Technical equipment, technological changes and institutions

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Аннотация. *В статье рассматривается развитие технических систем и технологий, воздействие экономических институтов на это развитие. Автор с точки зрения эволюционной экономической теории предлагает объяснение изменений в технике и институтах, предлагает логическую цепочку (цикл) изменений.*

Abstract. *The article examines the development of technical systems and technologies, the impact of economic institutions on the development. Author from the standpoint of evolutionary economic theory offers an explanation of the technique, and institutions within a logical chain of changes in production and technical systems.*

Ключевые слова: *техническое оборудование*, *технологические изменения*, *новые комбинации, институты, развитие, эффективность, принцип выявленных предпочтений П. Самуэльсона.*

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Both in the modern world, and in the remote past development of technical equipment and technologies were an indicator and expression of economic progress. The reason was the possibility to increase labor productivity and machinery, that means to create more products and items per man, to increase income and the general degree of mechanization and, hence, to raise the standard of well-being. The development of production and knowledge accumulation on certain directions of human activity became the tool of struggle against the decreasing return on factors of production - labor and capital. Scientific and technological advance permanently provides the effect of movement of factor return curve upwards to the right. Thereby, escape from a dangerous point of return decrease with the following reduction of per capita income is provided. Decreasing return arises, when at using additional unit of the factor of production with the other factor invariable, there is a decrease of limit and then average value of the product on the factor (labor or capital). Technological and institutional changes become the factors of withstanding possible decreasing return.[1]

Underdeveloped countries of Africa, Latin America and Central Asia have a serious problem with this effect. It is either not detected due to chronic technological backlog, or is reproduced only thanks to a transfer of certain technologies from the outside, from the developed industrial countries. Return reduction on production factors are so considerable there, that in some countries, especially in sub- Sahara Africa, there is hunger, that is, elementary foodstuffs shortage during certain periods of time. Besides, the return on the factors of production decreases because the institutions contributing to the development of knowledge and technologies are undeveloped. These countries are deprived of the possibility to use abilities and to increase production results. Many of them are raw materials colonies of strong industrial powers though the term "colony" has not been used for a long time, but, in essence, they are such colonies because they are structurally dependent on the developed states and supply them with relatively cheap raw materials.

It is difficult to apply the concept of "technical and economic paradigm" of C.Perez or the classification of technological development defining this or that stage of the development on dominating branch and the energy resource to such countries. Working out of development economic theory for such economic systems demands special approach. Not accidentally there appeared a separate school on developing countries in economic science - the development economy. Its aim was to study the "vicious circles" of the development, that is, poverty system from which the country cannot be pulled out, and to suggest the development models which can as though allow overcoming such backwardness of the country.

Development laws of technical equipment, technical systems and technologies are not stable. The specific character of their development doesn't imply leaps over some stages. Such cases are individual, not indicative and they are often defined by interpretative possibilities. In other words, the main mechanism of their development is a consecutive upward spiral of technology. In some isolated cases, the leap over some stages is possible, for the account of accelerated training and transference of ready technical systems to the professional environment which can take these systems in, systematically providing result augmentation.

Consider a known example. In 1965 at the beginning of microelectronics formation the Intel founder Gordon Earle Moore observed an interesting empirical regularity, applicable to the development of microelectronics: every year the density of elements (p-n transitions) per area unit should double. After a while G.Moore forcedly reconsidered this formulation. Doubling occurred in 18 months, and some time later, in modern period there is an increase of the period up to 3 years. The problem is that the cost of equipment and clean rooms increases faster than the returns from investments in this equipment. The efficiency increment from density increase does not compensate capital investments in the means of production which should provide the ultimate increment of this density. Besides, monopolization of microelectronics and concentration of the capital connected with the necessity of technological problem solution (the demand for capital concentration is often the response to the necessity of purely technical problems solution) became the consequence of competition for high effi-

[1] At rising return the product on this factor should increase, at positive scale effect on the amount surpassing the involved volume of the factors of production. Certainly, there are sectors with decreasing return in modern economy. - Author's note.

ciency, productivity increase of elements and chips. Two technical problems define the development of technologies in the given sphere. They are: increase of chips memory and their speed. Then, the problems of "clever" chips development are solved including the ones with the elements of mechanics.

The following groups of rules are of importance concerning the development of technical equipment and technologies:

1. The rules of product design and paper design work, engineering support of items in the workshops, information supply of the work, and the design methods presupposing the use of software, numerical calculations and computers.

2. Rules of interaction of various workshops, enterprise services, contracting with the client and contractors, expenses calculation and management, production distribution and market development, new knowledge adsorption within the firm and from educational system.

3. Operating rules, maintenance, safe operating mode, repair and utilization, tests and organization of pilot production.

4. Patenting rule of technical ideas, inventions, getting certificates of authorship and its protection, registration and research and development conduct.

5. Rules of cash security of a new idea, its production and marketing, commercialization, getting credit (bank system job), interaction with old equipment and technologies, duplicating possibility, loan of technical solutions, popularizations of new technological achievements (advertising). Looking for new markets (marketing).

If these rules differ in different systems, they define the efficiency of the actions which describe and program technical development in different ways. It is interesting to note, that even if it is possible to say that some rule is somewhere inefficient due to the internal efforts of qualified personnel, agents' internal burden increase and execution accuracy cannot worsen the general situation at all. Any rule, the inefficiency of which is obvious by some moment, can in time become more effective or more significant in the system of rules regulating this kind of activity, in particular, equipment and technologies perfection.

I will give the example concerning the visit of *Siemens* representatives to a Russian enterprise producing railway equipment. They were very much surprised, that there is a complete production cycle there, from designing up to final assembly, testing and even materials control in the special chemical laboratories the work of which was scrupulously studied by the German representatives. When asked about their unusual surprise, they said that in Germany the work of similar firms is organized differently and the firm having a complete production cycle is very rare. Details and components are bought in the market. And if some firm does not satisfy the customer, the client will simply change the producer. Russian engineers smiled because there should be more producers of the components in question for this system to exist. And if the situation in the economic system is different, then the enterprise has a complete cycle not to depend on anybody. Especially as such dependence is fraught with capture of enterprise's property, stoppage of its work with the loss of personnel potential, and etc. Protective function, together with the other ones, requires exactly such organization of production, which, by the way, emphasizes the technological level of the enterprise. German representatives couldn't but agree with this fact.

If there is legislation, that new houses should have photovoltaic cell on the roof for electric energy production, all construction firms cannot cancel this regulation and are compelled to include solar cell panels in the expenses, supplying this very *Siemens* with the orders and so on along the multiplying production chain. Then the law, which allows sending the created electric energy to the circuit, is passed. The agent's payment for the power use is reduced on the value of the energy from solar batteries, which he installed or used, sent to the circuit. That is, there are rules which allow sending additional energy to the general circuit. Thereby, the problems of energy savings and redistribution of payments for power use are solved and the development of new power engineering and microelectronics is stimulated by developing the production of photoelectric transducers.

Thus, even the market and rules structure define the production system structure, concentration processes, diversification, monopolism level and organization efficiency of the industrial enterprise.

Organizationally equipment and technologies development presupposes strong inertia when firms operate according to the established strategy with acceptable result, visible improvement of equipment and the basic means of its production. It is often heard about the behavior continuity or the inherited strategy, but whatever terms are used by the researchers to stand out of the colleagues crowd, the essence of the equipment development will hardly change, as it results from our fundamental knowledge in physics, chemistry, mathematics, engineering sciences, possibilities of designing and substantiation of technical decisions which are impossible without calculations. Certainly, the behavior logic in the competitive and even monopolized system forces the companies to concentrate the capital on the search of new technical decisions and technologies. There simultaneously appear risks because the view of income acquisition from these new decisions is absolutely not clear. They may be progressive from the engineering point of view, but are not supported by the demand of the consumers for these advanced systems. Therefore, making large investment and creating the means of production for new technical products, it is necessary to be sure that there will be a consumer of this production. And it is possible, if some financial resources will be simultaneously spent for consumer programming, that is, for creation of demand. Similar behavior and stylistics of equipment and technologies development and, above all, the models of their financing destroy the principle of consumer independence known in science. In modern economy and in the future he becomes informationally dependent. But that's another thing, how this dependence is expressed and what its essence is.

There is an opinion, in particular, the one of Ulrich Witt concerning coincidence of real income growth per capita with the growth of expenses on consumption connected with the estimation of human requirements saturability.[1] If to proceed from

[1] Witt U. Learning to Consume – A Theory of Wants and Growth of Demand // Journal of Evolutionary Economics, 2001, №11.

consumer independence, that is, to accept that there is no connection between consumption and production, then the needs can be quite filled with according to Ernst Engel (well-known E.Engel's law asserting, that the less share of the national income is spent by the population for foodstuff, the higher the standard of well-being, and vice versa). If the principle of consumer independence does not work, there is a connection between production and consumption, when consumption depends on production and in this case the needs become nonsaturable. The situation is worsened by the general population increase and variety change, because they are formed, and programmed by production which pays advertising in mass media and creates additional demand. Growth of expenses for consumption even mathematically cannot be infinite. Finally, it is limited by the amount of real income even subject to its increment. If the increment rates are identical, then the proportion of expenses for consumption is stabilized. And as the income grows, then, no wonder that the absolute value of expenses for consumption grows. Expenses for consumption are a part of the consumers' income, therefore income growth with the increase in welfare variety generates growth of expenses for consumption though the share of these expenses for different economic systems can remain invariable or can change in time. Other things being equal, if foodstuffs and clothes are rather cheap, it means higher standard of well-being of the given economy towards the rest.

The way the problem is formulated by U.Witt is not paradoxical, though it requires more precise definition. The fact is that consumption growth is possible at needs saturation. Why does suddenly anyone deny consumption growth and say, that it is possible only at unsaturated needs? It is far from reality as in such estimations it is important to know, what the current consumption is, that is, it is important to know the starting point (for example, hunger or restrained consumption or consumption in stagnating economy subjected to unreasonable institutional reforms, and etc.). Then, it is important to understand under what conditions and after what period of time there can be saturation and what it represents itself. Finally, approaching to saturation new welfare combinations change the consumption structure, preserving the needs for new combinations unsaturated. Besides, having different active income per head the consumption rate per head in various groups of population will also be different and the distance to saturation will be different too.

Processes of saturation will have their own stylistics and will be defined by the income and the initial standard of well-being on the segments of the people, so that separate groups and their requirements in comparison with the richest top groups will always be unsaturated. It creates diverse consumption and income distribution. In other words, consumption saturation for evolutionary economists is like the equilibrium point for neoclassics. It is a certain tempting talisman generating idle talks and really not existing, because to analyze saturation, it is necessary to understand how, when and for what period of time it can arise, and then due to what factors it disappears or does not disappear. But saturation on separate welfare kinds does not change the overall picture of variety growth and variety changeability which creates the general consumption unsaturation. With regard to scientific knowledge, research and development and technical systems, this reasoning is not productive in general. Here the needs are unsatiable due to the essence of science and technology development which combinatorially multiplies unresolved problems and thus generates requirements for their solution and creation of new devices, technologies, and, consequently, new consumer properties.

At the same time it is hardly pertinent to divide welfare into abstract and specific and especially to endow the consumer with a certain hierarchical thinking. If he thinks so, then he is automatically a reasonable subject and it is necessary to applaud encore to neoclassic, instead of being touched by one's own evolutionary logic. Incorrect emphases in evolutionary logic application really result in interpretation errors and incorrectness, though they help disclose the absurdity of U.Witt's positions with his own methods, using unreasoned estimations and assumptions. If the agent is irrational or restrictedly rational, how can he exactly think hierarchically? It is a direct sign of rational thinking, even at such primitive hierarchy, as ostensibly abstract and specific welfare. Of course, agents weigh and estimate different welfare, but they hardly estimate welfare kinds. Even according to the A.Maslow's hierarchy of needs it is evident, that the hierarchy of needs exists, but what the shares of welfare are in this hierarchy on the population groups is difficult to define, to say nothing about the factors influencing the given proportions change. The agent probably ranges welfare, but not the welfare groups. And how should knowledge, technologies and industrial output be ranged? The individual hardly ranges these welfare kinds. Most likely, the agent makes the decision about the purchase of this or that blessing in certain circumstances according to his income, current needs and his future-oriented behavior strategy. Or he decides to accumulate income on the purchase because his wage is not enough. The same refers to the firms – agents consuming industrial output and means of production.

So, demand and consumption growth are caused by population growth, economic changes[1] dealing with food variety as well and shifting consumption saturation to the area of permanent unsaturation, so that the share of consumption costs can be stable for a long time according to E.Engel's law, but it is necessary to specify, that this law particularly mentions, that the share of food costs does not increase and food expenses increase more slowly, than durables expenses. And taking into account the change of consumption quality and the quality of consumed blessings is also important. It is important with reference to knowledge the quality of which is its most important characteristic. The consumption structure should change towards better products, and depends on many factors of economic development and institutions. The share of low-quality goods should be reduced. Such process becomes the natural essence of consumption and production evolution. Besides, there is also increase of saving rate that allows concentrating a part of the

[1] The fact, that the agent (consumer) combines both rational behavior and other behavior models applying them occasionally is described by me in a number of early works of 2000-2001. Today economists begin to take a great interest in difficult evidence systems of trivial axiomatic facts proof and use rather artificial classifications and conclusions resulting from them for substantiation of these known facts.

national income on financing technological changes and technical progress which demands increased financial injections. If the logic and essence of financial system are separated from the development of technological systems (I managed to demonstrate this fact in my book "Structural Problems of Russia Economy"), then both development slowdown of technical sphere, unexpected shifts in consumption, and a collapse of the financial system, left to its own resources, are observed. The choice of consumer and the consumption rate are defined at each moment of time by the income size.[1]

The behavior model of the firm in the market, its choice of new means of production, technologies, financing of research and development and other kinds of activity also depend on income. Investments will be of great use, but their attraction is defined by the firm's assets and by the current or saved income. This is the fundamental relation between needs, possibilities and production, preferences and choice. There is an opinion that innovative results in the firm depend on the researches and development carried out in it. Partly it is true, but they mainly depend on stimulus and rules. And it is important to consider, that research and development are not a panacea when up to 30 % of them have negative result. The specific feature of both fundamental and applied scientific work is that there is a negative result there which is valuable by itself and makes brisk up the new search. Risk presents such result as there is nothing to return the resources spent on the researches and development, including the financial ones. The firm's size, certainly, influences the possibility of carrying out R&D. Small firms are hardly capable to do scale successful research and development if only they do not specialize in this activity. On the contrary, large corporations accumulate big financial resources on R&D and search of new technical decisions improving a product or creating its new versions or kinds. Successful R&D always strengthens the monopolistic power of the firms which carry them out. The patent right, certificates of authorship and judicial system imposing large penalties for imitation of somebody else's invention assist it.

Thus, R&D and creation of new technology introduce high uncertainty into firms' activity. Consumer preferences are unknown and not clear. Furthermore, it is impossible to establish them at this stage. They are just being formed. It will make no difference to the owner of firm and the proprietor what consumer preference is, when it is generated. But the consumption volume will not be known, that introduces additional uncertainty. This banal explanation of well-known processes is especially clear to those who directly carry out engineering and scientific development, to engineers, researchers, designers, creators of new products and software. Approbation of new technology is the creation of a product which is bought in the market.

Old products are pushed to the sidelines, if the new one is in fashion. The feverish demand supports the new product. Profitability of the old production decreases. Only then there appear firms-simulators copying technical decisions and capable to improve some elements of the design or product properties but only if there are technological possibilities which allow making it. Hence, the life cycle of a new technology, a new product or a firm is correlated with the life cycle of the sector and the market where the production takes place. Similar explanations are known, but there are also modern empirical evidences. However, under conditions of institutional changes of economic system, the agents' reaction and behavior logic change. If there is unit and unique production, no is possible, at least, quick imitation with operating institutions. If the rules change, the uncertainty of result increases greatly.

Demand for some blessing can outstrip supply, such relation being characteristic for knowledge-intensive production. There is shortage pushing the market price upwards. If products with short shelf life such as natural milk, sour cream, kefir, butter and so on are produced, then the requirements to the organization and safety of production are very high. Besides, there are rules of storage and delivery of such goods to the consumer. It is clear, that a "fresh" resource, quick processing and delivery are necessary for their production. Natural character of the products provides strong consumption, but impossibility to satisfy the demand can generate shortage arising because of insufficient number of such factories and technologies. Such products were made in the USSR, so deficiency was simply caused by the quality of foodstuffs with small variety. Of course, this quality, in comparison with the "chemical" variety of unnatural products which are consumed today, was much higher. High demand for such products would have influenced industrial systems operating in the capitalist system in the same way, because shortage is not socialism or capitalism feature as János Kornai reasoned rather opportunistically and preconceivedly in his time. It is a consequence of supply and demand imbalance, it arises in any economic system due to industrial (technological) or consumer reasons. Only at the expense of "chemicalization" of present-day consumption and partial under-consumption, it is possible to conceal artificially the original deficiency of consumer goods and services. Nobody has cancelled the queues in the hospitals, to an official of housing and communal department or to local authorities, because it is impossible to conceal time deficiency, as well as high demand for transaction and execution of various documents. Environmentally safe products with small shelf life are now available for rich, more well-to-do population. They are sold in special shops, that is, they are distinguished from the total mass of "chemical" foodstuff variety.

Institutionalists always see the future of human society through the prism of changes in technics and technology, organizational forms and individual reactions. They spoke about capitalism corrections, its improvement and revision, because the evolution algorithm of capitalist mode of production was never doubted. Capitalist institutions should be improved at the expense of the revision of the social control forms the necessity of which resulted from the rigid social criticism of capitalist society. Methods of social maneuvering and government control which were actively propagandized by institutionalists at different times and caused fierce criticism of neoclassics, supporters of free market, nevertheless, could not eliminate the basic contradiction between the public character of production and private-capitalist appropriation. In modern capitalism the private property institution is still dominat-

[1] The principle of revealed preferences of P.Samuelson was formulated in his article in 1948.

ing, that allows supervising means of production, including financial flows which in time turn to independent means of production for a limited circle of private proprietors, owners of capital. Let you have magnificent machine tools and equipment, cars and workshops, but if there is no financial flow, they will be in a static state, that is, they will not be involved in the process and will stand idle. Therefore, financial systems/financial institutions work becomes very important today and will keep this value in the future. It will be an original independent factor of production.

At the same time high value of engineering connected with the creation of new equipment and technologies as the elements, resisting return decrease at increasing population of the earth is preserved in the society. Organizational forms, which modern corporation has, transform into technostructure according to J.Galbraith in which an official starts to play the most important role, pushing the proprietor to the sidelines. Thus, the role of engineers, the possibility of proneness to conflict decrease and reconciliation of different social groups with corresponding social policy, creation of national planning system are the corner elements of the early institutionalism doctrine, borrowed and developed in the works of later, so-called, new institutionalists, represented by C.Ayres and J.Galbraith who strengthened technocratic and technological paradigm[1] of social development, underlining, that the economy future is defined by technical progress and science, the latter being its generator. The connection between the development of technical equipment and institutions was obvious, and these ideas were then traced in the works and models of neo-Schumpeter economic thought.

In a number of the publications of former period my attitude toward the position of such institutionalists and social development sociologists as D.Bell, E.Toffler was critical. They defended the idea of "the third wave", a postindustrial or information society. Certainly, there cannot be any post-industrialism. The basis of modern economy is production of goods and services and various blessings, including such special type as information. In perspective, the society will preserve the pivot of industrialism in which energy problem will worsen, the problems of management, distribution, motivation and control, processes of industrial systems automation, their supply with intellect will come to the foreground. All these problems are solved within complex management of big and small systems. If we speak about the stages which human society evolutionally passes, without any doubts, they are: the society before energy, power society which exists today and in the nearest future, post-power society which will manage to solve the problem of energy supply without environmental loss. The role of information increases, but knowledge always has the defining value, even during agricultural epoch, agronomical knowledge changed, became complicated, was accumulated and was important from the point of view of soil cultivation and production of new crop. Therefore, to speak about information society is to start a terminological bluff in science again which means nothing. The fact that information becomes a commodity is a reality of the present period. The sphere of services extends and the firms dealing with information consulting expand their activity. But it does not at all mean liquidation of industrial pivot of the economy and the sphere of production of goods which is a reflection of specific and basic needs in food, clothes, housing, travel (building of roads), and etc. Needs in information are often unreasonably simulated and superficial. The agent himself does not often understand, whether he needs the information which presents additional transactional costs for him. Information accumulation submits to the laws including those which result from possibilities of microelectronics to provide specific memory volume for a given data carrier. Of course, it enlarges brain possibilities of memorizing and storing of information, but, on the other hand, it reduces the efficiency of brain training and person's memory when there is a special device. As a result, in time it can affect person's qualification and the efficiency of his decision-making.

Orientation at the society forecast and "future scenario" is an integral feature of institutionalist methodology. The desire to forecast and foresee the future is symptomatic and from the analytical point of view it is rather laudable. By the way, it is difficult and thankless work, because if the forecast is untrue, the researcher looks unqualified specialist, though if we consider all the aspects, development nuances and the main factor – management, to predict what this factor will result in and how it will affect the development in the future is really difficult. In this case, it is necessary to have absolutely predictable management and fixed plan. And all the same, it is necessary to analyze why the system deviates from the plan, why it is in crisis, why it does not achieve fixed development parameters or, on the contrary, outstrips them, that can also be considered as a planning error. The problem of crises is a special talk.

It is interesting to notice, that the father of institutionalism T.Veblen distinguished the following consequences of economic crisis: firstly, according to him, there is a coercive redistribution of the capital between proprietors, and bankers, the owners of the monetary capital[2], are the winners; secondly, there is growth of capital concentration, at the expense of survival of the enterprise with greater possibilities. Small and average business is ruined in crisis. It is one more argument in favor of the fact that effective industrial structure should presuppose its frame - large industrial production as represented by large enterprises, corporations controlling the market in the country and having strong enough positions abroad.

In "The Theory of Business Enterprise" T.Veblen interprets the financial reason of crisis. Today it is possible to speak about the kernel of sense of such explanation even under conditions of intensive institutional changes and with sharp strengthening of "management" factor influencing economic dynamics.[3] Speculative activity and "credit inflation" warmed up by this activity provide prices increase which also supports great demand for credit, increasing its cost, that is, its interest rate. There appears an original pyramid when greater demand requires greater credit, and higher interest

[1] The so-called doctrine of technological determinism according to which capitalism will change its character. – Author's note.

[2] T.Veblen noticed that the real sector of economy, that is, a businessman, who is carrying out industrial activity, loses during such crisis. – Author's Note.

[3] If the best bankers curbing inflation are named in Europe, it means that either it is really so or it is a mistake. Author's Note.

rate provides credit supply. Businessmen are guided by expected gain. This chain works until there is an expectation of non-repayment of credits and there are banks which start to reduce credits. Two expectations are brought together, the first is that of high profits and the second one is true risk of credits failure. There is a “credit deflation”, that is, reduction of total amount of credits in the economy. Firms rely on their own means and, as a result, reduce production and employment. Thus, the crisis ground is in the work of financial institutions and money circulation, that early institutionalists clearly understood, paying attention to the functioning of technical equipment and institutions providing its development.

Technical progress is presented in three variants: labor-saving, economizing labor costs (the relation of marginal capital product to labor - increase), capital-saving, economizing means of production (the relation of marginal capital product to labor - decrease) and mixed, that is, economizing factors of production. Besides, extensive technical progress and intensive technical progress are usually singled out. The former is the one at which production factors are widely used and improved technical result is observed due to this process. The latter occurs only at the expense of efficiency increase of used production factors. Actually, the second type of technical development demonstrates the true value of changes in the equipment and technologies. Thus, technical progress increases efficiency of production factors, that is, output level at rather invariable value of capital (C) and labor (L). Technical progress and technological changes can result in the creation of a new kind of capital (personified technical progress) and cannot lead to the creation of a new kind of capital (unpersonified technical progress). Innovation personifies technical progress. It is an original unit of its carrier. If the relation of marginal capital product to labor does not vary, it is a neutral technical progress which is defined in the form of three scenarios: when the relation of capital to labor does not change (neutral according to Hicks), the relation of capital to the output does not change (neutral according to Harrod) and the relation of labor to the output does not change (neutral according to Solow), that is, the development is carried out due to capital. Certainly, cost relation of factors distorts actual possible correlations of factors. At the same time, the value of each development mode, at least, purely theoretically clears up. However, if in practice ratio change is observed, nontrivial estimation of technical changes and their influence on economic growth and development are required. As interesting feature is the fact, that human society has been accumulating knowledge for a long time, has been adsorbing it, has been transforming into technologies which were improved, so that true industrial breakthrough is being observed for two-three centuries. This development dynamics obtained its special type in the 20th century. It is connected with combinatorics of applied and fundamental discoveries. One discovery, for example, in physics, defined the next step which was not so long to be waited.

Thus, the combination of engineering and scientific personnel in the industry, its qualification, the abilities of processing information and acquisition of knowledge and finding the decisions in production allowed advancing the dynamics of scientific and technical development, interrelation and conditionality of its subsequent stages.

New ideas about balanced and unbalanced economic growth were just the reflection of success in the economy of technological development. Balanced growth is the dynamics when the variables of this process grow with steady speed, and the economic system sectors develop synchronously. In practice, growth is not, certainly, balanced, and this imbalance is introduced by the technical changes which are different in different sectors of economy. Imbalance also means different change rate of separate parameters and non-synchronous development of economy sectors, so that there appears some imbalance and structural dependence modes of some sectors on the others. It is also applicable to the countries developing unevenly due to objective reasons from the point of view of technical progress. These reasons are built in the development of their education sys, traditions, basic institutions, markets, accumulated knowledge and are connected with the state of science of each country. It is no coincidence, that studying developing countries R. Prebisch noticed that there was structural dependence mode according to which any scientific and technical achievements in a developing country are adsorbed and exported to the developed countries. This happens as a result of low wages, decreasing dynamics of export prices in relation to import and unequal trade conditions. Human potential in each country, health, life span, creativity, education and educational level and accumulated traditions of engineering creativity influence strongly scientific and technical results. And economic environment, institutions, home market and consumption characteristics (social standard) create and set up the possibilities of application and use of these results, providing the mode of their implementation or not providing. Imitations have a slightly different basis on the whole with reference to macroeconomic. They may have local character and co-exist with significant scientific and technical original discoveries.

Of course, institutional changes planned and carried out within the framework of economic policy define the development of technical systems and production greatly. They can make the game impossible or select not the most effective technical decisions as in the model of “chess game” considered in this book below. This will require either the reversal of these decisions in time, or the change of the basic vector of technical equipment development, for which time is required. The variant is also possible, that the society will reproduce some technical possibilities and create unnecessary technical devices, not providing itself with better possibilities immediately. It occurs at institutions’ and local requirements' bidding. They cannot anticipate technical development, therefore they are satisfied with what technical experts, working at corporations or corresponding laboratories co-operating with universities and scientific centers, suggest. Scientific problem formulation presupposes several stages (priority or pioneer problem), but it is carried out on the basis of the accumulated and advanced knowledge because only experts in this sphere can accomplish the formulation itself. Dilettanti can only play the role of a science-fiction writer, that is, they can guess the formulation of the problem. And the problem formulation does not mean its solution. This refers to the problem of getting and control of thermonuclear energy. Only sometimes it is possible to

understand at once that this problem should not be solved, that it requires correction and different methods of solution. Sometimes there is no need in this solution, especially if a convenient and economically reasonable alternative is somewhere suggested.

Financial system and financial institutions together with institutional changes influence the development of science and technology greatly. Actually, it is the institutional changes process and a financial flow which is subordinated to the logic of financial institutions. They define monetary range of technical system development and the possibilities of its perfection and use. Different kinds of equipment, different kinds of research work assume different limits of this range. One research requires one minimal amount of finance, and it is good, if greater volume is received (the upper limit). The other one requires absolutely other minimal and maximal amount of financial and other resources. Thus, there appears the structure of financing and distribution of scientific and technical results.

It is possible to present the life cycle of new products (innovations) and new technical decisions in an absolutely different way, not as a stereotypic life cycle known due to the curve in marketing, but as a certain cyclic process. This process develops according to the scheme: idea (basic researches) - carrying out research and development (applied researches) - formation of production techniques (working out, acquisition) – obtaining the product (preproduction) – production itself, starting batch production - prospects estimation and further work either at the stage of the idea, or carrying out applied researches and technology perfection.

It is interesting to note, that the whole succession reflects the observed process, its certain logic and stylistics of technical development in the economy at all the times and each stage possesses a certain independence and self-sufficiency. Moreover, it is conducted by different organizations with different efficiency level, result estimation, different agents and, probably, even in different countries, if the design is borrowed, or borrowed with the purpose of improvement and perfection. In any case, each stage is regulated by its own rules, it demands necessary amount of finance (minimally necessary or maximum for the execution of such works as, for example, experimental testing or engineering development, etc). Thus, there is a financial stream distribution between these stages of technical development cycle. Saturation of each stage with the resources, including information and accumulated technological groundwork, means completeness of the cycle and increases the possibilities of scientific and technical development of the system. If at some stage there is a malfunction, for example, in financing, or appearance of the rules preventing motivation, or there are institutions which demotivate personnel and promote manpower drain, then there is a disproportion of equipment and technologies development. Competitive potential of the system decreases and there is a scientific and technical lag. Certainly, this cycle works at different personnel qualification, that is, all the activity in all the areas is a derivative of educational system, including the possibilities of training and augmentation of abilities and experience at the research firms and organizations (laboratories, institutions, scientific centers). Each cycle stage can be organized in its own way and have its own features in the given country. Such difference creates various possibilities in competition of results. The bank of these results provides further development. Reproduction cycle of new result in science, technics and technologies allows receiving results of various quality. Scientific and technical product and innovation are greatly differentiated products often having unique characteristics. The more the results are accumulated, the wider the combinatory and cumulative possibilities concerning their further change and augmentation are. Thereby, the achieved success in scientific-technological development creates preconditions for further development. It is also possible and useful to employ this succession for analysis of technical equipment and technologies development on long intervals. But it allows understanding the logic of this development, and not limiting the idea about the so-called technological revolutions by usual historical classification according to the periods, stating what is observed in historical retrospective review.[1]

It is possible to present the following chain of development “science-manufacture” (see the Figure).

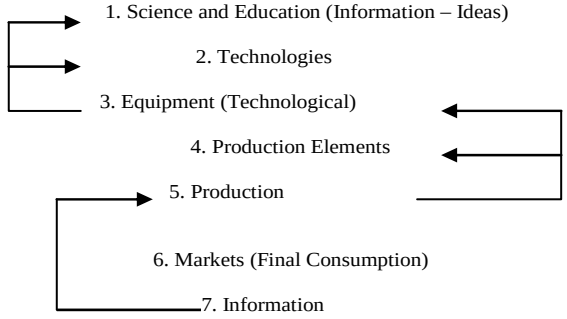

Figure. **The Logic of Industrial Systems Development.**

Science and education reproduce information and generate the ideas concerning the development of technologies for which the equipment is necessary. Demand for the equipment and the necessity of introduction of technologies of a certain class require the development of production elements. Together with production elements and using the available equipment it is possible to create industrial products and means of production which can be used for creation of consumer products. The next stage is delivery and sale of these products in the market, their final consumption and forming of information about future requirements and directions of further development. This information affects the change of production requirements, which, in turn, creates the necessity to change production elements and equipment. Then, the change of equipment will in time demand technology updating or replacement, or will demand to create new technology. That is also possible while moving from point 1 to point 2 without the influence of the so-called “market information” below on the scheme and then on the chain upwards (see the Figure). Thus, in essence the two processes modernize products, consumption, equipment and technologies. They are: 1) independently reproduced development of fundamental and applied exact sciences, which forms consumption and demand itself and is carried out by the researchers; 2) development on the basis of

[1] Such approach is used by K.Peres in his book “Technological Revolutions and Financial Capital”. – Author’s note.

information received from the markets, including information about the state of competitors' affairs which supposes the strategy of scientific and technical results replacement, adsorption and imitation. I would like to note specially, that these strategies are interwoven even for one agent, one corporation possessing several technical directions or several niches. To specify the basic content of the activity it is of importance to define the combination of the named processes in the total volume of the activity. Certainly, some separate agents cannot apply this or that behavior model at all for some time, being, for example, the leader of scientific and technical development in the given branch. Sometimes it is time long enough.

There are engineering fields where this cycle is rather conservative, that is, it is steady. Breakthroughs are hardly possible, or they are blocked by the state of knowledge on the problem. The same refers to the solution of individual technical problems, for example, gravitation creation at space stations with cosmonauts. The solution seems to have been a very important and necessary result, but at present it is almost impossible to get it technically and, probably, it is not economically reasonable. Thus, perfection is a constant process, and the so-called breakthrough is connected with reproduction intensification of some idea, engineering achievement and giving it a wide prospect. In my opinion, it is the essence of technical and economic dynamics. Moreover, modern correlation of technical and financial systems is such that financial system has its own internal development logic which differs greatly from the logic of technological systems functioning. It is this dual evolution of public system and institutions interaction stylistics generated by it which defines technological dynamics, many economic processes, and social development prospects.

If there is no rule which allow selecting, separating a second-rate technology from that of a grand master at the creation stage[1], then how pertinent it is to reveal allegedly existing regularity concerning the time of technological breakthroughs. Moreover, that the quality of each subsequent breakthrough may decrease because of knowledge saturation and possibilities of their technological application, or the resource restrictions connected with the characteristics of applied materials, despite the fact that new materials are created.

Technological expansion has a specific feature: it is always dependent on the past. Examples demonstrating the exception only prove the general rule. Here much depends on interpretation of the examples and estimation of the initial state of technical knowledge. Cardinal change of surfaces machining methods is hardly considered as usual technological change or technological revolution by the economists who are far from understanding technical equipment and its development laws. But in fact, if we calculate the economy of resources and durability and increase of operating life, we can consider it to be technological revolution.

Thus, breakthroughs in technology are prepared to this or that degree. And to define this degree is really important for understanding of social and economic development laws. It is interesting how this readiness changes and how the velocity of new knowledge appearance changes. But the most important thing is how it is applied in engineering sciences and technical equipment.

In each field of activity the chain mentioned has its own level of development. Therefore, the resources are distributed not only within the limits of the chain, but also between the kinds of activity. If at the products level there is a "compression" and negative information on the requirements, demand decrease appears owing, for example, to import analogues of better quality or cheaper ones, then at the production level and at the level of development and perfection of technology and equipment the motives change. The demand for ideas and scientific development is simply blocked. Therefore, during the crises the sphere of fundamental science and applied researches frequently suffers. If the researches are carried out in corporations' laboratories, they are reduced first of all. Though, such decisions depend on many factors.

The equipment and technologies form a system of rules. But institutional changes can also influence and they do influence the development of equipment and technologies and the rules which come into being under their impact. All these processes form a certain manufacturability level of economic system[2]. It is the manufacturability of the system that defines further possibilities of results augmentation, new combinations and their development. A new combination can be formed and invested, but, because of certain changes, resources deficiency or some other reason, it cannot be developed and it is replaced at once by newer combination or, in isolated cases, by the old combination. Here investment rules of a new combination are also important. Lack or reduction of necessary financing means cutting down the new combination, and there is no result. Later it may be used, but, probably, the firms and agents will pass to other kinds of activity. If there are several technological possibilities or innovations the question is which of them will be selected and by what criterion, or what part of the available variants will be realized. The decision depends both on the firm's scale, its specialization, possibilities to accumulate the investment, current state of the firm and the market, and assumptions regarding the preferences and their change. However, the firm can make the decision to create a new combination not at the expense of reduction or borrowing resources of previous production or technologies which it rejects, but at the expense of resources attraction and expansion. Not accidentally there are even theories of firms' growth as this growth presupposes firm expansion, concentration of capital, output diversification, product mix broadening, and involvement of new personnel. The output of previous production may not suffer at all. If so, there may be an explanation, that these resources are borrowed, transferred from other sectors and branches and taken from other firms. But they, in turn, can act in the same way. In this connection, there is no growth of a new combination for the account of the old one. Then what should be done with the specific resources? If we proceed from their presence and further specialization as the agent-firm develops, it is unlikely to transfer a part of

[1] Though, certainly, there are technical and economic parameters, which allow establishing the prospective advantages of one technology relative to another. But implementing technology these prospective estimations can come untrue.

[2] Sukharev O. S. Economy of Technological Development. - M: Finance and Statistics, 2008 - P. 55.

specific resources from the old combination to a new one without losses. Besides, it is important to note that, if at the level of a small system-firm the development of a new combination is possible, a product, in particular, at the expense of involving or creation of new resources, possibilities to attract them. The similar process is possible and even more probable for macroeconomic system which uses information-combinatory possibilities and high velocity of finance transfer more often.

These aspects were not considered in any way in the simple doctrine of life cycle called the doctrine of "creative destruction". In spite of the fact that this doctrine has become widespread among J.Schumpeter's followers, nevertheless, he was seriously and, in my opinion, fairly criticized even then by S.Kuznets and N.D.Kondratev. The former criticized the relationship of innovations and entrepreneurial abilities, especially the fact that the bundle of new combinations (innovations) is formed thanks to the concentration of entrepreneurial abilities. The latter said that it was improper to present economic statics and dynamics in the way J.Schumpeter had done it singling out one behavior model and putting his hope in it, like a horse in the races at the racecourse.

Imagine a firm which during crisis loses production of the previous product mix when demand falls. But it can stake everything starting a new project. It can launch the production of a new item hoping that sales of this new product will change its position. Two outcomes are possible. The first one: a new product will be a success and the second: the firm will not manage to realize a new combination successfully, and it will go bankrupt. However, in the course of time, it is possible to refuse this new project and transfer to previous stereotype production. The assertion that new combinations act as certain "creative destroyers" is incorrect, because thus linearly-unilateral connection between them is introduced which primitively interprets the true processes of technology development, and new products appearance, not conforming to the reproduction cycle of new scientific and technical results and the products, which are considered in this chapter.

In my opinion, the key to understanding of economic evolution in its true value is not its simple presentation as a change of innovative activity and technologies, but the disclosure of the reasons of "innovators" appearance and detailed explanation of the transformation mechanism of "an innovator" into "a conservative" and back. The analysis made in a number of my works result in considerable correction of Schumpeter's approach to economic evolution.

Functional changes are immanent content of technical systems evolution. It is connected with the progress in physics, chemistry, biology, engineering and medical sciences. At the same time, social system development, relations between the agents are also defined by the functional set which changes. Therefore, it is important to use the solution methods of design problems in the field of economic policy, institutional planning and management of various systems.

I consider examination of economic knowledge change and the degree they reflect the reality to be the main characteristic of the new evolutionary approach to the description of changes in economy, technologies and institutions. Besides, the use of this knowledge at decision-making and at formation of agents' behavior models is also very important. If the agents know the "prisoner's dilemma", they will use this model in their behavior which becomes more complicated, than in the description of the dilemma. Moreover, agents' behavior can transform the dilemma into impracticable model. That is, theoretical value of the design is lost because of the popularity of this model. To establish what is initial at the description of economic changes is difficult enough. It is not absolutely credible to ascribe these changes only to technical progress. Institutional changes gain independent value in this aspect. Besides, population growth, ecological changes, distributive impacts, channels of exchange, the structure of economy and its change have crucial influence on economic changes and on the content and possibilities of technological changes, scientific and technical progress. At least, these factors define the multiple-choice character of technological changes and predetermine the development trajectory: the choice of the model and the vector of scientific and technical development. Anyway, they strongly influence the problems statement, changes of requirements, possibilities to define these changes and to adapt to them. The second-rate decisions can get the upper hand over effective decisions, but thus the part of welfare is lost. Institutional changes and the changes in technical equipment and technologies change the kind of welfare criteria. (It will be discussed below.) I see the future of economic science in the ability to control these changes and plan them. Both financial, monetary institutions, organizational structures, functioning rules of economic subjects and the science itself are meant.

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