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Mechanism and sources of world economic growth

The introductory chapter of the book Economic Growth in Post-socialist Countries: Convergence or Divergence, ed. R. Rapacki, PWE, Based on a paper read at a conference in SGH, 16 November, 2006.

Abstract: The paper proposes a novel approach to the theoretical interpretation of the observed wide variation of economic growth rates between countries and over time. It argues for the need to have two distinctly different classes of theories of economic growth, one for the countries of Technology Frontier Area (TFA), another one for all the other countries. The two classes are outlined and some specific theories are discussed. The paper also discusses the long-term dynamics of the innovation rate and the rate of economic growth. The empirical part offers a new list of stylized facts for the TFA countries and another one for the non-TFA countries.
Keywords: Technology Frontier Area (TFA), variation of economic growth rates, innovation rate.
JEC codes: 040, 047.

1. Introduction

Over the past 20–30 years our statistical knowledge of the level and growth rate of GDP in different countries has expanded considerably. This knowledge now encompasses almost all the countries of the world economy. In addition, the quality and comparability of our statistical data have increased considerably, as too have the lengths of such data-runs. This new situation in the data sphere permits a more global and long-term approach to the problems of economic growth. Growth models can now be tested on rich data sets, which increases the demands on them, for they now are required to explain more things simultaneously.

In addition to the enormous wealth and variation of the statistical data on economic growth, there are certain fundamental characteristics of the data, termed “stylised facts", which the growth theory must explain first and foremost. Formulations relating to these facts have recently undergone an important evolution. Hence discussions of the mechanisms and sources of economic growth must in the first instance address these facts. I should like to draw special attention to two of them in particular. The first is the great acceleration in the growth rate of world GDP per capita, and still more per working hour, over the past two or three centuries. A sound explanation of this acceleration is required, and also – in the light of this explanation – an answer to the question if and when this acceleration may die away, and what will be the tempo of the growth rate return to the (very) low level observed in the previous centuries. The second important fact requiring explanation is the great increase over the past two-to-three centuries in the variation of the level of development, manifested presently in the high degree of duality of the world economy. In the light of this explanation, it is also necessary to answer the question if and when there will be once again a renewed significant convergence of the levels of GDP per working hour on the global scale.

2. Duality of the world economy

What interests us here is not only the average level of GDP per working hour and its growth rate in different countries or in the world economy, but also the variation of this level and this growth rate among countries. Information on the variation of the level is provided by the density of the distribution of global employment according to the level of value-added per working hour. This distribution for the 20th century and so far this century has been not only two-humped, but also strongly dual, i.e. with a great distance between the humps (Fig. 1).

The hump around high labour productivity refers principally to the most developed countries. Firms with such high productivity form what I call (Gomulka,1990) the *Technology Frontier Area* (*TFA*). Today this area consists first and foremost of the USA, western Europe and Japan. Employment in this area now amounts to around 15% of global employment. The hump around low productivity relates to the "developing countries", and more particularly to the less developed of them. In this sphere, one finds the majority of the (potential) work-force of the Indian sub-continent (India, Bangladesh and Pakistan), the majority of the (potential) work-force of China and also a large part of the (potential) work-force of the African continent. Overall, this sphere now accounts for some 60–70% of the (potential) global work-force.

However, in my interpretation of economic growth mechanisms it is another distribution that has fundamental significance. This is the distribution of internationally registered patents with respect to Y/L , where Y is the GDP and L is employment (Fig. 2).

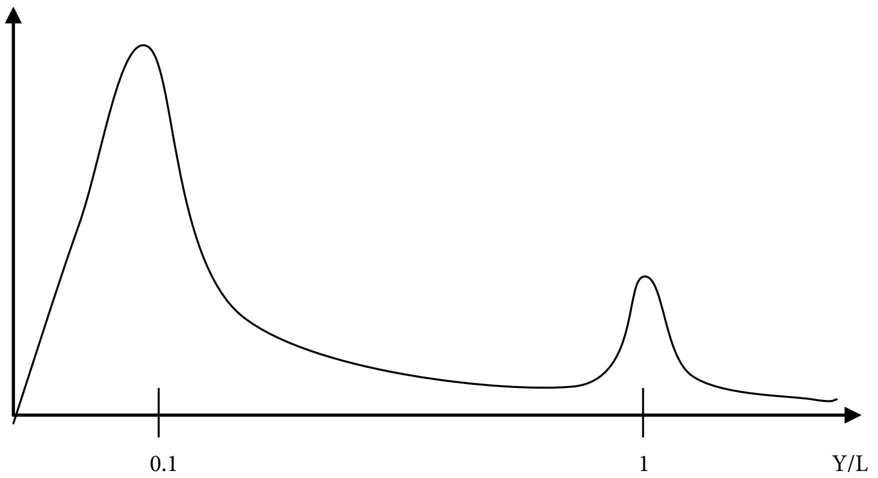

Figure 1. Density of the distribution of global employment according to the level of value-added per working hour, schematic diagram

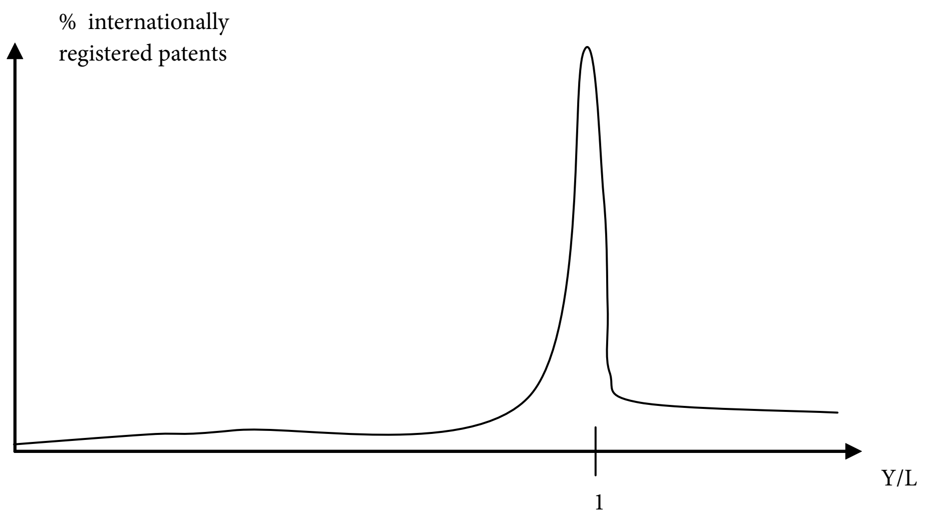

Figure 2. Density of the distribution of internationally registered patents with respect to value-added per working hour in the countries of origin of the patents, schematic diagram

This distribution confirms the exceptionally strong duality of the world economy at the end of the 20th and beginning of the 21st centuries in the creation of new technologies. In this creation the TFA countries are absolutely dominant with a share in internationally recognized patents accounting for some 95% of the world total. This strong duality means that in these two groups of countries the sources of technological progress are completely different, and hence there must be completely different mechanisms of economic growth. In the TFA, economic growth is determined by innovative activity of that area itself, in the short term by the size of the R&D (research and development) sector and in the long-term by the growth rate of that sector. On the other hand, in the non-TFA countries what determines technological progress – both in the short and in the long-term – is the rate of transfer from outside (diffusion) and the internal capacity for absorption (Abramovitz 1986, Gomulka 1971, 1990. Verspagen 1991). These differences are so fundamental that two different theories of economic growth are necessary – one theory relating to the TFA and the other to economic activity outside that area. This proposition is the foundation on which I built my interpretation of the sources and mechanisms of world economic growth.

In order to clear the ground for further discussion, I must first clarify the main assumptions regarding the production function, that is, the relationship between production factors and net production (value added, GDP), Y. The production factors divide into two classes: qualitative and quantitative. To the first belong physical capital K and the number of working-hours L. From this we have the formula that

$$Y = F\ (K, L; T, H, IN, P) \tag{1}$$

where T is the technology, H the human capital per employee, IN the institutions, and P the economic policy The fundamental assumption regarding F arises from the observation that in the long term K/Y is fairly stable. This simply means that the qualitative factors affect Y by increasing labour productivity. Hence, we have the following refinement of relationship (1)

$$Y = F\ (K, Q\ (T, H, IN, P)\ L) \tag{2}$$

where Q is the quality index of the production factors K and L. This index depends principally on the technological level of machines and instruments and the quality of the work-force. Formula (2) is a simplification since it treats T, H. IN and P as independent factors. However, institutions and economic policy have an influence on the degree of use of T and H and also on the changes in T and H. The institutions themselves may also influence economic policy. In my general presentation of the economic growth mechanism I shall pass over these simplifications in silence, treating them as of secondary importance. The division of the production factors into qualitative and quantitative also means that we are dividing the whole economy into two sectors: the conventional, producing standard goods and services, and the innovative-educational, producing qualitative changes. To the second sector are assigned first and foremost higher education and R&D activity.

A second important assumption is the linearity of F with respect to scale, or the assumption of constant returns to scale. It follows from this that $Y = QLF(K/Y*Y/QL, 1)$. Solving this equation for Y/QL, we obtain the relationship :

$Y/QL = f(K/Y)$, or

$$Y/L = f(K/Y)\, Q(T, H, IN, P) \tag{3}$$

In view of the stability of the K/Y ratio in a situation of balanced growth, equation (3) immediately implies that the wealth of nations in the long term is thus decided by qualitative factors, which means everything that increases the quality of capital and labour and how effectively these two factors are used.

3. The basic facts of economic growth

3.1. The facts in my interpretation

In part 2, I have already drawn attention to two "stylized facts" relating to the entire world economy, hence below my numbering will start at (3)'. Since I have stressed the significance of the division of this economy into the highly-developed or TFA segment and the rest of the world, it is likewise necessary to discuss the fundamental facts in relation to each of these two segments separately.

In relation to the TFA there are three facts which must be noted and explained. The first of them is the following:

(3)' *During the past two-to-three centuries, there has been a very non-steady (because far more rapid) growth of the sector producing qualitative changes than of the conventional sector.*

Let us denote by K and N the inputs of capital and labour in the conventional sector and by M and R the corresponding inputs in the innovative-educational sector producing qualitative changes. Then fact (3)' means that in the last 200-300 years the ratios M/K and R/N have systematically and rapidly been increasing. The growth rates of M and R in this period have been very high, as much as an order of magnitude greater than the growth rates of K and N. Two-to-three centuries ago, the sector of qualitative changes, with small inputs of N and R, was a tiny part – perhaps 1% – of the entire economy. Today, this sector constitutes about 10% of the economy. The technological revolution of the past two-to-three centuries may therefore be interpreted as being precisely the result of this change, of this exceptionally high rate of growth of the innovative-educational sector.

The second fact is the following:

(4)’ *The growth rates of both sectors, although very different, have been fairly stable during the period of the technological revolution. Likewise, the growth rate of the ratio Y/L has been fairly stable, although very much higher (an order of magnitude greater) than during the many centuries which preceded it.*

In the TFA the principal role was played by England and a small part of continental Europe in the 18th and 19th centuries, by the USA and a large part of Western Europe in the 20th century, and by the USA, the whole of Western Europe and Japan from the late 20th century onwards. We find the strongest confirmation of fact (4)’ in relation to the USA. The variation in the rate of growth of Y/L with time and between different parts of the TFA was and is relatively small, in spite of the periods of significant differences in both institutional arrangements and economic policy, and despite the fact that these differences have had a significant impact on the share of investment in national income.

From this we have the following, third fact:

(5)’ *The rate of growth of the ratio Y/L has been and is fairly stable over time and differs only to a small extent between countries, in particular, it depends only slightly on the ratio of investment to the national income.*

With respect to the non-TFA countries the principal fact is the following:

(6)’ *The rate of growth of Y/L varies strongly over time and between countries.*

This strong variation is evidence of the great influence of the level of development itself and the institutional factors and economic policy on the growth rate in this sphere. These parameters have an evidently great effect on the access to technology in the TFA and the possibilities of its absorption by less developed countries (IMF 2003, Acemoglu et al 2003).

And, finally, the last fact:

(7)’ *The growth rate of Y/L is strongly dependent on the level of investment as a fraction of the national income.*

This dependence is once again connected with the factors influencing the flow of technology from the TFA and its absorption in the non-TFA countries.

We shall return to facts (6)’ and (7)’ in Part 7, where we shall discuss them in a somewhat greater detail.

3.2. The facts according to Easterly and Levine

A different, though in part similar, list of the basic facts was proposed by William Easterly and Ross Levine (2001). Their facts are the following:

(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 of themselves to a great extent independent. 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. The second fact is:

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

Such an approach is first and foremost a polemic against the traditional Solow-Swan-type growth model, in which qualitative changes are given by assumption . Fact (2)" is compatible with a description which emphasises the high growth rate of the degree of duality of the world economy over the past 200-300 years (Maddison, 1995).

The next fact is:

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

In this formulation, the authors want to stress the large role in economic growth played by very many factors other than capital accumulation. These other factors are first and foremost economic policy and institutional changes. It is important, however, to distinguish between fluctuations of the growth-rate around a trend and changes in the trend itself. The authors do not introduce such a distinction. The subject of our special interest is only the possibility of influencing the trend growth rate. The fourth fact is:

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

The significant variation of the level of development and growth rate of places within the same countries is an indication of the great role of concentration, and sometimes of geography. In my approach this factor is ignored, since it deals with differences in the level of development and growth-rate between countries rather than between regions. Finally, the fifth and final fact:

(5)" *National policies influence long – run growth.*

In my approach the influence of economic policy is relatively small in TFA countries, but large in non-TFA countries,. The decision by Easterly and Levine not to differentiate between the TFA and elsewhere means that fact (5)" is a great simplification.

In the economic literature we have numerous attempts to answer the question: what constitutes a good economic policy. One of such answers was given by John Williams (1990), which sums up the recommendations of the Bretton Woods institutions (IMF, World Bank) in the form of a decalogue[1]. Although these precepts,

[1] These recommendations are: 1) fiscal discipline, 2) rational public expenditures, 3) low tax burden, 4) financial liberalization, 5) unified and competitive exchange rate, (6) trade liberalization, (7) liberal foreign direct investment regime, (8) privatization, (9) weeding out regulations which do not serve the public interest, and strengthening those that do, such as banking supervision, (10) secured property rights without excessive transaction costs.

which the author termed the "*Washington Consensus*", later became the subject of various criticisms, as Guy Pfeffermann (1998) observed: "*most countries whose governments have over a number of years made efforts to follow the precepts of the Washington consensus have moved to more rapid economic growth*". From the perspective of countries of the *emerging economies* type, especially those which have experienced fundamental institutional transformation, Williamson's recommendations are essentially of textbook type, although some of them are rather imprecise and incomplete. In the TFA countries, good economic policy has been well-defined, e.g. in the EU countries by the Maastricht criteria and the policy of the European Central Bank as regards macroeconomic policy and by numerous liberalization rules at the microeconomic level.

3.3. Interpretative side-tracks

Easterely and Levine's stylized fact (1)" is sometimes put into question. For some economists stress the key role of human capital in economic growth, particularly in the most developed countries. All countries are supposed to find themselves now in an economic phase based on knowledge (information). This approach does not give adequate weight to the role of knowledge (information) in the past. Differentiating between industrial civilization and information civilization seems to me to draw attention to a secondary question. Qualitative changes, including technological ones were usually, and within the TFA still are, a result of the R&D activity and education. In the distant past this sector was only a small part of the economy, and was also in part informal and was integrated with the sector producing conventional goods. But at that time even increases of knowledge small in themselves were sufficient to produce large percentage changes. Today, simply to maintain the historic growth rate and the historic percentage rate of innovation, large changes are required. The present stage of development is rather a continuation of the previous trends and not something qualitatively new. Nevertheless, Easterely and Levine's approach is confusing in as much as it concentrates on the immediate and relatively limited influence of human capital in the conventional sector, while ignoring the fundamental role of this capital in the TFA innovative sector. For the TFA these authors' suggestion that human capital and total factor productivity (TFP) are two almost independent growth factors goes against much evidence. But their approach may be justified for non-TFA countries, since there innovation comes to a large extent from outside.

I have also, in part, already drawn attention to another point of contention, this time relating to the role of physical capital. Namely, unlike Easterely and Levine, some economists have interpreted the very high economic growth rate in some countries, e.g. in South-East Asia, as the result principally of rapid accumulation of physical capital and not of a high innovation rate. This interpretation in its turn omits the fact that in non-TFA countries the import and absorption of technology are closely bound up with investment in fixed assets, and hence with capital accumulation in the conventional sector.

4. The Phelps model with corrections

One of the first attempts to model economic growth based on a division into conventional and innovative sectors was that of Phelps (1966). I shall present this model briefly in the version that I generalized (Gomułka, 1990) to the conditions present in the "technological revolution" period. This version facilitates my interpretation of growth in the TFA.

The equations of this model are:

$$Y = F\ (K, TN) \tag{4}$$

$$T' = H\ (E,T) \tag{5}$$

$$E = E\ (M, TV) \tag{6}$$

$$V = R^{\lambda}\ L^{1-\lambda},\ 0<\lambda<1 \tag{7}$$

$$L = N+R = L_o \exp\ (nt),\ n \geq 0 \tag{8}$$

where T' in equation (5) is the change in T per unit of time, as a result of research effort E. In this model T is a measure of quality of the standard production factors: fixed capital K and work-force N in the conventional sector, fixed capital M and work-force R (and more precisely innovative capital V) in the innovative sector producing qualitative changes. The total workforce L grows at a constant rate. The production functions F and H are linear with respect to scale, but the function E has the scale elasticity ε, where $\varepsilon < 1$. Phelps set out to answer and did answer two questions:

(1) what should be the optimal division of capital and labour resources between the conventional and innovative sectors and (2) what will be the constant growth rate of Y/L on the optimal path The answer to both these questions applies to a situation of balanced growth.

But during the technological revolution we have a situation when M/K and R/N are less than optimal. During this period, as we know from empirical data,

$$G_M >> G_K \text{ and } G_R >> G_N \tag{9}$$

where G denotes the growth-rate of the variable indicated by the subscript. Then M/K and R/N increase during this period to their optimal levels. Since the initial levels of these two ratios differ considerably from the optimal ones, their approach to the optimal state extends over many generations. The stability of these ratios in the past 20-30 years suggests that we have reached this state only quite recently. The data relating to these relations show that within the TFA about two centuries were needed to reach the optimal levels. This means also that globally we are still in the period of slow convergence to the optimal state.

The Phelps model implies that, in the equilibrium state, the growth-rate of Y/L is proportional to n, the population growth rate. But in the convergence period, the growth-rate of Y/L is higher since the growth rate of inputs M and R in the innovative-educational activity is above normal.

This model thus explains the exceptionally high growth-rate of GDP per capita within the TFA over the past 200-300 years by three circumstances: the initially large reserve of growth in the form of the low use of the potential innovative resources of the population, the public policies and market institutions adopted to make effective use of that reserve, and the high rate of population growth. All these factors are, however, transitory since after a certain time, probably in the course of 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 reserves of fixed capital M in the R&D sector 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, which means n will fall to zero. These three circumstances imply that the increment of T per unit of time will become almost constant with time rather than increase exponentially, as happened in the past 200-300 years and as is still happening.

5. Hat-shaped relationship for the TFA

As we noted at the beginning of this article, the world innovative sector is located almost entirely within the TFA. Independently of what model of qualitative change we use, we know very well that the rate of growth of inputs in this sector have over the past 200 years been exceptionally high and fairly stable. Hence it is not surprising that in this period the rate of innovation has also been exceptionally high and stable.

The Phelps model, both in the original and the modified form, gives a good explanation of the empirical facts. But we also know for certain that in the longer perspective there must occur a great slowdown in the growth rate of the inputs of fixed capital and labour in the world innovative sector. In general, this should mean, and certainly this is so for the Phelps model, a slow and prolonged decrease also of the growth rate of qualitative changes in the TFA, the rate in that model decreasing asymptotically to zero. If this is so, then on the scale of millennia, the period of some 300-400 years of an unusually fast growth will be something in the nature of superfluctuation. The growth-rate of GDP per capita or per working hour would return with time to the very low level before the technological revolution. Whence my proposed term to describe this superfluctuation as a "hat-shaped relationship" (Gomulka 1990).

6. Hat-shaped relationship for non-TFA countries

As we have already observed in Part 3, in non-TFA countries we observe a strong variation of the GDP growth-rate per capita 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. The process of assimilation of external innovations by the economy suggests an analogy to the process of assimilation of knowledge by pupils and students. This process is relatively slow in primary school, faster in secondary school and very rapid for university students. However, at the stage of working for a doctoral dissertation, progress in acquiring knowledge slows down again. Approximately the same happens in the case of economies. When the development gap is large, the absorption capacities are typically still little developed. On the other hand, when the development gap is already small, these capacities are typically large but the number of useful innovations which can be made available by transfer are also fairly small. 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 expectations *a priori* 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. (Gomulka, 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 a given country. Such a dependence is specific to each country. Its variation among 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 very great.

7. Problems with growth theory for non-TFA countries

A survey of the literature shows that economists may have great difficulties in modelling the economic growth of a country when the principal source of qualitative change is the purchase or cost-free diffusion of innovations from the TFA. The greater part of the technology stock that is the subject of transfer is not protected by patents. Moreover, connected with such transfers are various kinds of inputs, first and foremost investment in fixed capital and raising workers' qualifications. The transfer of *know–how* is easier if it is carried out by a foreign firm – the owner of this *know-how.* But foreign direct investment depends on a large number of institutional factors affecting the transaction costs, and also on tax burden and the quality and pay of the work-force. In other words the volume of transfer is a function of both economic policy and the institutional solutions adopted. A unified theory should therefore also model such policy and institutions. But this proves to be very difficult.

Evidence of the great impact of institutions and economic policy in the non-TFA countries is provided by the empirical data relating to a fairly large group of less developed economies which for decades, instead of catching up on the TFA countries, have been falling further behind them. Such countries, as it were, fall into a black hole, since weak development maintains and sometimes even expands barriers impeding the transfer of *know–how* from outside. This suggests a comparison with the phenomenon of hysteresis on the labour market, the obsolescence of qualifications and the decreasing chance of returning to work after prolonged unemployment.

The phenomenon of growth slowing down as an effect of the development gap decreasing has been confirmed empirically by the (strong) decrease in the growth rate of GDP per working hour over the past 20-30 years in successful countries, such as Japan and Western Europe. A slowing down of growth also took place in the years 1975-90 in countries with a centrally planned economy. But this latter slow-down in comparison with Japan and Western Europe began earlier than it should have and was stronger (Gomulka 1988).Hence also in the slowing-down growth phase, as the equilibrium point is approached, we observe the strong influence of institutions and also, in part, the influence of economic policy.

A good theory should have solid microeconomic foundations. The first theories of diffusion, such as, for example, the model of Nelson and Phelps (1966) did not have such a foundation. Likewise, later works, such as Gomulka (1970, 1971, 1990) or Barro and Sala-i-Martin (1995) were not based on the decisions of firms, households and governments. An exception is what is known as the AK model. This is an interesting theory, although it is a great simplification of reality. The principal simplification is the assumption that imported knowledge – both technological and of human capital type – costs nothing. His proposed production function is of the form given by equation (2). Of key importance here is the observation that K/Y is stable over time and has similar values for countries with different Q. For this to happen, Q*L must be proportional to K. Hence

$$Q= a \, {}^*(K/L) \tag{10}$$

where a is a constant. In other words, even if it is assumed that the actual acquisition of *know-how* costs nothing, the increase of Q which potentially may occur due to this acquisition demands investment in fixed assets, in order that this *know-how* may be absorbed and used by the economy. Relationship (10) may therefore be treated as the counterpart, for non-TFA countries, of the technological progress function for TFA countries. This means that in non-TFA countries the accumulation of fixed assets and technological progress (more generally, increase in the quality of K and L) cannot be treated as independent economic growth factors. Obviously the growth of K/L in these countries does not necessarily mean the growth of *know-how,* but in the long term the import and absorption of *know-how* always requires the growth of K/L. Substituting (10) in (2) we have:

$$Y = F(K, QL) = F(K, aK) = F(1, a)K = A^*K \tag{11}$$

where A is a constant. In the short term relationship (2) holds, while (10) and (11) relate to the long-term. Since Y' = AK' = A (I-δK) = A (sY-δK) = sAY – δY, then in this model of the growth rate of GDP per capita:

$$G_{Y/L} = As - \delta - n \tag{12}$$

where n is the growth rate of L, δ is the rate of depreciation of fixed assets, and s is the ratio of gross investment I to GDP.

In the AK model, what is sought is the optimal rate of savings, taking into account the elasticity of the marginal utility of consumption for households θ and the rate of discount ρ, and assuming that firms maximize profits. Hence, finally,

$$_{GY/L} = (A - \rho - \delta)/\theta \tag{13}$$

Thus in this model the variation of the growth rate of GDP per capita among countries is explained by differences in the preferences of households, described by the parameters ρ and θ. The differences in preferences explain also the differences in the optimal savings rate. This model implies that in non-TFA countries there ought to be a strong dependence of the growth rate of GDP per capita on this savings rate. This implication is empirically confirmed (inter alia in Bernanke and Gurkayank, 2001). This type of dependence is not observed in TFA countries (Jones, 1995). Nor do we have it either in the classical Solow-Swan model, nor, for example in the Phelps model. The assumption that knowledge (both technological and human capital type) is cost-free is a simplification. But expenditure on education and licensing is as a rule only a small fraction of the expenditure on fixed assets. This simplification may therefore be considered acceptable.

8. The "unified" theory of Parente and Prescott

The theory of Parente and Prescott (2003) is unified in the sense that it attempts to explain in a single model the three features of growth of the world economy, which the authors consider to be of key importance:

(a) More or less zero growth of GDP per capita for millennia up to around the year 1700, in spite of a certain positive growth of knowledge and population;
(b) Great acceleration of world GDP per capita growth during more or less the past 200–300 years, and
(c) Great variation between countries at the moment of time when the acceleration of GDP per capita begins.

The key analytical innovation here is the assumption of the parallel occurrence of two production functions: the "classical"(K) and the modern (N). In a function of type K one of the main production factors is "land", the supply of which is fixed. In functions of type N, however, all the factors are producible. The authors show that the choice of production function by producers maximizing profits depends on the level of the quality index, which in this paper is denoted by Q. Namely, for low Q producers always choose K-type functions, while as soon as Q passes a certain critical point, they start to choose only N-type functions. The choice of K explains property (a) and the transfer to N explains property (b). For full transition of an economy from K-type to N-type, technology with appropriate choice of parameters requires, as appropriate simulations show, a long period, even 100 to 200 years. But it must be stressed that in these authors' theory knowledge is accessible to all and its increase requires no expenditure. What differentiates countries is only the effectiveness with which that generally accessible knowledge is used. This effectiveness in its turn depends on institutions and economic policy. This variation explains property (c).

The economic growth mechanism in the above theory is driven by changes in Q which are autonomic and predetermined. The variation of the path of change is in its turn the result of the variation (also predetermined) of these changes over time and between countries. This unfortunately means that the Parente and Prescott model is not a complete or "unified" theory.

For in fact the authors ignore the very questions that are central and of the highest importance for long-term growth.. Their model is in truth closely akin to the neoclassical model of the 1950s-1960s, associated with such economists as Solow, Swan, Fergusson, or Denison. Missing from this model is the concept of the international diffusion of *know–how*. There is no description of the dynamics of the R&D sector (more generally the sector of qualitative changes). Nor is there any attempt to explain institutional changes. Finally, the authors' simulations assume a gradual, almost linear, growth of the rate of qualitative changes in the period 1700-1925, from about 0.1% per year to somewhat more than 1% per year, and then stabilisation at this higher level. However, in the TFA, the growth-rate of qualitative changes was fairly rapid in the period roughly 1750-1850, after which this growth became significantly slower, and the rate of change was thus almost stable. These authors do not analyse the effect on the results of the simulation produced by adopting a more realistic choice of the dynamics of the rate of qualitative change.

9. Empirical tests

Since the "unified" theory of Parente and Prescott does not explain a great deal, we shall now briefly turn to testing other theories of long-term growth over the last 250-300 years. We know that the explanation of the growth rate of qualitative changes is the key factor here. As I have argued, such an explanation must be fundamentally different for TFA and non-TFA countries.

A great many theoretical models imply that there must exist a positive connection between the long-term growth rate of GDP per capita and the rate of investment in fixed capital and human capital (Jones, 1995). This positive link is supposed to apply also to developed or TFA-type countries. In Jones' work, however, we are presented with extensive empirical evidence which questions the existence of such a connection in relation to developed countries. But the work of Bernanke and Gurkayank (2001) confirms its existence in non-TFA countries.

This empirical material agrees with my earlier interpretation of economic growth mechanisms, an interpretation which indicates the necessity of having two different theories, one for the TFA and one for non-TFA countries. In the TFA the growth rate of qualitative changes, in particular, technological ones, depends on the growth rate – and not the volume- of various inputs in the sector producing these changes. An appropriate theory here is, therefore, the Phelps model, but with my generalizations for the "technological revolution" period. Remember: this generalised theory is based on the argument that the exceptionally rapid development of these countries over the past 250-300 years was "driven" by the gradual activation of a fundamental reserve of growth in the form of the initially little used *talent pool* in the production of qualitative changes.

In the TFA countries there have been significant institutional and economic policy changes in the course of the past 200 years. But in spite of wars and crises these changes did not interfere with the mechanism of gradual use of this fundamental mechanism of long-term growth. As a result, inputs in the sector producing qualitative changes have been increasing exponentially at high and fairly stable rates.

In the non-TFA countries, changes in human capital are generated domestically, but technological innovations are mainly imported. Technological innovations are essential to support growth, hence here we return to the role of agents facilitating or impeding their transfer and their effective use. Hence AK-type models may be justified for the non-TFA countries, but are incorrect for the TFA countries. Hence too the large role of institutional and economic policy changes in the non-TFA countries, and its relatively small role for the TFA.

10. Long-term implications of the theory

In the light of the above analysis of the mechanism of economic growth it is possible to try and answer two questions about the future (a) If and when the currently observed strong duality of the world economy will disappear, and (b) what will the growth rate of the world economy be over the next 200 to 300 years.

It is easier to answer question (a) now than, for example, 30–40 years ago. For in the course of the past 30–40 years there have been great changes in the world economy which facilitate the answer. The most important of these relate to China and India. As a result of the cumulation of reforms, these countries set out on their own individual paths of rapid economic growth. Moreover, their population explosions came to an end or are about to end. As a result of systemic transformation, there has been a fundamental improvement in the institutions and economic policy in the countries of the former USSR and Central Europe. Finally, significant reforms of a fairly lasting character have taken place in several other large countries of "*emerging markets*" type, such as Brazil, Indonesia, Mexico and Turkey. All together, these changes are sufficient to predict a significant decrease in the degree of duality of the world economy in the course of the 21st century. The data on the degree of variation in development between regions in the TFA countries is evidence that differences in GDP per capita of the order of 1:3 may be preserved within the countries that have the same institutional-legal order. Likewise, before 1700 variation in GDP per capita in the 1:3 range was frequent and persistent. By elimination of strong duality in the world economy, we understand therefore a situation in which the segment of the population with income below 1/3 of the average income in TFA-countries will fall below a fairly small fraction, e.g. below 10 %. The degree of duality, as measured by the percentage of the population with per capita income below 1/3 of the average income in the TFA, rose during the 19th and 20th centuries, but during the 21st century should fall perceptibly. The events of the past 30 years or so even allow one to consider that – using my definition – by the end of the century the present high duality of the world economy will have been (almost) completely eliminated.

Answering question (b) is more difficult. The past 30–40 years have seen events which somewhat facilitate an answer. Firstly, in accordance with convergence theory, the rate of economic growth in Western Europe and Japan has slowed down considerably. Secondly, in the now much expanded TFA the possibilities for very rapid growth of the innovative sector have reached exhaustion point. Hence the ratios R/N and M/K which we spoke of in Part 4 can no longer increase as rapidly as before. Finally, there is the third essential fact that the world population is approaching stabilization. Although further rapid growth in the world number of innovators is always possible, this will happen principally through the better use of a now fairly stable talent pool.

This degree of use of the existing *talent pool* in non-TFA countries is however still fairly low. At the level of the world economy, therefore, we should still have a far more rapid growth of the R&D (more generally, qualitative change) sector than of the conventional sector. A simple calculation (Gomulka, 1990, chapter 13) shows that this capacity for rapid growth, if existing trends are maintained, will become exhausted by more or less the middle of the present century. From the perspective of the Phelps model, there should be then a slow and prolonged decrease in the percentage rate of innovation and in the growth rate of GDP per capita in the TFA countries and also in the world economy overall.

References

Abramovitz M. (1986), *Catching Up, Foreign Ahead, and Falling Behind*, Journal of Economic History, pp. 46385-406.

Acemoglu D., Johnson S., Robinson J., Thaicharoen Y. (2003), *Institutional Cuases, Macroeconomic Symptoms: Volatility, Crisis and Growth*, Journal of Monetary Economics, pp. 5049-123.

Barro R., Sala-i-Martin X. (1995), *Economic Growth*, McGrew Hill.

Bernanke B.S., Gurkaynak R.S. (2001), *Is Growth Exogenous? Taking Mankiw, Romer and Weil Seriously*, Macroeconomics Annual 2001, NBER, The MIT Press, Cambridge, ed. by S. Bernanke and K. Rogoff.

Easterly W., Kremer M., Pritchett L., Summers L.H. (1993), *Good Policy or Good Luck? Country Growth Performance and Temporary Shocks*, Journal of Monetary Economics 32, pp. 459-483.

Easterly W., Levine R. (2001), *It's Not Factor Accumulation: Stylized Facts and Growth Models*, The World Bank Economic Review 15, pp. 177-219.

Gomułka S. (1970), *Extensions of the Golden Rule of Research of Phelps*, Review of Economic Studies, 37(1), pp. 73-93.
Gomułka S. (1971), *Inventive Activity, Diffusion and the Stages of Economic Growth*, monograph No. 24, Aarhus, Denmark, Aarhus University.
Gomułka S. (1988), *The Gerschenkron Phenomenon and Systemic Factors in the Post – 1975 Growth Slowdown*, European Economic Review, 32(1-2).
Gomułka S. (1990), *The Theory of Technological Change and Economic Growth*, London and New York: Routledge.
Hall R.E., Jones C.I. (1999), *Why Do Some Countries Produce so Much More Output Per Worker than Others?* Quarterly Journal of Economics 11, pp. 483-116.
Hansen G.D., Prescott E.C. (2002), *Malthus and Solow*, American Economic Review 92, pp. 1205-17.
IMF, World Economic Outlook (2003, ch. III on *Growth and Institutions*, Washington DC, April.
Jones C.I. (1995), *Time Series Tests of Endogenous Growth Models*, Quarterly Journal of Economics 110, pp. 495-525.
Nelson R.R., Phelps E.S. (1966), *Investment in Humans, Technological Diffusion and Economic Growth*, American Economic Review 56, pp. 66-75.
Parente S.L., Prescott E.C. (2003), *A Unified Theory of the Evolution of International Income Levels*, presented at the conference on successes and failures in real convergence, NBP, October 23-24th.
Pfeffermann G.P. (1998), *The Way Ahead: Economic Reform in Latin America*, International Finance Corporation, Washington DC.
Phelps E.S. (1966), *Models of Technical Progress and the Golden Rule of Research*, Review of Economic Studies, 33, pp. 133-45.
Verspagen B. (1991), *A New Empirical Approach to Catching Up or Falling Behind*, Structural Change and Economic Dynamics, Vol. 2, No. 2, pp. 359–380.
Williamson J. (1990), *The Program of Policy Reform in Latin America*, Institute for International Economics, Washington DC.