In 1961, Nicholas Kaldor summarized in six statements what he thought at that time to be the most fundamental features of world economic growth. However, he limited his observations to modern times and a group of well-developed countries. The result of these limitations was that five of his stylized facts were about stability over time: in the growth both of labour productivity and capital per worker; in the real interest rate and the return on capital; in the capital/output ratio; and in the shares of capital and labour in national income. Only one fact noted significant cross-country variation in the trend rate of growth.

Jones and Romer, nearly half a century later, took note of Kaldor's facts, but proposed a very different list of six stylized facts. Their five facts are about changes and differences, and only one concerns stability.

1. **Increased flows of goods, ideas, finance and people - via globalizationa and urbanization - have increased the extent of the market for workers, producers and consumers.**
2. **Growth at the global level in both population and per capita GDP has accelerated, especially during the last two centuries.**
3. **The variation in the rate of growth of per capita GDP increases with the distance from the technology frontier.**
4. **Differences in measured inputs explain less than half of the enormous cross-country differences in per capita GDP.**
5. **Human capital per worker is rising dramatically throughout the world.**

6. **Relative wages of skilled and unskilled labour have been stable, not reflecting relative quantities of human capital.**

These are, the authors write, the 'new stylized facts' that growth models should explain. The facts (1), (3), (4) and (5) have strong support in the evidence. However, the important statement (2) does not have that kind of support. As Maddison (2007) estimated, and Fig. 2 of their paper shows, there was high stability in the global *per capita* GDP growth rate in the period 1500−1820, at a very low level of 0.07% per year, and then stability again in the period 1820−2000, at 17 times higher. Thus, a big acceleration in the growth rate took place towards the end of the first period and at the beginning of the second one, not throughout the five centuries. The authors note that most of their facts can be explained by partial models, but they would like economists to develop a single general equilibrium model that explains all the facts simultaneously.

2.3 The alternative new stylized facts by this author (2009)

The first two of my proposed seven facts apply to all countries, but the other five apply either to the TFA or to the non-TFA countries.

1. **The great acceleration in the growth rate of world GDP per capita, and still more per working hour, took place some two centuries ago, and a historically exceptionally high growth rate has since continued.**

The evidence is largely that provided by Maddison (2007). An explanation of this by now well-established fact is required, and – in the light of this explanation – an answer is needed to the question as to if and when such a fast growth may begin to decelerate, and eventually possibly die away.

2. **Over the past two centuries there has been a large variation in the rate of per capita growth between countries, leading to the very high degree of duality of the world economy observed by the end of the 20th century.**

This fact is well-documented and widely accepted; it is essentially the same as Easterly and Levin's fact (2) and Jones and Romer's fact (4). The information on high duality is best provided by density of the distribution of global employment according to the level of val-
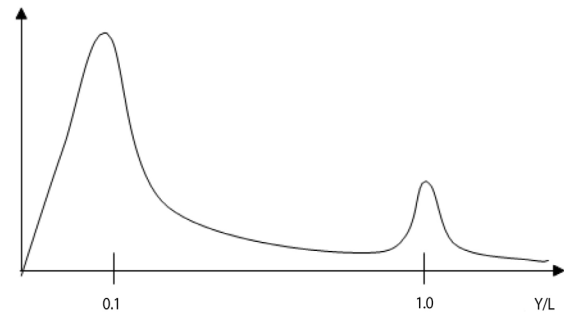

Fig. 1. Density of the distribution of global employment according to the level of value-added per working hour, schematic diagram.
Note: The area below the diagram is total global employment.
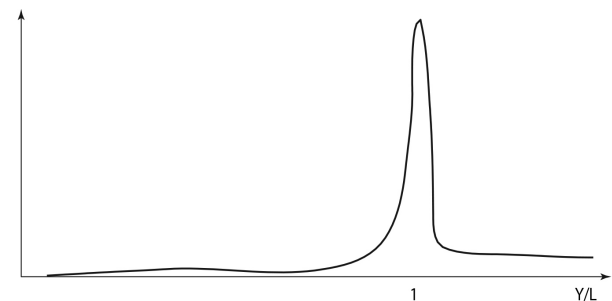Source: Author's own elaboration.

Fig. 2. Density of the distribution of internationally registered patents with respect to value-added per working hour in the countries of origin of the patents, schematic diagram.
Note: The area below the diagram represents global number of important patents per year.
Source: Author's own elaboration.

ue-added per working hour, Y/L. This distribution for the 20th century and, so far, this century, has been not only two-humped, but also strongly dual, as the distance between the humps is large (Fig. 1). The hump around a certain high labour productivity level, taken to be unity, refers mainly to economic activities in the most developed countries. Activities with such high productivity form the **technology frontier area (TFA)**. Today this area consists of the USA, western Europe, Japan, Canada and South Korea, but includes also high productivity islands in all other countries. Employment in this area now amounts to around 15% of global employment. The hump around a certain low productivity level relates largely to activities in the 'developing countries'.

We need to provide the reasons for this large duality, and an answer to the question if and when there will take place convergence of the levels of GDP per working hour on the global scale.

In my interpretation of worldwide economic growth mechanisms, another figure is crucial. Fig. 2 shows the density function of internationally registered patents *versus* labour productivity (Y/L); the area below the graph of this function represents 100% of the total world innovation output in any given period.

These two distributions reflect the exceptionally strong duality of the world economy at the end of the 20th and the beginning of the 21st centuries. In the creation of new important innovations, the TFA countries dominate, with a share in internationally recognized patents accounting for some 90−95% of the world total. This strong duality in inventive activity means that in the TFA and non-TFA countries the sources and mechanisms of technological progress are substantially different. Because of this difference, I propose other stylized facts to relate to each of these two groups separately.

In relation to the TFA countries:

3. **During the past two to three centuries, there has been a far more rapid growth of inputs of labour and capital in the sector producing qualitative changes than the growth of inputs in the sector producing conventional goods.**

Let K and N be the inputs of capital and labour in the conventional goods producing sector and M and R the corresponding inputs in the innovative and educational sector, producing qualitative changes. Two to three centuries ago, the sector of qualitative changes was a tiny part – perhaps 1% – of the entire economy. Today, this sector constitutes about 10% of the economy. In the last 200−300 years the ratios M/K and R/N in the TFA have, therefore, been systematically and rapidly increasing.

4. **The growth rates of inputs in both sectors have been stable over time. Likewise, the growth rate of the ratio Y/L has been stable, although very much higher (an order of magnitude greater) than during the many centuries that preceded it.**

5. **The rate of growth of the ratio Y/L has been and is stable over time, and differs only to a small extent between countries as it depends only slightly on the ratio of investment to the gross domestic product (GDP).**

The innovation rate in individual TFA countries depends on the size of the total TFA inventive activity. Given this direction of causality, national investments respond to the supply of opportunities created by this common activity.

With respect to the non-TFA countries, the principal stylized facts are the following:

6. **The rate of growth of Y/L varies strongly over time and between countries.**
7. **The growth rate of Y/L is strongly dependent on the level of investment as a fraction of the GDP.**

Qualitative changes have been particularly fast in several East Asia countries, correlated with exceptionally high savings and investment ratios (IMF 2017).

	1981−2000	2001−2015
China: savings, % GDP	35−43	39−52
GDP annual growth, %	9.9	8.6
India: savings, % GDP	20−28	28−41
GDP annual growth, %	5.6	7.3
Korea: savings, % PKB	26−40−34	34
Annual growth, GDP, %	8.5	4.0

In catching-up countries, the rate of innovation depends on absorptive capacity, which varies from country to country and may vary also over time.

The strong variation of the trend rate of growth of Y/L between non-TFA countries is evidence, now widely noted, of the influence on this growth rate of the institutional factors and economic policy in the catching-up countries. This dependence relates to the factors influencing the diffusion of technology from the TFA countries and its effective absorption in the non-TFA countries.

During the 20th century, the global economy became increasingly dualized in terms of technological level and *per capita* income. In other words, we have witnessed a divergence between the TFA and all other economies. This divergence trend was a continuation of a similar development observed in the 19th century. However, in the second half of the 20th century some important countries, such as China, the former USSR and India, implemented crucial institutional reforms. In China and the former USSR these included privatization of land and state companies, and the acceptance of foreign direct investments. The model of a centrally planned (and state-governed) economy was accepted to underperform the market economy model, in which the role of the state is limited largely to law making, law enforcement and income redistribution. All these changes decreased the role of politicians in current economic management and in investment decisions, and increased the role of innovators and entrepreneurs. As a result, a growing divergence was globally replaced by a growing convergence.

3 The role of institutions in economic growth according to Acemoglu and Robinson

There is a rich body of literature about the role of institutions in economic growth (IMF 2003; Balcerowicz 2008). Recently, this role has been examined in a series of articles and books by Daron Acemoglu and James A. Robinson. In 2012, they published an extensive monograph: *Why Nations Fail: The Origins of Power, Prosperity and Poverty.*

The main message of this book is that: "The most common reason why nations fail today (and why they failed also in the past – note by the author) is because they have economic and political extractive institutions" (Acemoglu and Robinson 2012, 368−369). The authors focus their discussion on some extreme situations, when political elites create legal instruments, or even take illegal actions, to seize a significant part of the wealth created by innovators and entrepreneurs. This lowers the incentive of potential innovators and entrepreneurs to create and introduce new important qualitative changes, such as new or improved products and more efficient methods of their production and distribution. This, in turn, translates into a slow pace of growth or even a long-term stagnation or recession.

Acemoglu and Robinson extensively studied the functioning of such development-blocking institutions over the last decades in the case of a few drastic examples: Zimbabwe after Mugabe coming to power; Egypt under the rule of Mubarak; and Uzbekistan under the rule of Karimov. It is evident that in those countries at least, **degenerated institutions**, or **extractive institutions**, as described by Acemoglu and Robinson, tend to be persistent. The examples above can be supplemented by some republics of the former USSR, such as Ukraine. In 2015, the GDP *per capita* in Ukraine, in purchasing power parity terms (PPP), was equal, according to the World Bank data, to 14.1% of the US GDP *per capita* and 29.3% of the Polish one, the latter equal to 48.1% of the US level. In 1989, the Ukrainian level was slightly higher than in 2015 as a proportion of the US level and, more remarkably, somewhat higher than the level in Poland. For comparison, the German GDP *per capita* in 2015 amounted to 85.6% of the corresponding US level.

The authors also focus on several crucial reforms, which reduced or even completely removed progress-blocking institutions. Above all, these include the 1688 political revolution in England, whose social and educational consequences triggered, they maintain, the start of an industrial revolution in England and the USA a century later. Reforms in continental Europe after the 1789 French revolution, and in Japan after the 1868 Meiji revolution (which introduced a parliament and a constitution, and stripped 250 regional oligarchs of power) were also fundamental. More recent examples are the 1979 political revolution in China, after the death of Mao and under the leadership of Deng Xiaoping, which triggered an economic boom of exceptional strength, and the transformation of political and economic systems in Central Europe and in the former USSR, which started in 1989 in Poland.

A comparison of situations before and after such fundamental changes makes it possible to identify and compare economic consequences of **inclusive** and **extractive political institutions**. Acemoglu and Robinson conclude that **inclusive institutions,** particularly political institutions, are necessary, although clearly not sufficient, to achieve economic success. **Inclusive institutions** are, according to Acemoglu and Robinson, the links in the cause-effect chains between innovation, economic growth and socially optimal wealth distribution. Acemoglu and Robinson's theory concentrates on the cause and effect relationship between political and economic institutions, and between institutions and economic growth.

Such a direction of causality is indeed often observed. However, there is also sometimes a reverse relationship in action. This reversed causality was in fact present in the former USSR, as well as in Central and Eastern Europe, for several decades before 1990. Despite central planning, predominant state ownership of enterprises and authoritative one-party political systems, it was possible to achieve marked technological progress, rapid development of education and a high degree of urbanization. Accumulation of these changes sparked, in turn, a strong social demand for political change, which led to fundamental shifts in economic and political institutions and policies.

Acemoglu and Robinson focus on rather extreme cases of extractive institutions in which there is limited interest on the part of the state, and underpinning elites, to develop innovation and investment incentives in the private economy. The extensive empirical study by Besley and Persson (2014, 930) suggest that there have been situations in which "governments have the knowledge about good policies and the will to implement them, but lack the ability – i.e., the state capacity – to carry them out". However, if there is the will, such

capacities can be slowly developed. The point Acemoglu and Robinson are making is that there have often been situations in which there is no such will because interest groups can create institutions and methods of governments that allow them to meet their wealth requirements through extraction. In those cases, there would be little incentive for such groups to develop economic institutions and policies that produce widespread benefits at a high rate. The statistical evidence on economic growth can be interpreted to support the view that since the start of industrial revolution in Europe by the end of the 18th century there were no such strong incentives present in most African countries until recently, and in most Asian countries until the middle of the 20th century.

4 Qualitative changes: the Phelps model with extensions

One of the first attempts to model economic growth based on a division into the conventional and innovative sectors was that of Phelps (1966). I generalized it in several directions (Gomułka 1970, 1971), and for the conditions under stylized fact (3) (Gomułka 1990). This theory, as well as the present day endogenous growth models, assumes that institutions are those of a competitive market economy. Moreover, the original Phelps model applied only to the TFA.

The equations of this model are:

$$Y = F(K, TN) \tag{1}$$

$$T' = H(E, T) \tag{2}$$

$$E = E(M, TV) \tag{3}$$

$$V = R^{\lambda} L^{1-\lambda}, \ 0 < \lambda < 1 \tag{4}$$

$$L = N + R = L_o \exp(nt), \ n \geq 0 \tag{5}$$

where T' in equation (2) is the change in T per unit of time, as a result of research and education effort E. In the original model T' represents technological innovations. In my adaptation of this model T is a measure of quality, denoted earlier in this paper by Q, of the fixed capital K and work-force N in the conventional sector, and of the fixed capital M and work-force R (more precisely, of the innovative capital V) in the sector producing qualitative changes. Therefore, R denotes not only the number of researchers, as in the original model, but also teachers. The total workforce L grows at a constant rate.

The production functions F and H are assumed linear with respect to scale, but the function E has the scale elasticity ε, where ε < 1. Phelps only considered balanced growth paths and set out to answer two questions:

1. What should be the optimal division of capital and labour between the two sectors, conventional and innovative?
2. What will be the growth rate of Y/L on the optimal path?

The answer to both these questions provided by Phelps applies only to a situation of balanced growth. However, during the last two centuries, as we know from empirical data,

$$G_M \gg G_K \text{ and } G_R \gg G_N \tag{6}$$

where G denotes the growth rate of the variable indicated by the subscript. If (6) applies, the ratios M/K and R/N increase towards their optimal levels. Since their initial levels differ considerably from the optimal ones, their approach to the optimal state extends over a fairly long period. During that period, we have an exceptional situation, one of technological revolution. The data show that for the current TFA about two centuries were needed to reach the optimal levels. However, globally inequalities (6) still apply, so we continue to be in the period of slow convergence to the optimal state.

This extended model explains the exceptionally high growth rate of *per capita* GDP within the TFA over the past 200 years by three circumstances: the initially large growth reserve in the form of the low use of the stock of potential innovative talent of the population; the public policies and market institutions that have been developed to make gradually effective use of that reserve; and the high rate of population growth.

All these factors are, however, transitory since after a certain time, probably during the present century, we shall reach a situation of total use of the world talent pool, which must mean a fall in the growth rate of R to the level n. The growth rate of the fixed capital M in the research and development (R&D) and educational sectors will also fall to the level of the growth rate of K (and Y). One must also expect stabilization of the world population at some stage, possibly sometime this century, which means n will fall to zero.

In general, this should mean, and certainly this is so for the (extended) Phelps model, a slow and prolonged decrease in the growth rate of qualitative changes in the TFA, the rate in that model decreasing asymptotically to zero. Thus, according to this theory, the period

of some 300−400 years of an unusually fast growth will be something in the nature of a huge fluctuation in the history of civilization. The growth rate of *per capita* GDP would return with time to the (very) low level before the technological revolution. My proposed term "hat-shaped relationship" (Gomułka 1971, 1990) can be used to describe this superfluctuation.

5 Hat-shaped relationship for non-TFA countries

As observed by all the authors of the stylized facts listed above, in non-TFA countries we have a strong variation of the *per capita* GDP growth rate, both over time and between countries. In these countries, much depends on a potentially very large number of factors, which have an influence on the transfer and absorption of technology from outside. Two factors are of fundamental importance. One of them is the technological gap, or more generally the qualitative gap, since the greater this gap the greater the growth **reserve** and the greater the number of innovations ready for possible use. Another factor is the absorption capacity itself. When the development gap is large, the absorption capacities are typically undeveloped. On the other hand, when the development gap is already small, these capacities are typically large but the number of innovations that can be made available by transfer is also smaller than before. Thus, even without theoretical inspiration, one may **expect** that countries will develop most rapidly at the intermediate stage between the very undeveloped and developed stages. Hence, the expectation is that the growth rate of GDP per working hour for all non-TFA countries at any given time and for individual countries over time will also form a hat-shaped relationship (Gomułka 1971, 1990).

In the hat-shaped dependence of the growth rate of GDP per working hour on the development gap, the gap is measured by the ratio of Y/L in the TFA to Y/L in each country. Such a dependence is specific to each country. Its variation between countries arises from the fact that countries with similar development levels may, and generally do, have significantly different institutions and/or economic policies, in addition to different natural resources. The empirical data confirm that the variation of the growth rate of GDP per working hour for countries with a similar level of development may be great. The importance of international diffusion for the develop-

ment was noted first by economic historians (e.g., Veblen 1915; Gerschenkron 1962; Abramowitz 1979, 1993).

6 Trends of the 20th century

Recently, ten economists attempted to answer the question asked in the title of this paper: will the main trends of the 20th century continue in the 21st century? Their analysis was published in a book edited by Ignacio Palacios-Huerta (2013). Possibly the most extensive answer was proposed by the Massachusetts Institute of Technology economist Daron Acemoglu. He organized his analysis around ten (social, economic, technological and political) trends of the 20th century.

As the focus of this paper is long-term economic growth, I shall make use of only three of Acemoglu's trends. These are numbered (1), (2), and (3) below. Moreover, I shall somewhat redefine them, and complement with two more trends of my own. The aim is to assess whether all of them, or which of them, will continue into the 21st century.

Thus, selected key 'stylized trends' concerning global economic development in the 20th century are as follows:

1. **GDP growth per capita in the most technologically advanced economies was highly volatile in the 20th century, but the fluctuations took place around an extraordinarily stable growth trend. This trend was common for all economies from this group, hence it was almost unrelated to economic policies conducted by the countries concerned.**
2. **In less technologically advanced economies, GDP growth per capita was not only strongly diversified between countries, but also, in many cases, unstable over time; thus, it was strongly dependent on economic policies.**
3. **The world's population was rising at a fast pace and had quadrupled, increasing from 1.5bn in 1900 to 6.0bn in 2000.**
4. **The most technologically advanced countries accounted for almost the total global output of significant innovations. In those countries, the labour and capital inputs in R&D and education of all types, i.e., in the sector producing qualitative changes, rose during the 19th and 20th centuries much (5−10 times) faster than the labour and capital inputs in the sector producing conven-**

tional goods, triggering the so-called technological revolution.

5. **The 20th century saw a strongly rising dualism of the global economy, i.e., a significant divergence between the most technologically advanced economies and all the other economies. This trend was a continuation of a similar phenomenon witnessed in the 19th century.**

7 Trends in 21st century

The five trends of the 20th century listed above are also largely applicable to the 19th century, so they are essentially valid for the last 200 years. Earlier, in the Middle Ages and the protocapitalistic epoch, the sector producing qualitative changes was both very small and expanding very slowly, which translated into a very low pace of economic growth *per capita*. The variation between countries in labour productivity was also low. The five trends represent the capitalist epoch. The key characteristic of this epoch is an exceptionally fast growth of the sector producing qualitative changes, in terms of inputs several times faster than the growth of the sector producing conventional goods and services. The economic growth has thus been highly unbalanced in this epoch. In the TFA, the innovative talent pool, initially almost wasted, started to be employed more and more over time. Today that talent pool may be fully employed in the technologically most advanced countries. However, at the global level there is yet a large reserve of innovative talent still unemployed in the area outside the TFA. That reserve is large enough to support a fast growth of GDP *per capita* for much of the 21st century. But once the total global innovative talent is fully employed, which should happen before the end of this century, a new epoch should start, one of gradual deceleration of economic growth.

My detailed answers to the question whether the 20th century five trends will continue in the 21st century are therefore as follows:

In the case of trend (1), we will see its continuation for the reasons presented above.

The same will happen to trend (2), but in this case, some of the non-TFA countries today will join the group of developed economies and thus will be governed by trend (1).

According to demographic projections, the world population will rise rapidly in the first half of the 21st

Tab. 1. Key changes in the 21st century

	2000	2100
Population (bn)		
TFA	1	2
Non-TFA	5	8
GDP *per capita*, index (TFA in 2000 = 1)		
TFA	1	4
Non-TFA	0.2	2.4
Total	0.3	2.7
Total GDP, index (TFA in 2000 = 1)		
TFA	1	8
Non-TFA	1	19

Note: gross domestic product (GDP) according to purchasing power parity (PPP).
TFA: technology frontier area.
Source: Author's own elaboration.

century, whereas in the second half it is likely to stabilize. This will bring a major change in trend (3). The implication of this change will be a stabilization, during the second half of the 21st century, of the size of the global innovation talent pool.

Trend (4) has already begun to change substantially. As I mentioned earlier, by the end of the 20th century, the developed economies had already fully exhausted their potential innovation pool. A situation typical to the early 20th century in the TFA can still be observed in the emerging economies, which are still far from full use of their innovative potential. Increasing engagement of this resource will underpin the global GDP *per capita* growth close to the current levels for the better part of the 21st century. Hence my comment about trend (1).

Trend (5) concerning the global economy dualism will change dramatically in the 21st century; this conclusion is supported by the empirical works of academic economists as well as by the extensive reports of international institutions over the last 20−30 years. The growing divergence of the 20th century has already started to be replaced by a growing convergence. However, the convergence between developed and developing countries need not be complete. Large regional differences in GDP *per capita* are present, and can be persistent, within technologically advanced countries.

To present the effects of the convergence process on the global GDP at the end of the 21st century, I shall

resort to a simple numerical exercise, based in part on two assumptions:

1. Total populations of the TFA and non-TFA regions in 2100 will be, respectively, 2 bn and 8 bn.
2. The ratio of the *per capita* GDP in non-TFA countries to that in TFA countries was 20% in 2000 and will be 60% in 2100.

The results of the exercise are shown in Tab. 1. The assumed doubling of the TFA population is mostly due to the geographical expansion of this region.

The results of the exercise imply that the global GDP will rise by 11−12 times in the current century, with the average growth rate slightly over 2.6%. The global *per capita* GDP will rise by nine times, with the average growth rate of 2.2%. Exceptionally high growth rates will be witnessed in the first half of the 21st century.

8 Geopolitical consequences until 2050

Because of the outstandingly fast economic growth in China since 2000, in 2015 its GDP in PPP terms was equal to (international) USD 20,253 bn. This means that it was 10% higher than that of the USA and six times higher than that of the Russian Federation (RF). However, the USA are still significantly outperforming in terms of the GDP *per capita* (USA=100.0; China=25.8; RF=43.6). I assume that in the years to come these differences will narrow, but will never vanish. In the forecast presented above, I have assumed that the convergence progress will halt when the GDP *per capita* in China and the RF reach 60% of the US level. It cannot be known when such an equilibrium will be reached, but the international comparisons suggest that 2050 may be quite a good guess. Moreover, I assume annual population growth rates at -0.5% in the RF, and 0.5% in both China and the USA.

Given the above, in 2050 national GDP in China will be 2.5 times higher than in the USA and 14 times higher than in the RF. The population of China will still be four times higher than in the USA, but about 14 times higher than in the RF.

However, the geopolitical position of a country depends not only on GDP and population, but also on the achieved level of technology and science. Bearing this in mind, the current technological leaders (USA, European Union, Japan, Canada) are likely to maintain their dominant position; however, they are also likely to be put under pressure by China and other countries of the "new world".

Anticipation of growing economic and technological strength of China may be viewed by the current military superpowers, USA and RF, as a threat to their presently dominant position in the military area. However, the numbers shown above suggest that the RF may feel more threatened than the USA and the European Union.

9 Final remarks

The above-mentioned forecasts neglect two global megarisks: nuclear world war and large adverse climate changes. There is also a considerable risk that the global population will increase during the century significantly above the 10 bn assumed in our forecast exercise. However, if cataclysms of this kind do not materialize, then the 21st century will witness a large leap of the present world economy towards a global market economy with a stable population and a fairy low, eventually even very low, rate of economic growth. Moreover, by the end of the 21st century the average *per capita* GDP will be some nine times higher than in the year 2000, the global economic integration will be (probably) much deeper than at present and the distribution of income and (especially) wealth will be more equal. However, in terms of the GDP and population growth, the world economy after the 21st century would resemble the one before the technological revolution of the last 200 years.

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