COWLES FOUNDATION FOR RESEARCH IN ECONOMICS

AT YALE UNIVERSITY

Box 2125, Yale Station
New Haven, Connecticut

COWLES FOUNDATION DISCUSSION PAPER NO. 256

SOVIET POSTWAR ECONOMIC GROWTH

AND CAPITAL LABOR SUBSTITUTION

Martin L. Weitzman

October 30, 1968

SOVIET POSTWAR ECONOMIC GROWTH AND CAPITAL LABOR SUBSTITUTION*[1]

by

Martin L. Weitzman
Yale University

Introduction

As with any other country, statistics on economic growth in the U.S.S.R. can be analyzed on several levels. The approach taken here is to interpret the data by fitting aggregate production functions. Obviously this technique has certain severe drawbacks and even under the best of circumstances it may yield an incomplete picture of economic growth. Nevertheless, it can be a useful way of synthesizing economic information which might otherwise be difficult to interpret. In any event, the production function approach is especially interesting in the Soviet context because the very high rate of growth of capital allows for a relatively rich sampling of capital-labor and capital-output ratios. This permits added statistical power for testing the appr-priate <u>form</u> of the production function.

Basic Facts of Soviet Postwar Growth

The two constant price series utilized in this study are displayed in tables 1 and 2. They are derived from

---

* The research described in this paper was carried out under grants from the National Science Foundation and from the Ford Foundation.

dissimilar sources and their coverage differs.

The estimates of table 1 are for industry alone and rely directly on Soviet data. Official Soviet gross value of output series for industrial sectors (July 1, 1955 prices) are aggregated using synthetic 1960 value added weights to obtain a total industrial output series. Official Soviet figures on "basic productive industrial funds" (July 1, 1955 prices) are used to form an index of gross fixed industrial capital stock (no attempt is made to convert stocks into service flows). Man-hours worked is for the industrial sector alone.

Table 2 presents estimates of output, fixed capital services (gross), and man-hours worked for the non-agricultural non-service economy (industry, construction, transportation and communications, and distribution). These are derived essentially from Western sources. My intention was to include as many activities of the non-agricultural economy as possible, consistent with the principle of <u>not</u> including service outputs which are measured directly in terms of factor inputs (like education or housing). Output series are aggregated using synthetic 1956 value added weights. Capital services are built up out of constant price investment data.

A more detailed description of the data sources

TABLE 1

Year	Y	g_Y(%)	K	g_K(%)	L	g_L(%)	K/Y
1950	33.17		34.16		81.47		1.030
1951	38.22	15.2	38.01	11.3	86.14	5.7	.995
1952	42.62	11.5	42.24	11.1	89.26	3.6	.991
1953	47.37	11.1	46.83	10.9	93.09	4.3	.989
1954	53.44	12.8	52.05	11.1	97.54	4.8	.974
1955	60.46	13.1	58.26	11.9	99.27	1.8	.964
1956	66.37	9.8	65.22	11.9	97.34	-1.9	.983
1957	72.97	9.9	72.30	10.9	97.44	.1	.991
1958	81.16	11.2	80.50	11.3	99.74	2.4	.992
1959	90.58	11.6	89.69	11.4	100.87	1.1	.996
1960	100.00	10.4	100.00	11.5	100.00	-.9	1.000
1961	109.50	9.5	111.55	11.6	99.54	-.5	1.019
1962	120.38	9.9	123.60	10.8	102.72	3.2	1.027
1963	131.36	9.1	137.76	11.5	106.37	3.6	1.049
1964	141.94	8.1	152.80	10.9	110.92	4.3	1.076
1965	153.53	8.2	167.58	9.7	115.69	4.3	1.092
1966	167.26	9.0	183.14	9.3	118.68	2.6	1.095
1967	183.65	9.8	199.82	9.1	122.46	3.2	1.088

INDEXES OF OUTPUT, CAPITAL, AND LABOR FOR THE SOVIET UNION

(INDUSTRY--DIRECT SOVIET SOURCES)

TABLE 2

Year	Y	g_Y(%)	K	g_K(%)	L	g_L(%)	K/Y
1950	38.84		37.87		80.79		.975
1951	43.66	12.4	41.35	9.2	84.51	4.6	.947
1952	47.47	8.7	45.13	9.2	87.09	3.1	.951
1953	51.99	9.5	49.39	9.4	89.71	3.0	.950
1954	57.80	11.2	54.30	9.9	93.87	4.6	.939
1955	64.36	11.3	59.93	10.4	95.47	1.7	.931
1956	70.26	9.2	66.55	11.0	93.65	-1.9	.947
1957	77.60	10.4	73.93	11.1	94.50	.9	.953
1958	84.71	9.7	81.86	10.7	98.10	3.8	.966
1959	92.38	9.1	90.51	10.6	100.88	2.8	.980
1960	100.00	8.2	100.00	10.5	100.00	-.9	1.000
1961	107.54	7.5	110.49	10.5	98.73	-1.3	1.027
1962	115.51	7.4	121.96	10.4	100.96	2.3	1.056
1963	122.76	6.3	134.22	10.1	103.87	2.9	1.093
1964	131.12	6.8	147.33	9.8	108.01	4.0	1.124
1965	141.96	8.3	161.27	9.5	112.38	4.0	1.136
1966	151.97	7.1	175.86	9.0	114.90	2.2	1.157

INDEXES OF OUTPUT, CAPITAL, AND LABOR FOR THE SOVIET UNION (AGGREGATED INDUSTRY, CONSTRUCTION, TRANSPORTATION AND COMMUNICATIONS, AND DISTRIBUTION--WESTERN ESTIMATES) is reserved for the appendix. Having experimented with a variety of output indices (with various price bases, diverse interest rates, different imputations for value added weights, etc.) and other measures of capital, I can report that results are not much changed. Limitations of space preclude a more detailed report of the alternatives, but there is not much difference.[2] The two series presented here were selected for their contrasting coverage and somewhat different origins.

Both series show similar trends. The rate of growth of output apparently has declined somewhat over time. Capital grows more steadily, decelerating slightly toward the end of the period. Man-hours employed increases erratically. The low growth rates of labor from 1956 to 1960 are mostly due to the reduction of the length of the work week and work day. The growth of the labor force is curtailed in the early sixties as a result of sharply lower wartime births.[3] Capital output ratios remain roughly constant or decline slightly up to the mid fifties, but rise more or less steadily thereafter. The trend of a non decreasing capital-output ratio which clearly rises after the mid fifties would be more sharply established if one could expunge the effects of technical change from output.[4]

The observation that a retardation in output growth has taken place without a slowdown of the same magnitude in the growth of inputs has been the starting point for several discussions of the residual's somewhat paradoxical behavior.[5] When output is divided by a (usually geometrically) weighted index of inputs, it is discovered that the growth of total factor productivity, while volatile from year to year, has declined over the long run. Of course the magnitude of productivity growth is influenced by the choice of factor weights, but no matter what figures are used, growth of the residual seems to decline over time. By process of elimination output deceleration is implicitly attributed to the stalled growth of efficiency, technical change, or whatever else is believed to stand behind the residual.[6]

It is important to bear in mind that this approach relies on what in effect are some hidden assumptions about the production function. Basically it is presumed that the expression

$$Y(t) = A(t)F(K(t),L(t)) \qquad (1)$$

is a serviceable approximation relating output Y to capital K and labor L at time t. In order to get at the unknown residual A, the form of F is implicitly postulated, usually to be a Cobb-Douglas production function with prescribed weights. In this paper an alternative specification in emphasized.

Role of the Elasticity of Substitution in Explaining Soviet Growth

A widely accepted measure of the ease with which K and L can be substituted for one another is the elasticity of substitution, σ , which is defined as follows:

$$\sigma \equiv \frac{\frac{\partial F}{\partial L}\frac{\partial F}{\partial K}}{F\frac{\partial^2 F}{\partial K \partial L}}$$

A 1 per-cent change in the ratio of prices or marginal rate of substitution between capital and labor is associated with a σ per-cent change of factor ratios in the opposite direction. As is well known, a production function additive in the two factors has an infinite elasticity of substitution, the Cobb-Douglas has unit elasticity, and a fixed coefficient production function has zero elasticity of substitution.

Because there is a basic identification problem in distinguishing between A(t) and F(K,L) , a unit elasticity of substitution production function and A(t) declining in growth over time are not the only ways of explaining the Soviet growth record. So long as the elasticity of substitution for the function F(K,L) is of the appropriate magnitude, (it would have to be less than one), a slowdown in the growth of output could be accommodated with both exponential growth of A and with the capital and labor series presented.

This is most easily seen by logarithmically differentiating (1) to obtain

$$g_Y = g_A + \eta_K g_K + \eta_L g_L \qquad (2)$$

The rates of growth of Y , A , K , L, $\left(\frac{\frac{dY}{dt}}{Y}, \frac{\frac{dA}{dt}}{A}, \frac{\frac{dK}{dt}}{K}, \frac{\frac{dL}{dt}}{L}\right)$ are denoted, respectively, by g_Y , g_A , g_K , g_L . Also $\eta_K \equiv \frac{K\frac{\partial Y}{\partial K}}{Y} = \frac{K\frac{\partial F}{\partial K}}{F}$ and $\eta_L \equiv \frac{L\frac{\partial Y}{\partial L}}{Y} = \frac{L\frac{\partial F}{\partial L}}{F}$ are the imputed competitive shares of capital and labor. Note that if F(K,L) exhibits constant returns to scale, as we shall assume, then $\eta_K + \eta_L = 1$.

So long as the elasticity of substitution were less than unity, the condition $g_K > g_L$ would imply that η_L would increase over time, and η_K would decline.[7] It follows that g_Y would tend to decline over time due to the increasingly heavy weight of the slower g_L . This is in contrast with the Cobb-Douglas function where the factor share weights remain constant. Such an effect might be quite pronounced in the Soviet case because g_K is very high relative to g_L.

For the purposes of this paper, it is useful to think of the elasticity of substitution as a measure of the rate at which diminishing returns sets in as one factor is increased relative to the other. A less than unit elasticity of substitution implies eventual difficulty in increasing output by primarily incrementing one factor because diminishing returns set in strongly and rapidly. Such a situation would have special relevance for the Soviet case because capital has grown so fast relative to labor.

Fitting a CES Production Function

Because it is not possible to identify both $A(t)$ and $F(K,L)$, one cannot proceed further without assuming explicit functional forms. For reasons that will become clear, the constant-elasticity-of-substitution (CES) production function was thought to be a superior specification for the production side.[8] This production function can be written in the form

$$F(K,L) = \gamma(\delta K^{-\rho} + (1-\delta)L^{-\rho})^{-\frac{1}{\rho}} \qquad (3)$$

with $\sigma = \frac{1}{1+\rho}$ the (constant) elasticity of substitution.

On the side of the residual, I can hope that Hicks neutral exponential technical change

$$A(t) = e^{\lambda t} \tag{4}$$

is not too bad a description of reality.[9]

It goes without saying that I have no good _a priori_ reasons for believing in this specification over and above some very fine alternatives. A few other specifications were also tried, and some of these will be reported. However, the relatively simple form

$$Y(t) = \gamma e^{\lambda t}[\delta K(t)^{-\rho} + (1-\delta)L(t)^{-\rho}]^{-\frac{1}{\rho}} \tag{5}$$

$$\rho = \frac{1-\sigma}{\sigma}$$

was felt to explain the data as well as any other expression tested, and better than most.

Because (5) is non-linear in the parameter, identification is often accomplished by utilizing factor price data to estimate a linear form. For example, the relevant parameters can be estimated by regressing the log of labor productivity on the log of wages. Personally, an aggregate production function has always impressed me as being a tenuous enough concept even _without_ depending for its measurement on first derivatives and a marginal productivity theory of distribution. At any rate, this is out of the question as a meaningful alternative for the present model. Instead, equation (5) was estimated <u>directly</u> by using a non-linear regression program[10] which chose parameter values to minimize the sum of square residuals Φ defined as

$$\Phi = \sum_t \left\{ \log Y(t) - \left[\log \gamma + \lambda t + \frac{\sigma}{\sigma-1} \log \left(\delta K(t)^{\frac{\sigma-1}{\sigma}} + (1-\delta) L(t)^{\frac{\sigma-1}{\sigma}}\right)\right] \right\}^2$$

Results for the data of Table 1 (industry--direct Soviet sources) are[11]

$$\sigma = \underset{(.032)}{.343} \qquad \lambda = \underset{(.0041)}{.0156} \qquad \delta = \underset{(.053)}{.699} \qquad \gamma = \underset{(.036)}{.850}$$

$$\bar{R}^2 = .9997 \qquad\qquad d = 1.24$$

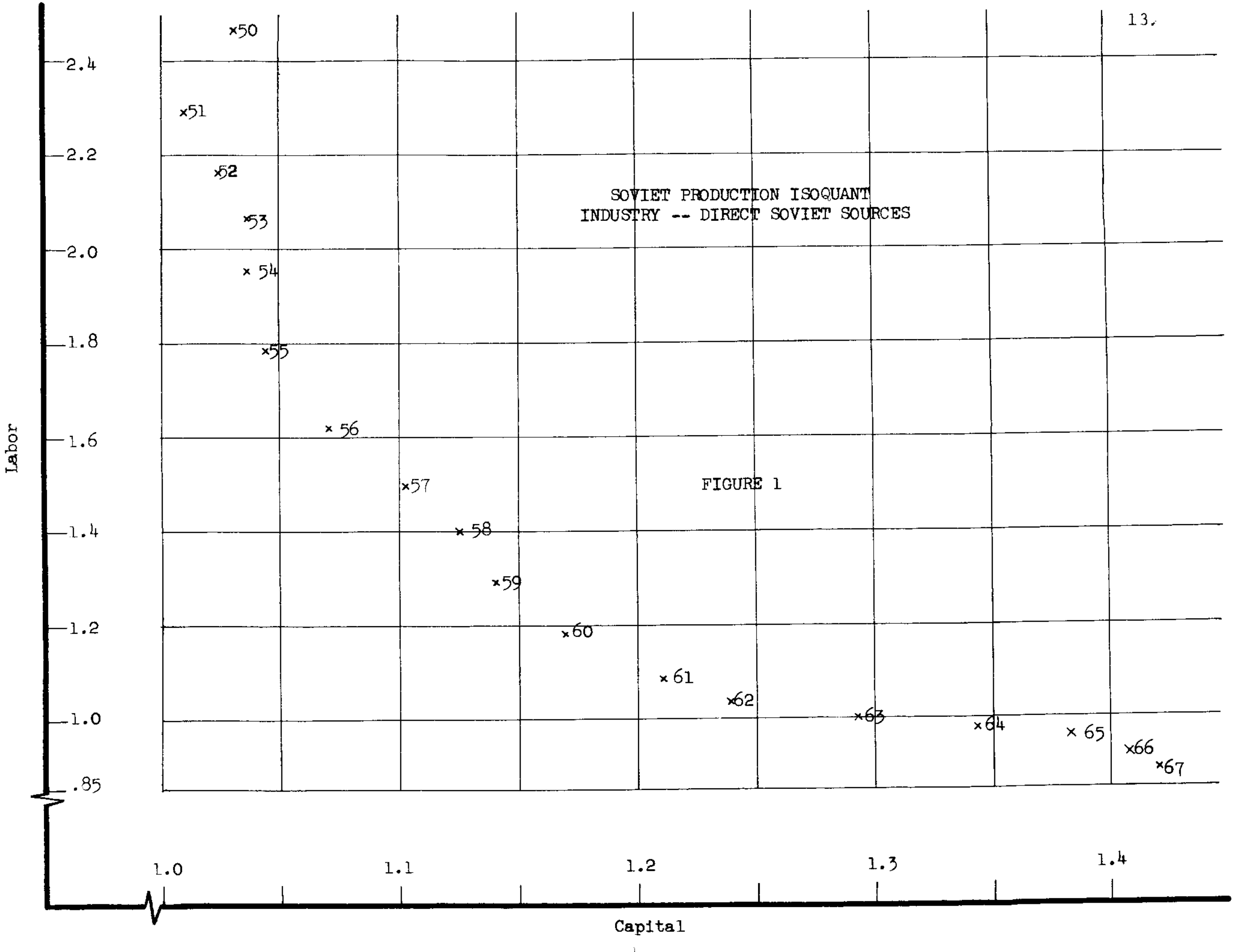
Results for the data of Table 2 (industry, construction, transportation and communications, distribution--Western estimates) are

$$\sigma = \underset{(.018)}{.274} \qquad \lambda = \underset{(.0029)}{.0134} \qquad \delta = \underset{(.041)}{.587} \qquad \gamma = \underset{(.026)}{.875}$$

$$\bar{R}^2 = .9998 \qquad\qquad d = 1.78$$

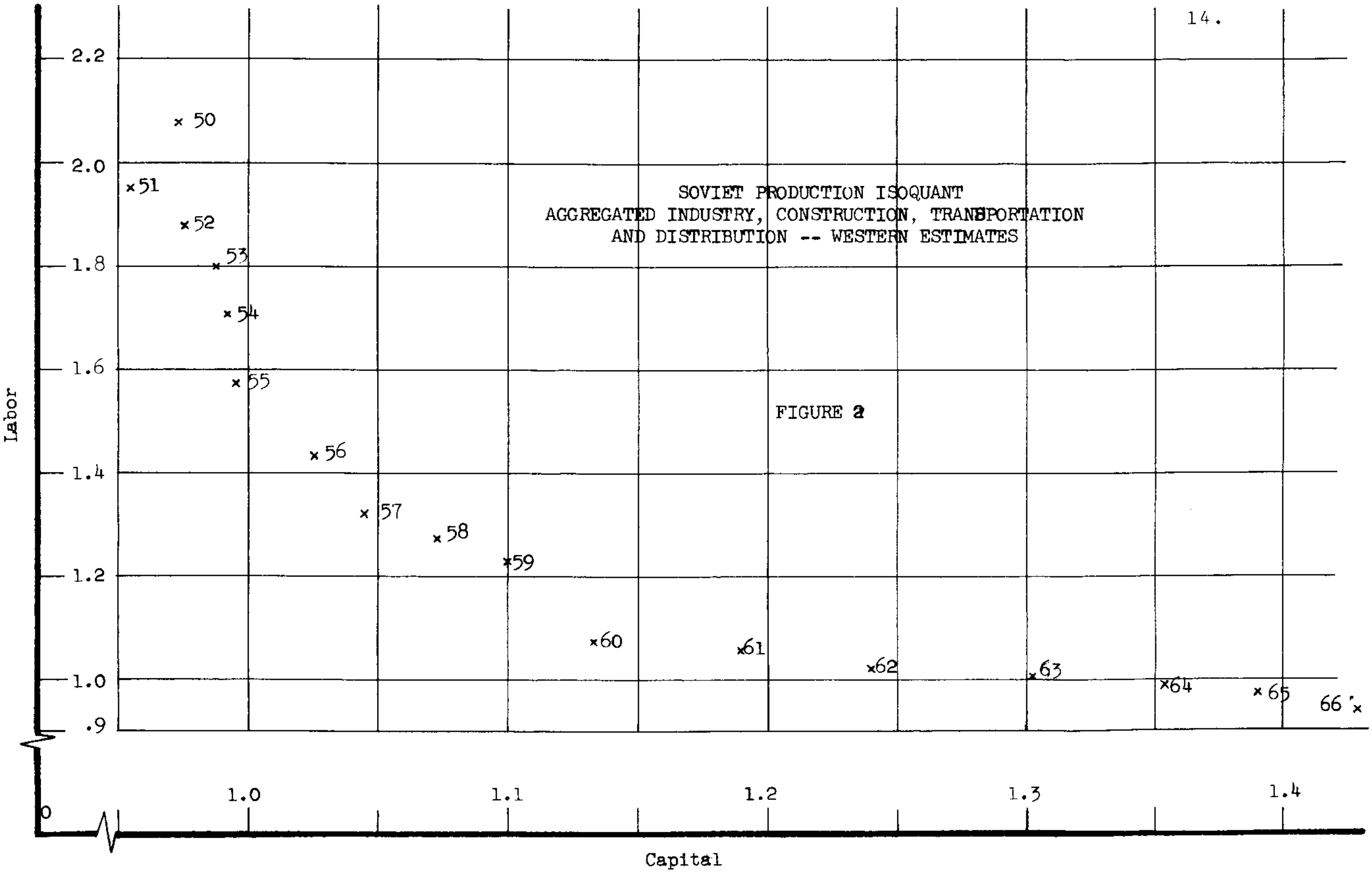
The result of these regressions can be interpreted as saying that, given the specification (5), an elasticity of substitution significantly less than one has an important role to play in explaining the postwar pattern of Soviet growth. To see this graphically, a scatter diagram of the implied production isoquant after technical change has been detrended is presented in figures 1 and 2.[12] It is obvious that a Cobb-Douglas production function would make a poor fit to this isoquant. In fact, forcing a unit elasticity of substitution production function increases the error sum of squares over ten times for industry and twenty times for the non-agricultural non-service economy, pushing the Durbin-Watson statistic in both cases down to about .25.

The story being told by the regressions and the isoquants is something like the following. In absolute terms technical change, growing at about one and a half per-cent a year, is respectable but certainly not spectacular. As somewhere around 10 or 15 percent of output increases, technical change is not nearly so significant a determinant of growth as in some other economies. The Soviet record is primarily that of a classical model of economic growth with the prime mover being the growth of capital. In the early fifties it looks as if non-agricultural labor is practically surplus, with output going up almost proportionally to capital. By the sixties, this is no longer the case. The marginal productivity of labor has moved up to a point where


SOVIET PRODUCTION ISOQUANT
INDUSTRY -- DIRECT SOVIET SOURCES
FIGURE 1
Labor
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.85
Capital
1.0
1.1
1.2
1.3
1.4
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67

SOVIET PRODUCTION ISOQUANT
AGGREGATED INDUSTRY, CONSTRUCTION, TRANSPORTATION
AND DISTRIBUTION -- WESTERN ESTIMATES

FIGURE 2



manpower availability is an important damper on continued high output growth.[13]

Alternative Specifications

When somewhat different assumptions were used to compose data, the same broad picture emerged. More interesting were the effects of different production function specifications. Still working with exponential technical change, not much was gained by forcing factor bias. Specifying it to be disembodied capital augmenting decreased the error sum of squares by 8% , clearly an insignificant improvement. Specifying labor augmenting technical change increased the error sum of squares over five times. As might be expected, in both cases the technical change parameter increased somewhat, as did the elasticity of substitution (up to about .4) .

In an effort to determine how well a systematic decrease in the rate of growth of the residual combined with a Cobb-Douglas production function could cope with the observed data pattern, the model

$$Y(t) = \gamma e^{\lambda t^{\alpha}} K(t)^{\beta} L(t)^{1-\beta} \qquad (6)$$

was tested. A decreasing rate of growth of technical change would be given by the case $\alpha < 1$. Point estimates of α for both sets of data were about .5 with asymptotic standard errors of about .12. The error sum of squares was about midway between that obtained from the straight Cobb-Douglas model with exponential technical change and from the CES specification of equation (5). That is, the industry sum of squared residuals was about five times greater and the non-agricultural, non-service sum about ten times greater than the respective error sum of squares for the CES model (5). The Durbin-Watson statistic is about .4 . Clearly, the decreasing rate of technical change specification (6) is an improvement over the straight Cobb-Douglas model with steady exponential technical change. This was anticipated by our comments on the behavior of the residual. But just as clearly the alternative (6) yields inferior results to the CES with steady exponential technical change.

An equation like (6) was run with a CES function substituting for the Cobb-Douglas. Here the estimate of γ was about .7 with an asymptotic standard error of about .2 . The estimate of σ increased very slightly and the error sum of squares was reduced by about 15% below that obtained from the direct estimation of (5). Thus, the hypothesis $\gamma < 1$ could not really be justified in this case.

At first it was thought that the Soviet case might provide a good test of the "embodiment hypothesis".[14] After World War II the surviving capital stock was old and it was much diminished by the war. A strongly non steady state situation like this might allow one to distinguish between embodied and disembodied technical change.

Because the capital stock data of Table 2 were derived from constant price investment data going back to 1928 and a fairly meaningful survival curve was available, the crucial ingredients were present for putting together a "jelly" series (surviving capital weighted exponentially be date of creation). This was done, and the sum of squared residuals

$$\Phi = \sum_t \left\{ \log Y(t) - [\log \gamma + \frac{\sigma}{\sigma-1} \log (\delta J(t)^{\frac{\sigma-1}{\sigma}} + (1-\delta)L(t)^{\frac{\sigma-1}{\sigma}})] \right\}^2$$

$$J(t) = \sum_{v=-\infty}^{t} e^{\lambda v} I(v)\ S(t-v)$$

was minimized with respect to σ , λ , δ and γ .[15]

Results were disappointing. The error sum of squares was reduced by only 7%. This result could have been attained by good old fashioned capital augmenting disembodied technical change without any other frills. Since the assumption of capital augmenting technical change is also a prerequisite to meaningful capital aggregation in the embodied case,[16] little was felt to have been gained over the disembodied model (the parameter estimates were also similar). It is true that if one goes back into the late forties for a few years, the embodiment approach wins big because the gigantic percentage increases in output of that time are better explained by weighting heavily the new additions to an abnormally aged (due to badly depressed investment during the war) capital profile. But this would be an unfair test because it is not clear what is happening during a war recovery period in general.

Finally, an attempt was made to estimate the form

$$Y = \gamma \, e^{\lambda t} \, (\delta K^{-\rho} + (1-\delta)L^{-\rho})^{-\frac{\mu}{\rho}}$$

$$\rho = \frac{1-\sigma}{\sigma}$$

Here μ is a parameter measuring the extent of uniform economies of scale. Point estimates of μ turned out to be very close to 1 (1.01 and .95) but the linearized standard errors of the estimate were about .08 . Actually, forcing $\lambda = 0$ and re-optimizing yielded only slightly worse results than setting $\mu = 1$. This duplicates the traditional difficulty of disentangling technical change from economies of scale. Estimates of the other parameters were almost unchanged; most of the trade-off is evidently between λ and μ .

Comparisons with the American Economy.

In order to compare the results obtained here with those for the U.S. economy, a direct estimate of a production function of the form (5) for American manufacturing data was made.[17] (I have also included a multiplicative term of the form $e^{\Theta U}$, U = unemployment, Θ a parameter to be estimated, for a few of the regressions). Although the data covered the years 1919 to 1966, various subperiods were also tried (especially 1950-1966), and runs were made omitting recession years and/or war years. The general picture which emerged did not seem to be terribly dependent upon which particular permutation of ad hoc adjustments was used.

Even the best fits were generally less good than in the Soviet case (standard errors about three times as large). This is undoubtedly largely due to the much greater stochastic element in U.S. production because business cycles cause capacity utilization to vary a great deal. It may also be due, at least in part, to the relatively more important role of technical change. This role, it might be reasonable to assume, is probably one of the most poorly specified parts of the production function model. One might suspect that a model reflecting a situation with greater growth of technical change relative to output growth would inherently possess greater output variance because much of the "error" could be due to the undetected swings of technical change, now much wider, in an unobserved variable merely assumed to grow smoothly over time.

Estimates of λ were uniformly close to each other in every regression (about 2.3% per year with standard errors of only about .2%). However, the elasticity of substitution has such a large asymptotic standard error that it looked as if it could easily have been anywhere between 0 and 1.5 . This was partially verified by directly fixing a few values of σ and subminimizing the error sum of squares. Thus, for example, $\sigma = .3$ gave as good a fit as $\sigma = 1$. It was also observed in a scatter diagram analogous figures 1 and 2 that the hoped for "isoquant" really looked more like the interior of an ellipse. There is simply too much auto-correlation (and too high a standard error) in the U.S. data to be able to pull out even a reasonably precise estimate of the elasticity of substitution, at least by the methods employed here. If capital and labor grow at comparable rates, the growth of output is not much affected by the elasticity of substitution,which can hardly be expected to be measured with precision in such situations. The Soviet case, with its greater variety of input configurations and less erratic growth record affords a much better experiment for measuring a "second order" parameter like the elasticity of substitution.

It is interesting to ask why the Soviet economy has exhibited a slowdown while nothing comparable has occurred in the U.S. economy. This is undoubtedly a question deserving a fuller study, but in the spirit of the analysis carried out here several answers suggest themselves. Although no statistical evidence could be found one way or another, the U.S. elasticity of substitution may well be greater than the Soviet, so there is little to explain along the lines of the argument that diminishing returns caused a slowdown. Or, technical change in the U.S. may really be labor augmenting. However, even if these differences did not exist, there would still be other important contrasts between the two economies. In Equation (1), λ is such a larger percentage of g_Y in the American case that the overall effect of changes in η_K (or η_L) on output are reduced. Furthermore the American capital-labor ratio grows so much slower relative to the Soviet that changes in η_K and η_L would tend to be much more gradual.

As a matter of fact, in situations where capital does not grow appreciably faster than labor, little is to be gained by going over from the Cobb-Douglas to the CES model because the drag due to even a low elasticity of substitution would be minimal.[18] Of course, this is emphatically <u>not</u> the appropriate case for the Soviet economy. A major finding of this paper is that in the Soviet case a less-than-unit elasticity of substitution is identifiable and may even provide an explanation of at least part of the historical growth record of that economy.

Conclusion

Having come this far with dehydrated statistics alone, it seems a shame not to end up on a somewhat more speculative note.

The data of tables 1 and 2 have an air of diminishing returns about them. Given the structure which was imposed, the regressions verify the existence of a less-than-unit elasticity of substitution. During the early years the Soviet economy could grow extremely fast by piling up productive capital at rates which were unprecedented in history. But by now the accumulation of capital has outstripped labor by a wide enough margin that the drag due to diminishing returns has cut into output growth. Although a continuation on the same scale of a strategy of capital deepening can still yield growth rates which are high by Western standards, the days of relying on capital formation alone for producing 10 to 15 per-cent increases in industrial output would appear to be over. Instead, labor and technical change will have to be increasingly relied upon as alternative sources of future economic growth.

Labor is more important these days because the great past accumulations of capital have combined with a sufficiently low elasticity of substitution to increase its marginal product dramatically. But can the growth of man-hours be stepped up? Demographers estimate that the growth of the working age population will increase in the near future, but not by much.[19] After that, it should decline. But not all of the new labor recruits will find themselves employed in non-service industries. The labor intensive services sector of the Soviet economy is expanding at a much faster rate than most other branches, a situation which has more than one Soviet Economist nervously eying the consequences for industry.[20] It seems safe to say that the growth of the non-service labor force cannot rise significantly above what is has averaged in the past five years.

This rests the spotlight, finally, on technical change. If the Soviets want to continue their high rates of growth into the future, they will have to encourage more actively the residual element. Theirs would then become a growth scenario resembling a little more closely the contemporary expansion of Japan and a few Western countries; the distinctive feature of high rates of growth of capital and output would likely remain but technical change would be doing more of the pushing.[20]

The questions which this line of reasoning opens up are so conjectural that only one will be pursued here. What administrative changes, if any, would be needed to coax out increased rates of technological progress? For example, might a greater degree of industrial autonomy be necessitated on issues relating to innovation? With their demonstrated commitment to rapid economic growth, the Soviet leaders may well continue their recent policy of hammering out those pragmatic organizational compromises considered necessary to secure future growth.[22] If so, the question of what administrative structure would be most conducive to stepped up technical change looms as an important one for Soviet economic society.

Appendix

Data Sources and Compilation

The purpose of this appendix is to explain in some detail the sources and compilation of the data utilized in this study. At first I had in mind to provide a very detailed report, but it became increasingly apparent that limitations of space would preclude this option. Therefore, a somewhat abbreviated version will be presented. My aim is to provide information which would facilitate the reproduction of figures used in this study. Unfortunately, it will often be possible to provide only a general description of data sources and compilation rather than the specific history, with full citation, of each individual figure. Readers so inclined are invited to write me for more detailed particulars.

A great deal of data is obtained from Soviet statistical yearbooks. Sometimes data are revised in later years, if so usually by an insignificant percentage. Unless otherwise noted, data from a more recent publication takes precedence in cases of duplication. When a date is associated with the annual Narkhoz (Narodnoe Khoziaistvo SSSR) or Tsifrakh (SSSR v Tsifrakh) volumes it always signifies the date of the yearbook, not the date of publication (which is almost always the following year).

Labor

The number of industrial workers and other personnel are from Trud v SSSR, p. 81. These figures include members of industrial cooperatives engaged in industrial work. They are reproduced in table 3.

The situation for non-agricultural non-service workers and personnel is a little more confused (see table 4). Here industrial workers and personnel are estimated exclusive of producers' cooperatives (this category was abolished after 1959). Workers and personnel of producers' cooperatives are added in separately. Industry (without producers' cooperatives), construction, transportation and communications, trade, forestry, and the "other and residual" category are available from tables of the Trud section of Narkhoz and Tsifrakh volumes under the title "Sryednyegodovaya Chislyenost Rabochikhe Slyzhashchikh po Otraslyem Narodnova Khoziaistvo". Only one half of the original number in the "other and residual" category is included on the grounds that this is roughly the percentage breakdown appropriate to non-repair activities as suggested by the data of p. 68 of Current Economic Indicators for the U.S.S.R. [1965]. Data on independent artisans and members of producers' cooperatives are taken from p. 90 of Current Economic Indicators [1965] for all years except 1951 and 1954 which were extrapolated freehand. The agricultural workers included are meant to proxy these engaged in non-agricultural activities, not including fishing and hunting. They are taken as half the numbers (including workers "drawn in" from industry) given in the Narkhoz and Strana Sovietov volumes under the title "Chislyenost Rabotnikov, Zanyatikh v Kolkhozakh, Sovkhozakh, e Gosydarstvyennikh Podsobnikh Syelskokhozaistvyennikh Predpriatiakh".

The index for hours worked per year per man is given in table 5 as a product of average number of workdays per year and average length of the workday. Strictly speaking, this index pertains only to workers in large scale industrial enterprises, but for lack of other information it is applied indiscriminently to other sectors as a rough indication of working conditions prevailing throughout the economy.

Column (1), actual average number of days worked, is from the Promyshlyennost section of Trud v SSSR and Narkhoz under the title "Ispolzovaniye Kalendarnovo Vryemyeni Rabochikh v Promyshlyennosti".

Column (2) lists the average scheduled number of hours worked per day per wage worker in large scale industry.

From 1950 to 1956, an 8 hour day was in effect (Moorsteen and Powell [1966], p. 649). In February of 1956 the Twentieth Congress of the C.P.S.U. called for a program to gradually reduce the standard workweek from 48 to 41 hours. In March of 1956 hours worked on Saturdays and before special holidays were reduced from 8 to 6. Thereafter the changes were somewhat more gradual. The mid-1956 effective working day was 7.6 hours (40 Years of Soviet Power, p. 296); mid-1957 was 7.5 hours (1957 Tsifrakh, p. 420); end of year 1958 was 7.4 hours (1958 Narkhoz, p. 665); end of year 1959 was 7.3 hours (1959 Narkhoz, p. 596); end of year 1960 was 6.67 hours (1960 Narkhoz). Middle of year figures from 1961 on are steady at 6.67 hours. Middle of the year figures from 1958 to 1960 are obtained as a linear combination of figures from the two nearest preceeding and following dates.

The labor indexes of tables 1 and 2 are obtained by multiplying the "workers and personnel" figures of tables 3 and 4 by the hours worked per man per year index of table 5 and normalizing to 1960 equals 100.

Output

With the exception of non-ferrous metals, the sources of the industrial output series of table 1 are official Soviet sectoral indexes. These are aggregated with 1960 sector-of-origin value added weights and shown in table 6. The original Soviet sectoral indexes are composed for each sector by weighting physical units with 1955 wholesale industrial prices. They are listed in terms of 1940=100 in every Narkhoz, Tsifrakh, and Promyshlyennost volume under the title "Tyempi Rosta Valovoi Produktsi Promyshlyennosti po Otraslyam". The rule that the figures appearing in the latest yearbook take precedence is more important here because minor revisions have occured from time to time. The sector indexes are listed in table 6 normalized to 1960=100. It would take us too far afield to discuss why these sectoral indexes differ (slightly) from the Western estimates cited later, but I believe that the Soviet values are accurate and the difference explainable primarily by the more limited Western coverage. The non-ferrous metals estimates are from Soviet Economic Performance: 1966-67 [1968] p. 22 for 1960-1967 and from Noren [1966] p. 280 for 1950-1959.

Sector-of-origin value added weights are derived the same way as in Noren [1966] p. 304 except that a 10% interest rate is used. The procedure involves imputing for each sector the labor and capital costs. Labor costs are wages and salaries and social insurance deductions. Capital costs are 10% interest on the value of mid-year capital stock plus amortization charges as determined by Soviet economic authorities. Relative weights are the sum of labor and capital charges. It makes little difference, e.g., if the interest rate is changed 3 or 4 per-cent.

The output index of table 2 was derived exclusively from Western sources. For aggregation, 1956 imputed value added weights were utilized. Component series are shown in table 7.

The civilian industrial series from 1960 to 1966 is from Soviet Economic Performance: 1966-67 [1968] p. 22. The civilian industries series from 1950 to 1959 is obtained by weighting with the sector weights of the source just cited the sector series of Noren [1966] p. 280 for all industrial sectors except machinery; the civilian machinery series is from Dimensions of Soviet Power [1962] p. 120. The weights used for aggregating within each industrial sector are 1955 industrial wholesale prices, while the weights used for aggregating sectors are 1960 imputed value added weights.

The munitions series (primarily military machinery) is from Moorsteen and Powell [1966] pp. 623, 624 and Moorsteen and Powell [1968] p. 51. This series is nominally expressed in 1937 prices, a drawback which is not particularly bothersome given its other shortcomings. The munitions index is particularly unreliable in its derivation and is one of the reasons why I prefer to work with the industrial series based directly on Soviet sources to that which could be obtained by adding together Western estimates of civilian and non-civilian industries.

The construction index is from Moorsteen and Powell [1966] p. 392 and Moorsteen and Powell [1968] table A-6-X p. 33. This is a constant price (1950) materials-input index of construction, including capital repairs.

Transportation and communications is from Kaplan [1967]. This series is in 1955 price weights. I would like to thank Professor Kaplan for extending this index to 1966 for me on the basis of incomplete data in Strana Sovietov.

Finally, the series on trade is from the same pages as the munitions series. These figures are mostly based on Soviet constant price series, which probably use 1955 prices.

The 1956 value added weights were created in conceptually the same way as for the individual sectors of industry. A 10% interest rate was used. The capital data arefrom Strana Sovietov pp. 35, 36. Depreciation rates are assumed to be 2%, 7%, 2%, and 1% for, respectively, industry, construction, transportation and communications, and trade. Reallocating the labor from forestry, artisans, producers' cooperatives, and "others and residual" to industry, splitting non-agricultural labor in agriculture 50-50 between industry and construction as suggested by Current Economic Indicators for the U.S.S.R. [1965] p. 68, and making some additions to construction because of non-professional construction labor from Trud v SSSR p. 121, my 'guestimates' for 1956 total imputed labor engaged in work broadly defined as industrial, construction, transportation and communications, and trade are, respectively, 21, 5.2, 5.84, 3.83 millions. Wage structure is from 1965 Narkhoz p. 567. 10% of the value added by transportation and communications is arbitrarily deducted as applicable to municipal transportation, not covered by the output index. The weight for the munitions industry is the value added by the entire machinery sector minus the value added by the civilian machinery sector covered by Soviet Economic Performance: 1966-67 [1968], p. 22.

The resulting non-agricultural non-service index is a hodge-podge of constant price series of varying accuracy with somewhat different base year prices. It goes without saying that the accuracy of the value added weights is questionable, although modest variations had little effect on end results.

Capital

The industrial fixed capital stock index of table 1 is based directly on official series. Soviet "industrial productive basic funds" appear in official statistical books as a 1955 price-based series expressed as an end of the year index with the end of 1940 equals 100. The series measures existing capital stock gross of depreciation. For the years 1949 to 1957 and 1959 the index is from Promyshlyennost SSSR [1964] p. 68. 1964 and 1958 are from 1965 Tsifrakh p. 27. 1963 and 1960 are from 1964 Narkhoz p. 68. 1962 is from 1963 Narkhoz p. 55. 1961 is from 1962 Tsifrakh p. 33.

Starting with 1965 Narkhoz, the Soviets have published a capital stock series which differs slightly from the one which had been published previously. The new series covers only a few years of the fifties and early sixties, but every comparable year is almost identical with the old index, and both series show the same percentage increase for 1965 over 1964 (1965 for the old series is printed in 1965 Tsifrakh p. 27. The only substantive difference is for the end of year 1964 industrial fixed capital stock which is about 1.3% higher in the new series. My working hypothesis is that the revised series differs mainly in that the end of year 1964 capital stock was pushed up a little to bring it more in line with output values. Capital stock figures computed from the perpetual inventory method have a way of drifting over time and the 1964 change may be in the nature of a realignment. In any event, the industrial capital stock series listed in publications printed after 1965 Narkhoz are chain linked to the earlier series with 1964 being the last date of the "old" series. Data for 1965, 1966, and 1967 are from 1967 Tsifrakh p. 24. 1964 is from 1965 Narkhoz p. 64. I have also tried the alternative of not chain linking the two series at 1964, but letting the old series in terms of 1940=100 take precedence before 1964, and the new series in terms of 1940=100 after and including 1964. There is very little difference in the regression results, since the only effect is to increase capital stocks by about a per-cent for years after 1963. The "old" and "new" official capital stock figures together with the series used in this study are shown in table 8.

Finally, the capital series of table 1 is obtained for each year by averaging values for the end of the year with the end of the previous year, and normalizing to 1960=100.

The capital series of table 2 is somewhat more difficult to describe because it is built up out of constant price gross investment series. This investment series is also used to compute the capital "jelly" index, with each surviving investment weighted exponentially by its year of creation.

The basic source of the constant price investment series is the 1950 constant price indexes in Moorsteen and Powell [1966] and [1968]. There are three components: construction, installation, and equipment.

To obtain the relevant construction series in 1950 prices, the Moorsteen and Powell (hereafter M-P) series of residential construction 1937 prices, table 3-2, is converted to 1950 prices and subtracted from the table D-8 series of total non-agricultural construction in 1950 prices. To subtract off so-called "non-productive" capital (assumed to be primarily buildings and structures) like that employed in science, art, health, education, and recreation, the construction investment in these areas implied by the data of p. 203 Strana Sovietov is calculated as a percentage of total construction and installation investment on p. 198 of Strana Sovietov. This same percentage of M-P total construction and installation investment in 1950 prices, table A-4, is subtracted from 1950 price non-agricultural non-residential construction investment, leaving the construction investment series (in 1950 prices) appropriate to industry, construction, transportation and communications, and trade.

The 1950 constant price installation series which was used is straight out of M-P table A-4. Total constant price equipment investment from 1928 to 1960 is also from M-P table A-4. From 1961 to 1966 it is chain linked to 1960 from new (1955 constant price) data available in Strana Sovietov p. 206. From this total constant price equipment series is subtracted for each year gross investment in agricultural equipment in 1950 prices, M-P table D-6.

As a result of these manipulations a series in 1950 prices of non-agricultural, non-residential, non-service investment in construction, installation and equipment is obtained for each year from 1928 to 1966. These indexes are shown in table 9. The three series are (imperfectly) converted to 1956 prices by multiplying each by a conversion factor obtained from comparing the 1956 current price investments of M-P table A-5 with the 1950 price value of investments in 1956, M-P table A-4.

The non-agricultural, non-residential, non-service construction capital stock of beginning 1928 was obtained from the information of M-P table B-1. Installation is from table T-21 . Pre-1928 investment in equipment was guessed at from the information of M-P [1966] p. 12. It makes little difference if even substantial errors creep into this last calculation because very little pre-1928 equipment survived into even the early fifties.

Construction and installation are assumed to last forever. The equipment survival curve is based on the information in M-P (1966) chapter 2, section 5, although I have spread out the retirements a bit more than is the case for the survival curve in M-P [1966] p.66 (a correction is made to eliminate agricultural equipment). Surviving pre-1941 investment of all types is reduced by 20% to cover war losses and territorial changes as suggested by the information in M-P [1966] chapter 2, section 6. The capital stock of a given year is the average of the beginning and end of year values. In addition, construction and installation stocks are set back one year because of presumed gestation lags of that length of time.

From this information a 1956 price capital stock series is built up out of the three separate categories of investment. However, in order to create an index of capital <u>services</u>, equipment should be weighted heavier because of its finite lifetime. A machine of lifetime T costing \$1 delivers an annual service of $\frac{r}{1-e^{-rT}}$ dollars with r the appropriate interest rate. It follows that the annual capital services delivered by such a machine are greater by a factor of $\frac{1}{1-e^{-rT}}$ than the annual services del vered by a machine costing \$1 and lasting forever.

The weight of equipment should therefore be increased by

$$\Sigma\, w_i \left(\frac{1}{1-e^{-rT_i}}\right)$$

over that of construction and installation, where w_i is the percentage of original equipment investment which is retired at age T_i . This information is available from the survival curve. r is set at 10% . The weight of machinery is increased by 25.5% on the basis of this calculation.

The capital service series displayed in table 2 is the results of the calculations which have been described here.

TABLE 3

Year	Industrial Workers and Personnel (Millions)
1950	15.317
1951	16.230
1952	16.873
1953	17.617
1954	18.499
1955	18.868
1956	19.561
1957	20.192
1958	20.807
1959	21.400
1960	22.291
1961	23.475
1962	24.297
1963	25.057
1964	25.933
1965	27.056
1966	28.105
1967	29.000

SOVIET INDUSTRIAL WORK FORCE

TABLE 4

Year	Industry	Construction	Transportation and Communications	Trade	Forestry	Producers' Cooperatives	Independent Artisans	Non-Agricultural Activities of Agricultural Workers	"Others and Residuals"	Total
1950	14.144	2.569	4.624	3.325	.444	1.50	.264	1.500	.484	28.854
1951	15.006	2.678	4.899	3.405	.450	1.55	.240	1.500	.517	30.245
1952	15.556	2.788	5.160	3.495	.462	1.55	.220	1.500	.540	31.271
1953	16.261	2.843	5.352	3.463	.416	1.60	.214	1.525	.575	32.249
1954	17.016	3.179	5.536	3.668	.400	1.70	.190	1.525	.605	33.819
1955	17.367	3.190	5.650	3.725	.389	1.80	.164	1.550	.635	34.470
1956	18.500	3.550	5.840	3.826	.390	1.70	.195	1.600	.646	35.747
1957	19.144	4.000	5.996	4.017	.377	1.20	.145	1.650	.669	37.198
1958	19.675	4.421	6.332	4.190	.367	1.30	.156	1.700	.732	38.873
1959	20.207	4.800	6.663	4.389	.352	1.40	.174	1.800	.870	40.655
1960	22.291	5.143	7.017	4.675	.359	category abandoned	.174	1.700	.984	42.343
1961	23.475	5.270	7.308	5.010	.378		.174	1.550	1.064	44.229
1962	24.297	5.172	7.509	5.253	.389		.174	1.450	1.118	45.362
1963	25.057	5.237	7.718	5.487	.399		category abandoned	1.400	1.186	46.484

Table 4 (cont'd)

Year	Industry	Construction	Transportation and Communications	Trade	Forestry	Producers' Cooperatives	Independent Artisans	Non-Agricultural Activities of Agricultural Workers	"Others and Residuals"	Total
1964	25.933	5.370	7.982	5.752	.404			1.250	1.275	47.966
1965	27.056	5.617	8.259	6.009	.402			1.200	1.381	49.924
1966	28.105	5.768	8.437	6.261	.409			1.250	1.457	51.687

SOVIET NON-AGRICULTURAL NON-SERVICE WORK FORCE (MILLIONS)

TABLE 5

Year	Average Number of Days Worked per Year	Working Day (Hours)	Hours per Man-Year
1950	276.3	8	2210.4
1951	275.7	8	2205.6
1952	274.8	8	2198.4
1953	274.5	8	2196.0
1954	273.9	8	2191.2
1955	273.3	8	2186.4
1956	272.1	7.6	2068.0
1957	267.4	7.5	2005.5
1958	268.0	7.433	1992.0
1959	266.5	7.35	1958.8
1960	266.9	6.985	1864.3
1961	264.2	6.67	1762.2
1962	263.4	6.67	1756.9
1963	264.5	6.67	1764.2
1964	266.5	6.67	1777.6
1965	266.4	6.67	1776.9
1966	263.1	6.67	1754.9
1967	263.1	6.67	1754.9

HOURS WORKED PER YEAR BY WAGE EARNERS IN SOVIET LARGE SCALE INDUSTRY

TABLE 6

	1960 value-added weights	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
Electric power	4.61	27.58	31.71	35.69	41.15	46.61	53.98	60.77	57.70	77.43	89.23
Fuel Industry	15.14	41.08	45.04	49.58	53.82	58.92	66.57	71.39	77.62	86.12	92.35
Ferrous Metals	7.28	37.03	42.68	48.12	53.56	59.00	65.48	71.55	76.36	82.43	90.38
Nonferrous Metals	3.61	36.8	43.0	51.4	56.5	62.7	70.8	76.0	79.8	83.3	94.0
Chemicals	4.02	25.06	30.43	34.78	40.15	46.29	55.75	63.17	70.97	80.31	89.51
Machine Building and Metal Working	29.93	23.81	27.91	32.34	37.43	43.52	51.61	58.69	66.45	75.64	86.93
Wood and Paper Products	9.68	46.60	52.45	55.44	57.82	64.39	69.39	72.96	78.57	86.73	95.24
Construction Materials	6.27	18.08	22.84	26.66	30.56	35.48	42.44	48.73	58.66	70.88	84.72
Glass and Ceramics	.90	27.40	31.15	35.19	39.36	45.76	53.69	61.34	68.85	77.61	88.73
Soft Goods	10.61	40.00	47.86	51.79	57.14	65.36	71.43	76.43	80.71	86.79	93.93
Processed Foods	7.95	42.54	48.25	52.63	58.33	64.47	68.42	74.56	81.14	87.28	95.61
Index of Industrial Production	100.00	33.16	38.22	42.62	47.37	53.44	60.46	66.37	72.97	81.17	90.58

SOVIET INDUSTRIAL PRODUCTION (DIRECT SOVIET SOURCES)

Table 6 (cont'd)

	1960 value-added weights	1960	1961	1962	1963	1964	1965	1966	1967
Electric power	4.61	100.00	112.39	127.29	143.66	160.03	177.88	193.66	211.06
Fuel Industry	15.14	100.00	105.10	111.33	119.83	128.90	137.11	145.33	154.96
Ferrous Metals	7.28	100.00	108.37	117.57	126.78	137.03	146.86	157.74	168.62
Nonferrous Metals	3.61	100.00	108.9	118.5	128.0	137.8	149.6	162.7	178.4
Chemicals	4.02	100.00	113.17	130.05	150.77	173.27	197.06	222.38	250.38
Machine Building and Metal Working	29.93	100.00	115.06	132.56	149.72	164.01	179.51	200.78	225.47
Wood and Paper Products	9.68	100.00	104.08	109.18	115.31	122.45	127.55	131.97	140.82
Construction Materials	6.27	100.00	111.93	121.05	129.80	141.34	153.90	168.68	183.53
Glass and Ceramics	.90	100.00	111.68	123.50	134.49	149.93	161.34	176.22	193.74
Soft Goods	10.61	100.00	103.93	107.50	109.64	112.86	113.57	123.93	137.50
Processed Foods	7.95	100.00	106.58	116.23	122.37	125.88	142.54	149.12	160.09
Index of Industrial Production	100.00	100.00	109.50	120.38	131.36	141.94	153.53	167.26	183.65

SOVIET INDUSTRIAL PRODUCTION (DIRECT SOVIET SOURCES)

TABLE 7

	1956 value-added weights	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
Civilian Industries	55.69	55.21	61.55	66.08	72.90	81.24	90.25	100.00	110.26	120.29	130.98
Munitions	5.96	65.32	77.46	85.78	81.39	86.47	97.69	100.00	103.47	107.41	108.67
Construction	13.19	56.23	64.15	71.70	78.87	86.79	95.85	100.00	109.06	122.26	136.23
Transportation and Communication	17.97	51.76	57.88	63.73	70.03	77.77	90.01	100.00	113.23	125.02	138.97
Trade	7.19	54.51	61.03	65.83	77.23	89.72	93.15	100.00	113.20	119.34	126.82
Aggregated Non-Agricultural Non-Service Output	100.00	55.28	62.14	67.55	73.99	82.27	91.60	100.00	110.44	120.56	131.48

NON-AGRICULTURAL, NON-SERVICE OUTPUT (WESTERN SOURCES)

Table 7 (cont'd)

	1956 value-added weights	1960	1961	1962	1963	1964	1965	1966
Civilian Industries	55.69	140.18	150.42	162.47	173.55	186.73	201.73	216.30
Munitions	5.96	129.48	157.23	175.14	182.66	177.46	179.77	192.49
Construction	13.19	145.66	151.70	156.23	159.62	165.28	172.45	181.13
Transportation and Communications	17.97	152.57	164.90	178.13	193.70	213.41	240.41	257.61
Trade	7.19	137.84	142.82	151.13	157.39	165.46	181.33	197.12
Aggregated Non-Agricultural Non-Service Output	100.00	142.32	153.05	164.40	174.72	186.62	202.05	216.29

NON-AGRICULTURAL, NON-SERVICE OUTPUT (WESTERN SOURCES)

TABLE 8

Year	"Old" Series	"New" Series	"Composite" Series Used in This Study
1940	100	100	100
1945	92	95	
1949	130		130
1950	145	141	145
1951	161		161
1952	179		179
1953	198		198
1954	221		221
1955	248	250	248
1956	277		277
1957	305		305
1958	343	341	343
1959	379		379
1960	426	424	426
1961	472		472
1962	523		523
1963	586		586
1964	644	653	644
1965	706	715	705.0
1966		780	769.3
1967		851	839.3

SOVIET END OF YEAR CONSTANT PRICE INDUSTRIAL PRODUCTIVE BASIC FUNDS (as reported in official statistical books before and after 1965 Narkhoz)

TABLE 9

Year	Construction	Equipment	Installation
1928	9.08	4.12	1.08
1929	13.50	5.56	1.37
1930	21.54	9.26	2.01
1931	23.58	9.14	2.17
1932	24.70	10.39	2.22
1933	19.07	7.53	1.93
1934	24.44	7.61	2.16
1935	31.80	10.98	2.69
1936	45.42	15.72	3.67
1937	36.34	15.70	3.28
1938	31.80	18.56	3.28
1939	33.76	17.35	3.25
1940	32.85	17.17	3.13
1941 1st half	16.49	8.75	1.58
1941 2nd half	5.25	2.12	.50
1942	10.12	5.92	1.00
1943	10.28	5.38	.97
1944	14.17	13.01	1.64
1945	13.39	17.89	1.94
1946	18.67	20.82	2.54
1947	17.13	23.22	2.98
1948	25.65	24.79	3.70
1949	36.98	24.36	4.49
1950	42.00	31.75	5.47
1951	48.42	33.72	6.02
1952	58.07	33.01	6.32
1953	62.94	38.16	6.93

(Table 9 cont'd)

Year	Construction	Equipment	Installation
1954	69.22	45.80	7.93
1955	73.43	58.63	9.20
1956	75.12	76.58	10.67
1957	75.29	85.09	11.73
1958	78.86	98.04	13.28
1959	87.09	110.99	14.55
1960	96.18	122.58	15.54
1961	99.55	136.94	16.7
1962	100.71	153.24	18.0
1963	104.06	168.45	19.2
1964	108.12	188.66	20.8
1965	113.55	200.29	22.0
1966	120.07	212.29	23.3

GROSS NON-AGRICULTURAL, NON-RESIDENTIAL, NON-SERVICE INVESTMENT IN FIXED CAPITAL, EXCLUDING CAPITAL REPAIRS, IN 1950 PRICES (Billion Rubles)

FOOTNOTES

1. I am indebted to Raymond P. Powell for his advise on innumerable aspects of Soviet statistics. However, he should not be blamed for the deficiencies of either the numbers I have ended up using or the conclusions I have drawn from their use. Michael Madow has been a great help in efficiently carrying out most of the statistical computations.

2. Most of the difference shows up in the form of a slightly altered estimate of the rate of growth of technical change. Estimates of the other parameters remain about the same.

3. See the survey articles by Brockett and DePauw and by Feshbach in New Directions in the Soviet Economy, Part III, J.E.C. [1966].

4. The choice of 1950 as a starting date was made because, as well as there being some pre 1950 data availability problems, the erratic post-war recovery presents a major analytic problem which is probably best ignored altogether. My feeling is that a few years of the early fifties

might also have been dropped but being as data starved as I was, I did not want to exercise this option. Some alternative regressions were run starting in 1951 instead of 1950, but there was little difference in the results.

5. See, e.g., Balassa [1964], Kaplan [1968], Moorsteen and Powell [1966] and [1968], and Noren [1966].

6. As an explanation for the decreased growth of the residual, Moorsteen and Powell stress the notion that after 1953 productivity at first rose very rapidly while the economy broke away from the "rigidities and irrationalities" of Stalinism. However, "by the late 1950's the more manageable inefficiencies of the economy had been largely remedied, and resistance to further movement toward the frontier, at least within existing institutional arrangements, had become severe." (Moorsteen and Powell [1968], p. 9). This argument may well contain important elements of truth. However such strongly declining growth rates of A(t) as result from specifying F(K,L) as Cobb-Douglas with assigned factor weights strike me as unlikely. First of all, technological progress is at least partially a result of research and development, which is best thought of as a round-about method of production typically favored as capital becomes more plentiful and real rates of return decline. Also, the Soviet literature has been paying steadily increasing

attention to questions of efficiency since the mid-fifties. Whether this is reflected in practice is difficult to say, but the ideas of Liberman, Kantorovich and others would appear to have influenced economic policy to a certain degree, especially lately. These considerations would appear to justify an <u>increase</u> in the growth of technical change over the period of the fifties and sixties. Unfortunately, the sad truth must be that we really have no good independent information on this question.

7. Proof: Let $k \equiv \frac{K}{L}$, and $f(k) \equiv F(\frac{K}{L}, 1)$

Then $\sigma = \frac{-f'(f-kf')}{kff''}$, and $\eta_L = \frac{f-kf'}{f}$ (assuming constant returns to scale).

$$\frac{d\eta_L}{dk} = \frac{-kf''}{f} - \frac{(f-kf')f'}{\left(f^2\right)} = \frac{-kf''}{f}\left(1 + \frac{f'(f-kf')}{kff''}\right) \gtrless 0$$

according as $\sigma \lessgtr 1$. Naturally $\eta_K(=1- L)$ moves in a direction opposite to that of η_L.

8. See Arrow, Chenery, Minhas, and Solow [1961].

9. From here on in I fall into the bad habit of using the terms "residual", "total factor productivity", "technical change", and "technological progress" interchangeably. "Residual" is really the best term because it most aptly conveys the notion that what is being identified is <u>any</u> contribution to growth other than capital and labor as conventionally measured and combined in constant-returns-to-scale fashion.

10. The I.B.M. Share program 309401 (revised 8/15/66) entitled "Least Squares Estimates of Non-Linear Parameters" was used. It is based on an algorithm devised by D.W. Marquardt (see Marquardt [1963]). While this algorithm can at best obtain only a local minimum, converging to the same parameter values with different initial estimates makes me confident that the estimates given here are in fact global optima.

11. Numbers in parentheses denote the standard errors of the coefficients to a linearized regression about the optimal parameter values. Let the non-linear model be expressed in the general form $Z = g(X,\beta) + \varepsilon$ with ε assumed normally distributed, Z dependent and X independent observations and β parameters. Let $\hat{\beta}$ be the minimizer of $||Z-g(X,\beta)||^2$. Standard errors reported are those of the least squares estimater of β in the linear regression model

$$Z = g(X,\hat{\beta}) + B(\beta-\hat{\beta}) + \omega ,$$

ω normally distributed and $B = \frac{\partial g}{\partial \beta}\Big|_{X,\hat{\beta}}$. The least squares estimate of β is $\hat{\beta}$. Standard errors so obtained (i.e., the diagonal terms of the matrix $[B^TB]^{-1}$) are valid only asymptotically as the sample size goes to infinity, or as the function g is close to being an inner product in X and β . I have checked the accuracy of this approximation for parameters σ and λ by moving out two standard errors in both directions and ascertaining the increase in mean square error after subminimizing the error sum of squares over all possible values of the free parameters. Even the properties of this, more refined, test are large sample as far as using an F-statistic is concerned. The results vindicated a cautious adoption, in this case, of the asymptotic standard error. As usual, $\bar{R}^2$ denotes the percentage variance explained by the (non-linear) regression, corrected for degrees of freedom, and d is the Durbin-Watson statistic.

12. The data are from Tables 1 and 2. For each year (1950 is t = 0) values of $\frac{K(t)}{Y(t)e^{\hat{\lambda}t}}$ and $\frac{L(t)}{Y(t)e^{\hat{\lambda}t}}$ are are plotted (with $\hat{\lambda}$ the least squares estimate of λ).

13. Unfortunately, not much direct evidence can be brought to bear on this hypothesis, although it is easy to find lots of quotes in the Soviet press stressing the more-necessary-than-ever need to employ labor resources rationally.

(Footnotes)

14. See Solow [1960] and [1964].

15. S(u) denotes the precentage of capital stock surviving after u years. I(t) is real investment at time t, and J(t) is capital "jelly" at time t.

16. Aggregating capitals of differing vintages into a single "jelly" is meaningful only under the assumption that all technical change is capital augmenting. This is a severe restriction when the elasticity of substitution is different from one. See Solow [1964] and Fisher [1966].

17. The coverage of the American and Soviet data are not entirely comparable. Soviet industry includes mining, fishing and logging, all of which are excluded from U.S. manufacturing. The capital series are from Gordon [1967]. Output is from Gordon [1967], based on Kendrick's and O.B.E. data. The labor series is manhours worked in manufacturing, B.L.S., based on establishment data. Unemployment rate is from O.B.E. data.

18. See Nelson [1965] where a Taylor series expansion of a CES function is carried out in order to demonstrate this conclusion.

19. See, e.g., Feshbach [1966] pp. 713, 714.

20. Some recent articles in Voprosi Ekonomiki have discussed aspects of this problem.

21. It is at this point that our ignorance of what constitutes the residual becomes really annoying. What is it that should be pushed--increasing returns, labor skills, new inventions, optimal use of resources, better organization, or what? Naturally, I evade the issue. A few courageous researchers have tried to make a more specific breakdown of the residual (see, e.g., Brubaker [1968]). Their approach is suggestive, but an overpowering amount of ad-hocery is sometimes involved in cooking up the relevant figures.

22. I am thinking mostly of the "New Economic System". Although the main emphasis has been on increased efficiency in combining resources and on the quality of production, one of the subsidiary aims of this set of reforms has been to quicken technical change. However, this is likely to be change of the once-and-for-all variety, some of the effects of which can already be seen in the 1967 output results.

References

Arrow, K. J., H. B. Chenery, B. S. Minhas, and R. M. Solow [1961]. "Capital-Labor Substitution and Economic Efficiency", Review of Economics and Statistics, XLIII, 225-50.

Balassa, B. [1964], "The Dynamic Efficiency of the Soviet Economy", American Economic Review, May, 1964, 490-506.

Bergson, A. and S. Kuznets, eds. [1963], Economic Trends in the Soviet Union, Harvard University Press.

Brubecker, E. R. [1968], "Embodied Technology, The Asymptotic Behavior of Capital's Age, and Soviet Growth", The Review of Economics and Statistics, (August, 1968), 304-311.

Domar, E. D. [1961], "On the Measurement of Technological Change", Economic Journal, LXXI, 709-29.

Feshbach, M. [1966], "Manpower in the U.S.S.R.: A Survey of Recent Trends and Prospects", pp. 703-88 in Part III of J.E.C. [1966].

Fisher, F. M. [1966], "Embodied Technical Change and the Existence of an Aggregate Capital Stock," The Review of Economic Studies, XXXII, 263-88.

Gordon, R. J. [1967], Problems in the Measurement of Real Investment in the U.S. Economy, unpublished PH.D. thesis, Massachusetts Institute of Technology, June, 1967.

Joint Economic Committee, U.S. Congress (Washington)
[1962] Dimensions of Soviet Economic Power
[1965] Current Economic Indicators for the U.S.S.R.
[1966] New Directions in the Soviet Economy
[1968] Soviet Economic Performance: 1966-67

Kaplan, N. M. [1967], "Growth in Soviet Transport and Communications", American Economic Review, December, 1967, 1154-67.

______, [1968], "The Retardation in Soviet Growth", The Review of Economics and Statistics, (August, 1968), 293-303.

Marquardt, D. W. [1963], "An Algorithm for Least Squares Estimation of Non-Linear Parameters", Journal of Society of Industrial and Applied Mathematics, 11, No. 2.

Mikhalevsky, B. M. and Yu. P. Solovyev [1966], "Proizvodstvennaya Funktsya Narodnovo Khoziastva S.S.S.R. v 1951-1963 g", Ekonomika i Matematicheskiye Metody, No. 6. 823-40.

Moorsteen, R. H. [1962], Prices and Production of Machinery in the Soviet Union, 1928-1958, Harvard University Press.

Moorsteen, R. H. and R. P. Powell [1966], The Soviet Capital Stock 1928-1962, R. Irwin, Inc.

Moorsteen, R. H. and R. P. Powell [1968], Two Supplements to the Soviet Capital Stock, The Economic Growth Center of Yale University.

Nelson, R. R. [1965], "The CES Production Function and Economic Growth Projections", The Review of Economics and Statistics (August, 1965), 326-328.

Noren, J. H. [1966], "Soviet Industry Trends in Output, Inputs, and Productivity", pp. 271-326 in Part II-A of J.E.C. [1966].

Revenko, A. P. [1966], Sopostavlenie Pokazatelei Promyshlenovo Proizvodstva S.S.S.R. i S.Sh.A., Moscow.

Solow, R. M. [1957], "Technical Change and the Aggregate Production Function", Review of Economics and Statistics (August, 1957), 312-20.

Solow, R. M. [1960], "Investment and Technical Progress", Chapter 7 in _Mathematical Methods in the Social Science_, (Arrow, Karlin and Suppes, eds.), Stanford University Press.

______,[1964], "Capital, Labor and Income in Manufacturing", _The Behavior of Income Shares_, Princeton University Press.

Tsentral'noe Statisticheskoe Upravlenie pri Sovete Ministrov S.S.S.R. (oscow)
Forty Years of Soviet Power [1958]
Narodnoe Khoziaistvo S.S.S.R. (Narkhoz)[1958-1966]
Promyshlenost S.S.S.R. [1957, 1964]
S.S.S.R. v Tsifrakh [1959-1967]
Strana Sovetov za 50 Let [1967]
Trud v S.S.S.R. [1968]