1-1-1981

Regional Production Functions for Soviet Agriculture - Factor Endowment, Variable Proportions and Modernization

Elizabeth Clayton

Occasional Paper 8103
April, 1981

Occasional Papers

The Center for International Studies of the University of Missouri-St. Louis issues Occasional Papers at irregular intervals from ongoing research projects, thereby providing a viable means for communicating tentative results. Such "informal" publications reduce somewhat the delay between research and publication, offering an opportunity for the investigator to obtain reactions while still engaged in the research. Comments on these papers, therefore, are particularly welcome. Occasional Papers should not be reproduced or quoted at length without the consent of the author or of the Center for International Studies.

Regional Production Functions for Soviet Agriculture: Factor Endowment, Variable Proportions and Modernization, 1965-1975

Elizabeth Clayton

Regional Production Functions for Soviet Agriculture: Factor Endowment, Variable Proportions and Modernization, 1965-1975

Elizabeth Clayton
Professor of Economics
University of Missouri-St. Louis
St. Louis, Missouri 63121

Telephone: (314) 553-5554

Prepared for the Conference on the Rural Economy,
Kennan Institute, April, 1981

In the past sixteen years, the Soviet Union has modernized its agricultural system by expanding its technology and changing its mode of production. From a position of low rank and priority, agriculture has raised its status and its claims on capital investment. Tractors have become ubiquitous, the wheat belt has shifted 200 miles northward, and in R & D agriculturalists, the Soviet Union outnumbers the United States. Even the prospects for changing the course of whole rivers so that they flow south now seems more feasible.

Yet Soviet agriculture continues to be criticized for inefficiency. In part, this conclusion is based on old data, for their output growth exceeds ours. In part, it represents a pricing problem, for their food is highly subsidized (as Vlad Treml has shown), and subsidies create queues.[1] While the output has grown, the costs have grown faster while prices have been relatively stable. The queues reflect inefficiency in distribution or consumption but not necessaily in production. Nevertheless, the reputation persists and this paper examines its authentication.

The charges of Soviet agricultural inefficiency are built from comparisons between countries of growth rates, yields, and so on. As is well known, the base of a comparison can serve a purpose. This need not be a devious or suspect act but merely reflect the clients of the comparison. Thus most comparisons of Soviet agriculture have focused on the United States as a referent because this is an eminently legitimate concern of the clients, our Congress. Nevertheless the Soviet Union's agriculture has been modernizing rapidly and ought also to be compared to other modernizing agricultures not only for a measure of its success but for its modernizing strategy,

or socialist structural transformation.

Transforming an agricultural structure implies more production efficiency, or increasing farm output from existing inputs. This interpertation is too narrow because most output really is increased by augmenting the existing inputs by modern manufactured ones. Although the farm does not produce these new inputs, as it did the old ones, it is often credited with the enhanced output that comes from the. A formulation that takes into account these relationships of the complements and substitutes for basic inputs is the production function.[1] The basic inputs are labor and land, and the new inputs are mechanical, chemical and biological technology.

A production function may seem an odd statistical tool to apply to the Soviet Union.[2] It is incontestably a phenomenon of neoclassical economics, relying on assumptions of equilibrium and profit maximization that seem chimerical in the light of Soviet experience. It considers nothing at all about the level or composition of demand, focusing instead on the components of aggregate supply. At its simplest level, a production function may be an empty formalism expressing only the intuitively obvious fact that agricultural output cannot be increased without more inputs and the both should be fully measured. Extended to the Soviet experience, it would predict that agricultural production will decrease if livestock are destroyed (as during collectivization) or that it will increase if fertilizer deliveries grow (as during the recent decade).

Nevertheless, the available production function studies also have a certain intuitive plausibility that commends them. First of all, they express a purely technical or engineering relationship and a willingness to separate the that aspect of efficiency from the economic. Second, they

are generalized and have been applied to the study of agriculture in a diversity of economic systems; thus the Soviet estimates can be compared to others.[3] Finally they classify our knowledge in a way that is fairly independent of ideology. If the first approximation to an efficiency study of Soviet agriculture is purely technical and independent of ideology, e.g., the nationalization of land, then the second approximation that includes it can more accurately separate the pure effects of public land ownership.

The production function is particularly appropriate for studying a system whose prices are known to be in disequilibrium. At the simplest level of estimation, this data is not required. I will stay at this level and rely in this essay on my estimates that have been published elsewhere, along with some extensions.[4] This is not to deny that the more complex production functions are useful, for they are. They more clearly incorporate the assumption of optimization and the principle of duality. Michael Wyzan has worked with them and I hope that he will pursue that path.[5]

The distinction that I make is between technical (or engineering) efficiency and economic efficiency. In graphic terms, this is the difference between being on an isoquant and being at a tangency of an isoquant and an isocost line. Yet economics is not all tangencies and intersections. There is in addition the ephemeral componet known as "system" or "organization," which includes income distribution and motivational incentives. In my work on production functions I have explored rather deeply the literature on agricultural development in less developed economies and will link that information to production function estimation. This is a departure from past practice, where agriculture most often has been compared between the Soviet Union and the United States. Here the Soviet Union's production efficiency is seen primarily as a focal point for today's developing countries who find

socialized agriculture to be alluring.[6]

Many of our well-known judgements about socialized agriculture are more accurately described as testable hypotheses that are subject to empirical verification. The production function formulates the test and defines their boundaries so that they are reasonable in both economic logic and technological particulars. Although socialized agriculture probably is attractive because of its effects on income distribution, it also has efficiency consequences, which the production function tests. Two questions of Soviet agricultural efficiency are examined here: the relative resource base, or proportions of factors of production, e.g., labor and land; and the optimal scale. Although these are related to questions of factor incentives and income distribution, those are more or less ignored.

An advantage of the production function is its multidimensionality, when the inputs and outputs are many. For example, consider the off-cited conclusion that the private plots in Soviet agriculture are more efficient because they produce 23 percent of the nation's food on only 3 percent of its land.[7] A simple production function tells us that output depends on both labor and land. The private plots are more precisely described as labor-using and yield-increasing. They conserve on land, the resource in shortest supply, but use generously the more available resource which is labor. Their greater effectiveness is the sum of the high yield from land, the intensive use of labor, and the specialization in land-saving, labor-using products such as meat and vegetables.

This view of the private plots uses an argument of comparative advantage that is most often found in international trade theory. Its extensions shed some light on the critical differences between the private and socialized ownership of agricultural land. A first extension is that

the two sectors differ less in ownership than in factor proportions. If the assumptions of trade theory are met, there will over time be a tendency toward a factor-and commodity-price equalization between the sectors even without factor mobility, i.e., the transfer of socialized land to private use. This occurs primarily through product specialization.

A second extension of trade theory is that the specialization of the sectors depends on their factor proportions, or the land per worker. In this light, the private plots can be more critically viewed as a residual employer for surplus labor as yet unabsorbed into the more industrialized economy.[8] There is some support for this view in the Soviet data. First, the recent relaxation of restrictions on private production have not appreciably increased output. Overall the pool of agricultural labor has shrunk and the output on private plots has declined. Nevertheless, in the republics where the pool of agricultural labor has increased, the private plot production also has grown, e.g., in Azerbaidzhan, where private plot output increased by 43 percent between 1970 and 1979.[9] Thus, holding farm labor on the private plots (or by a domestic passport system or other control) is a policy that is labor-using and job-creating.[10]

This argument does not deny that private plot production meets a necessary demand but focuses instead on its comparative advantage, where the trading-producing units with different resource endowments are not nations but sectors. Although the need to mobilize surplus labor is appropriate for a static, developing economy where workers are in surplus, it disappears when opportunities are available in a modern sector. Further, no labor force rejects an augmentation of its musclepower and a release from backbreaking work. Capital-using production, either in agriculture or manufacturing, is an attractive alternative. Nevertheless, many developing countries falter in privately supplying and allocating capital

and rely on public finance of investment and forced saving. Historically and politically the Soviet Union linked agricultural capital formation to land nationalization and collectivization.[11]

This combination of a land reform (the nationalization) a new economic organization (the collective), and the public supply of capital has attracted the developing economies.[12] These countries have sought to modernize food production but face a dilemma between that goal and political stability because capital allocations are most effective on the largest farms. This attractiveness stems from several sources: they are diversified so their riskiness is less; they can generate savings from consumption to repay credit; they often have the political clout that passes for eligibility.[13] More important yet, the costs of public administration are lower when supplying a few large farms than when supplying many small farms. In short, the large farms have scale advantages for farmers and bureaucrats alike.[14] Their drawback is that they enhance the existing income inequalities and favor the rich. The Soviet model that enlarges farm size and modernizes technology but avoids the income distribution consequences of private land ownership is appealing to economies that are concerned with both equity and efficiency.

The introduction of capital as a third factor of production expands a production function to considerations of scale, optimal farm size, and the use of manufactured inputs. The Soviet farms have been criticized for being too large and therefore inefficient. Our ability to evaluate this argument is somewhat ambivalent. On one hand, a production function analysis seems ideal for this purpose. Using a Cobb-Douglas production function, the input coefficients should sum to one if the returns to scale are constant (and the farm size is optimal). Such a finding would indicate that today's scale is indeed appropriate. My production function estimates led to such a

conclusion, but only tentatively.[15]

On the other hand, optimal farm size will differ between republics on the basis of factor proportions and product specialization. While the private and socialized sectors can be compared on these characteristics, the collective and state farms are not so sharply contrased. Their factor proportions are known (and shown in Table 2 below), but their specializations differ by republic and require a more extensive analysis than this paper allows. This gap in our knowledge of Soviet agriculture is significant and deserving of remedy.

There is yet another problem. My production function considered only those inputs used directly on the farm, but as agriculture is modernized the line between outputs and inputs that are "farm" or "off-farm will change. Thus the "off-farm" inputs to Soviet agriculture include not only the planners but the hydrologist in the Ministry of Water Supply, the research scientist in a seed institute, the chemist in the fertilizer industry and the mechanic in a repair facility of Sel'khoztekhnika. Incorporating the effects of this infrasturcture is at best incomplete.

One off-farm input of considerable importance to developing agriculture is the public investment in people, such as the human capital in education.[16] By ignorance or malice, an uneducated and unskilled worker can waste many modern inputs. For example, the genetically advanced seeds are more productive only with the proper fertilization in accurately measured amounts. Human capital in education affects a production function estimate in two ways. The first is its own-effect, where educated workers are more productive than poorly educated workers. This effect is surprisingly absent in my production function estimates.

The second effect is the complementarity of education with manufactured

inputs.[17] In the Soviet estimates, this effect is so strong that it causes data collinearity; either the manufactured inputs or the human capital is statistically redundant. It further is two-directional; a Soviet Study of northwestern farms indicates that new capital equipment increases output not at all where the labor force is more than 92 percent unskilled or ill-educated.[18] Education seems further correlated even with the location of new fertilizer manufacturing plants.[19] A first approximation to answering the question of optimal farm size again examines the regional variation in factor proportions. The progenitors of this perspective, Vernon Ruttan and Yujiro Hayami, classify the world's agricultural systems into land-saving (such as Japan) and labor-saving (such as the United States).[20] Each class conserves on the resource in shortest supply, even directing its technology toward that goal.[21] The republics of the Soviet Union differ considerably in their agricultural land-labor ratios. The data are shown in Table 1, where the republics are grouped by their ratios of hectares per worker. (The second number indicates the share of arable land in production and will be discussed below.)

Table 1: Land per worker (Z/L) and Land utilization (Z/Ar), in Soviet agriculture, by republics, 1979

Group I			Group II			Group III		
	Z/L	Z/Ar		Z/L	Z/Ar		Z/L	Z/Ar
RSFSR	12	.57	Ukraine	6	.80	Georgia	1	.24
Kazakhstan	22	.19	Belorussia	5	.66	Azerbaidzhan	2	.31
			Moldavia	3	.71	Armenia	2	.33
			Lithuania	7	.66	Uzbekistan	2	.15
			Latvia	7	.67	Kirghizia	3	.13
			Estonia	8	.64	Tadjikistan	2	.19
						Turkmenistan	2.5	.03

Definitions:

(1) Z: sown hectares of crop land;

(2) L: annual number of workers taking part in state farm or collective farm labor;

(3) Ar: hectares of arable land.

Source: Narodnoe Khoziaistvo v 1979 g., TsSU, Moscow: 121; 290, 304; 240

Using this framework, the republics of the Sovie Union may be grouped by their factor proportions and compared for the appropriate technology that would conserve their scarcer resource. The republics of Group I (in Table 1) possess an agricultural resource endowment that resembles the United States; their appropriate technology would be labor-saving (and land-using). In Group III, the endowment resembles that of Japan and its appropriate technology would be land-saving, labor-using, and yield-increasing. (Its analog is the private sector as discussed earlier.) The republics in Group II are intermediate to the others in factor endowment and in the appropriate direction of their technology.

The Soviet republics indeed differ in their growth strategies by resource endowment. The relative land availability (the Z/L of Table 1) is negatively correlated with yield ($r = -0.65$) and positively correlated with labor productivity ($r = +0.42$). (Both correlation coefficients are significant, in that the probability that either equals zero is only 0.0001, but this is due to the partial identity.) At polar extremes, the republic of Georgia has adopted a land-saving strategy of agricultural development. The RFSFR has adopted a labor-saving strategy. The republics of Group II have used a mixed strategy.[22]

Optimal farm size also is related to regional resource endowment and factor proportions. Berry and Cline, in a world-wide study of developing

agricultural systems, show that a larger farm size is associated with a higher labor productivity and a lower land productivity (yield), as these farmes replace labor by capital and hold more land out of use.[23] Applying the results of this study to the Soviet Union, the farm size would be larger in the north than in the south because of the different land-worker ratios. These data are shown in Table 2, which indicates that the Soviet Union follows this common pattern: the farm size is larger where land is relatively more available. Overall, of course, the average Soviet farm is extremely large; Berry-Cline found a predominance of large farms (over 1000 hectares) only in Venezuela, Peru, and Brazil. Nevertheless, the relative Soviet farm size reflects factor endowments.

The Berry-Cline relationship has two corollaries that are relevant to Soviet agriculture. The first is that more land will be held out of use where available land is greater, but this result does not hold for the Soviet Union. As Table 1 indicates, there is more unused land in the south. This disparity reflects the south's need for irrigation. A second corollary is that small farm (private plot) production is more appropriate in the south where the land per worker is low, where labor is in "surplus," and where it can be applied intensively. This is partially confirmed by Soviet experience; in the north (Group I), the share of agricultural land in private use is less than 3 percent but in the south (Group III) it is greater than 6 percent. However, the greatest share is in the west (Group II) where 7 percent is held in private use on the collective farms and 10 percent by worker-employees, usually from the state farm.

The discussion thus far indicates that the Soviet union has not one but three agricultural production systems, differentiated on the basis of factor proportions and other relevant characteristics. In addition, some previous

work of mine indicates a strong Soviet preference for regional self-sufficiency in food production, indicating autonomy of demand, and Ken Gray has rationalized these preferences by observing the transport minimizing bias in agricultural planning.[24] Thus a production function was estimated for each of the three regions, for the eleven years (1965-75) and this result compared to a national estimate. The estimation equation in each case was:

$$Q^* = A + b_1 Z^* + b_2 HP^* + b_3 FERTR^* + b_4 LABOR^* + b_5 HERDS + e, \text{where}(*)$$

indicates a logarithm, Q is the value of putput in 1965 prices, Z is sown hectares, HP is capital measured in horsepower capacity, FERTR is delivered fertilizer in 100 percent nutrient units, LABOR is the annual participation in state and collective farms, and HERDS is the productive livestock inventory measured in cattle-equivalent units.

The precision of the production function estimates, as shown by a Chow test, is significantly enchanced.[25] Nevertheless, some of the coefficients do not significantly differ from zero, including all of those for Kazakhstan-RFSFR. Several explanations are possible. First, the model may be mis-specified including omitted variables. This is discussed below and implies that a more sophisticated model such as that of Don Green is appropriate for this region.[26] Second, it indicates that the RFSFR is comprised of more than a single group and should be subdivided as data become available. Finally, it may indicate that these inputs are not as productive in this region as in others and that the policy of regional autonomy is not efficient in production. This can be seen from the outpt elasticities. Since the estimation is in logarithms, its coefficients indicate an output elasticity for each input in each region, e.g., the input coefficient of .23 for land in the west indicates that a 10 percent increase in land would increase output there by 2.3 percent. A coefficient that is not significantly different

from zero indicates that these inputs at the margin have little if any effect on output.

The consequences of an omitted input for the estimation depend on the optimization assumptions, or the behavioral model, behind the equation. This point can be illustrated by the input of water from rainfall and from irrigation. If an input quantity cannot be foreseen except for assuming that it will equal a constant (most likely the mean), then the optimizer-decision-maker has no special knowledge to use in deciding the quantity of the input to use. An example is the water from rainfall, where the quantity is variable but unknown. However, if an input can be forecast and its quantity chosen to reflect this knowledge, the estimated coefficients are biased measures when the input is omitted from the equation. An example is irrigated or drained land, where the quantity can be forecast. Unfortunately the ability to include this variable in these equations is beyond the scope of this paper. In particular, as much as 40 percent of irrigated land in some republics is in private use. Since the other inputs in this sector, particularly labor, are not known, the data for incorporating irrigated land in the estimating equation now are inadequate.

This paper has examined the different resource endowments of the republics of the USSR with their variable factor proportions. The focus of this work was the different paths to agricultural modernization that each endowment requires. These can be divided into labor-saving and land-saving modernization. The Soviet Union then was divided into three agricultural regions whose resource endowments are roughly similar within the region but different between the regions. Production functions, Cobb-Doublas linear in logarithms, were then estimated for these three regions. Two of the regions, the south and the west, were found to have relatively

well-behaved production functions comparable to those in other agricultural systems. These are the regions with rapid growth. However, the production function for the dominant agricultural region, including Kazakhstan and the RFSFR, were not well-behaved and require further sub-divisons on the basis of resource endowments.[27]

This regional approach to production analysis in the Soviet Union suggests a number of fruitful steps for further analysis. First is an examination of the factor-augmenting technology according to the regional resource endowments. In particular, some work elsewhere has found that technology augments the scarcer resources in response to price incentives, usually with a lag of 7-8 years, e.g. where the price of labor is relatively high, the technology tends to be labor-saving. The USSR, with its land nationalization and economic planning, has no similar price incentives, but should follow similar strategies for its technology. Its ability is of considerable interest. Second, this paper suggests that regional specialization of output can supplement the differences in factor endowments and eventually equalize factor incomes. The USSR has a long-standing commitment to national equality in labor income, to which regional specializations could contribute. Thus far, specialization has been pursued only because of climate; but it has considerable prospects for growth.

Table 2: Land per worker (Z/L) and Average farm size (Z/N) in Soviet agriculture, by collective and state farms, by republics, 1979

Group I (north)			Group II (west)			Group III (south)		
Collective farms (kolkhozy):								
	Z/L	Z/N		Z/L	Z/N		Z/L	Z/N
*RSFSR	11	4,700	Ukraine	5	3400	Georgia	1	400
Kazakhstan	15	10,800	Belorussia	4	2000	Azerbaidzhan	3	1200
			*Moldavia	2	2400	Armenia	2	500
			Lithuania	6	1900	*Uzbekistan	1.5	1700
			* Latvia	7	2600	Kirghizia	3	3200
			Estonia	8	2900	Tadjikistan	2	2400
						Turkmenistan	2	2300
State farms (sovkhozy):								
	Z/L	Z/N		Z/L	Z/N		Z/L	Z/N
*RSFSR	11	5,500	Ukraine	5	3400	Georgia	1	700
Kazakhstan	23	15,000	*Belorussia	5	2400	Azerbaidzhan	2	700
			Moldavia	2	1300	Armenia	2	600
			Lithuania	5	2000	Uzbekistan	3	2700
			*Latvia	6	2900	Tadjikistan	2	2600
			Estonia	7	3100	*Turkmenistan	2.5	1500

Definitions:

(1) Z: sown hectares of crop land;

(2) L: annual number of workers taking part in state farm or collective farm labor;

(3) N: number of collective or state farms at the end of the year.

* Median

Source: Narodnoe Khoziaistvo v 1979 g. TsSU, Moscow: 290-1, 302-4, 240

Table 3: Production function estimates, Soviet Union 1965-75, national and regional

	Land b_1	HP b_2	FERT'R b_3	LABOR b_4	HERDS b_5
National (N=165)	.28	.03+	.27	.34	.06+
North (Group I, N=22)	-.45+	-.52+	.30+	.19+	1.18+
West (Group II, N=66)	.23	.32	-.00+	.27	.13+
South (Group III, N=77)	-.00+	.04+	.35	.30	.33

+: Coefficient does not significantly differ form zero

R^2= .99 in all estimates

Sources:

(1) Land: sown area (Z); see Table 1.

(2) HP, FERTILIZER, HERDS, See sources and inethodology in Clayton, 1980 Herds are an aggregation of cattle, swine, sheep, goats and poultry in cattle-equivalent units.

(3) Labor: See Table 1.

BIBLIOGRAPHY AND FOOTNOTES

1. Valdimir Treml, "Agricultural Subsidies in the Soviet Union, " Foreign Demographic Analysis Division, Report No. 15, Bureau of the Census, 1978.

2. A production function is the statistical relationship between output and inputs. In this paper, its form is a Cobb-Douglas production, function, linear in logarithms:

$$Q^* = a + b_1 L^* + b_2 Z^* + b_3 F^* + b_4 HP^* + b_5 HERDS + e$$

Where an asterisk (*) denotes a logarithm, Q is the quality of output valued in 1965 prices; L is the labor on collective and state farms; F is the fertilizer deliveries; Hp is the capital stock measured in horsepower; and HERDS is the productive livestock inventory of cattle, swine, sheep and goats and poultry.

3. Elizabeth Clayton, "Productivity in Soviet Agriculture," Slavic Review 39 (3), September 1980: 446-459 compares the agricultural system of the Soviet Union with other agricultural systems studied by Yujiro Hayami and Vernon Ruttan, "Agricultural Productivity Differences Among Countries," American Economic Review 60 (5), December 1970: 895-911 and their more complete study Agricultural Development: An International Perspective, Baltimore, 1971.

4. Clayton, op. cit.

5. Michael Wyzan, "Actual and Optimal Prices in Soviet Agriculture," working paper, nd

6. A.R. Khan and D.P. Ghai, Collective Agriculture and Rural Development in Soviet Central Asia, London, 1979; D. Ghai, A.R. Khan, E. Lee and S. Radwan, Agrarian Systems and Rural Development, London, 1979.

However, there has been a recent departure from this view in R.A. Berry and W.R. Cline, Agrarian Structure and Productivity in Developing Countries, Baltimore, 1979, where a smaller farm size is shown to be a more productive (and intensive) use of farm labor.

7. Wall Street Journal, March 3, 1981; 1

8. Barney Schwalberg pointed out the residual characteristic of the labor force in Soviet construction and agriculture at the Conference on Soviet Economy in the Year 2000, Washington, D.C., October, 1980.

9. Narodnoe Khoziaistvo Azerbaidzhanskoi SSSR za 60 let, Moscow, 1980: 119.

10. Frank Durgin, "The Inefficiency of Soviet Agriculture versus the Efficiency of U.S. Agriculture: Reality or an Idol of the Mind?" ACES Bulletin, 20 (3-4), Fall-Winter 1978: 1-36

11. James Millar, "Financing the Modernization of Kolkhozy," The Soviet Rural Community, Urbana, 1971: 276-306.

12. Khai and Ghan, op. cit.

13. Berry-Cline, op. cit.: 6-14

14. W. Flinn and Frederick Buttel, "Sociological Aspects of Farm Size: Ideological and Social Consequences of Scale in Agriculture," American Journal of Agricultural Economics 62 (5), December, 1980: 946-953.

15 Elizabeth Clayton, "Economic Reforms in Bulgaria and Romaina: Prospects for the 1980's" Economic Reforms in Eastern Europe and Prospects for the 1980's, Brussels, 1980: 141-148 examines the economic validity of large size in a socialist agricultural system.

16. A.B. Soskiev, Vospoizvodstovoi ispol'zovaniia trudovykh resursov sel'sekogo khoziaistva, Moscow, 1978.

17. This is also true in Hayami-Ruttan, op. cit., and Zvi Griliches "The Sources of Measured Productivity Growth: United States Agriculture 1940-60," Journal of Political Economy 71 (4), August, 1963: 336.

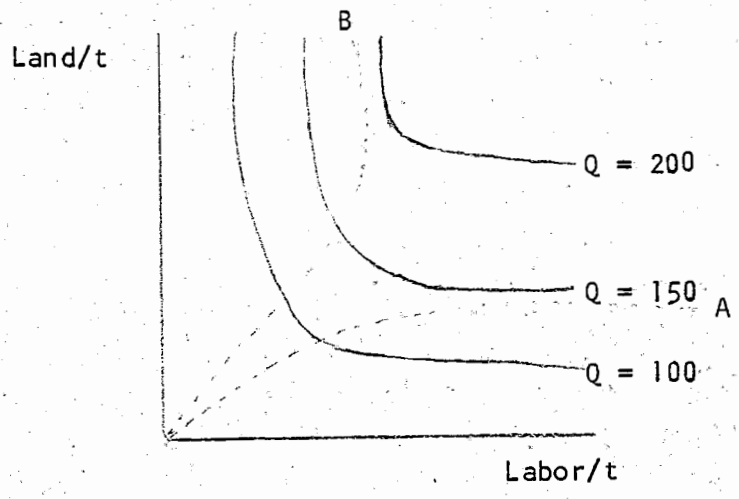
18. V. N. Iakimov, Tekhnicheskii progress i vosprizvodstvo rabochei sily v kolkhozakh, Moscow, 1976: 90

19. Elizabeth Clayton, "Regional Self-Sufficiency in the Soviet Union, "Soviet Regional Development: Trends and Perspectives, Newton MA, 1979: 81-92.

20. Hayami-Ruttan, op. cit.

21. Hans Binswanger, Vernon Ruttan et al., Induced Innovation: Technology Institutions and Development, Baltimore, 1978.

22. This can be illustrated by the following isoquant set, where path A is a land-saving strategy and path B is a labor-saving strategy:



23. Berry-Cline, op. cit.

24. Kenneth Gray, "Soviet Agricultural Specialization and Efficiency," Soviet Studies 31 (4), October 1979: 542-558.

25. The sources of these variables and their definitions are:

Z: land, hectares of sown area in all categories of economic organization;

L: labor, agricultural workers on collective and state farms;

HP: capital equipment, in horsepower units;

F: fertilizer deliveries in 100 percent nutrient units, excluding feed supplements;

HERDS: head of livestock measured in cattle equivalents, where cattle = 1; poultry = .02; swine = 0.5; sheep and goats = 0.1

Q: output, rubles in 1965 prices in all categories of organization.

Source: Narodnoe Khoziaistvo for the relevant year Moscow.

26. Donald Green, "Soviet Agriculture: An Econometric Analysis of Technology and Behavior," Soviet Economy in a Time of Change, ed. John Hardt, Vol. 2, Washington, D.C. 1979: 116-132

27. Sel'skoe Khoziaistvo, Moscow, 1971 provides the most recent data, showing that in 1970 the land per worker in the RFSFR ranged form 5.4 hectares in the Northwest raion to 16.4 hectares in East Siberia: 114, 447, 452.