TECHNOLOGY AND CRISIS: A HISTORICAL RETROSPECTIVE OF QUANTITATIVE REFLECTION

ТЕХНОЛОГІЯ І КРИЗА: ІСТОРИЧНА РЕТРОСПЕКТИВА КІЛЬКІСНОГО ОПИСУ

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This article throws a quantitative spotlight on one separate part of a united qualitative picture of the economy, namely: the link of crisis with technical innovation. The passing from words to figures is not a trivial deed and the article claims to find the most adequate way regarding the proclaimed narrow scope.

It is proven here that the technologically determined factor of unavoidable temporal recession exists. This techno-factor is a cold hard fact in itself, not belonging to some school of economic thought or even to some field of science and at the same time influencing all them. The word 'factor' is used in this formulation instead of, say, 'cause' to make room for other, mainly avoidable, possible factors of recession such as financial and other discoordinations; and to take its own place in the recognized set of factors. A notion of "sinking" S-curve of development of the whole economy is also proposed in addition to the well-known S-shaped logistic curve of diffusion of a separate technology.

The results have turned out to be both an approval and disapproval of some established ideas, concepts, verbal descriptions, subconscious comprehensions and superstitions; and settled or mediated some disputes between the competing schools.

Забуте відкриття Рікардо про зв'язок криз з технологічними змінами доведене ним як на якісному, так і на кількісному рівнях, повернуто до сучасного наукового обігу. На цій основі надано кількісне тлумачення і прогнозування технологічно-інноваційного аспекту сучасних криз, упущеного внаслідок однобокої уваги до фінансового аспекту та до проблем втрати скоординованості.

1. HISTORY

The state of the art around crisis and the factor of innovation is as follows.

A leapfrog pattern of innovative progress is universally recognized in narrative descriptions.

Ricardo (1821) considered the case when "improved machinery is *suddenly* discovered".

Marx considered "radical change in the mode of production" (1867) or "decisive changes" (1878) and "revolution in the instruments of labour" (1867). He wrote that "The instruments of labour are largely modified all the time by the progress of industry. Hence, they are not replaced in their original, but in their modified form. On the one hand ...[there is a] reason for the only gradual pace of the introduction of new machinery... On the other hand competition compels the replacement of the old instruments of labour by new ones before the expiration of their natural life, especially when decisive changes occur. Such premature renewals of factory equipment on a rather large social scale are mainly enforced by catastrophes or crises." (1878).

Schumpeter (1942) formulated this as "the perennial gale of creative destruction".

Such paraphrases are also very common up to now, e.g. Rothaermel (2000): "Technological discontinuities" or Pérez (2002): "irruption of the technological revolution", "big revolutionary leaps in technology", "discontinuous leaps", "the real leap ahead" or "quantum jump in productivity".

After all, a mere common sense suggests that no manager would commit to change technology for a gain just percentage as much, but rather times as much.

At the same time, the link of crisis with just such leapfrog pattern of innovation has not been recognized by everybody, yet.

Marx recognized this, but indicated an opposite direction of causality. As it could be seen from the aforesaid quotation, in his opinion it is "catastrophes or crises" that enforce renewals of equipment, not vice-versa as it actually is.

Pérez (2002) recognizes this conditionally, that this aspect should be obligatory embedded within more general context. Regarding the Kondratiev wave, she criticizes "the attempt to confine the analysis ...within a narrowly defined economic system and to search for endogenous causes". "...waves are not economic cycles but a much wider systemic phenomenon where social and institutional factors play a key role". "The focus is shifted from economic measurement to the qualitative understanding... Moreover, the very occurrence of those big revolutionary leaps in technology has been explained here by a combination of economic pressures and social 'overadaptation'.".

Further, Pérez declares that she would not deal with "GNP or ...any other economic aggregate". Because the nature of fluctuations is deeper "and can only express itself in the inner workings of the economy". "After the irruption of the technological revolution, a divergence in trends would be observed" and "Whether the sum of these differing trends comes out as a 'downswing' or not depends on the changing relative growth rates". At that "it is not even likely that the ...process ...should lead to regular up and down trends in the economy as a whole". "Nor can prediction be made about the length or depth of the recession".

Here one cannot but agree with the need of a wide, systemic and holistic covering all the factors and with drilling down from the macro-level into the inner working of the economy. This articleonly specifies further the following.

Once new technology has emerged and only starts its diffusion through the economy, a prediction can be made whether techno-recession is going to take place within the diffusion process; and if so – its length. As to the depth of recession, it is controllable by the intensity of investment and capital accumulation, and by the trade-off between initial hardships and rewards of further higher growth. Consequently, if investment is predictable or even controllable, then the depth is predictable/controllable as well.

Such techno-factor of unavoidable recession works to some degree autonomously, as an objective phenomenon that would take place even under ideal financial capital, ideal social and institutional factors, and ideal behavior and psychical soundness of all the participants.

Still, as already underlined, it is fatal and unavoidable only as a downturn as such, not as an exact depth of it. So that although financial capital and all the other factors cannot prevent techno-recession as such, they can substantially influence the specifics of the procedure to alleviate it, not aggravate to an extent of Great Depression. Computatively, the situation of techno-recession manifests itself as an impossibility to thread a non-recession transition path to higher level of development. So that, within the latter context techno-recession is to some degree a not-autonomous one.

This also means that techno-recession is to some degree an endogenous one, in the sense that, it is determined by internal engineering and economic items.

All this reshapes the established comprehension of the character of interplay between factors and the casting of roles, so that it is quite possible that financial bubbles are pricked by real structural change.

Apart of those who are inclined to recognize the innovation-crisis link, some scientists do not recognize the link altogether. Here is the main point of disagreement with the Keynesians, e. g. Taylor (2011), who consider recessions as exeptions, deviations and detours from some right path, to be corrected by government, while the truth is, that, regarding the unavoidable techno-factor, recession is the right balanced path itself.

At the same time, the techno-factor continues to be under groundless attacks. This crisis "left no monuments to human invention, only piles of financial ruin" wrote Skidelsky (2009a,b). "The 'creative destruction' theory of boom and bust is no guide to today's economic turbulence" (Ibid.)

Ferguson (2010) is sure that "the big academic winners of this crisis have been the proponents of behavioural finance, in which the ups and downs of human psychology are the key" and that the opponents "have failed to learn from decades of economic research on expectations".

The mass consciousness believes that it is the financial disaster, which has affected the real economy. Even Pérez (2010) has reduced the role of technological revolution here to being "directly relevant to financial innovation". So, the techno-factor is overlooked or underestimated, while in this aspect the current "unique" crisis is quite typical and of the same nature as all the previous ones.

Returning to history. The idea of the possibility of innovation-crisis link ascends to Ricardo (1821, chapter On Machinery), who concluded that at introduction of machines a temporal decline of output and employment can take place, before whole society will enjoy all the advantages of higher productivity.

"All I wish to prove, is, that the discovery and use of machinery may be attended with a diminution of gross produce; and whenever that is the case, it will be injurious to the labouring class, as some of their number will be thrown out of employment" (Ibid). "But with every increase of capital he would employ more labourers; and, therefore, a portion of the people thrown out of work in the first instance, would be subsequently employed" (Ibid.).

By using words such as "may be" or "whenever that is the case", Ricardo had underlined that not all discoveries obligatory cause crises, but only some of them. At that, whether an innovation were fraught with unavoidable recession (whether it were "radical" enough) can be disclosed only by numerical analysis of the transition to its introduction.

Let us also notice, that Ricardo clearly attributed temporal recession to the beginning of introduction of machines, that is to the bust-boom sequence, in contrast to the boom-bust rhetoric being in fashion today.

These ideas are still literally valid until today, being reformulated and modified by many authors. In the Schumpeterian (1934) description they sound as follows: "As a rule the boom finally means a step in the direction of mechanizing the productive process and hence necessarily a diminution of the labor required per unit of product; and often though not necessarily, it also involves a diminution of the quantity of labor demanded in the industry in question in spite of the extension of production which occurs.".

Rothaermel (2000) declared in modern terms that "Not every innovation must necessarily lead to the destruction". Not a very happy notion of positive (negative) technological shock also contains some hints about this.

Balaguer (2009) expressed analogous thoughts more straightforwardly: "the most important moment occurs not in routine innovation, but in radical innovations. ...Crises ...the inevitable reverse side of the same coin".

As to numerical and analytical reflections of the aforesaid narratives and textual facts regarding economic development and technological leap, they could be divided in the explicit and the implicit traditions. The former being more fruitful, still set into oblivion, the latter belonging to the now-mainstream field.

The tradition of explicit numerical reflection of technological leap also ascends to Ricardo (1821), who underpinned his qualitative conclusions by explanatory numerical examples. Naturally, he focused on illustrating the recession-fraught new technologies, not the recession-safe ones. Below is his example of substitution of horses for men. Put instead of the word "horse" the word "machine" or "technology", and you would get an explanation of the phenomenon of Jobless Recovery in USA in the current "financial" crisis.

"If I employed one hundred men on my farm, and if I found that the food bestowed on fifty of those men, could be diverted to the support of horses, and afford me a greater return of raw produce, after allowing for the interest of the capital which the purchase of the horses would absorb, it would be advantageous to me to substitute the horses for the men, and I should accordingly do so; but this would not be for the interest of the men, and unless the income I obtained, was so much increased as to enable me to employ the men as well as the horses, it is evident that the population would become redundant, and the labourers' condition would sink in the general scale. It is evident he could not, under any circumstances, be employed in agriculture; but if the produce of the land were increased by the substitution of horses for men, he might be employed in manufactures, or as a menial servant."

This and other Ricardo's simplest numerical examples have two distinctive features:

– explicit considering separate characteristics of old and new technologies;

– focusing attention on the peculiarities of the transition from the old to the new. What occurs during the first transition year when "the capitalist employs half his men in constructing a machine", "but what would be the case the following year?" and so on.

These requirements of explicitness are crucial for numerical catching techno-recession, even though they seem so simple that the science might not put much thought into it.

Anyway, the most sophisticated modern quantitative schemes neglect this, whereby creating the weakest point that emasculates them from the opportunity to catch turning points of techno-recession, only smooth development trend being left. This in turn provoked an active search for a mysterious host of shocks that every now and then knocked off that trend.

And all this when the way of working of at least one of "shocks" had been discovered by Ricardo long ago and described in terms of new machinery, investment and the related hardships of accumulation of fixed capital imposed on the economy as a whole. The point is that the nature of those hardships of primitive accumulation holds for modern times albeit being not so painful.

In other words, sometimes the society as a whole is bound to sacrifice current welfare and redirect its efforts to accumulation of the potential for the sake of the future (that's another matter, that the unavoidable initial hardships could be distributed so unevenly, that some group might even improve its wellbeing).

"to elucidate the principle", Ricardo deliberately considered the extreme case of "*suddenly* discovered" and instantly implemented machinery, while he was aware about gradual character of implementation when the old and the new coexist until attaining saturation and full displacement of the former.

This affords to specify further that the manifestation of progress measured in averaged characteristics of all, old and new technologies mixed together has the form of gradual improvement of productivity, energy intensity, etc, notwithstanding the technological leap lying behind this gradualism.

Unfortunately, analyses of progress, confined within dealing with such data about gradual improvement of the averages, take dominance now. Moreover, that give birth to a purely gradualist way of thinking about development, the underlying leap being left lost beneath the averages.

The Ricardo's explicit direction was followed only in the 19th century by such scientists as Roscher (1854) and Böhm-Bawerk (1884) who proposed more complicated numerical examples compatible with the Ricardo's ones.

As to the Marx's (1878) Schemes of Reproduction, he considered an economy with unchanged technology, unlimitedly growing by accumulation of fixed capital fed by unlimited intake of additional labour, that is, the case was about a purely extensive growth. Only quite independent examples of different levels of progress were considered, the main feature of the progressive example being a higher weight of intermediate production (of Department I). At that, no consideration had been given to the issues of transition from old to new technology.

Kliman (2001) states "that Marx sought to explain how the transition from simple to expanded reproduction can occur", not a technological transition; and that Marx had shown "the expansion of means of production at the expense of consumption". All this is true, still such transition under technological statis is of doubtful practical importance.

So that, the main verbal curser of crises fell behind his predecessor Ricardo as to quantitative underpinning of his words.

Not less surprising is, that Schumpeter (1939), having partly repeated Ricardo into different words, partly supplemented him, left no underpinnings at all.

This vacuum has been filled by the aforesaid direction of divers implicit quantitative approaches.

In the over-aggregated Cobb-Douglass production function progress is reflected as a mere multiplier to the function, gradually growing.

Leontief, naturally, had started the construction of his renown technological coefficients as averaged characteristics of a static economy. Later Leontief *et all* (1977) passed to analysis and prediction of the dynamics, based on forward projections of his tables; and on this point he left a tradition, living until now, of dealing with projections of averaged coefficients (that is, anew, of reflection new technologies implicitly).

All such approaches belonging to the implicit tradition loose ability to catch techno-recessions due to excessive aggregation and do not consider this type of recession at all. They catch only general upward trends and resort to a variety of additional artificial shocks to compel their economies to fluctuate around those trends.

The only modern quantitative approach, which directly proclaims the techno-recession to be its object, is the Real Business Cycle theory (RBC), Warren (2012). The RBC is based on stochastic simulation method and has found stochastic dependence between technological and cyclical changes that might be interpreted as a stochastic proof of the existence of the technology-crisis link.

Nevertheless, the recent crisis has provoked a series of vigorous attacks against the RBC, e.g. Lord Eatwell declared that "the idea that what happened over the past two years has anything to do with a negative technological shock is nuts. ... It is ludicrous. There is no possible link, but this is what most economics undergraduates in this country are being taught", Simoney (2009).

Here takes place a confusion of the right idea and its poor analytical and numerical tractability, so that "the baby is thrown out with the bath water". The core of the problem is that it has not been yet fulfilled everything on the deterministic level to focus only on the stochastic one.

Regarding the RBC this article proposes to upgrade it by incorporating the techno-recession into the non-stochastic, deterministic part of the RBC's analysis, that is, instead of a mere trend to deal with a balanced development path already containing possible turning points of possible recessions. The goal is to widen the scope of deterministically explained fluctuations, resembling stochastic ones but not being them actually. After that, appropriately modified stochastic part could be overbuilt further.

Besides, on the first step only techno-factor could be taken into account, the preference between work and leisure also could be added further.

The notions of **recession-fraught** and **recession-safe** new technologies are proposed as looking a bit more adequate. The both are eventually positive, with the difference that the implementation of the former goes through an initial unavoidable negative phase. Such clarification affords to escape distorted and profaned perceptions of the idea of connection of crisis with technology as if the cause of booms and busts lay in good and bad technological changes.

The RBC closely relates to the Dynamic Stochastic General Equilibrium (DSGE) approach – now the main central banks' tool for forecasting and monetary policy analysis. So, analogous upgradings are proposed for the DSGE regarding enforcing ability to forecast the time of recessions deterministically, rather than dealing with probabilities of its advent.

It is astonishing that the DSGE model developed for the European Central Bank (ECB) includes 40 stochastic and deterministic parameters of 10 types of shocks, all these being brought into play for explanation of only 7 statistical macro data time-series, Smets and Wouters (2002).

Under such an abundance of degrees of freedom, there is no problem to calibrate parameters for any theory. Isn't it time to trim them with the Occam's razor. The way of disaggregating and drilling into the data looks more fruitful than piling up a reach variety of parameters over poor data.

Generally, the current situation in economic science regarding numerical and analytical reflections of technological leap and of crisis is a sort of an interjacent between implicit and explicit directions that might be characterized as "quasi-explicit".

On the one hand. Some statistical measurements of the height of productivity leap have been already fulfilled, e.g. Maliranta (2009). And some research groups already consider new technologies explicitly. Say, the theorists of Cambridge Multisectoral Dynamic Model of the British Economy (MDM), criticize the tradition where "Technological change ...represented as an exogenous trend" Barker (1987, 2009) and declare that in their analysis "capital is given an explicit empirical content". They consider at microlevel a "precise description of capital equipment", at that «technological change is represented as a menu of options... (commercially available, in development stages, technologically feasible)".

On the other hand. All these explicit and separate data are used only as a "row material" to determine the orthodox averages: "The projections of coefficients are based on the supply and use tables drawn from official sources and incorporate Cambridge Econometrics' view on expected technical and other changes". So that "addiction" to the tradition of averages has not been altogether overcome yet, and the MDM is still catches trend only.

Now, it is but a step to catch techno-recession as well: to commit a crucial passage from collection of explicit data to its also explicit use in the main calculations. This would provide the sufficient degree of disaggregation.

Apart of Cambridge Econometrics, explicit new technologies have been considered by Idenburg and Wilting (2000) and by Nishimura (2003) that also was fulfilled without catching techno-recessions.

As it could be derived from this overview, in fact, the main object here is not techno-crisis but techno-growth, where techno-recession might emerge as a side effect, undesirable but unavoidable temporary complication, a special case called a recession-fraught one.

An increased attention to such special case is understandable, but it should not overshadow that our main concern is growth and that the explicit approach is first of all an effective instrument of forecasting and planning techno-growth along with all the other phases of techno-cycle. At that, the intensity of investment and capital accumulation is first of all a determinant of the speed on growth phase, rather than of the depth on recession phase.

In principle, it is an easy matter to cause crisis just by disorders, discoordinations and imbalances. However, it is much more typical when all these avoidable, but importunate subjective factors accompany an unavoidable objective techno-factor; because, substantial real and financial structural changes in time of change always challenge the ability of the society to cope with complications.

Comparatively to competing explanations of crisis, techno-recession is the most economical version, that is, no special efforts is wasted for searching for shocks, and minimum initial assumptions are adopted. And according to the Occam's razor – the principle of succinctness – the simpler theory has more chances to be correct, and more complex competing theories should be put on the back burner, albeit not all of them are to be altogether rejected.

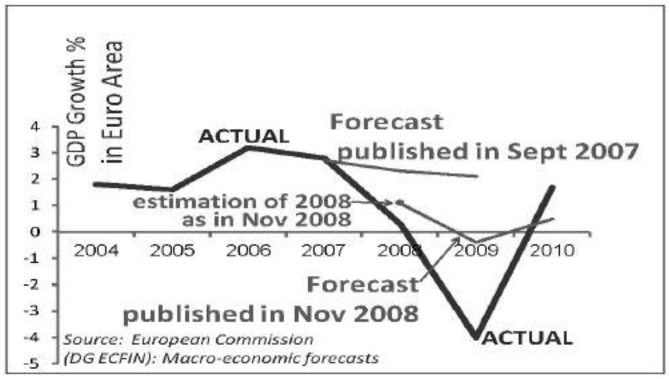
For example, the Keynesian version of recession as a decline of effective aggregate demand, literally meaning that the population had massively lost its appetite for food and manufactured goods, and refused to spend its money income, looks both more complicated and less plausible, than technological temporal decline under unchanged aspiration of people for the welfare.

The urgency of committing the final step to the explicit approach one could see from a poor ability of official and private forecasting teams to preview turning points of output, employment and other quantity indicators of real development. **Figure 1.1** shows this on an example of forecast of GDP growth in Euro Area, where the decline of 2009 had been "predicted" not earlier than it actually began. So, in the pre-crisis year of 2007 the official forecasts for 2008-2009 were a mere extrapolation of the previous actual data. In the end of 2008 the forecast for 2009 was 0,4% decline, while actual decline was tenfold deeper, of 4%.

Consequently, crisis forecasting/explanation mainly took the form of verbal prophesying and general warnings, e. g. "...there can be little doubt as to how such a process will end. But that it will end is a certainty, the only question is the exact date of the disaster", Prasch (2011).

Thus, the goal of this article is the following: – to revive and develop the Ricardo's forgotten tradition of explicit numerical reflection of new and old technologies and return it into the modern scientific circulation; – provide quantitative explanation and prediction of the turning moments of time regarding at least one aspect of crisis, namely, techno-recession (in other words – to incorporate

Fig. 1.1. **The EU forecasting services have problems with turning points**



turning points in balanced growth path, traditionally comprehended as a steadily upward movement).

For that, first, the potentials of the explicit reflection are disclosed on an explanatory numerical example of a typical recession-fraught situation based on works of Roscher (1854) and Böhm-Bawerk (1884). All the phases of an endogenous techno-cycle (initial techno-recession, consequent growth, overheating and stagnation) are illustrated in conjunction with investment and accumulation processes.

Second, this further is approved and detailed on an actual case of crisis.

2. GLOBAL FISHER-FOLK OF THE TWENTY FIRST CENTURY

«Suppose a nation of fisher-folk, ...dwelling naked in caves, and living on fish caught by the hand in pools left by the ebbing tide... and each man catches and eats three fish per day. But now one prudent man limits his consumption to two fish per day for 100 days, lays up in this way a stock of 100 fish, and makes use of this stock to enable him to apply his whole labour-power to the making of a boat and net. By the aid of this capital he catches thirty fish a day», Roscher (1854) cited by Böhm-Bawerk (1884).

Further Böhm-Bawerk's considerations are as follows: "Here the Physical Productivity of capital is manifested in the fact that the fisher, by the aid of capital, catches more fish than he would otherwise have caught—thirty instead of three. Or, to put it quite correctly, a number somewhat under thirty. For the thirty fish which are now caught in a day are the result of more than one day's work. To calculate properly, we must add to the labour of catching fish a quota of the labour that was given to the making of boat and net. If, e.g. fifty days of labour have been required to make the boat and net, and the boat and net last for 100 days, then the 3000 fish which are caught in the 100 days appear as the result of 150 days' labour. The surplus of products, then, due to the employment of capital is represented for the whole period by 3000 - (150 × 3) = 3000 - 450 = 2550 fish, and for each single day by 3000/150 - 3 = 17 fish. In this surplus of products is manifested the physical productivity of capital.".

As one could notice, Böhm-Bawerk had specified the Roscher's starting condition that 50 days of labour have been required to make the boat and net, and the life-length of a boat and net equals to 100 days.

This illustrative example had been used for those time disputes as to legitimateness of interest on capital. Now it will stand us in good stead for contemporary disputes as to macroeconomic impact of innovation including the phase of recession.

The only additional specifications: that the nation of fisher-folk amounts to 150 men/workers, and 1 boat-and-net, invented by "some clever savage", can be produced by 50 workers in 1 day.

The Steady state of the Fisher-Folk economy after having attained full maturity or saturation by the new technology and materialization of all the potential opened by the productivity leap (after attaining the highest upper ceiling afforded), when investment turns into a simple supporting the accumulated capital stock, is characterized by the following balanced indicators:

- 100 workers are employed in fishing, everybody being equipped with a boat and a net. They catch 3000 fish per day. Previously all the 150 workers were in this industry, from which a structural change in favor of boat and net making could be seen;
- 50 workers (33% of labor force) are employed in gross capital formation, producing 1 boat-and-net unit per day, that serves 100 days;
- labor productivity in the Fishing industry: 30 fish per day;
- per worker consumption: 20 fish per day (3000 fishes/1500 workers);
- labor productivity in the Boat and Net industry: 0,02 boat-and-net units (further called boats) per worker per day;
- capital stock: 100 boats;
- capital retirement because of wear and tear: 1 boat per day replaced by 1 unit produced;
- increase of average nation's welfare: plus 17 fish per day.

If a fish were accounted as a simplified proxy for money, then:

- gross income in the Fishing industry: 3000 fishes per day;
- net income in the Fishing industry: 2000 fishes per day (3000 fishes gross income minus 1000 fishes laid out for depreciation of the fixed capital);
- net income in the Boat industry: 1000 fishes per day (proceeds from 1 boat sold to the Fishing industry);
- total net income in the economy: 3000 fishes per day (2000+1000); total gross income 4000;
- level of savings out of net income: 33% (1000 fishes/3000 fishes), let's call such saving rate at a steady state a "steady" rate; level of savings out of gross income: 25% (1000/4000).

But for attaining such a prosperity of plus 17 fishes, boats in amount of 100 must be previously accumulated. The economy has to go through some transition path.

Although, the above shown upper ceiling of development under productivity leap afforded by the new technology is a unique one, a transition path to it is not unique at all.

The **main variant** corresponds to the case when the "steady" saving rate – 33% – is taken for determining the dynamics of the transition, see **Figures 2.1-2.3**. **Figure 2.1** simultaneously reflects both the dynamics of per worker consumption and of overall production of consumption goods, for amount of workers is constant. Figure 2.2 shows productivity leap between the old and new technologies (horizontal lines) and gradual average productivity growth along with gradual substitution of the old by the new. Noteworthy, that in parallel with the decline in fish output, no decline takes place as to productivity in the fishing industry, compare **Figures 2.1** and **2.2**, because the fish output decline is ascribed to the decline of labor engaged in fishing, that is redirection of structure of the nation's efforts in favor of boat output, see **Figure 2.3**.

At first, average per head consumption declines from 3 to 2 fishes per day, then it turns to growth, having restored the starting level on the 6th day, after the zero day, see **Figures 2.1** and **2.9**. The next ongoing growth is a process of gradual substitution of the old "hand" technology by the new "boat" one via investments. The growth process is undermined from the moment when the life-length of the first boat elapses, that is after 100 days from the beginning of diffusion of the new technology. From then on, 1 boat produced goes not for accumulation but for simple replacement of the retired one; the achieved steady state is also referred to saturation or upper ceiling, or stagnation.

Over-saved accelerated paths emerge when the saving rate is higher than the "steady" rate. Such dynamics are not so "highly disciplined" ones. **Figures 2.4-2.6** show this for the starting saving rate of 50%. The heightened saving means that in the production sphere more workers are to be initially engaged in boat making: 75 workers instead of the previous 50 workers, correspondingly declining the amount of fishers to 75 instead of 100, compare **Figures 2.1** and **2.5**.

This affords to arm the fishers more intensively, with 1,5 boats per day, and provide more quick growth, **Figure 2.4**. Soon all the 75 fishers have been set into boats and further growth becomes possible only by returning of some boat makers to fishing and reducing boat output, **Figure 2.5**. This means reduction of the saving rate and deceleration of growth, See **Figures 2.6** and **2.4**. But even though the steady state level has been exceed.

The turning point comes when the life-lengths begin to elapse. At that moment of the over-saved path, the amount of retired boats has exceeded the boat-producing capacity. Thus, the phase of **Overheating** means a temporary heightening over the steady level, which cannot hold for a long time. The main distinction between the initial recession and the recession after overheating is that the latter is caused only by structural adjustment not accompanied by productivity leap.

Then begins wavelike convergence to the steady state parameters with the wave-length corresponding to the capital's life-length: Kondratiev Waves, see **Figures 2.4-2.6**.

Fig. 2.1. **Dynamics of consumption per worker at the "steady" saving rate 33%**

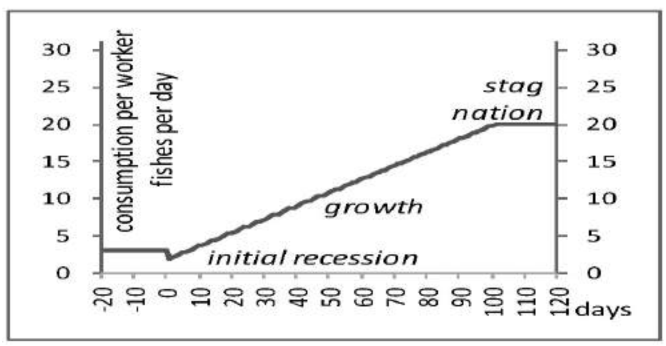


Fig. 2.2. **Productivity leap and dynamics of productivity growth in the Fishing Industry at the "steady" saving rate 33%**

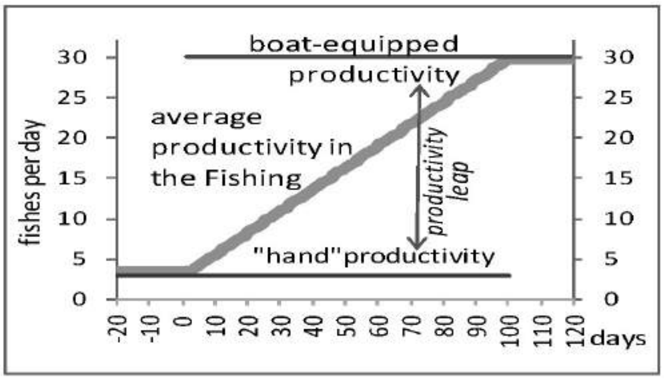


Fig. 2.3. **Dynamics of employment structure at the "steady" saving rate 33%**

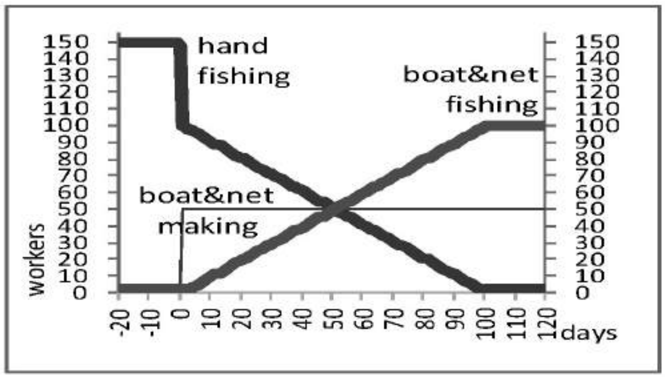


Fig. 2.4. **Dynamics of consumption per worker at the starting over-saving 50%**

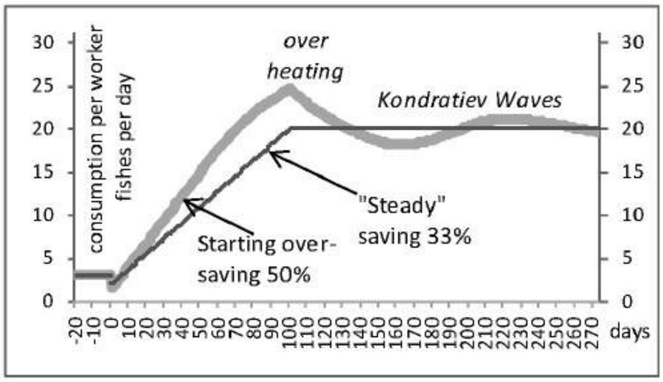
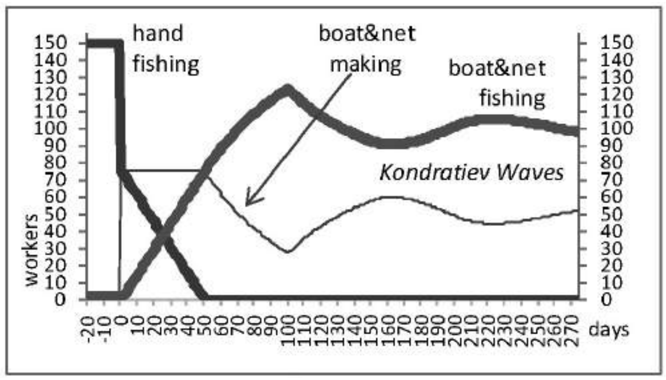


Fig. 2.5. **Dynamics of employment structure at the starting over-saving 50%**



Sub-saved decelerated paths emerge when the saving rate is lower than the "steady" rate. **Figures 2.7** and **2.8** show this for the initial saving rate of 10%. This means that fewer workers are initially engaged in boat making: 15 workers instead of the "steady" 50 workers, correspondingly increasing amount of fishers to 135 instead of 100, see **Figures 2.3** and **2.7**. Fishers are being armed with 0,3 boat per day, so that up to the beginning of the retirement the capital stock accumulated amounts to only 30 boats, 105 fishers still remaining boatless, **Figure 2.8**. If the same low saving rate persists, the economy "hangs" in stagnation at sub-level of sub-upper ceiling, Figure 2.7. Now further growth is possible only by intensifying saving. Figures 2.7-2.8 shows the variant when savings rise up to the "steady" rate 33%. This causes the "halfway" recession followed by growth lasting until attaining the highest possible upper ceiling as such, Figure 2.7.

A set of crucial periods of recessions considered above is shown in **Figure 2.9** in expanded scale display. As it could be seen: the lesser intensity of savings (of accumulation), the lesser the depth of recession at the expense of postponing the prosperity.

It is essential that all these cases of savings-accompanied-by-recessions are the situations when the society is bound to sacrifice current consumer production and redirect its efforts to accumulation of the potential for the sake of the future; and when the intensity of saving determines the intensity of structural change.

One can avoid the waves and halfway recessions by duly coordinated policies, but the initial temporary recession of overall welfare at the beginning of diffusion of new technology in such cases is unavoidable.

Such is the real, physical aspect of recessions and waves since the past epochs of the enclosure movement in England and other primitive capital accumulations and up to modern times, albeit not so severe for the latter, where it takes the form of a sort of "growing pains" and in fact is a modern non-primitive accumulation. The only way to avoid the unavoidable would be to "hang" in stagnation by doing nothing.

Let us also notice that in the fisher-folk economy the duration of the recession, the time required for restoring the pre-recession level, is constant, and does not depend from the intensity of investment, see point A in Figure 2.9. This affords to expect that something analogous also hold for real economies

Open catching-up economies could escape recessions by an inflow of foreign investments, if available, Germany and France are such early examples. But this option stays out of the global economy, taken in a whole, which is a closed one and has no external sources, except from the Martians might be.

Anyway, all transition paths tend to finish and stop on the steady state, thrusting into the upper ceiling. For further growth a steamboat is to be invented (then the economy would contain new and old types of capital).

Consequently, the dynamics of diffusion of the boat-technology shows a pattern of S-shaped logistic curve from emergence to saturation. Such S-shaped curve is very typical in reality, e. g. Walk (2012) has collected many factual evidences that just in this way cars substituted for horses (starting from the 1900); steam for sail and then motor for steam in the maritime propulsion world; networked personal computers for the stand-alone ones; latex for oil-based paints; fiber optic for conventional communications. The same shape logistic trajectory was followed at diffusion of supertankers, microprocessor chips, industrial energy conversion technologies, etc.

Walk (2012) proposes to take this fundamental trajectory for granted and directly organize predictions of the dynamics of technological performance as

Fig. 2.6. **Dynamics of saving at the starting over-saving 50%**

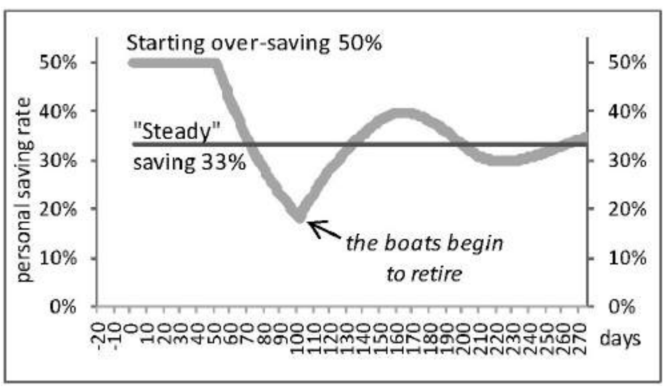


Fig. 2.7. **Dynamics of consumption per worker at the starting sub-saving 10%**

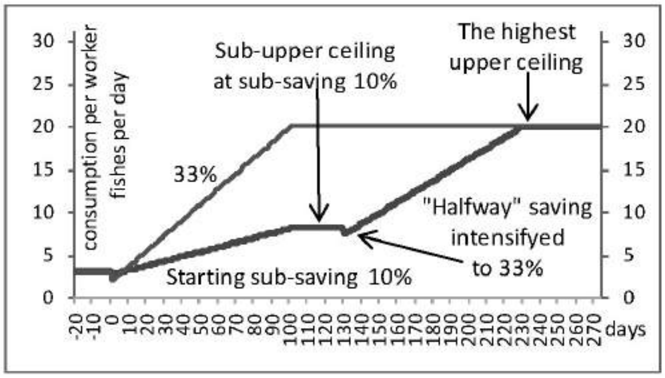


Fig. 2.8. **Dynamics of employment structure at the starting sub-saving 10%**

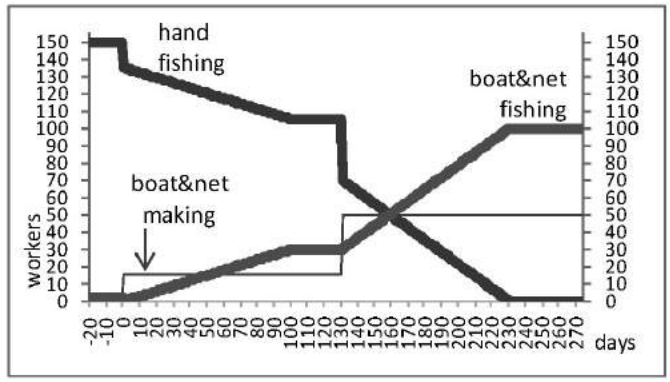
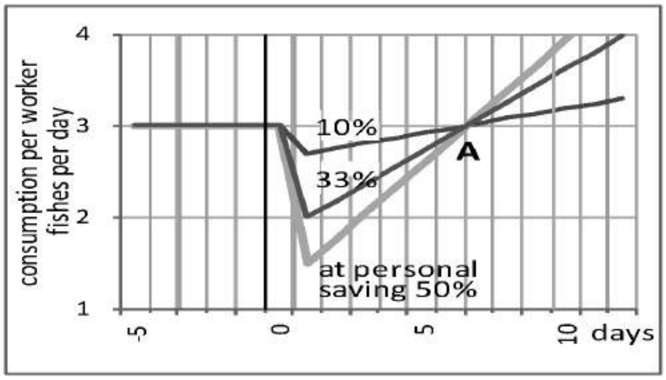


Fig. 2.9. **The higher saving, the deeper initial recession and the quicker next growth**



estimation of the parameters of the S-curve (the inflection point, midpoint, slope, saturation level).

Our example shows that such pre-assumption would become excessive if to take into account that the process of technology's implementation is a part of general growth of the whole economy. Such holistic view also affords to propose a notion of "sinking" S-curve of development of the whole economy, gradually co-opting new technology until ultimate embracing it; where by "sinking" is understood initial recession. At that, it is important that as to the example, the "sinking" trajectory of the whole takes place in parallel with the underlying "not-sinking" trajectory of the progressive boat-technology.

Almost continuous growth of actual economies is a relay of newer and newer technologies, where more new could advent even earlier than attaining saturation by less new, the latter turning into the old and might begin to retire even earlier than its life-length.

At that, it should be underlined that not all new technologies command an initial recession. Say, if manufacturing of a steamboat would require the same 50 workers per day, then the initial recession would be passed up. So that only the recession-fraught cases or situations of technical progress, requiring substantial efforts for initial accumulation, stipulate initial recession. As relentless reality proves us, these situations now and again repeat.

If only 0,5 worker were enough for handling a steamboat, then an involuntary unemployment would emerge, because job creation at launching a steamboat be less than job loss at quitting a boat. This is a **physical involuntary unemployment** connected with temporary physical absence of working places sufficient to absorb all the labor released.

Let us also notice that the variety of saving rates technically needed for investment at different phases reflects on the certainty with which private saving would be accordingly flexible to provide this technical need.

The great recession in the Fisher-Folk country described above implies some reconsiderations of the established pattern of growth accounting. Productivity leap should supersede the total factor productivity and all the like. And the role of benchmark should be taken over by the upper ceiling of development afforded by new technologies. Policy discourses, like "we are above or below the potential trend?" must turn into "we are above or below the ceiling?" or "how has the ceiling been pushed up by recent technological achievements?" and finally the main question: "whether all transition paths to the ceiling are fraught with recession?".

3. PASSING TO ACTUAL CRISES

The last "financial" crisis of 2008-2010 is deemed to be a unique one, still, its real indices are quite typical with the previous crises and carry all signs of existence of technology-determined real component of recession just as in the fisher-folk's economy.

First, crises do no harm to evergrowing labor productivity that at crises even accelerates, **Figure 3.1**. In the current Great Recession acceleration of productivity is so high that it has provided output recovery (in the US from the 3d quarter of 2009) earlier than recovery of employment. That is output of fewer workers is higher than of more workers somewhile earlier (the phenomenon of Jobless Recovery).

This might be seen even more clearly in terms of productivity of new productive units as opposed to the old ones, if the traditional statistics would not hide this leap beneath the averages. An analogous Jobless Recovery took place at the recessions of 2000-2001 and of the early 1990s in the US, as well.

Second, intensification of structural changes (of structural leap) at crises can be seen from intensification of occupational changes, **Figure 3.2**.

One should agree that it makes a great difference in what way unemployment has increased in 1 million persons: either when just 1 million lost their jobs; or when 6 million – lost, and 5 million – found. The latter witnesses labor mobility. At both recessions (on the early 1990s and on 2008-2010) in Figure 4.2 the graph of those who found new jobs strongly leaps. And only temporary advance of those who lose leads to temporary aggravation of unemployment.

Now, let us acquaint with more profound analysis of the recession of the early 1990s in the UK to make sure that the signs are not deceiving; and in addition – to demonstrate an importance of accounting for heterogeneity.

The simplest analytical tractability of the idea of explicit reflection (of the set-up of fisher-folk economics) already sufficient to catch actual declines of output and employment, is to implant explicit new and old technologies into the dynamic input-output framework. This is the first step forward, comparing with the traditional dealing with improvement of average technological coefficients.

Below is a meaningful outline of Ryaboshlyk (2006) and Рябошлик (2010). The explicit analysis of the early 1990s in the UK had been performed in the real terms, using 1992 basic prices. The whole economy had been divided in 13 industries. For lack of the required statistical data, it was resorted to rough estimations and proxies for the characteristics of the existing old technologies and the new ones being implemented along with investments.

The new technologies opened a potential of increasing labour productivity and decreasing power intensity and other efficiency parameters in each industry as follows.

Figure 3.3 shows productivity leap by industries. For example, in Mining and quarrying productivity became 2,5 times as large as with the old technology (plus 150%) apparently due to North Sea oil and gas fields. Average total productivity leap amounted to 30% that at once gave approximate potential of rising welfare.

Figure 3.4 shows changes in total intermediate inputs needed per unit of output. Under the new technology the group of production and construction industries require less intermediate consumption, which testifies energy and material saving (share of the intermediates in output of Agriculture decreased in a third, for Electricity, gas and water supply – in 2% and so on). And the opposite holds services and distribution industries. Say, share of intermediate consumption for Public administration and Education health and social work had roughly doubled and rose in 95 and 124% respectively. This could be explained as rising of quality of services due to using more medical technology, teaching aids, *etc*.

But at the same time such progress must be paid for by investments in new equipment and buildings. **Figure 3.5** shows capital-output intensity changes regarding equipment. A clear tendency to rising of efficiency of new equipment could be observed – the capital intensity had lowered almost in all industries except for non-market Public administration and over-computerised Financial intermediation.

The data was also collected about capital-labour ratio, capital stocks of the existing technologies and their age distribution, labour force, inventories, etc. Capital life-lengths ranged from 9 to 80 years.

The rising of efficiency of the new capital does not remove the problem of its accumulation, because initially it is absent. So that a task of search for the optimal transition path maximising consumption was set, specifically: to maximize the discounted sum of levels of personal consumption by years.

The remarkable result of these calculations is that under those characteristics of new and old technologies in the early 1990s there was no transition path to the new level of development that could escape the temporary initial recession at the beginning of diffusion of the new technology. To all efforts to thread a non-recession path, the computer's response was: "the solution does not exist".

Thus, it had been proved that the recession of the early 1990s had material, physical roots explained deterministically and connected with a quasi-negative technological leap.

Figure 3.6 shows the "Moderate" transition path, the most close to the actual dynamics, and corresponding to discount rates (showing to what degree the present is deemed to be more valuable than the future) in the range from 20% to 30%.

"Quick" over-saved paths of deeper initial recessions, with subsequent quicker growth and even overheating, had been generated under an assumption that to consume in the present is almost of the same value that in the future. These implausible, but theoretically feasible, options are not shown here.

As it can be seen in Figure 3.6, the explicit approach reliably predicts recessions and further growth as far as 5-6 year horizon, integrating short- and middle-run.

The essence of such forecasting capacity lies in watching and fixing the beginning of diffusion of new technologies and forecasting how this beginning will further proceed. At that, it is essential that all industries of the whole economy are to be encompassed.

In more distant years (the right part of the **Figure 3.6**) the forecast parts with the actuality and shows how would develop the economy of UK if next technological leaps detained and the development turned into stagnation (for Japan it was not only a supposing option in the period of 'lost decade').

Altogether, this wide-span forecast, generated due to the explicit approach, discovers the notion of a "sinking" S-curve of development of the whole economy gradually co-opting all the bundle of new technologies at hand. This is qualitatively different from the well-known traditional not-sinking S-curves of individual technologies constituting just this bundle.

One might suggest that the next technological leaps in the UK did come and they were not the quasi-negative ones, while the leap of 2008 was just of this type and at least partly "guilty" for that recession.

4. HETEROGENEITY IS ESSENTIAL. CLOSING THE QUESTION PUT BY NOBEL PRIZE WINNER PISSARIDES

It is quite reasonable that along with the output decline, the forecast of aggravation of structural unemployment had been provided as well. That is the situation when the amount of new capital is not yet sufficient to absorb all the labour released from old technologies. As for frictional unemployment, which occurs upon leaving one job and before starting another, and which is much lower, it was accounted as an endogenous data.

Firstly, unemployment was forecast under assumption that the amount of labour released from old technologies is directly proportional to the contraction of output. Even that already afforded to catch a general pattern of the unemployment dynamics, see **Figure 4.1**.

Fig. 3.1. **At crises productivity accelerates**

Moreover, further sophistication had been achieved after accounting for that output contraction releases the labour with the lowest productivity, preserving the most productive labour, so that a reduced amount of output requires relatively less amount of labour. Thus, contraction of output causes relatively higher layoffs in the nonlinear variant, than could be expected from applying the strict linear dependence. Indeed, as Figure 4.1 shows the nonlinear variant had generated less optimistic, higher unemployment than the previous linear one, being much more close to the actual data.

It so happened that Nobel Prize winner Pissarides (2006) had analyzed the same unemployment time series in the terms of "short-term fluctuations" around the smoothed trend or "natural unemployment". At that he doubted: "whether the deviation is the cyclical component is open to question".

The above analysis had closed this question and showed that this did be the technology-determined cyclical movement.

Thus, Explicit approach explicitly deals with recessions of output and employment, rather than with a probability of their advent. And it is shown on an actual case that this framework is already workable even at very rough estimations of the basic data.

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Fig. 3.2. **The leaps of occupational changes at crises are the signs of structural changes**

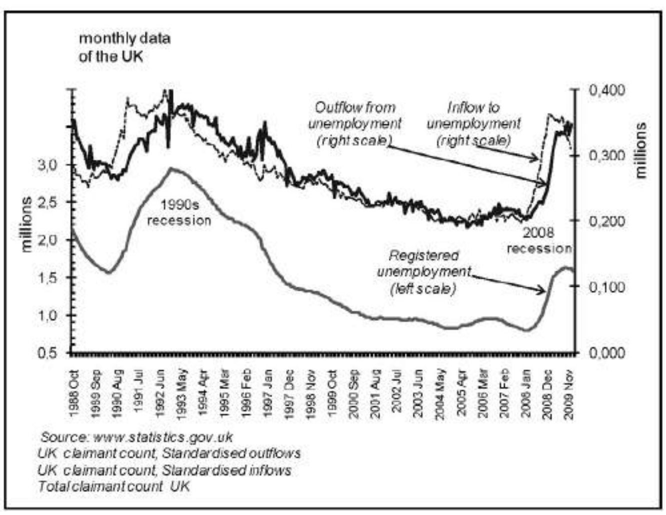

Fig. 3.3. **Labour productivity leap provided by new technology by Industry**

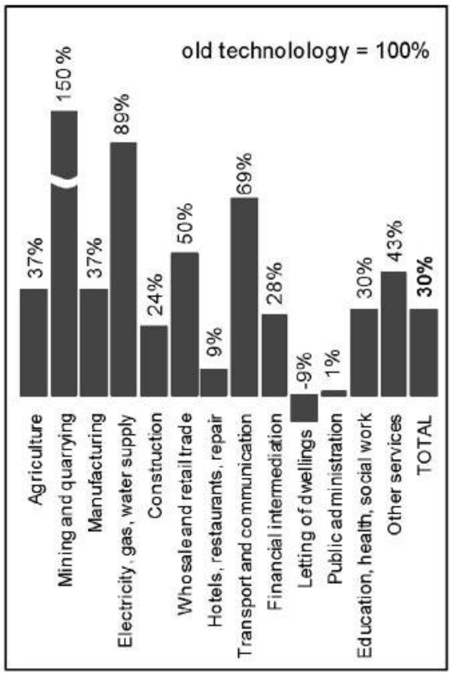

Fig. 3.4. **Change of total intermediate consumption by industry**

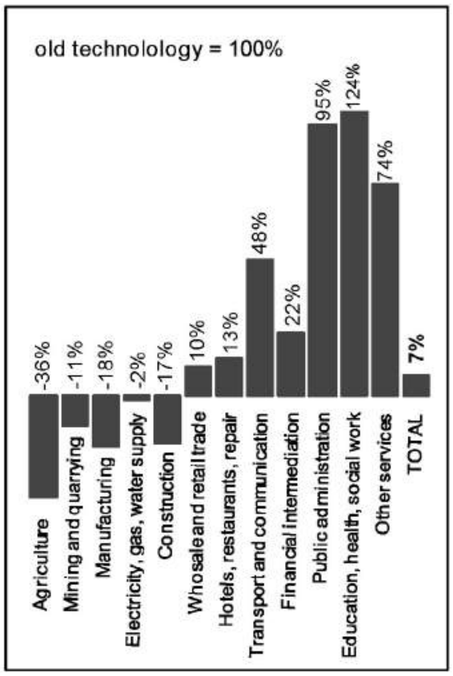

Fig. 3.5. **Capital-output intensity changes regarding equipment**

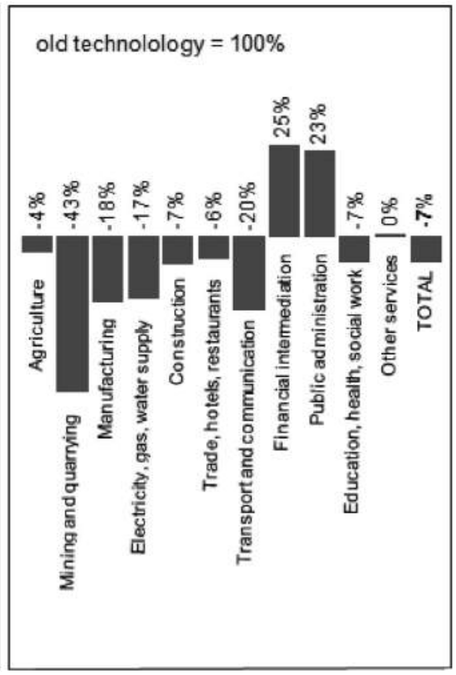

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Fig. 3.6. **Forecast of output in the UK**

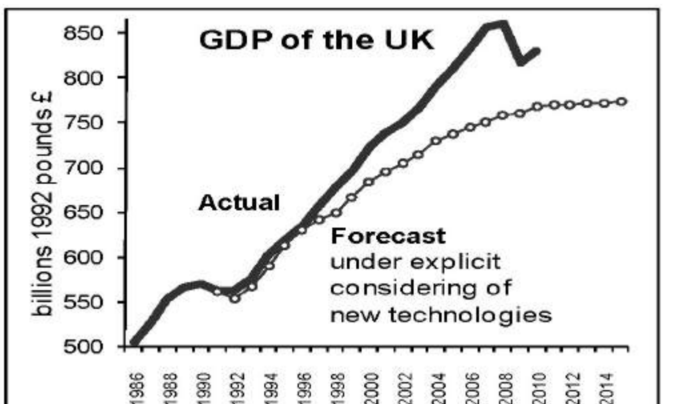

Fig. 4.1. **Linear and nonlinear forecasts of unemployment in the UK**