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ECONOMETRIC EVIDENCE FROM THE UKRAINE

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Agricultural Specialization: Econometric Evidence from the Ukraine

1. Converging Rates of Marginal Product Transformation and the Autarky Hypothesis

During the past fifteen years several attempts have been made to quantify the comparative efficiency and trends in performance of Soviet agricultural policies. One methodology has been to compare partial productivity indices (such as labor productivity and yields) for Socialist and non-Socialist analogue regions which are chosen to minimize climatic and geographical differences.[1] Yet another approach has in effect created an historical analogue, by making comparisons of Soviet agriculture with itself over time, through aggregate production function formulations applied to time series data.[2] These latter studies relate output indices to measured input indices and attribute residual growth of aggregate output (total factor productivity) to "technological change."

The present paper is a disaggregated production function study of an available time series of data related to production of individual crops grown in the twenty-five oblasts of the Ukraine. What is sought is evidence of improvement over time of the locational distribution of crop production. While agricultural location in the West is generally considered to be within the competency of decentralized decision-making, it is an object of deliberate policy making in the Soviet Union where marketing decisions continue to be centrally planned. The many unresolved and perplexing issues of decision making in this area have been described by this author elsewhere.[3]

Unlike analogue studies and aggregate production function studies, the present methodology relates measured trends in Soviet performance in this area against absolute standards of allocative efficiency suggested by the logic of price theory.[4] These standards are absolute in the sense that they transcend economic systems--and hold for production anywhere.

It must be noted that there is a particular irony involved in attempted Western quantitative judgment of Soviet performance by standards of static efficiency. Often, the very basis of Western interest in command economies is skepticism that central allocation can proceed well without all the information necessary for efficient economic functioning. Yet the western observer has much less information to make quantitative measurements of economic efficiency than do the planners he is judging. The present problem of efficiency involves multiproduct, spatial, and temporal aspects which are imperfectly captured, even by the most refined linear programming models.[5]

The present analysis is simplified, however, by examining trends in interregional production costs alone, a subset of the full problem which also involves the cost of transporting state procurement. This approach is partially justified if a common Western perception is valid, that Soviet agriculture has been characterized by a high degree of regional self-sufficiency, or autarky.[6] The historical record provides evidence that this has been the case. For instance, a single-minded desire to minimize transportation costs accompanied by professed skepticism about previous capitalist patterns of specialization led in the 1930's to the expansion of cotton and sugar beet cultivation to regions where these crops had not been previously grown.[7] Steps were taken to eliminate entirely the interoblast transportation of potatoes after 1939, and to significantly reduce the interoblast transportation of sugar.[8] Cotton production soon proved unsuited for the new areas of the RSFSR and Ukraine to which it had been extended, but sugar beet cultivation remained scattered in the Far East, Eastern Siberia and elsewhere until the transportation minimization goal yielded to broader economic calculations in the mid 1960's.[9] There were reports in Soviet publications in the mid-1960's of continued restrictions on the interoblast shipment of vegetables and fruit which were thought to have contributed to decisions to locate winter greenhouse production near northern industrial cities. These investments have recently been reconsidered.[10]

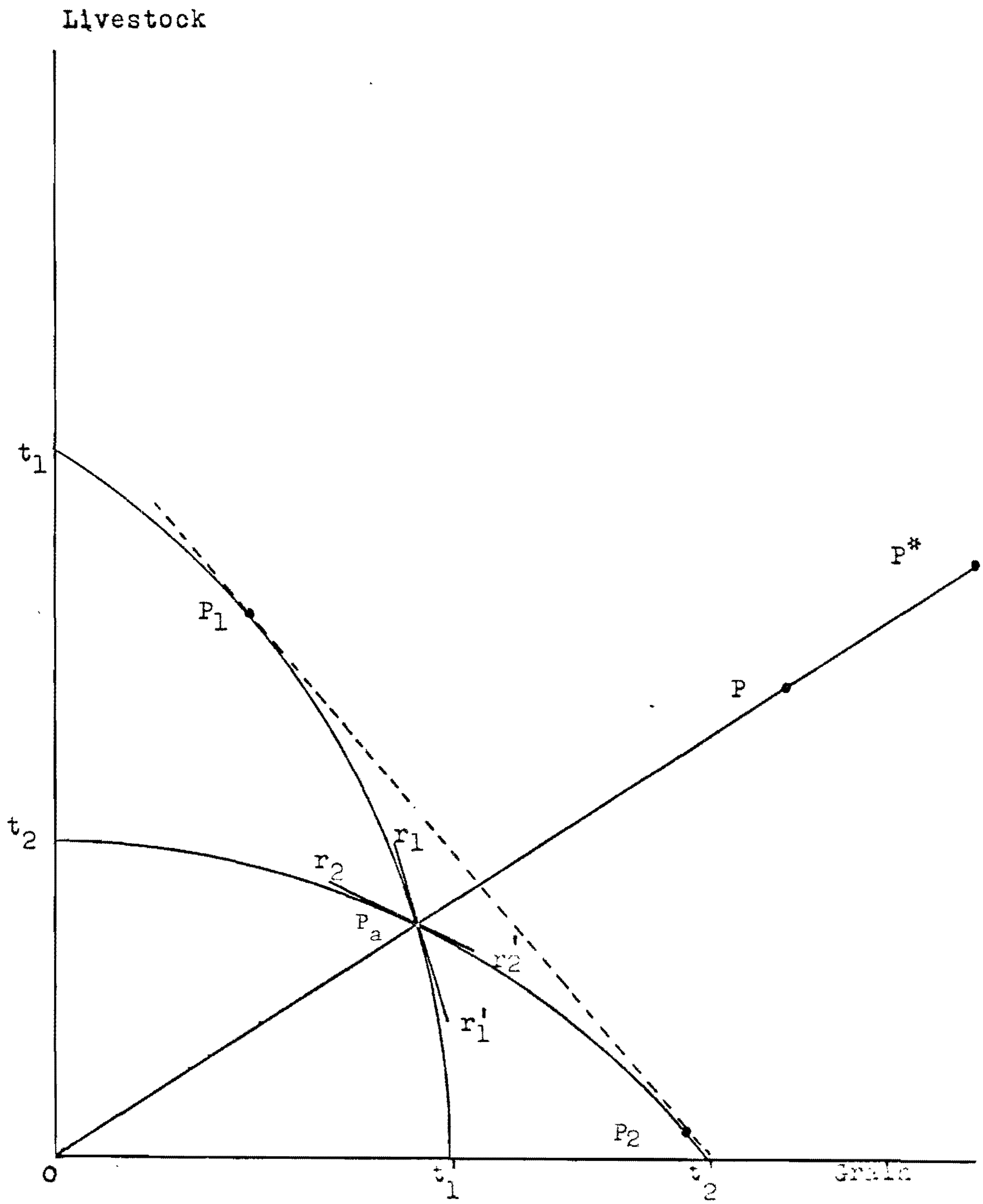
The 1960's brought a reorientation toward regional specialization evidenced by official decrees and the commissioning of research institutes, Gosplan and the Ministry of Agriculture to find correct patterns of specialization.[11] The growing rejection of transportation cost minimization as the prevalent criterion of agricultural location is evident also in the blossoming in the mid-1960's of linear programming models which concentrated on the minimization of production costs through increased specialization, with only slight formal inclusion of transportation considerations. Such an applied modelling effort was executed by M.E. Braslavets and the Ukrainian Republic Gosplan in the course of preparing oblast agricultural procurement quotas for twenty products for the 1966-1977 Five Year Plan.[12]

Production cost reduction can clearly be achieved up to a point through increased specialization and expenditure of <u>transportation</u> resources. The effects of such a policy would be potentially observable in increased "total" factor productivity, especially were the study not to include transportation inputs. A policy emphasizing production cost reduction could, of course, be overdone to the detriment of efficiency at the economy-wide level. Only insofar as current Soviet criticism is correct, that past autarky was excessive, is evidence of increased interregional specialization evidence, within limits, of increased general cost efficiency.

In neoclassical terms, a change in emphasis from transportation cost to production cost minimization, a move away from relative regional autarky in farm procurement, would be reflected in a convergence of marginal rates of product transformation among regions. This idea is illustrated in Fig. 1. Here (t_1-t'_1 and t_2-t'_2) represent the net product transformation curves of two agricultural regions. The relative shapes of these two curves indicate that Region 1 is a relatively more able livestock produceer than Region 2 which is better suited for grain production. A policy limiting the specialization of the two regions might have each producing
equal quantities of both products, represented by P_a, a point on both curves. (An overall combination, $P = 2P_a$, is produced.) With this outcome the marginal rates of product transformatin (MRPT) of the two regions are not equal, as is indicated by the intersection at P_a of the lines r_1-r'_1 and r_2-r'_2 whose slopes are equal to the respective rates of transformation. An effort to reduce overall production cost would result in greater livestock specialization by Region 1, and greater grain specialization by Region 2. If transportation costs were totally ignored, a production cost minimization pattern (for the overall

Figure 1

Dispersion of Marginal Rates of Product Transformation



combination P*) would result in production of combinations P_1 and P_2. These combinations would be characterized by identical marginal rates of product transformation (MRPT) in both regions (indicated by the dotted line).

Our interest essentially is whether there has been convergence of the MRPT's of twenty-five oblasts over time, which would indicate support for the hypothesis that Ukrainian procurement policy has succeeded in rectifying a situation of relative agricultural autarky. Given immobilities in capital stocks, this process, if it occurs, should be strung out over and observable in the years for which data is available. Measurements of MRPT are devised and the dispersion across regions of these is computed (for the period 1956 to 1973). The trends of dispersion are then found.

2. Production Functions and the Marginal Rate of Product Transformation

Were Soviet agriculture a market economy, questions about inter-regional efficiency might be resolved by specifying a neoclassical technology and firm behavior such that MRPT would be equated to price ratios adjusted for transport costs. Relative prices would then be observed and some empirical conclusion drawn. However, in the Soviet case there are two problems. First, no continuous series of regionally differentiated procurement price data is available to the investigator. Secondly, Soviet farms pursue profit or output maximization under the constraint of fulfillment of plan. If the outcome is not "voluntary", relative procurement prices ratios (even if available) will reveal little about MRPT.

Table 1

Sugar Beet Shadow Prices

Region & Republic	Full cost (otsenka) (ru./cent.)	Cost (sebestoimost') (ru./cent.)
Kirgizhia	1.26	1.09
Ukraine-Forest Steppe	1.26	1.16
Ukraine-Polesye	1.30	1.19
Armenia	1.32	1.32
Ukraine-Steppe	1.35	1.21
Moldavia	1.41	1.29
North Caucasus	1.56	1.39
Central-Blackearth	1.65	1.60
Kazakhistan	1.86	1.85
Georgia	1.90	1.90
Volga-Viatsky	1.90	1.90
Latvia	2.10	2.08
Lithuania	2.11	2.07
Polvolzh	2.14	2.08
Central	2.20	2.20
Urals	2.32	2.26
Belorussia	2.38	2.36
West Siberia	2.48	2.40
East Siberia	2.54	2.50
Far East	3.00	3.00

Buckwheat Shadow Prices

Region & Republic	Full cost (otsenka) (ru./cent.)	Cost (sebestoimost') (ru./cent.)
Central Blackearth	5.46	4.22
Latvia	5.62	5.20
Estonia	5.63	5.40
Urals	5.70	4.73
West Siberia	5.78	4.10
Lithuania	5.97	5.22
Polvolzh	6.44	5.20
East Siberia	6.45	5.62
Kazakhistan	6.80	6.36
North Caucasus	7.23	2.33
Belorussia	7.23	6.87
Volga-Viatsky	8.10	8.10
Central	8.17	8.17
North-West	8.50	8.50
Ukraine-Polesye	8.61	4.93
Ukraine-Forest Steppe	8.63	5.29
Far East	8.80	8.80

Source: V.S. Mikheeva, Matematicheskie metody v planirovanii razmeshcheniia sel'skokhoziaistvennog'o proizvodstva (Moscow, 1966), p. 64.

Another approach taken in a preliminary fashion by western commentators has been to examine changes in regional growth rates of procurement in the light of burgeoning quantity of sebestoimost' (or prime) cost data.[13] While sebestoimost' data can be useful (it included conceptually all normally thought of costs except rent and interest) it is particularly inadequate for agriculture in that sebestoimost' does not include the opportunity cost of land. This point is illustrated in Table 1, wherein sebestoimost' cost is given for both sugar beet and buckwheat for a number of regions of the USSR. A full cost measure (otsenka) which includes a rental element calculated in a Soviet linear programming exercise is given in the first column. The table illustrates that, especially for crops (like buckwheat) which are land intensive, and especially in areas of great fertility (like the North Caucusus), sebestoimost' differs from full cost significantly.

The approach taken here is to combine sebestoimost' together with available data on land inputs, in a specified neoclassical production function in order to deduce marginal products and proxies for MRPT. Because of data stringencies there is not much room for experimentation in the specification of technology. The particular approach is to use Cobb-Douglas production functions for each product, in each region. A production function technology is needed in order to derive measurement of margins from available average product data.*

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*Another possible technology for getting MRPT's (other than separate production functions for each product) would be the specification of an entire transformation function, as done by Y. Mundlak for an investigation of the transformation relationships of several products in Australian agriculture. His function was a translog production function which can be separated into one function of the inputs and another of the outputs. This procedure has three consequences. (1) In this specification MRPT are not affected by input intensities; this means that transformation curves shift homothetically with changes in any or all inputs. This is unrealistic for

The assumptions of this approach are outlined below.

(a) Assumption about the regional production functions.

The form below represents the deterministic production function for a product i, produced in the j^{th} oblast at year t, with inputs subscripted, k; k = 1, ..., n.

(Eq. 1) $$Z_{ijt} = A'_{ijt}\, N_{1ijt}^{C_{1ij}}\, N_{2ijt}^{C_{2ij}}, \ldots, N_{kijt}^{C_{kij}}, \ldots, N_{niit}^{C_{nij}}$$

or, dropping, i, j and t subscripts for notational convenience:

(Eq. 1) $$Z = A'\, N_1^{C_1}\, N_2^{C_2}, \ldots, N_{k'}^{C_k}, \ldots, N_n^{C_n} = A' \prod_{k=1}^{n} N_k^{C_k}$$

(b) Variations of land quality

The n^{th} input, N_n, called land, is assumed to be homogeneous within a region, but heterogeneous among regions. Land in an area j is denotable $q_j L_j$ where L_j is the land area in hectares in region j, and q_j adjusts for differential quality among regions.

(c) Aggregation of non-land inputs

The subset of non-land inputs, k = 1, ..., n-1, expressed in monetary units with prices P_k so that $R_k = P_k N_k$ (Eq. 1)' can be written as:

(Eq. 1)" $$Z = Z'(qL)^{C_n}\left(\prod_{k=1}^{n-1} P_k^{-C_k}\right) \cdot \left(\prod_{k=1}^{n-1} R_k^{C_k}\right) \text{ by substitution.}$$

(Eq. 2) $$R = \sum_{k=1}^{n-1} P_{kj}\, N_{kj}.$$

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a situation where the ratio of other resources to land increases over time. (2) This formation almost always means that outputs are produced jointly, which is realistic for agriculture; however, this specification does not allow for use of average product data, which attributes inputs directly to outputs (as available data does). (3) Specification of an entire transformation function as done by Mundlak requires estimation of several parameters, for which the data used is less than adequate. Thus even though it violates the spirit of the discussion of joint costs in Gray (1979), the present exercise specifies individual production functions and uses the average cost data available. (cf. Y. Mundlak, "Specification and Estimation of Multi-product Functions," Journal of Farm Economics (May, 1963).)

R will be referred to as the ruble input, or alternatively, as non-land input. Money prices, P_{kj}, used for aggregation are assumed proportional to the marginal products of each input in natural units for each crop within each region. I.e.:

(Eq. 3) $$(\partial Z/\partial N_k)/P_{kj} = (\partial Z/\partial N_{k'})/P_{k'j} \qquad \text{for } k \neq k'.$$

(d) Ruble and land-input production function

Assumptions (b) and (c) make possible the writings of the production function given in (Eq. 1) in natural units, in ruble terms (restoring all superscripts) as:

(Eq. 4) $$Z_{ijt} = A_{ijt} R_{ijt}^{\alpha_{ij}} L_{ijt}^{\beta_{ij}}$$

where $A_{ijt} = A'_{ijt} \, q_j^{\,j} \prod_{k=1}^{n-1} P_{kijt}^{-C_{kij}}$,

$$\alpha_{ij} = \sum_{k=1}^{n-1} C_{kij} \text{ and } \beta_{ij} = C_{nij}$$

If it is assumed that $\alpha + \beta = 1$, (Eq. 4) can be rewritten in "per-hectare" form.

(Eq. 5) $Z/L = A(R/L)^{\alpha}$ i.e., Yield = A (rubles/hectare)$^{\alpha}$.

(e) Intra-regional mobility of all inputs

Within a region both land and non-land inputs are mobile among crop and livestock processes.

Definition of the marginal rate of product transformation through the k^{th} input

By the assumption of mobility (e), within a single region, j, one product, z, can be transformed into product z', by transfering a unit of any one input k from one production process to the other, leaving all other input assignments unchanged. We here define the marginal rate of product transformation through the k^{th} input (MRPT-k) to be the transformation thus achieved. It is expressed as the ratio of marginal products of the input k in producing the two products z and z'.

(Eq. 6) $$\frac{\partial z}{\partial z'}\bigg|_{dN_k} = (\partial Z/\partial N_k) \div (\partial Z'/\partial N_k)$$

If a region distributes inputs efficiently among crops, it is on its production transformation frontier, and the marginal rate of product transformation, as we normally speak of it, exists. In this case, in that region:

(Eq. 7) $$\frac{\partial z}{\partial z'}\bigg|_{dR} = \frac{\partial z}{\partial z'}\bigg|_{dL}$$

Assumptions (b) and (c) (concerning the homogeneity of land and the form of aggregation of non-land inputs) assure that the partial derivatives of the production functions with respect to the aggregates L and R are non-ambiguous.*

Given these assumptions, the <u>marginal rates of product transformation</u> for two products, z and z' in a region j are given as:**

(Eq. 8) $$\text{MRPT-land} = \frac{\partial z/\partial L}{\partial z'/\partial L'} = \frac{\beta}{\beta'} \cdot \frac{Z/L}{Z'/L'}$$

for land, and

(Eq. 9) $$\text{MRPT-non-land} = \frac{\partial z/\partial R}{\partial z'/\partial R'} = \frac{\alpha}{\alpha'}\ \frac{Z/R}{Z'/R'}$$

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*I.e., the changes in output resulting from the increase of land or non-ruble input devoted to a product within a region will be non-ambiguous in the sense that it does not make any difference <u>which</u> plot, or <u>which</u> ruble input increases. The assumption (c), needed to make dR nonambiguous, is strong in that it implies that inputs are not rationed, <u>or are rationed in a uniform manner</u> such that their marginal products are proportional to their prices. There remains, of course, the standard Cambridge (England) objection to the use of aggregates in production functions.

**The marginal product of R (or L) in the Cobb-Douglas, $Z = AR^{\alpha}L^{\beta}$ is simply the average product of R (or L) multiplied by α (or β). This is true whether or not $\alpha + \beta = 1$.[1]

A ratio of average products will be called an average rate of product transformation through the input k (ARPT-k). These are easily calculable from published Soviet data on yields and non-land cost (sebestoimost').

3. Average Product Data Available

Relatively long series of both agricultural yields and sebestiomost' data are available in the statistical handbooks published by the Central Statistics Administration. However, the most geographically detailed cost data available at the Union level are quite aggregate averages for Soviet republics and the extremely heterogeneous economic regions of the RSFSR. Average data for regions this large are likely meaningless for the purpose at hand. Data from the Ukraine represents the best opportunity to investigate the possible convergences of MRPT. It is available as averages for the (province) oblast' level. Figure 2 is a map of the Ukraine depicting its twenty-five oblasts.* This cost data is the most detailed long series that has been found.

Yields (i.e., average land products, Z/L) are available for several crops for the period 1956 to the present. Sebestoimost', essentially average non-land and non-interest resource cost (R/Z), is available for several products (crops and livestock) from 1956 to 1973.** An available Appendix contains a detailed discussion of the components of sebestoimost' and the nature of the Ukrainian time series. A major problem involves the prices

*While an economic region of the RSFSR averages 659,000 sq. miles, a Ukrainian oblast' averages 9,270 sq. miles. For comparison, the state of Wisconsin, with an area of 56,000 sq. miles, would contain about six oblasts.

**Only years 1956-1971 were available at the time of the calculation of production function coefficients.

Fig. 2 Ukrainian SSR: Oblasts

used in forming the ruble aggregate, and changes in these prices over the period studied. These data are not adjustable given published information, and aspects of the robustness of the conclusions of this chapter are discussed in the appendix.

4. Relationship of Average and Marginal Rates of Transformation: Test of the Equivalence of their Trends

As indicated by (Eq. 8) and (Eq. 9) the marginal rate of product transformation through an input k (MRPT-k) equals the ratio of average products of the input k, corrected by a factor which is the ratio of exponents (output elasticities) of the factor k in the production functions for the two products considered. This factor (α/α', for ruble-inputs; β/β', for land inputs) may in general vary among oblasts.

As a possible assumption, in addition to assumptions (a) - (e), we could add the following:

(f) Interregional proportionality of average and marginal rates of product transformation

(Eq. 10) $(\alpha/\alpha')_j = (\alpha/\alpha')_{j'}$, and, $(\beta/\beta')_j = (\beta/\beta')_{j'}$, for $j \neq j'$ (different oblasts).

Whether or not (f) is true is of significant interest for a study of the interregional convergence of marginal rates of product transformation. In fact, if equality of ratios can be assumed, there is no need for econometric estimation of the parameters of each of the production relationships specified above, estimation which is precarious given the nature of the data and the fact there are only fifteen time series observations for individual oblasts.

If the proportionality between marginal and average rates of product transformation for two goods is the same in all regions, then the interregional variance of the marginal rate of product transformation is proportional to the average rate. That is:

$$\text{(Eq. 11)} \qquad \underset{j}{\text{Var}}\ (\text{MRPT-R}) = 1/25 \sum_{j=1}^{25} (\text{MRPT-R}_j - \overline{\text{MRPT-R}})^2 = (\alpha/\alpha')^2 \underset{j}{\text{Var}}\ (\text{ARPT-R})$$

where j is the subscript identifying each of the twenty-five regions of the Ukraine, and the rates of transformation are taken to be for the two products z and z'.

This means that if the interregional variance of average rates of product transformation diminishes over time, so too does the interregional variance of the marginal rates of product transformation.

In a situation of competitive market equilibrium the condition (f) would be implied were the rental income shares of both crops z and z' identical for all regions. (I.e., were $\alpha_{ij} = \alpha_{ij'}$, and $\alpha_{i'j} = \alpha_{j'i'}$ for all regions $j \neq j'$ and crops i.)

In fact, rental income shares deducible from actual landlord-tenant lease agreements in Illinois indicate that for several crops in this state the landlord's share <u>does</u> vary across the state.* Even for Illinois, this does not disprove the validity of (f), however, since where the landlord's share of one crop is less it is generally also less for other crops. Ratios may be unchanged.

Assumption (f) is tested by testing the more stringent conditions that $\alpha_{ij} = \alpha_{ij'}$ for oblasts, j, in the Ukraine. The regression techniques, and a form of the "Chow test" are described in detail in Appendix II.

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*Deducing Cobb-Douglas shares from actual lease agreements is not easy, since actual farming operations involve several products, and typically the landlord contributes more than just land. However, work by F.J. Reiss of the University of Illinois shows that Cobb-Douglas-like "rent factors" for corn, soybeans, wheat and "hay & pasture" do vary significantly with location within Illinois and average yields. The rental share is higher where yields are higher.[2]

This approach indicates that the hypothesis that the "α's" are equivalent interregionally cannot be rejected with great confidence for any of the five crops considered. For grain the probability of error in rejecting equivalence is greater than 75%, for vegetables and sunflower it is greater than 50%, and for potato and sugar beet, it is greater than 25% and 10% respectively. This result indicates that information on trends in the interregional dispersion of average rates of transformation may not be valueless.

5. Trends in Interregional Dispersion of Estimated Average Rates of Product Transformation Among Certain Crops.*

Both yield and sebestoimost' data are available for the Ukraine for the eighteen years 1956-1973 (except 1967, for which sebestoimost' is lacking) for individual oblasts in which five crops are grown. These crops are: grain (excluding corn), sugar beet, sunflower seed, vegetables, and potatoes. Complete data series are available for all twenty-five Ukrainian oblasts for grain, vegetables and potatoes. Complete series are available for only nineteen oblasts for both sugar beet and sunflower seeds. Since grain is grown in all areas and occupies the majority land area it is chosen as the "nummeraire" crop. All rates of transformation are rates of transformation of each of the other four crops into grain.**

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*Dispersion measures formed from unbiased estimates of stochastic variables are not necessarily unbiased estimates of the dispersion of these variables in the population. (E.G., in the linear regression of y on x, the sum of squares of the estimated $\hat{y}$ is smaller than the sum of squares of y.) Therefore, all dispersion measures studied for trends in this chapter are not guaranteed to be unbiased estimates of the dispersion of actual rates of transformation (even in the case that the rates be unbiasedly estimated). Possible bias from this is difficult to analyze given the complex formation of some of the estimates. Any constant or proportional bias of the dispersion measures would not necessarily cause bias in the trends.

**Throughout this chapter the rate of transformation of products "X" into grain (denoted G) is taken to be dG/dX. (There could be some confusion that it is the inverse.) The rate of transformation is inverse to the price

Average rates of product transformation (through both land and ruble inputs) for eighteen years are given in Table 2. This table gives ARPT for the Ukraine average yield (ARPT-L) and sebestoimost' data (ARPT-R), and also the range of ARPT in the twenty-five oblasts. A considerable amount of variation is indicated. Using either input, the maximum ARPT usually runs about double the minimum ARPT.

The object of the investigation is to see if the dispersion of ARPT diminishes over time. Three dispersion measures are used: the variance, standard deviation, and coefficient of variation.* Each of these dispersion measures is calculated for each year and then those for all years are correlated with time. Table 3 reports the directions of trends and the levels of statistical significance. Correlations of all dispersion measures for sugar beet, potato, and vegetables are negative (i.e., dispersion decreases over time). For these three crops eight of the negative correlations are significant at better than the 10% level and six at the 5% level. Significant decline in dispersion for potatoes is especially striking. Trends in the various dispersion measures for sunflower seed with grain do not display this pattern--there is no significant trend in any direction.

(or marginal cost) ratios. Thus, the expression for ARPT-R is (sebestoimost' of X ÷ sebestoimost' of G, i.e., R/X ÷ R/G). For ARPT it is (yield X, i.e., G/L ÷ X/L = L/X ÷ L/G). MRPT are these ratios multiplied by the appropriate ratios of elasticities indicated in (Eq. 8) and (Eq. 9).

*The standard deviation is the square root of the variance. The lesser known coefficient of variation is the standard deviation divided by the mean. The latter statistic is more relevant in expressing variation when the size of the phenomenon is changing.[3]

Table 2 Ukraine Average Rates of Product Transformation, 1956-1973

Inter-oblast Range of ARPT-L, 1956-1973

	SUGAR BEET			POTATO			VEGETABLE			SUNFLOWER SEEDS		
	AVE	MAX	MIN	AVE	MAX	MIN	AVE	MAX	MIN	AVE	MAX	MIN
1956	0.66	0.82	0.44	1.65	3.81	0.60	1.38	2.08	0.72	1.38	2.18	0.68
1957	0.77	1.35	0.42	3.43	14.00	0.87	1.65	3.33	0.81	1.73	2.98	1.29
1958	0.62	0.91	0.34	2.21	4.94	0.87	1.53	2.73	0.70	1.39	2.20	0.97
1959	0.86	1.47	0.41	2.92	7.74	1.11	1.86	3.22	0.87	1.84	2.89	1.33
1960	0.71	1.02	0.48	2.18	3.53	0.97	1.52	2.37	0.88	1.78	2.59	1.13
1961	1.06	1.63	0.67	2.97	6.57	1.20	2.02	3.29	1.08	1.62	2.06	1.21
1962	1.06	1.71	0.71	2.50	4.49	1.25	1.63	2.64	0.96	1.50	2.24	1.07
1963	0.93	1.43	0.58	2.22	4.15	1.03	1.46	2.23	0.94	1.27	2.09	0.75
1964	0.73	1.25	0.41	2.31	5.23	0.95	1.44	2.23	0.79	1.34	2.08	1.04
1965	0.89	1.17	0.63	2.65	4.12	1.49	1.77	3.16	1.22	1.61	3.21	0.95
1966	0.95	1.25	0.70	2.45	4.77	1.17	1.88	3.13	0.98	1.58	2.63	0.95
1967	0.85	1.26	0.55	2.58	4.20	1.07	1.75	2.39	1.03	1.45	2.93	0.88
1968	0.63	0.95	0.35	2.26	4.07	1.03	1.49	2.29	1.05	1.28	1.99	0.96
1969	0.93	1.16	0.67	2.65	4.48	1.58	2.14	3.45	1.40	1.69	2.80	0.99
1970	0.79	1.16	0.55	2.61	5.79	1.24	1.91	2.93	1.14	1.94	3.08	1.23
1971	0.95	1.31	0.71	2.53	4.59	1.30	2.03	2.95	1.45	1.93	3.02	1.08
1972	0.86	1.19	0.56	2.51	5.14	1.23	1.84	3.01	1.01	1.67	2.62	1.01
1973	0.97	1.57	0.63	2.94	4.67	1.27	1.97	3.18	1.23	2.21	7.62	1.44

Inter-oblast Range of ARPT-R, 1956-1973

	SUGAR BEET			POTATO			VEGETABLE			SUNFLOWER SEEDS		
	AVE	MAX	MIN	AVE	MAX	MIN	AVE	MAX	MIN	AVE	MAX	MIN
1956	0.19	0.33	0.12	0.64	2.08	0.21	0.88	1.57	0.49	0.93	1.58	0.32
1957	0.30	0.76	0.14	1.58	5.88	0.26	1.36	2.59	0.56	1.69	3.29	1.05
1958	0.32	0.56	0.18	2.02	7.33	0.31	1.51	2.69	0.68	1.20	2.15	0.69
1959	0.52	1.09	0.25	2.37	7.65	0.37	2.30	5.31	0.78	1.68	2.40	0.17
1960	0.37	0.72	0.26	1.69	5.58	0.43	1.56	2.83	0.81	1.46	2.68	0.79
1961	0.52	1.32	0.30	3.77	18.48	0.48	2.44	4.50	0.83	1.38	1.93	1.06
1962	0.53	1.55	0.31	2.93	11.73	0.58	1.89	3.17	0.84	1.37	5.70	0.73
1963	0.42	0.78	0.26	1.95	7.42	0.45	1.71	3.09	0.93	1.03	2.91	0.45
1964	0.43	0.65	0.28	1.79	4.78	0.52	1.77	3.21	0.77	0.96	1.65	0.53
1965	0.55	0.79	0.43	1.97	4.09	0.94	2.12	3.34	1.12	1.38	2.51	0.82
1966	0.57	0.79	0.34	1.98	4.78	0.71	2.16	3.92	0.85	1.37	2.36	0.90
1968	0.46	0.64	0.30	1.92	4.27	0.75	1.80	3.05	1.09	1.21	2.10	0.88
1969	0.52	0.62	0.37	2.14	4.00	1.18	2.07	3.09	1.27	1.45	2.57	1.05
1970	0.49	0.70	0.33	2.27	4.71	1.14	2.06	3.36	1.10	1.64	2.90	1.07
1971	0.50	0.69	0.36	2.01	3.67	1.10	2.09	3.33	1.27	1.71	3.71	1.22
1972	0.47	0.69	0.35	1.98	4.28	0.96	1.91	3.23	1.10	1.48	3.75	0.96
1973	0.49	0.68	0.38	2.32	4.84	1.09	1.86	3.59	0.97	1.62	2.53	1.28

Table 3 -- Correlation of Time and Interregional Dispersion of Average Rates of Product Transformation (ARPT) Between Four Other Crops and Grain, 1956-1973. (Significance level in parenthesis; correlations with better than 10% and 5% significance are starred and double-starred.)

	Variance		Standard Deviation		Coefficient of Variation	
	Non-land	Land	Non-land	Land	Non-land	Land
Sugar beet	-.357	-.037	-.292	.042	-.641	-.195
	(.157)	(.878)	(.255)	(.864)	(.006) **	(.556)
Potato	-.340	-.451	-.414	-.496	-.842	-.681
	(.130)	(.052) *	(.096) *	(.034) **	(.000) **	(.002) **
Vegetables	-.207	-.333	-.124	-.297	-.550	-.692
	(.569)	(.174)	(.639)	(.231)	(.021) **	(.002) **
Sunflower	.091	.337	.107	.329	-.060	.167
	(.727)	(.169)	(.686)	(.180)	(.815)	(.514)

Table 4 -- Time Trends of Average Costs of Four Other Crops Relative to Grain Using ARPT Measures, 1956-1973.
(Significance level in parenthesis; levels of 10% and 5% are starred and double-starred.)

	Land Inputs		Non-land Inputs	
	Intercept (to)	Trend (t)	Intercept (to)	Trend (t)
Sugar beet (N = 19)	.742	.010 (.111)	.312	.013 (.002) **
Potato (N = 25)	2.44	.010 (.600)	1.38	(.021) (.518)
Vegetable (N = 25)	1.50	.025 (.014) **	1.55	(.033) (.050) *
Sunflower (N = 19)	1.43	.015 (.128)	1.24	(.011) (.648)

$$(\text{ave. ARPT}_i)_T = to + tT$$

$$T = 1, \ldots, 18$$

$$(\text{ave. ARPT}_i)_T = \sum_{j=1}^{N} \text{ARPT}_{ijT}/N$$

Table 4 indicates that the costs of all four crops relative to grain cost increase with time. The coefficient of variation (which takes into account variation relative to the size of the phenomenon studied) is thus a measure of interest. Trends in this measure are strikingly negative and significant, except for sunflower seeds.

In summary, the results of this section indicate that ARPT of sugar beets, potatoes and vegetables (but not of sunflower seed) with grain have converged interregionally over time. If assumption (f) is tenable, these results also imply that MRPT have converged, indicating an interregional movement towards most minimization in production of the three crops.

6. Estimation of Individual Cobb-Douglas Functions for Five Crops; Trends in Interregional Dispersion of Estimated Marginal Rates of Product Transformation

Although assumption (f), that the ratios of Cobb-Douglas exponents are proportional across regions, could not be strongly disproven by the test described in part 4 above, neither was it strongly supported. Individual production functions for each oblast can be estimated, however, employing alternative assumptions. These are:

(f') (Alternative assumptions)

a. Production functions homogeneous of degree one.

(Eq. 12) $\alpha_{ij} = 1 - \beta_{ij}$ for all regions j and products i.

b. Neutral technological progress a log-linear function of time.

(Eq. 13) $A_{ijt} = t^{o}_{ij}\ e^{t_{ij}T}$ where T is time.

The first assumption helps to preserve degrees of freedom.* The second

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*It also simplifies the regression, allowing estimation of the "per-hectare" form, (Eq. 5) with average product data alone. The assumption of homogeneity of degree one is a common one. "When we try to imagine a situation (which rarely if ever occurs in fact) of an agriculturalist increasing all inputs simultaneously, in uniform proportions, few, if any of us, expect 'economies of scale', i.e., an increase in output in greater is needed to account in some way for the possibility of technological change.

Still, two circumstances bode ill for attempted estimation of production functions for five individual crops in each of nineteen to twenty-five individual oblasts. (1) There are few years of observation, (2) The assumptions (a) - (f'), especially the assumption (c) about the ruble-input aggregate, are quite strong.* For these reasons, the parameters estimated should best be regarded as tentative. Their ratios (i.e., α/α' and β/β') used to adjust the ARPT perhaps approximate the true proportions of ARPT to MRPT, and are an alternative to no adjustment at all.

The equation to be estimated, once for each of the five crops, for each of from nineteen to twenty-five regions is:

(Eq. 14) $$\ln (Z_{ijT}/L_{ijT}) = \ln t^{o}_{ij} + t_{ij}T + \alpha \ln (R_{ijT}/L_{ijT})$$
$$T = 1, \ldots, 11, 13, \ldots, 16$$

Two methods are used to estimate this equation. (These methods are described in more detail in Appendix III. One is the method of ordinary least squares (OLS), in which a separate regression is simply run for each product and region. The other method used is to estimate the equations for all (up to five) crops in each oblast simultaneously. This is a generalized least square (GLS) procedure which seeks to take advantage of the "seemingly unrelated equations" situation, described by Arnold Zellner.[4] It can be

proportion than the increase in inputs--except perhaps in a few anomalous cases. In constructing production functions for agriculture therefore, it is customary to introduce the mathematical constraint that the exponents should add up precisely to one." (Colin Clark, "The Value of Agricultural Land," Journal of Agricultural Economics, 1969, p. 2.)

*An Appendix available from the author discusses the sebestoimost' time series. Individual production function estimates in this section were made with 1956-1971 data only, before 1972 and 1973 Narodnoe Hospodarstvo were available. There are fifteen rather than sixteen observations because 1967 sebestoimost' data was not published at the oblast level.

expected that the errors affecting the yield of one crop will be contemporaneously correlated with disturbances affecting the yields of another crop, in the same oblast. (I.e., if in a particular year the weather is bad and one crop suffers, so might another.) In a situation like this, efficiency may be gained through GLS estimation.

The estimated exponents obtained from these regressions were used to calculate the oblast MRPT from the AROT, which were developed in part five, above. Given assumptions (a) - (f), the results [(α/α')ARPT-R and (β/β')ARPT-L] are conceptually exact, though heroically measured, marginal rates of product transformation, through ruble and land inputs.

The interregional dispersions of these measures were found for every year exactly as for ARPT above and then the resultant dispersion measures were correlated with time. The results are reported in Tables 5 and 6.

Table 5 reports trends of the interregional variances and standard deviations, while Table 6 reports trends in the coefficients of (interregional) variation. (Like Table 3 these tables present trends in dispersions of rates of transformation through both land and non-land resources. These tables also reflect the proliferation of choice by reporting both GLS and OLS versions.)

Table 5 shows no support for the hypothesis of converging rates of transformation, except perhaps for potatoes. The variance and standard deviation of the rate of transformation of potatoes for grain do decline (significantly) with time (in non-land GLS and both land and non-land OLS versions). However, trends in the dispersion of rates of transformation through land are nearly always positive. These positive trends are also significant for vegetables and sunflower seed and, in one instance, for potatoe.

Table 5 -- Correlation of Time and the Interregional Variance and Standard Deviation of Estimates of Marginal Rate of Product Transformation (MRPT) Between Four Other Crops and Grain, 1956-1973.
(Significance level in parenthesis; levels of 10% and 5% or better are starred and double-starred.)

	OLS Estimates of MRPT			
	Non-land		Land	
	Variance	Standard Deviation	Variance	Standard Deviation
Sugar beet	-.050 (.342)	.068 (.791)	.253 (.311)	.295 (.233)
Potato	-.433 (.080) *	-.413 (.092) *	-.068 (.785)	-.009 (.972)
Vegetable	-.005 (.983)	.093 (.723)	.445 (.062) *	.500 (.033) **
Sunflower	-.289 (.260)	-.231 (.625)	.415 (.084) *	.441 (.064) *
****	GLS Estimates of MRPT			
Sugar beet	.355 (.159)	.435 (.073) *	.253 (.312)	.276 (.268)
Potato	-.296 (.247)	-.247 (.659)	.349 (.152)	.408 (.090) *
Vegetable	.09[illegible] (.710)	.146 (.582)	.311 (.207)	.335 (.171)
Sunflower	.121 (.649)	.169 (.522)	.367 (.131)	.370 (.127)

Table 6 -- Correlation of Time and the Coefficient of (Interregional) Variation of Estimates of Marginal Rates of Product Transformation (MRPT) Between Four Other Crops and Grain, 1956-1973.
(Significance level in parenthesis; levels at 10% and 5% are starred and double-starred.)

	OLS Estimates of MRPT	
	Non-land	Land
Sugar beet	-.691 (.002) **	-.084 .738
Potato	-.910 (.000) **	-.637 (.005) **
Vegetable	-.755 (.000) **	.160 (.531)
Sunflower	-.508 (.036) **	.290 (.243)
*****	**GLS Estimates of MRPT**	
Sugar beet	-.388 (.120)	-.117 (.647)
Potato	-.625 (.007) **	.257 (.303)
Vegetable	-.433 (.047) **	-.092 (.717)
Sunflower	.029 (.909)	.209 (.589)

Table 7 -- Time Trends of Average Costs of Four Other Crops Relative to Grain Using Various MRPT Measures, 1956-1973.
(Regression coefficient (t); significance level in parenthesis; correlations with better than 10% and 5% significance are starred and double-starred.)

	Land Inputs		Non-land Inputs	
	MRPT-OLS	MRPT-GLS	MRPT-OLS	MRPT-GLS
Sugar beet	.062 (.118)	.004 (.133)	.002 (.003) **	.003 (.002) **
Potato	.053 (.211)	.008 (.036) **	.000 (.987)	-.007 (.807)
Vegetable	.085 (.005) *	.006 (.013) **	.014 (.119)	.018 (.053)
Sunflower	.015 (.120)	.015 (.129)	.006 (.706)	.019 (.605)

$$(\text{ave. } MRPT_i)_T = t_0 + tT$$

$$T = 1, \ldots, 18$$

$$(\text{ave. } MRPT_i)_T = \sum_{j=1}^{N} MRPT_{ijT}/N$$

However, trends of the relative measure of variation, reported in Table 6 give strong support for the hypothesis, especially for potatoes, and also for sugar beets and vegetables, although not for sunflower seeds. There are no significant positive trends for any crop. The decline of interregional dispersion of rates of transformation through non-land resources is uniformly negative (except for sunflower seed), and significant at the 5% level for all these except the GLS estimate of sugar beet. As Table 7 indicates, this particular measure of relative variation has particular relevance since the (MRPT) "cost" of all four crops relative to grain increases in the period 1956-1973, for all but one measure used.

7. Observations Concerning the Results of This Investigation

The approach followed in parts 5 and 6 above seems to indicate that the marginal conditions for interregional production cost minimization are increasingly achieved for potatoes, sugar beet and vegetables, but not sunflower seed. Given the multi-product and multi-input nature of the approach, and the possible choice of estimation techniques and representations of rates of transformation and of dispersion measures, there is a plethora of measures of conflicting sign. However, focus on those trends which are "significant" at the 10% level or better reveals the following:

(1) All trends using all dispersion measures of the average rates of transformation of these three crops are negative. Several are significant. There are no significant positive trends for sunflower.

(2) Every trend of the coefficients of (relative) variation of transformation through non-land input, in each approach (ARPT, MRPT-OLS, and MRPT-GLS) are significantly negative (except the MRPT-GLS formulation for sugar beet which is negative but significant at only the 12% level).

(3) All but one of the contradictory significant positive trends in variance or standard deviation occurs with the marginal rate of product transformation through land. Realistic relaxation of assumption (b), that land is homogeneous within oblasts, would call for discounting trends based on transformations through land in favor of trends based on transformations through more mobile labor, machinery, and materials components of sebestoimost'. That is, if the cultivation of grain and potatoes occurs predominantly on different types of land within an oblast, we cannot expect the rate of product transformation occuring through "potato land" to grain production to be measurable by a ratio of the marginal (grain) product of "grain land" to the marginal (sunflower) product of "sunflower land". The effect of non-homogeneous land within oblasts is an obvious consideration in an attempt to understand the difference in the results between transformation through land and non-land resources, and between sunflower and the other three crops. It needs further study.

One additional observation should be made. Although the estimation of simple production functions with this kind of data is precarious, the results achieved are supportable by some separate evidence from a Soviet source. Under the assumption that input shares ("α" and "β" exponents) are equivalent for all oblasts, the best estimates of these shares for the five crops are those achieved in the available Appendix from the regressions utilizing the large sample of pooled time-series and cross-section data. The factor share of non-ruble inputs in sugar beet, vegetables, and potato production are high while the non-land input shares for grain and sunflower seeds are low. That is, the first crops are not land-intensive, while the latter crops are. The implication of this is that were land rent imputed into the "full cost" of grain and sunflower this cost would increase significantly over sebestoimost'.* Sugar beet, potatoes, and vegetable sebestoimost' would not differ so much from "full cost". Indeed these same products are grouped in exactly this way in the contrast of shadow price and sebestoimost' contained in the Soviet work from which Table 1 is taken, the result of a linear programming formulation which yielded optimal crop distributions with limited land.**

It is an interesting reflection that these regressions do indicated that the relative marginal costs of grain and sunflower compared to those of vegetables, sugar beet and potatoes are more than is indicated by relative sebestoimost', and that this neoclassical approach agrees with an independent Soviet calculation through linear economics.

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*The relationship between sebestoimost' and full cost can be shown explicitly in the case of the Cobb-Douglas function. Consider a production function for an individual product Z: $Z = R^{\alpha}L^{\beta}$. The incremental ruble input required for one more unit of output (other inputs fixed) is $R/Z \div \alpha$. (Same calculation as that involved for Eq. 4.) The more land-intensive the crop is (i.e., the smaller α is) the more incremental ruble input exceeds sebestoimost'. (This appears to be particularly the case with grain and sunflower seeds.) When agriculture really is efficient (with no unutilized resources and equivalent marginal rates of technical substitution of inputs for all products) this "blown-up" sebestoimost' is really orthodox marginal cost. (I.e., on the production frontier, the alternative of producing more Z through more land involves an equivalent opportunity cost of another product Z'.)

**Table 1 indicates that the full cost of non-land-intensive sugar beets never exceed sebestoimost by more than 15%. On the other hand, the full cost of buckwheat grain in some areas of the Ukraine exceeds sebestoimost' by around 75%.

FOOTNOTES

[1]Alec Nove, "Agricultural Performance Compared: Belorussia and Eastern Poland," Zbigniew M. Fallenbuchl, ed., Economic Development in the Soviet Union and Eastern Europe, Vol. 2: Sectoral Analysis (New York: Praeger,); D. Gale Johnson, "Agricultural Production," in A. Bergson and S. Kuznets, Economic Trends in the Soviet Union (Cambridge, Mass.: Harvard Univ., 1963).

[2]A number of updated productivity studies by Diamond and associates at the CIA date back to Douglas B. Diamond, "Trends in Output, Inputs, and Factor Productivity in Soviet Agriculture," New Directions in the Soviet Economy (Washington; Joint Economic Committee, 1966); see also Diamond and C. Krueger, "Recent Developments in Output and Productivity in Soviet Agriculture," Soviet Economic Prospects for the Seventies (Washington; JEC, 1973).

[3]Kenneth R. Gray, "Soviet Agricultural Specialization and Efficiency," Soviet Studies, Oct. 1979, pp. 542-558. "The Efficient Location and Specialization of Soviet Agricultural Procurement," unpublished Ph.D. dissertation, University of Wisconsin, 1976.

[4]Another study using similar methodology but focusing on the marginal product of capital is Judith Thornton, "Differential Capital Charges and Resource Allocation in Soviet Industry," Journal of Political Economy, May/June 1971, pp. 545-561.

[5]Gray, 1976, ch. 4.

[6]For instance, Jerzy F. Karcz, "An Organizational Model of Command Farming," in Morris Bornstein, Comparative Economic Systems (Homewood: Irwin, 1969), pp. 278-299.

[7]A. Libkind, "Sdvigi v razmeshchenii sel'skokhoziaistvennykh kul'tur," Problemy Ekonomiki, No. 3, 1938, p. 62.

[8]Libkind, p. 67.

[9]Gray, 1976, pp. 140-145; N.I. Zhukovsky, Novoe v sel'skom khoziaistve Sibiri (Moscow, 1958), p. 49; Razmeschenie i spetsializatsiia sel'skogo khoziaistva SSSR (Moscow, 1969), pp. 129-130.

[10]G. Lisichkin, 'Gektary, tsentnery, rubli,' Novy Mir, No. 9, 1965, p. 227; Vasilets, 'Zimnii ogorod,' Pravda, Nov. 20, 1977; G. Gukasov, 'Zabytyi tsvet abrikosa,' Izvestiya, April 30, 1975.

[11]Gray, 1976, p. 98.

[12]See Gray, 1976, Chpt. 4 for a review of Soviet use of linear programming in this field; specifically, M.E. Braslavets, Ekonomiko-matematicheskie metody v organizatsii i planirovanii sel'skogo khoziaistva (Kiev, 1968), pp. 383-393.

[13]For example, after perusal of regional data on prime costs and growth rates of grain procurement, Jerzy Karcz concluded that the latter were "not conducive along cost reducing lines." ("The New Soviet Agricultural Programme," Soviet Studies, Oct. 1965, p. 147.)

[14]R.G.D. Allen, Macro-Economic Theory: A Mathematical Treatment (London, 1968), p. 50.

[15]Descriptions of Illinois farm lease practices are contained in a number of University of Illinois College of Agriculture/Agricultural Experiment Station Bulletins (e.g., Nos. 728, 745, and 677) authored by Franklin J. Reiss. A paper in process in 1975 and tentatively titled, "Relations of Gross Value of Production and Landlords' Gross Cash Rents" contains percentage rent factors and was to be published in Economics for Agriculture, 1975.

[16]See Taro Yamane, Statistics: An Introductory Analysis (New York: Harper and Row, 1973), pp. 77-79. The variance divided by the mean squared is the "relative variance."

[17]Arnold Zellner, "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias," Journal of the American Statistical Association (1967), pp. 348-368.