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Life Cycle of the Centrally Planned Economy: Why Soviet Growth Rates Peaked in the 1950s[1]

ABSTRACT

The highest rates of growth of labor productivity in the Soviet Union were observed not in the 1930s (3% annually), but in the 1950s (6%). The TFP growth rates by decades increased from 0.6% annually in the 1930s to 2.8% in the 1950s and then fell monotonously becoming negative in the 1980s. The decade of 1950s was thus the "golden period" of Soviet economic growth. The patterns of Soviet growth of the 1950s in terms of growth accounting were very similar to the Japanese growth of the 1950s-70s and to Korean and Taiwanese growth in the 1960-80s – fast increases in labor productivity counterweighted the decline in capital productivity, so that the TFP increased markedly. However, high Soviet economic growth lasted only for a decade, whereas in East Asia it continued for three to four decades, propelling Japan, South Korea and Taiwan into the ranks of developed countries.

This paper offers an explanation for the inverted U-shaped trajectory of labor productivity and TFP in centrally planned economies (CPEs). It is argued that CPEs under-invested into the replacement of the retiring elements of the fixed capital stock and over-invested into the expansion of production capacities. The task of renovating physical capital contradicted the short-run goal of fulfilling plan targets, and therefore Soviet planners preferred to invest in new capacities instead of upgrading the old ones. Hence, after the massive investment of the 1930s in the USSR, the highest productivity was achieved after the period equal to the average service life of fixed capital stock (about 20 years) – before there emerged a need for the massive investment into replacing retirement. Afterwards, the capital stock started to age rapidly reducing sharply capital productivity and lowering labor productivity and TFP growth rates.

[1] This paper was initially presented at the AEA conference in Boston in January 2006.

1. Introduction

In the second half of the 20th century the Soviet Union experienced the most dramatic shift in economic growth patterns. High post-war growth rates of the 1950s gave way to the slowdown of growth in the 1960s-1980s and later – to the unprecedented depression of the 1990s associated with the transition from centrally planned economy (CPE) to a market one. Productivity growth rates (output per worker, Western data) fell from an exceptionally high 6% a year in the 1950s to 3% in the 1960s, 2% in the 1970s and 1% in the 1980s. In 1989 transformational recession started and continued for almost a decade: output was constantly falling until 1999 with the exception of one single year – 1997, when GDP increased by barely noticeable 0.8%. If viewed as an inevitable and logical result of the Soviet growth model, this transformational recession worsens substantially the general record of Soviet economic growth.

The nature of Soviet economic decline from the 1950s to 1980s does not fit completely into the standard growth theory. If this decline was caused by the over-accumulation of capital (investment share doubled in 1950-85 from 15% to over 30%), how could it be that Asian countries were able to maintain high growth rates with even higher share of investment in GDP and higher growth of capital/labor ratios?[2] Why in the 1980s, as the conventional saying held it, the Soviet Union maintained the Japanese share of investment in GDP with very "un-Japanese" results? If, on the contrary, the Soviet growth decline was caused by the specific inefficiencies of the centrally planned economy, why CPE has been so efficient in the 1950s, ensuring high growth rates of output, labor productivity and total factor productivity? In the 1950s the Soviet defense spending was already very high and rising (from an estimated 9% in 1950 to 10-13% by the end of the decade), whereas Soviet investment spending, although increased markedly, was still below 25% by 1960. Medium-high share of investment spending and very high share of defense expenditure is not exactly the kind of combination that could account for high productivity growth rates even in market economies.

[2] In China and some Southeast Asian countries high growth still coexists with high investment/GDP ratios. Chinese growth rates stayed at close to 10% a year for nearly three decades (1978-2005); the share of investment in GDP during this period increased from 30% in 1970-75 to nearly 50% in 2005 (Wang, Yan and Yudong Yao, 2001; China Statistical Yearbook) .

2. Growth accounting for the USSR

For decades Soviet experience with economic growth was a textbook proof of the "disease of over-investment" resulting in the declining factor productivity. It was even referred to as the best application of the Solow model ever seen. Most estimates of Soviet economic growth found low and declining TFP (in the 1970s–1980s TFP was even negative) suggesting that growth was due mostly to large capital and labor inputs and in this sense was extremely costly.

More recently, parallels have been made between East Asian and Soviet growth. Krugman (1994), referring to the calculations by Young (1994), has argued that there is no puzzle to Asian growth; that it was due mostly to the accelerated accumulation of factor inputs – capital and labor, whereas TFP growth was quite weak (lower than in Western countries). The logical outcome was the prediction that East Asian growth is going to end in the same way the Soviet growth did –over-accumulation of capital resources, if continued, sooner or later would undermine capital productivity. It may have happened already in Japan in the 1970s - 1990s (where growth rates declined despite the high share of investment in GDP) and may be happening in Korea, Taiwan and ASEAN countries after the currency crises of 1997. The only other alternative for high growth countries would be to reduce the rates of capital accumulation (growth of investment), which should lead to the same result – slowdown in the growth of output. Radelet and Sachs (1997), however, challenged this view, arguing that East Asian growth is likely to resume in two to three years after the 1997 currency crises.

A different approach (based on endogenous growth models and treating investment in human capital as a separate source of growth) would be that in theory rapid growth can continue endlessly, if investments in physical and human capital are high. According to this approach, all cases of "high growth failures" – from USSR to Japan - are explained by special circumstances and do not refute the theoretical possibility of maintaining high growth rates "forever". The logical "special" explanation for the Soviet economic decline would be of course the nature of the CPE itself that precluded it from using investment as efficiently as in market economies.

To what extent the Soviet economic slowdown was caused by the specific CPE factors and to what extent it reflected the more general process of TPF decline due to the over-accumulation of capital? Gomulka (1977), Bergson (1983), Ofer (1987) and others using Cobb-Douglas production function attributed the slowdown in growth rates to the very nature of the extensive growth model, where the contribution of technical progress to growth was small and falling in line with the accumulation of capital. Weitzman (1970), Desai (1976), however, pointed out that another explanation is also consistent with the stylized facts, namely constant rates of technical progress, but low capital/labor substitution (CES – constant elasticity substitution – production function) leading to declining marginal product of capital. The debate about the most appropriate form of the production function is summarized in Offer (1987), Easterly and Fisher (1995), Schroeder (1995), Guriev and Ickes (2000).

Easterly and Fisher (1995) argue that Soviet 1950-87 growth performance can be accounted for by a declining marginal capital productivity with a <u>constant</u> rate of growth of TFP. They show that the increase in capital/output ratio in the USSR was no higher than in fast growing market economies, such as Japan, Taiwan, Korea (table 1). The reason for poorer Soviet performance is seen in low elasticity of substitution between capital and labor that caused a greater decline in returns to capital than in market economies. In this case, however, the question of interest would be why exactly the elasticity of substitution was low and whether this low level is related to the nature of the planning system. The recent endogenous growth models suggest that physical, human and organizational capital can substitute for labor virtually without limits.

Besides, there is still no exhaustive explanation for the “golden period” of Soviet growth of the 1950s, when output per worker was growing at about 6% a year both – in industry and in the economy overall, while capital per worker was increasing by 3.9% and 7.4% respectively. An explanation of Soviet economic growth based on low elasticity of capital/labor substitution, has to point out to factors that accounted for the dramatic decline in returns to capital from the 1950s to the 1980s.

Table 1. Growth in the USSR and Asian economies, Western data, 1928-87 (average annual percent)

Period/ country	Output per worker	Capital per worker	Capital/ output ratio	TPF growth (unit elasticity of substitution)	TPF growth assuming 0.4 elasticity of substitution
USSR (1928-39)	2.9	5.7	2.8	0.6	
USSR (1940-49)	1.9	1.5	-0.4	1.3	
USSR (1950-59)	5.8	7.4	1.6	2.8	1.1
USSR (1960-69)	3.0	5.4	2.4	0.8	1.1
USSR (1970-79)	2.1	5.0	2.9	0.1	1.2
USSR (1980-87)	1.4	4.0	2.6	-0.2	1.1
Japan(1950/57/65/-85/88/90)			2.3 - 3.2	1.7 - 2.5	
Korea (1950/60/65-85/88/90)			2.8 – 3.7	1.7 - 2.8	
Taiwan (1950/53/65-85/88/90)			2.6 – 3.1	1.9-2.4	

Source: Easterly, Fisher, 1995.

3. Why the elasticity of capital-labor substitution was low in centrally planned economies?

A plausible explanation for low capital/labor substitution may be associated with the inability of the centrally planned economy (CPE) to renovate obsolete capital stock as quickly as the market economy does. It is well documented that in CPEs actual service life of fixed capital stock was long, retirement of machinery and equipment and buildings and structures was slow and the average age of equipment was high and growing (Shmelev and Popov, 1989).

Typically in the USSR the service lives of machinery and equipment, buildings and structures were very high, and the retirement rate, respectively, very low. In industry in the 1980s it was just 2-3%, as compared to 4-5% in U.S. manufacturing for all capital stock, and 3-4%, as compared to 5-6% in the U.S. manufacturing, for machinery and equipment. Consequently, the major part of gross investment was used not to replace the retiring capital stock (since retirement was low), but to expand it. While in the U.S. manufacturing 50-60% of all investment was replacing retirement, and only 40-50% contributed to the expansion of capital stock, in Soviet industry the proportion was reversed: replacing the retirement required about 30% of gross investment, while over 70% contributed to the expansion of capital stock or to the unfinished construction.

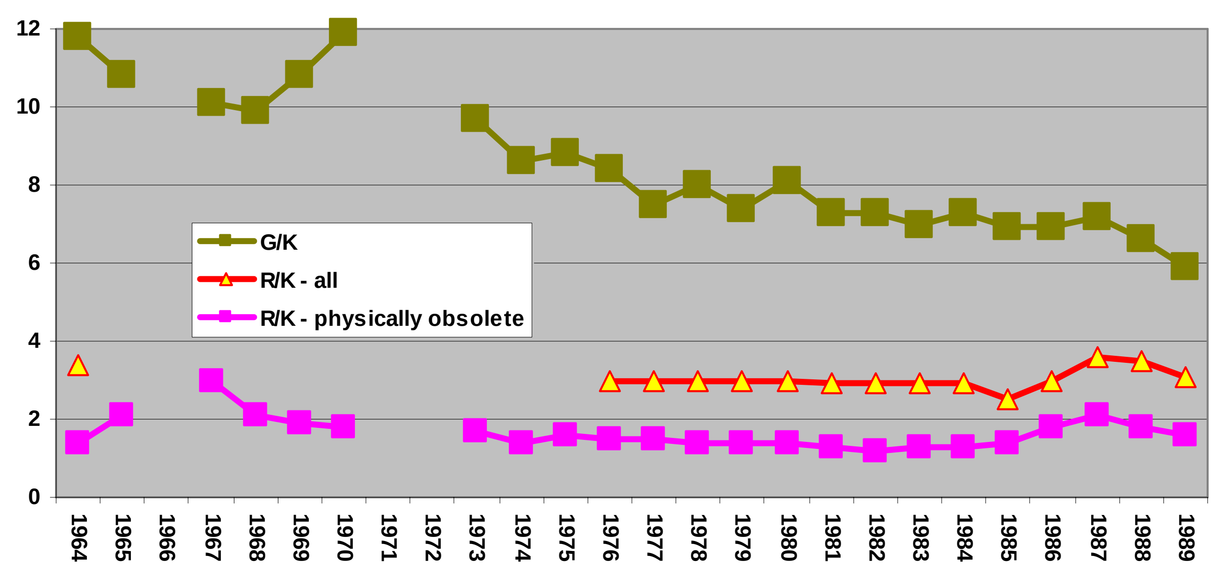
The production capacities were brought into operation mostly through the construction of new and the expansion of existing plants, not through reconstruction of old capacities: of 16 types of capacities, on which data are available, in 15 cases the share of those capacities brought into operation through reconstruction of the old ones was lower than 50% over the whole period of 1971-1989; the unweighed average indicator of the share of reconstructed capacities was just 23% (*Narodnoye Khozyaistvo SSSR* for various years).

The reason for massive investment in the expansion of capital stock at the expense of investment to replace retirement was the permanent concern of Soviet planners about expanding output and meeting production quotas. Replacing worn out aged machinery and equipment usually required technical reconstruction and was associated with temporary work stoppage and reduction in output. Even if the replacement could have been carried out instantly, the resulting increase in output (because of greater productivity of new equipment) was smaller than in case of the construction of new capacities or the expansion of existing capacities: in the latter case there was a hope that the new capacities would have been added to the existing ones that will somehow manage to operate several more years.

Aged and worn out equipment and structures were thus normally repaired endlessly, until they were falling apart physically; capital repair expenditure amounted to over 1/3 of annual investment. The capital stock meanwhile was getting older and was wearing out, the average age of equipment and structures increased constantly.

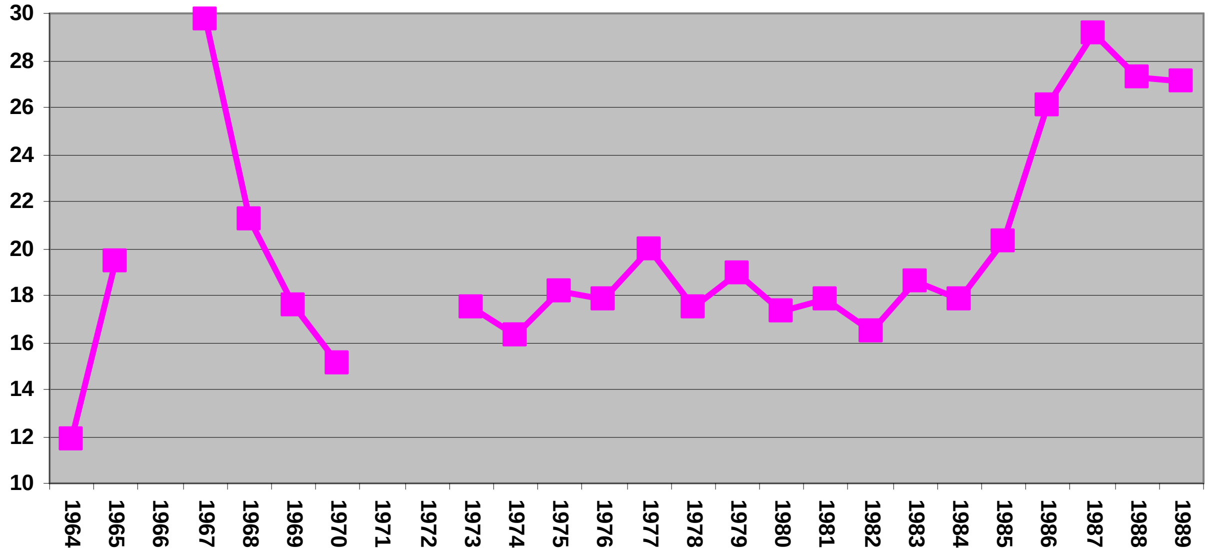
The official statistics suggest that the share of investment into the reconstruction of enterprises (as opposed to the expansion of existing and construction of new enterprises) increased from 33% in 1980 to 39% in 1985 to 50% in 1989 (Narkhoz, 1989, p.280), but this is not very consistent with the other official data. For instance, the retirement ratio in Soviet industry was not only very low (below 2% and about 3% respectively for the retirement of physically obsolete and retirement of all assets), but mostly falling or stable in 1967-85 (see fig. 1). Only in 1965-67 (right after the economic reform of 1965) and in 1986-87 (acceleration and restructuring policy) there was a noticeable increase in the retirement rate.

Fig. 1. Gross investment and retirement in Soviet industry, as a % of fixed capital stock



The share of investment to replace retirement in total gross investment also stayed at an extremely low level of below 20% for the most part of the 1960s-1980s; only in 1965-67 and in 1985-87 there were short-lived increases in this ratio – up to 30% (fig.2).

Fig. 2. Share of investment to replace retirement in total gross investment in Soviet industry, %



Besides, accumulated depreciation as a percentage of gross value of fixed capital stock (gross value minus net value, divided by gross value) grew from 26% in 1970 to 45% in 1989, and in some industries, such as steel, chemicals and petrochemicals, exceeded 50% by the end of 1980s. The average age of industrial equipment increased from 8.3 to 10.3 years in the 1970s-1980s, and actual average service life was 24-28 years (as compared to a 13 years period, established by norms for depreciation accounting). The share of equipment over 11 year old increased from 29% in 1970 to 35% in 1980 and to 40% in 1989, while the share of the equipment used for 20 years and over - from 8 to 14% (table 2).

The planners' reluctance to modernize existing plants and heavy emphasis on new construction - a policy that was supposed to increase output as much as possible, in the long run led to the declining capital productivity. Capacity utilization rate in Soviet industry was falling rapidly, although official statistics registered only a marginal decrease (Shmelev and Popov, 1989; Faltsman, 1985; Valtukh, Lavrovsky, 1986). Growing "shortages" of labor force during the 1970s-1980s may be regarded as a sign of an increasing share of unloaded production capacities. On the whole, as was estimated by a *Gosplan* specialist, the excess capacities, not equipped with labor force, constituted in late 1980s about 1/4 of all capital stock in industry and 1/5 of capital stock in the entire economy. In the mainstream production of all industrial plants 25% of jobs were vacant, while in the mainstream production of machine-building plants - up to 45%. In machine-building there were only 63 workers per every 100 machines. The number of these machines exceeded that in the U.S. by a fraction of 2.5, yet each Soviet machine was actually operating twice less time in the course of a year than the American one (Shmelev and Popov, 1989). Meanwhile, the shift coefficient (number of shifts a day) in Soviet industry declined from 1.54 in 1960 to 1.42 in 1970, to 1.37 in 1980, and to 1.35 in 1985 (Narkhoz, various years).

Table 2. Age characteristics of equipment in Soviet industry

Years	1970	1980	1985	1989
Share of equipment with an age of: - less than 5 years	41.1	36.0	33.7	31.6
- 6-10 years	29.9	28.9	28.5	28.6
- 11-20 years	20.9	24.8	25.5	26.2
- over 20 years	7.8	10.3	12.3	13.7
Average age of equipment, years	8.3	9.31	9.91	10.32
Average service life, years	24.0	26.9	27.9	26.2
Accumulated depreciation as a % of gross (initial) value of capital stock	26	36	41	45

Source: *Narodnoye Khozyaistvo SSSR* (National Economy of the USSR) for various years.

It may seem that the whole problem of under-loaded production capacities, or rather "the shortage of the labor force", as it was usually referred to by Soviet planners, had a simple and feasible solution, especially in the centrally planned economy. To resolve the whole issue of labor shortage, it was necessary to cut the investment in new plants and equipment, increasing the investment in the replacement of obsolete capital stock. Because this type of structural maneuver involved the change of macroeconomic (not microeconomic) proportions, it may seem that it could have been carried out quite easily in a directively planned economy.

However, as was already mentioned, excess investment in new construction resulted not from mismanagement, but from the very idea of directive planning carried out through setting the production quotas and oriented towards constant increases in output. Shortages were inevitable in such a system and resulted from disproportions created through central planning almost by definition, while capital investment were regarded as a major mean of eliminating the bottlenecks resulting from shortages. So capital investment was diverted to create new production capacities that would have allowed expanding production of scarce goods. The whole planning procedure looked like an endless chain of the urgent decisions forced by emergency shortages of different goods that manifested themselves quicker than the planners were able to liquidate them.

This was a sort of a vicious circle, a permanent race, in which decisions to make capital investment were predetermined by existing and newly emerging shortages. It turned out, therefore, that any attempts to cut the investment in new plant and equipment led to increased distortions and bottlenecks, resulting, among other things, in the lower capacity utilization rate, while the increased investment in the construction of new production facilities contributed to the widening of the gap between job vacancies and the limited supply of the labor force, also causing the decline in the capacity utilization. Under central planning, unfortunately, there was no third option.

As a result, the CPE with the inherent and unavoidable low capital/labor elasticity trap was doomed to survive through a life cycle linked to the service life of fixed capital stock. Assuming the service life of capital stock is about 20 years, in the first 20 years of the existence of the CPE the construction of new modern production capacities led to rapid increases of labor productivity even though the capital/output ratio rose. In the next 10 years production capacities put into operation 20 years earlier started to retire physically, which contributed to the slow down of the growth rates, but was compensated by the continuing expansion of fixed capital stock. After 30 years of the existence of the CPE, it entered the stage of the decline: over half of the capital stock was worn out and falling apart (but not completely replaced), while the newly created production capacities were just barely enough to compensate for the decline in output resulting from aging of the capital stock.

To summarize, low elasticity of capital/labor substitution is the intrinsic feature of the CPE because it is oriented towards the expansion of the capital stock at the expense of the replacement of the retirement. Such an investment strategy can produce best results in the first 30 years (a period equivalent to 1.5 times service life of capital stock), but later inevitably leads to a rapid decline in capital productivity. Viewed in such a way, CPEs, despite all their inefficiencies and high costs of growth, can support reasonable growth rates, but only in the first several decades of their existence – for the Soviet Union, where the CPE emerged in the early 1930s after the roll back of New Economic Policy, this was probably a period until the 1960s. Later the CPE is doomed to witness a severe decline in capital productivity associated with the aging of fixed capital stock.

There are papers that consider the low ability of the CPE to replace retirement as the important stylized fact; it is used in the theoretical models of the CPEs to explain particular features of their performance. Ickes and Ryterman (1997) demonstrate that in the absence of the mechanism of exits of firms inefficient enterprises will tend to be allocated less resources than efficient ones and that this will generate an industrial structure that is bi-modal in nature, one in which inefficient enterprises agglomerate at one end of the size spectrum and efficient enterprises agglomerate at the other end. Iacopetta (2003) explains the gap between high level of research and inventions in the CPEs and poor innovation activity and performance by the perverse Soviet managerial compensation system, which generated incentives for the managers to perform only a modest retooling activity out of fear of breaking the production norm that the planner imposed upon the firm.

In this paper the same stylized fact (inability of the CPE to properly replace retiring elements of capital stock) is used to explain cyclical patterns of growth of TFP in a planned economy and the life cycle of CPE.

4. Effects of low investment to replace retirement: numerical example

Consider an economy with growing gross investment, $G(t)$, that exceeds the retirement of fixed capital stock, $R(t)$, and so is partly used to expand the existing capital stock by the amount equal to net investment, $I(t)$. Retirement of fixed capital stock, in turn, is equal to investment made m years ago, where m is the service life of capital equipment:

$$G(t) = R(t) + I(t),$$
$$R(t) = G(t\text{-}m).$$

This is a set up of the Domar model (Domar, 1957) that assumes constant rates of growth of gross investment and shows that in the growing economy depreciation, equal to capital stock divided by the average service life, $D(t) = K(t)/m$, is larger than retirement, $R(t) = G(t\text{-}m)$, so that the future growth of capital stock can be financed from part of depreciation that exceeds retirement, i.e. future growth can build up on the previous growth, so that the economy can remain in the growth equilibrium, even if all profits are consumed and are not used to finance investment. Gross investment, $G(t)$, is equal to the sum of investment that goes to replace retiring elements of the capital stock, $R(t)$, and net investment, $I(t)$, that contribute to the expansion of the capital stock:

$$K(t) = K(t\text{-}1) + G(t) – R(t),$$
$$I(t) = deltaK(t) = K(t) – K(t\text{-}1) = G(t) – R(t).$$

The Domar model explicitly demonstrates that in fast growing economies the share of investment in replacing retirement, $R(t)/G(t)$, is low, whereas the share of investment in the expansion of the capital stock, $I(t)/G(t)$, is high, so that there is a cumulative mechanism to promote growth – the faster economic growth, the smaller portion of gross investment is needed to replace retirement, so the larger portion is used for the expansion of the capital stock, that leads to the expansion of output (assuming constant COR).

But the Domar model can also be used to demonstrate the effect of the big push. If the economy is in a no-growth equilibrium, so that gross investment is equal to retirement,

$G(t) = R(t) = G(t\text{-}m)$, but at a certain point experiences a "big push", so that investment start exceed annual retirement of fixed capital stock, then growth can be maintained indefinitely even if all profits are consumed and are not used to finance investment. In this paper the basic setup of the Domar model is used to demonstrate another effect: the impact of the "big push" on the growth rates of the economy is not sustainable, if the ability of the system to invest into the replacement of the retirement of the fixed capital stock is constrained.

Unlike investment into the expansion of the capital stock (construction of new production capacities), investment in the replacement of the retirement does not create new jobs. Let us make a distinction between the actual retirement of capital equipment due to the end of its service life, $G(t\text{-}m)$, and annual investment into the replacement of retirement, $R(t)$. The reasonable assumption for the market economy would be that investment in the replacement of retirement (reconstruction of existing production capacities) is higher than the actual retirement of capital equipment (wear and tear of the capital stock), $R(t)>G(t\text{-}m)$, because machinery and equipment, buildings and structures become not only physically obsolete, but also technologically obsolete: it may pay off to replace a piece of machinery before its actual physical retirement by a more technically advanced one. Suppose, therefore, that investment into the replacement of the retirement is equal to actual retirement, $G(t\text{-}m)$, plus an additional 10% of gross investment, $G(t)$:

$$R(t) = G(t\text{-}m) + 0.1G(t) \qquad (1)$$

Capital stock this year is equal to the capital stock in the previous year, plus net investment, equal to the difference between gross investment and investment into the replacement of retirement:

$$K(t) = K(t\text{-}1) + I(t) = K(t\text{-}1) + G(t) - R(t) \qquad (2)$$

Gross investment is a constant share of income, $Y(t)$:

$$G(t) = aY(t) \tag{3}$$

(later it is assumed that *a* is equal to 5% before the "big push" and 10% afterwards).

Finally, the most important equation is the one that describes the increase in income. The assumption here is that this increase is proportional to the increase in the fixed capital stock, $deltaK = I(t) = G(t)–R(t)$, but also depends on the share of investment into the replacement of retirement in total gross investment, $R(t)/G(t)$:

$$deltaY = b[G(t) – R(t)]*R(t)/G(t) \tag{4}$$

The rationale for such a relationship is twofold. First, if the growth of the labor force is limited, then productivity of the investment into the expansion of capital stock (creation of new production capacities, i.e. new jobs, requiring new employees) is constrained by the labor force shortage: the increase in output in newly created production capacities would be accompanied by the decline in output in the old plants, from where workers will have to leave in order to take new jobs at the newly created plants. On the contrary, if all gross investment are used to replace retirement (to reconstruct the existing production capacities without creating new jobs), so that $R(t)=G(t)$, then $R(t)/G(t)$ is equal to 1 (maximum) and the productivity of new investment is the highest.

Second, if the speed of structural change is high enough as compared to the rate of retirement of capital stock due to physical wear and tear, so that it requires the re-allocation of capital and labor from old industries/regions/plants to new ones and this re-allocation is associated with adjustment costs (re-training of employees, shut down of physically non-obsolete capacities), the productivity of new investment in the expansion of production capacities may be lower as compared to investment into the reconstruction of the old capacities. A certain pace of structural change is necessary in any economy for the technical progress to proceed. But this pace may be so high that it requires the shut down of physically non-obsolete enterprises, if the country is catching up rapidly with the technological leader and/or changes it's specialization in the international trade. Imagine, for example, that a country switches from export of agricultural output to export of industrial goods and has to reallocate labor and capital from agriculture to industry. Even if private returns from investment in industry are greater than from investment into agriculture, social returns (taking into account adjustment costs) can be lower. Hence, the productivity of investment into the expansion of fixed capital stock is assumed to be proportional to the share of investment into the replacement of retirement in total gross investment, $R(t)/G(t)$.

The last equation is the one that links output in the current year to output in the preceding year:

$$Y(t) = Y(t-1) + deltaY(t-1) \quad (5)$$

Assume now that in the initial year capital stock is equal to 20, output is equal to 20, gross investment is equal to 1 (the share of gross investment in income is thus 5%), retirement is also equal to 1, and service life of the capital stock is 20. So the system is not growing, and maintains stable no-growth equilibrium (growth rates of output are defined as $delta(t)/Y(t)$). After the first 20 years the "big push" occurs – investment in the year 21 increase to 2, so that the share of investment in income rises to 10%. The trajectory of the growth rates, assuming *b*, the productivity of new investment, is equal to 10, is shown at fig. 3 below (the trajectory in the middle) – growth rates increase to 31% a year right away, then gradually decline in the course of the next 20 years to 13% and then after some fluctuations stabilize at a level of 16%[3].

Growth rates could be better than that, if we change the rule for the investment into the replacement of retirement, given by equation (1). To get the maximum possible growth rates, it is necessary to find the optimal investment into the replacement of the retirement

[3] For the illustration purposes the year of the "big push" is set as 1930. The assumption that the system was in the no growth equilibrium in 1910-30 is not that far from reality: even though Russian/Soviet output fell from 100% in the 1913 to about 30% in the 1920 and then recovered to about 130% by 1930, fixed capital stock in this period most probably did not change much – investment were generally enough only to replace retirement, not to expand the capital stock.

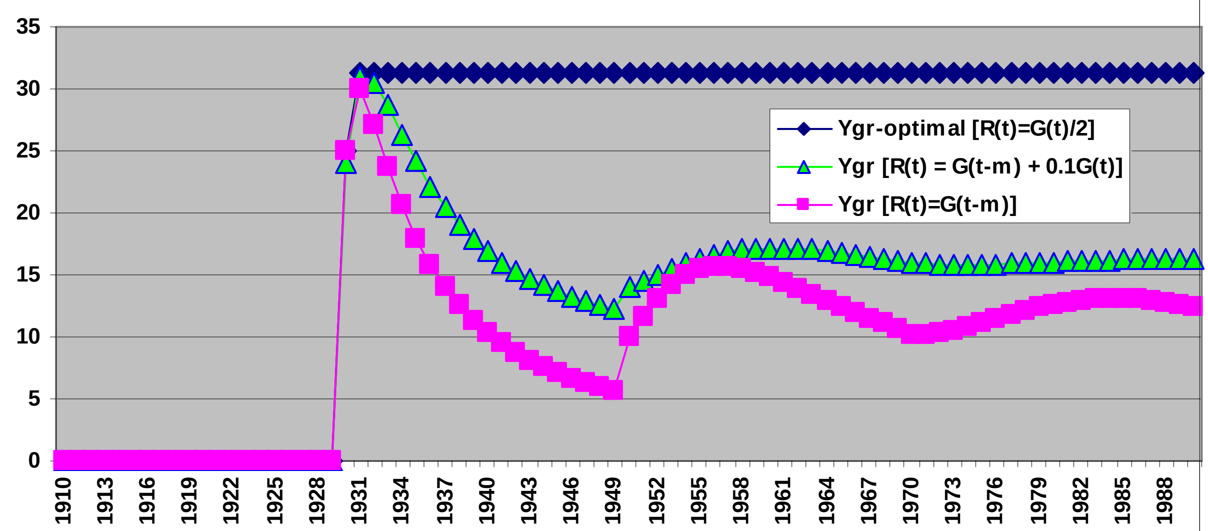
of fixed capital stock, *R*(t)*, by taking the FOC of equation (4). Differentiating (4) and equating it to zero, we get:

$$R^*(t) = G(t)/2 \qquad (6)$$

Using this expression (6) instead of the equation (1), i.e. assuming that investment into the replacement of retirement are equal exactly to half of the gross investment, we get the best possible trajectory for the growth rate – it shoots to 31% a year right away and stays at this level thereafter (upper trajectory at fig. 3).

The other extreme case is the lowest possible investment into the replacement of retirement: it is assumed that this investment is equal to the actual retirement of the fixed capital stock due to the expiration of its service life, *R(t) = G(t-m)*, and this expression is used instead of equation (1). The result is that the growth rate shoots up to 30% right after the "big push", gradually declines to 5 % in the course of the next 20 years, and then stabilizes after some fluctuations at a level of 12% - the lower trajectory at a chart below (fig. 3).

Fig. 3. Growth rates after the "big push" in a market economy (with investment to replace retirement higher than actual physical retirement of capital stock), %



The point of these simulations is to show that in all cases the growth rates after the "big push" stabilize at a positive level. This is not the case, however, if the assumptions are slightly modified, so as to allow for the investment into the replacement of retirement of the fixed capital stock, $R(t)$, to be below the actual physical retirement, $G(t\text{-}m)$. Equation (2) will then have to be modified, so that the increase in the capital stock is equal to gross investment minus actual retirement, $G(t\text{-}m)$, and not the investment into the replacement of retirement, $R(t)$:

$$K(t) = K(t-1) + G(t) - G(t-m) \qquad (2')$$

Equation (4) will have to be modified as well, so that the increase in the fixed capital stock is defined accordingly:

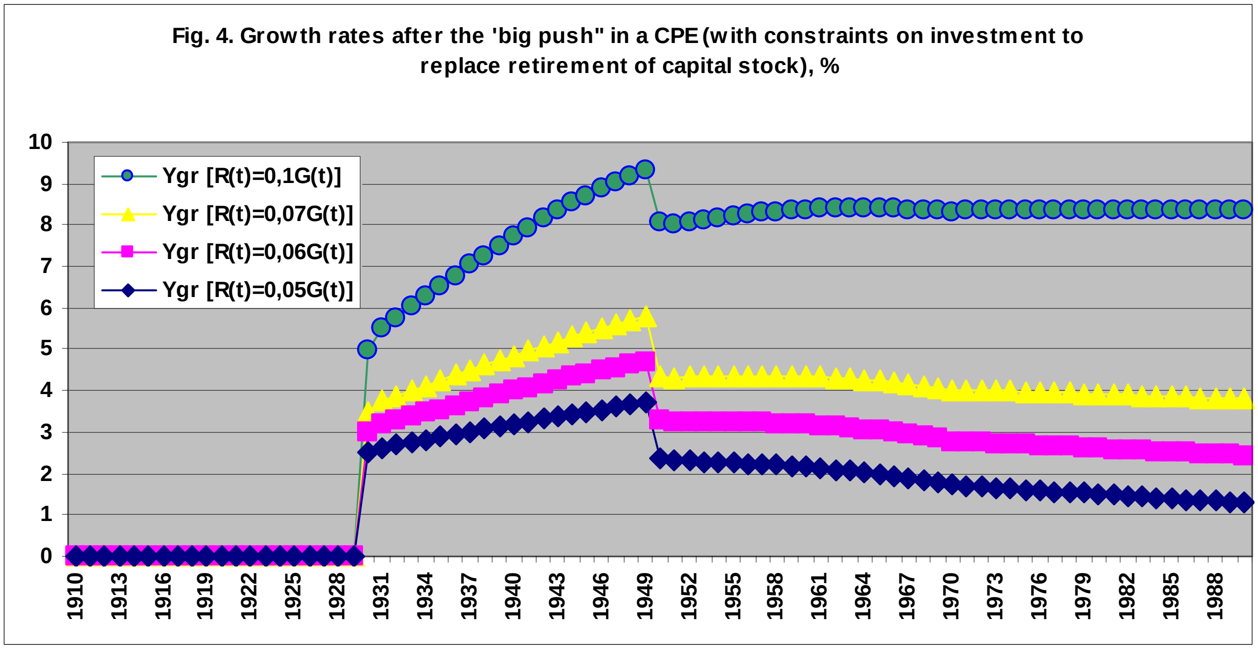
$$deltaY = b[G(t) - G(t-m)]*R(t)/G(t) \qquad (4')$$

Finally, for describing investment into the replacement of retirement, let us use the simplest rule – a constant fraction of gross investment, c, small enough to make investment to replace retirement lower than the actual physical retirement of fixed capital stock:

$$R(t) = cG(t) \qquad (1')$$

This equation (1') replaces the equation (1). As a result, the new trajectories of growth rates, shown at the chart below (fig. 4), are very different from the ones that were obtained previously under the assumption that investment into the replacement of the retirement is higher than actual retirement.

If c is equal to 0.1, i.e. investment into the replacement of the retirement of fixed capital stock are only 10% of total gross capital investment, then growth rates after the "big push" increase immediately to 5%, then gradually grow to 9% in the course of next 20 years, but afterwards fall and converge after some fluctuations to a level of 8% (the upper trajectory on a fig. 4). The next two trajectories (assuming *c* equal to 0.07 and 0.06 respectively) are similar – growth rates converge to 3.6 and 1.8 % respectively), but the last trajectory (*c=0.05*) does not produce any convergence to a positive growth rate – it falls constantly and in the long run approaches zero.



The results of the simulation therefore demonstrate more rigorously the intuitively clear effect of the impact of the constraints on investment into the replacement of the retiring elements of the capital stock: in the presence of such constraints, the "big push" can lead to a temporary increase in the growth rates, but later, after a period equal to the service life of the fixed capital stock, they fall and converge to a low positive level or even to zero (if the investment into the replacement of retirement are low enough).

The fact that growth rates in the USSR started to fall in the 1960s, 30 years after the "big push", and not 20 years after, as the simulation exercise suggests, should be explained probably by the impact of the Second World War that resulted in the destruction of the large portion of fixed capital stock. For 10 years (1940-50) capital stock, in fact, did not increase (first it was destroyed during the war, then increased to the pre-war level during reconstruction), so 10 years should be added to the life cycle of 20 years. Besides, the average service life of capital stock is a very statistically uncertain indicator. In the 1970s – 1980s for machinery and equipment the service life was about 25 years (implying a retirement ratio of 4%) – see table 2, but for the earlier period the statistics is absent. If the service life in the 1930s-1950s was about 30 years, the peak of the growth rates in the 1950s could be explained even without the impact of the war.

5. Conclusions

The highest rates of growth of labor productivity in the Soviet Union were observed not in the 1930s (3% annually), but in the 1950s (6%). The TFP growth rates by decades increased from 0.6% annually in the 1930s to 2.8% in the 1950s and then fell monotonously becoming negative in the 1980s. The decade of 1950s was thus the "golden period" of Soviet economic growth. The patterns of Soviet growth of the 1950s in terms of growth accounting were very similar to the Japanese growth of the 1950s-70s and Korean and Taiwanese growth in the 1960-80s – fast increases in labor productivity counterweighted the decline in capital productivity, so that the TFP increased markedly. However, high Soviet economic growth lasted only for a decade, whereas in East Asia it continued for three to four decades, propelling Japan, South Korea and Taiwan into the ranks of developed countries.

This paper offers an explanation for the inverted U-shaped trajectory of labor productivity and TFP in centrally planned economies (CPEs). It is argued that CPEs under-invested into the replacement of the retiring elements of the fixed capital stock and over-invested into the expansion of production capacities. The task of renovating physical capital contradicted the short-run goal of fulfilling planned targets, and, therefore, Soviet planners preferred to invest in new capacities instead of upgrading the old ones. Hence, after the massive investment of the 1930s in the USSR, the highest productivity was achieved after the period equal to the service life of capital stock (about 20 years) – before there emerged a need for the massive investment into replacing retirement. Afterwards, the capital stock started to age rapidly reducing sharply capital productivity and lowering labor productivity and TFP growth rates.

The simulation exercise allows to demonstrate clearly that under very reasonable assumptions (that the productivity of new investment is proportional to the share of investment into the reconstruction of existing production capacities in total investment, and that investment into the reconstruction of these capacities is lower than the actual retirement due to physical wear and tear) growth rates first increase and than fall to very low level or even zero after the "big push" – the initial increase in the share of investment in GDP.

Among many reasons of the decline of the growth rates in the USSR in the 1960s-1980s, the discussed inability of the centrally planned economy to ensure adequate flow of investment into the replacement of retirement of fixed capital stock appears to be most crucial. What is more important, even if these retirement constraints were not the only reason of the decline in growth rates, they are sufficient to explain the inevitable gradual decline after 30 years of relatively successful development. To put it differently, the centrally planned economy is doomed to experience a growth slowdown after three decades of high growth following the "big push". In this respect, Chinese relatively short experience with the CPE (1949-79) looks superior to the Soviet excessively long experience (1929-91). This is another reason to believe that the transition to the market economy in the Soviet Union would have been more successful, if it had started in the 1960s.

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APPENDIX

Market economy after the "big push" (with investment to replace retirement equal to actual physical retirement of capital stock plus another 10% of gross investment), %

Years	G(t)	G(t-m)	[R(t) = G(t-m)+0.1G(t)]	K(t)	deltaY(t)	Y(t)	Ygr [R(t) = G(t-m) + 0.1G(t)], %	G/Y	R/K
1929	1	1	1	20	0	20	0	0,05	0,05
1930	2	1	1,2	20,8	4,8	20	24	0,1	0,057692
1931	2,48	1	1,248	22,032	6,199742	24,8	30,99871	0,1	0,056645
1932	3,099974	1	1,3099974	23,82198	7,564143	30,99974	30,500579	0,1	0,054991
1933	3,856389	1	1,3856389	26,29273	8,87765	38,56389	28,637819	0,1	0,0527
1934	4,744154	1	1,4744154	29,56246	10,16188	47,44154	26,35077	0,1	0,049875
1935	5,760342	1	1,5760342	33,74677	11,4483	57,60342	24,131384	0,1	0,046702
1936	6,905172	1	1,6905172	38,96143	12,76646	69,05172	22,162686	0,1	0,04339
1937	8,181818	1	1,8181818	45,32506	14,14141	81,81818	20,479453	0,1	0,040114
1938	9,595959	1	1,9595959	52,96143	15,59426	95,95959	19,059649	0,1	0,037
1939	11,15539	1	2,1155385	62,00127	17,14342	111,5539	17,865247	0,1	0,034121
1940	12,86973	1	2,2869727	72,58403	18,80574	128,6973	16,85799	0,1	0,031508
1941	14,7503	1	2,4750301	84,8593	20,59732	147,503	16,004472	0,1	0,029166
1942	16,81003	1	2,6810033	98,98833	22,53415	168,1003	15,277076	0,1	0,027084
1943	19,06345	1	2,9063447	115,1454	24,63254	190,6345	14,653475	0,1	0,025241
1944	21,5267	1	3,1526701	133,5195	26,90949	215,267	14,115753	0,1	0,023612
1945	24,21765	1	3,421765	154,3153	29,38296	242,1765	13,649543	0,1	0,022174
1946	27,15595	1	3,7155947	177,7557	32,07211	271,5595	13,243278	0,1	0,020903
1947	30,36316	1	4,0363157	204,0825	34,9975	303,6316	12,887599	0,1	0,019778
1948	33,86291	1	4,3862907	233,5592	38,18131	338,6291	12,574881	0,1	0,01878
1949	37,68104	1	4,7681038	266,4721	41,64755	376,8104	12,29887	0,1	0,017893
1950	41,84579	2	6,1845793	302,1333	52,70532	418,4579	13,987227	0,1	0,02047
1951	47,11632	2,48	7,1916325	342,058	60,93933	471,1632	14,562833	0,1	0,021025
1952	53,21026	3,099974	8,4209999	386,8473	70,88301	532,1026	15,044258	0,1	0,021768
1953	60,29856	3,856389	9,8862444	437,2596	82,65346	602,9856	15,53337	0,1	0,02261
1954	68,5639	4,744154	11,600544	494,2229	96,37811	685,639	15,983485	0,1	0,023472
1955	78,20172	5,760342	13,580513	558,8441	112,2212	782,0172	16,367389	0,1	0,024301
1956	89,42384	6,905172	15,847555	632,4204	130,3908	894,2384	16,673644	0,1	0,025059
1957	102,4629	8,181818	18,428109	716,4552	151,1379	1024,629	16,901294	0,1	0,025721
1958	117,5767	9,595959	21,353629	812,6783	174,755	1175,767	17,055441	0,1	0,026276
1959	135,0522	11,15539	24,660605	923,0699	201,5757	1350,522	17,144184	0,1	0,026716
1960	155,2098	12,86973	28,390704	1049,889	231,9752	1552,098	17,17671	0,1	0,027042
1961	178,4073	14,7503	32,59103	1195,705	266,3738	1784,073	17,162178	0,1	0,027257
1962	205,0447	16,81003	37,314499	1363,435	305,2392	2050,447	17,109122	0,1	0,027368
1963	235,5686	19,06345	42,620306	1556,384	349,0922	2355,686	17,025177	0,1	0,027384
1964	270,4778	21,5267	48,574481	1778,287	398,511	2704,778	16,916985	0,1	0,027315
1965	310,3289	24,21765	55,250541	2033,365	454,1381	3103,289	16,790217	0,1	0,027172

1966	355,7427	27,15595	62,730218	2326,378	516,6863	3557,427	16,649634	0,1	0,026965
1967	407,4113	30,36316	71,104292	2662,685	586,9467	4074,113	16,499191	0,1	0,026704
1968	466,106	33,86291	80,473508	3048,317	665,797	4661,06	16,342133	0,1	0,026399
1969	532,6857	37,68104	90,94961	3490,054	754,2107	5326,857	16,181098	0,1	0,02606
1970	608,1068	41,84579	102,65647	3995,504	853,267	6081,068	16,018207	0,1	0,025693
1971	693,4335	47,11632	116,45967	4572,478	969,0069	6934,335	15,934814	0,1	0,02547
1972	790,3342	53,21026	132,24368	5230,568	1101,158	7903,342	15,879797	0,1	0,025283
1973	900,45	60,29856	150,34356	5980,675	1252,415	9004,5	15,846646	0,1	0,025138
1974	1025,691	68,5639	171,13305	6835,233	1425,801	10256,91	15,834316	0,1	0,025037
1975	1168,272	78,20172	195,02887	7808,476	1624,712	11682,72	15,840158	0,1	0,024977
1976	1330,743	89,42384	222,49811	8916,72	1852,968	13307,43	15,860762	0,1	0,024953
1977	1516,039	102,4629	254,06686	10178,69	2114,888	15160,39	15,892541	0,1	0,024961
1978	1727,528	117,5767	290,32953	11615,89	2415,366	17275,28	15,932076	0,1	0,024994
1979	1969,065	135,0522	331,95869	13253	2759,948	19690,65	15,976281	0,1	0,025048
1980	2245,06	155,2098	379,71573	15118,34	3154,929	22450,6	16,022475	0,1	0,025116
1981	2560,553	178,4073	434,46255	17244,43	3607,45	25605,53	16,068392	0,1	0,025194
1982	2921,298	205,0447	497,17442	19668,56	4125,605	29212,98	16,112167	0,1	0,025278
1983	3333,858	235,5686	568,9544	22433,46	4718,57	33338,58	16,152307	0,1	0,025362
1984	3805,715	270,4778	651,04931	25588,12	5396,733	38057,15	16,187652	0,1	0,025443
1985	4345,388	310,3289	744,86774	29188,65	6171,857	43453,88	16,217339	0,1	0,025519
1986	4962,574	355,7427	852,00013	33299,22	7057,244	49625,74	16,240767	0,1	0,025586
1987	5668,298	407,4113	974,24119	37993,28	8067,931	56682,98	16,257552	0,1	0,025642
1988	6475,092	466,106	1113,6152	43354,75	9220,907	64750,92	16,267504	0,1	0,025686
1989	7397,182	532,6857	1272,4039	49479,53	10535,35	73971,82	16,270584	0,1	0,025716
1990	8450,717	608,1068	1453,1785	56477,07	12032,91	84507,17	16,266885	0,1	0,02573

CPE economy after the "big push" (with investment to replace retirement equal to 5% of gross investment), %

Years	G(t)	G(t-m)	R(t)= 0.05G(t)	K(t)	deltaY(t)	Y(t)	Ygr [R(t)= 0,05G(t)], %	G/Y	R/K
1929	1	1	1	20	0	20	0	0,05	0,05
1930	2	1	0,1	21	0,5	20	2,5	0,1	0,004762
1931	2,05	1	0,1025	22,05	0,525	20,5	2,625	0,1	0,004649
1932	2,1025	1	0,105125	23,1525	0,55125	21,025	2,6890244	0,1	0,004541
1933	2,157625	1	0,1078813	24,31013	0,578813	21,57625	2,7529727	0,1	0,004438
1934	2,215506	1	0,1107753	25,52563	0,607753	22,15506	2,816769	0,1	0,00434
1935	2,276282	1	0,1138141	26,80191	0,638141	22,76282	2,8803384	0,1	0,004246
1936	2,340096	1	0,1170048	28,14201	0,670048	23,40096	2,9436069	0,1	0,004158
1937	2,4071	1	0,120355	29,54911	0,70355	24,071	3,006502	0,1	0,004073
1938	2,477455	1	0,1238728	31,02656	0,738728	24,77455	3,0689526	0,1	0,003992
1939	2,551328	1	0,1275664	32,57789	0,775664	25,51328	3,1308902	0,1	0,003916
1940	2,628895	1	0,1314447	34,20679	0,814447	26,28895	3,1922483	0,1	0,003843
1941	2,710339	1	0,135517	35,91713	0,85517	27,10339	3,2529629	0,1	0,003773
1942	2,795856	1	0,1397928	37,71298	0,897928	27,95856	3,3129732	0,1	0,003707
1943	2,885649	1	0,1442825	39,59863	0,942825	28,85649	3,3722211	0,1	0,003644
1944	2,979932	1	0,1489966	41,57856	0,989966	29,79932	3,430652	0,1	0,003583
1945	3,078928	1	0,1539464	43,65749	1,039464	30,78928	3,4882146	0,1	0,003526
1946	3,182875	1	0,1591437	45,84037	1,091437	31,82875	3,5448612	0,1	0,003472
1947	3,292018	1	0,1646009	48,13238	1,146009	32,92018	3,6005476	0,1	0,00342
1948	3,406619	1	0,170331	50,539	1,20331	34,06619	3,6552337	0,1	0,00337
1949	3,52695	1	0,1763475	53,06595	1,263475	35,2695	3,7088827	0,1	0,003323
1950	3,653298	2	0,1826649	54,71925	0,826649	36,53298	2,3438064	0,1	0,003338
1951	3,735963	2,05	0,1867981	56,40521	0,842981	37,35963	2,3074531	0,1	0,003312
1952	3,820261	2,1025	0,191013	58,12298	0,85888	38,20261	2,2989533	0,1	0,003286
1953	3,906149	2,157625	0,1953074	59,8715	0,874262	39,06149	2,2884875	0,1	0,003262
1954	3,993575	2,215506	0,1996787	61,64957	0,889034	39,93575	2,2759869	0,1	0,003239
1955	4,082478	2,276282	0,2041239	63,45576	0,903098	40,82478	2,2613784	0,1	0,003217
1956	4,172788	2,340096	0,2086394	65,28846	0,916346	41,72788	2,2445833	0,1	0,003196
1957	4,264423	2,4071	0,2132211	67,14578	0,928661	42,64423	2,2255172	0,1	0,003175
1958	4,357289	2,477455	0,2178644	69,02561	0,939917	43,57289	2,204089	0,1	0,003156
1959	4,451281	2,551328	0,222564	70,92557	0,949976	44,51281	2,1802002	0,1	0,003138
1960	4,546278	2,628895	0,2273139	72,84295	0,958692	45,46278	2,1537438	0,1	0,003121
1961	4,642147	2,710339	0,2321074	74,77476	0,965904	46,42147	2,1246039	0,1	0,003104
1962	4,738738	2,795856	0,2369369	76,71764	0,971441	47,38738	2,0926538	0,1	0,003088
1963	4,835882	2,885649	0,2417941	78,66787	0,975116	48,35882	2,0577555	0,1	0,003074
1964	4,933394	2,979932	0,2466697	80,62133	0,976731	49,33394	2,0197577	0,1	0,00306
1965	5,031067	3,078928	0,2515533	82,57347	0,976069	50,31067	1,9784946	0,1	0,003046

1966	5,128674	3,182875	0,2564337	84,51927	0,9729	51,28674	1,9337838	0,1	0,003034
1967	5,225964	3,292018	0,2612982	86,45322	0,966973	52,25964	1,8854244	0,1	0,003022
1968	5,322661	3,406619	0,266133	88,36926	0,958021	53,22661	1,8331945	0,1	0,003012
1969	5,418463	3,52695	0,2709231	90,26077	0,945756	54,18463	1,7768488	0,1	0,003002
1970	5,513039	3,653298	0,2756519	92,12051	0,92987	55,13039	1,7161147	0,1	0,002992
1971	5,606026	3,735963	0,2803013	93,99057	0,935031	56,06026	1,6960366	0,1	0,002982
1972	5,699529	3,820261	0,2849764	95,86984	0,939634	56,99529	1,6761144	0,1	0,002973
1973	5,793492	3,906149	0,2896746	97,75719	0,943672	57,93492	1,6557012	0,1	0,002963
1974	5,887859	3,993575	0,294393	99,65147	0,947142	58,87859	1,6348381	0,1	0,002954
1975	5,982573	4,082478	0,2991287	101,5516	0,950048	59,82573	1,6135704	0,1	0,002946
1976	6,077578	4,172788	0,3038789	103,4564	0,952395	60,77578	1,5919487	0,1	0,002937
1977	6,172818	4,264423	0,3086409	105,3647	0,954197	61,72818	1,5700291	0,1	0,002929
1978	6,268237	4,357289	0,3134119	107,2757	0,955474	62,68237	1,5478738	0,1	0,002922
1979	6,363785	4,451281	0,3181892	109,1882	0,956252	63,63785	1,5255519	0,1	0,002914
1980	6,45941	4,546278	0,3229705	111,1013	0,956566	64,5941	1,5031399	0,1	0,002907
1981	6,555067	4,642147	0,3277533	113,0143	0,95646	65,55067	1,4807229	0,1	0,0029
1982	6,650713	4,738738	0,3325356	114,9262	0,955987	66,50713	1,4583946	0,1	0,002893
1983	6,746311	4,835882	0,3373156	116,8367	0,955215	67,46311	1,4362592	0,1	0,002887
1984	6,841833	4,933394	0,3420916	118,7451	0,95422	68,41833	1,4144317	0,1	0,002881
1985	6,937255	5,031067	0,3468627	120,6513	0,953094	69,37255	1,3930391	0,1	0,002875
1986	7,032564	5,128674	0,3516282	122,5552	0,951945	70,32564	1,372222	0,1	0,002869
1987	7,127759	5,225964	0,3563879	124,457	0,950898	71,27759	1,352135	0,1	0,002864
1988	7,222849	5,322661	0,3611424	126,3572	0,950094	72,22849	1,332949	0,1	0,002858
1989	7,317858	5,418463	0,3658929	128,2566	0,949698	73,17858	1,3148518	0,1	0,002853
1990	7,412828	5,513039	0,3706414	130,1563	0,949895	74,12828	1,2980501	0,1	0,002848