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Allocative and Technical Efficiency of Corporate Farms in Russia

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Allocative and Technical Efficiency of Corporate Farms

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Russian agriculture appears to have recovered from the general collapse of the early 1990s and the financial crisis of 1998. Estimation of the current level of technical efficiency of agricultural producers will reveal the potential for growth through increasing the productivity of existing resources without increasing their volume. Identification of factors that have a negative influence on efficiency is a prerequisite for the development of productivity improvement programs for agriculture.

Russian and Western studies of efficiency trends in Russian agriculture in the 1990s produce widely differing results. Some researchers find that efficiency increased during the transition, while others conclude that efficiency decreased[1]. We can only say with certainty that the huge improvements in efficiency originally expected at the beginning of reforms in 1991-92 have not materialized. The objective of this study is to analyze the efficiency of Russian corporate farms (also called agricultural enterprises or farm enterprises) using the data of a survey conducted in 2002-03. The study examines two forms of efficiency: technical efficiency and allocative efficiency. Technical efficiency measures show how efficiently the farm uses the available inputs to produce a given output. In other words, technical efficiency determines whether the farm achieves maximum output using a given bundle of factors of production. Allocative efficiency measures show how far the farm is from the point of maximum profitability given the existing market prices for inputs and products. Thus, allocative efficiency determines whether the factors of production are used in proportions that ensure maximum output at given market prices.

The basic approach to estimating allocative efficiency is through the *value of marginal product (VMP)*. The value of marginal product is calculated from econometrically estimated production functions. The use of an agricultural input is allocatively efficient if the value of marginal product is equal to its price. Technical efficiency is usually estimated by one of two approaches: parametric (*stochastic frontier analysis, SFA*) or non-parametric (*data envelopment analysis, DEA*). Both methods calculate an efficiency index, which measures the distance of the observed firm (corporate farm in our case) from a point on the production frontier. Firms lying on the production frontier are absolutely efficient, and the "inefficiency" of the remaining firms increases with the distance from the production frontier[2].

Data and Methodology

[1] The first view is advanced in Z. Lerman, Y, Kislev, A. Kriss, and D. Biton (2003), "Agricultural output and productivity in the former Soviet republics," *Economic Development and Cultural Change*, 51(4): 999-1018; P. Voigt and V. Uvarovsky (2001), "Developments in productivity and efficiency in Russia's agriculture: The transition period," *Quarterly Journal of International Agriculture*, 40(1): 45-66; the second view in S. Osborne and M. Trueblood (2002), *Agricultural Productivity and Efficiency in Russia and Ukraine: Building on a Decade of Reform*, Agricultural Economic Report 813, ERS/USDA, Washington; D. Sedik, M. Trueblood, and C. Arnade (1999), "Corporate farm performance in Russia, 1991-95: An efficiency analysis," *Journal of Comparative Economics*, 27: 514-533.

[2] The two approaches to technical efficiency are described in T. Coelli, D.S. Prasada Rao, and G. Battese (1998), *An Introduction to Efficiency and Productivity Analysis*. Boston: Kluwer.

The analysis reported in this article uses the data of 144 corporate farms (generally former *kolkhozes* and *sovkhozes*) that participated in the 2003 BASIS survey in three oblasts (Rostov, Ivanovo, and Nizhnii Novgorod). Table 1 presents the basic characteristics of the surveyed corporate farms.

Table 1. Basic characteristics of surveyed corporate farms

	Unit of measurement	Number of respondents	Mean	Standard deviation	Min	Max
Agricultural land	hectares	144	4,093	2,624	4	14,242
Land used in agriculture	hectares	141	3,351	2,504	0	14,242
Total number of workers	people	137	122	83	10	408
Fertilizer (used)	tons	106	99	142	0	811
Gasoline (purchased)	tons	141	65	70	2	636
Diesel fuel (purchased)	tons	142	173	165	5	1,015
Tractors	pieces	130	20	12	0	68
Grain harvesters	pieces	132	5	4	0	21
Trucks	pieces	137	11	8	0	34
Equity	million rubles	131	5	6	0	46
Debt	million rubles	90	59	522	0	4,959

For allocative efficiency analysis, we estimated Cobb-Douglas production functions by the OLS method and then calculated the value of marginal product for each factor of production (VMP_i). The value of marginal product was compared with the marginal cost. Given the estimated Cobb-Douglas production function

$$Y=aX_1^{b1}X_2^{b2}\ldots X_k^{bk},$$

the marginal product of factor i is calculated as

$$MP_i=\Delta Y/\Delta X_i=b_iY/X_i,$$

where Y is the geometrical mean of the output (the mean of its natural logarithms); X_i is the geometrical mean of input i; b_i is the OLS estimated coefficient of input i (the elasticity of input i). The marginal product obtained in physical units is then multiplied by the price of the output P_Y, which gives the value of marginal product of input i: $VMP_i=MP_i \times P_Y$. Allocative efficiency is determined by comparing the value of marginal product of factor i (VMP_i) with the marginal factor cost (MFC_i). We assume that farms are price takers in the input market, so that the price of factor i (P_i) approximates MFC_i. If $VMP_i > P_i$, input i is underused and farm profits can be raised by increasing the use of this input. If, conversely, $VMP_i < P_i$, the input is overused and to raise farm profits its use should be reduced. The point of allocative efficiency (and maximum profit) is reached when $VMP_i = P_i$.

The technical efficiency of production of specific commodities was estimated using input-oriented DEA models with variable returns to scale (VRS)[3]. Input-oriented estimation is more appropriate than the output-oriented alternative because one of the objectives of the study is to determine the efficiency of input use for the production of a given output and find ways to

[3] The DEA program used in this study has been developed by Aleksandr Usol'tsev on the basis of standard linear programming algorithms published in the literature. The work has been carried out at the Analytical Centre for Agri-Food Economics in Moscow as part of the BASIS Russia project.

optimize input use. The impact of external factors on technical efficiency was then estimated by second-stage regression analysis.

The efficiency was estimated for "total farm" production as well as for crop and livestock production separately. The "total farm" production function was estimated using the value of output in money units ("gross output" model). Crop and livestock production functions in turn were estimated on two levels of aggregation: using the value of output in money units to estimate "whole crop" and "whole livestock" models; and using the data on the physical output of each commodity (in physical units) to estimate specific commodity models (grain, sunflower, beef, milk, and pork). The commodity models should be robust to intentional and unintentional distortions of financial performance measures that affect the value of output. This consideration is particularly relevant for transition countries with a large shadow economy.

Allocative Efficiency Analysis

The estimated coefficients of production functions for specific crops and for crop production as whole are presented in Table 2. The different models produce similar results. All the coefficients are positive, which means that the output increases with the increasing use of each input (keeping the use of all other inputs constant). Most models described 70%-80% of the observed variability.

Table 2. Crop production functions

	Models in physical units			Models in value units**	
	Grain	Grain (Rostov*)	Sunflower	Model 1	Model 2
Constant	1.848	0.920	-	1.062	1.510
Land	0.415	0.861	1.161	0.207	0.178
Labor	-	-	-	0.314	0.257
Purchased inputs (total value)	X	X	X	0.516	X
Fertilizer	0.101	0.060	-	X	0.076
Seeds	0.328	-	-	X	0.566
Weather	0.370	0.482	-	X	X
Pre-reform status					
Marginally profitable	0.319	0.601	0.587	X	X
Profitable	0.283	0.473	0.505	X	X
Unprofitable	0	0	0	X	X
Rostov regional factor	-	X	-	0.483	0.688
R^2_{adj}	**0.73**	**0.64**	**0.80**	**0.70**	**0.70**
Number of observations	**103**	**46**	**45**	**114**	**107**

Table 2 shows only factors that are statistically significant at 10% level.
X — not included in the model; - — not statistically significant.
* Estimated only for Rostov Oblast.
** In Model 1, all purchased inputs are aggregated by value; in Model 2, fertilizers and seeds are included separately (in value units). Labor defined as the average annual number of workers engaged in crop production. Output defined as the value of crop production.

Land is estimated to be the most significant factor of crop production. Purchased inputs, and in particular fertilizer and seeds, also have a significant positive impact on output. Labor is statistically significant in the aggregated crop production models and not significant in the commodity models. This is probably due to the high correlation between sown land and labor, so that in some models the combined effect of both these factors is reflected in the estimated coefficient of one of them (land).

Crop output is seen to depend on weather conditions. Pre-reform performance is also significant: corporate farms that were profitable (and marginally profitable) in the past are estimated to produce more than the formerly unprofitable farms.

Farm machinery (tractors, grain harvesters, feed combines, trucks) is not statistically significant in any of the crop production models. This result shows that farm machinery (acquired mainly in the pre-reform period) is not a limiting factor in the sample. Machinery, however, can prove to be a limiting factor for the most efficient farms. This indirectly follows from the observation that a substantial number of corporate farms in the sample (though definitely not all the farms) actually purchase machinery.

The estimated coefficients of production functions for specific animal products and for livestock production as whole are presented in Table 3. As in crop production, the livestock models have a satisfactory explanatory power. Labor and cattle numbers are the most significant factors in livestock production functions, which confirms the extensive character of the Russian livestock sector. The high estimated coefficients of these factors probably incorporate also the effect of fixed assets on output. Fixed assets were not directly included in the models because of low reliability of the available data.

Table 3. Livestock production functions*

	Beef		Milk		Pork		Livestock **
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	
Constant	-1.731	-1.840	1.575	-	-	-4.867	1.319
Labor	-	-	0.366	0.267	0.791	0.507	0.280
Number of cattle	0.763	0.680	0.705	0.801	0.613	0.844	0.303
Purchased inputs	X	0.054[#]	X	-	X	-	0.481
Weather	0.397	-	0.401	-	-	-	X
Ivanovo regional factor	0.454	-	-	-		-	X
Feed quality[##]	-0.673	-0.731	-	-	-	-	X
R^2_{adj}	**0.851**	**0.815**	**0.909**	**0.938**	**0.811**	**0.752**	**0.760**
Number of observations	**77**	**75**	**72**	**50**	**45**	**47**	**98**

Table 3 shows only factors that are statistically significant at 10% level.

X — not included in the model; - — not statistically significant.

*In Model 1, feed is expressed in feed units from the survey; in Model 2, feed is expressed in terms of inputs used for its production (labor, fertilizers, and agricultural machinery). Feed is not statistically significant in any of the models. Output defined as production of beef, milk, or pork in physical units

**Output defined as the value of livestock production.

[#]Fertilizer only.

[##]Share of concentrated feed in ration.

The distance of the farm from the oblast capital does not have a significant effect on livestock output (the same result is observed in crop production). This is probably the outcome of two oppositely directed effects. On the one hand, the farm's distance from the oblast center limits its access to the markets for inputs and products, and to some extent reduces the availability of government support. On the other hand, remote farms do not have to compete for skilled labor. The pre-reform status of the farm is not statistically significant in livestock production (contrary to crop production, see Table 2).

The value of marginal product (VMP) for commodity models and for crop and livestock production as a whole is presented in Table 4. The estimated coefficients of the inputs are taken from Tables 2 and 3. For comparison, Table 4 also shows the value of marginal product for the "gross output" production function, which aggregates the values of both crop and livestock products.

Table 4. Comparison of values of marginal product with factor prices

Factor	Units	Model	Coefficient	VMP, rubles	Factor price, rubles
Land	hectares	Grain	0.414	682	500-1500[1]
		Grain (Rostov)	0.860	1,738	1,500-2,000[1]
		Sunflower	0.410	1,319	1,500-2,000[1]
		Crop production M1	0.207	332	500-1,500[1]
		Crop production M2	0.178	292	500-1,500[1]
		Gross output	0.401	446	500-1,500[1]
Fertilizer	tons (active substance)	Grain	0.100	2,496[2]	2,619[3]
		Grain (Rostov)	0.060	1,835[2]	2,619[3]
	rubles	Crop production M2	0.076	1,469	2619[3]
Seeds	tons	Grain	0.330	2,239	1,500-3,518[4]
	rubles	Crop production M2	0.566	3,702	n/a
Labor	man-years	Crop production M1	0.314	22,120	12,000-18,000[1]
		Crop production M2	0.257	19,270	12,000-18,000[1]
		Livestock production	0.280	25,628	12,000-18,000[1]
		Gross output	0.410	25700	12000-18000[1]
Livestock	head	Milk	0.705	4,297	n.a.
		Beef and veal	0.760	23,691	n.a.
		Gross output	0.303	2,037	n.a.
Purchased inputs	million rubles	Crop production M1	0.516	0.704	1
		Livestock production	0.481	0.439	1
		Gross output	0.163	0.546	1

[1] expert estimate; [2] calculated per ton of fertilizer based on the average active substance content of one ton of purchased fertilizers; [3] weighted average price per ton for fertilizer purchases in the survey; [4] lower limit is the cost of seeds from own production; upper limit is the average market price.

In the grain and sunflower models, the value of marginal product of land varies from 682 rubles/ha for all grain to 1,738 rubles/ha for grain in Rostov Oblast. These estimates are higher than the value of marginal product of land in crop production as a whole and in the gross output model, where VMP varies from 292 rubles/ha to 446 rubles/ha. The estimates are close to the market price of land, which suggests that land prices adjust to the actual economic productivity of land. This means that on the whole land is used efficiently by corporate farms.

The value of marginal product for fertilizer is 1,469 rubles/ton for crop production as a whole and 2,496 rubles/ton for grain. The return to fertilizer in grain production is much higher than the average because grain is one of the most profitable commodities. In the Rostov grain model, however, the value of fertilizer marginal product is lower (1,835 rubles per ton), which probably reflects the effect of decreasing returns to scale (the use of fertilizer is much higher in Rostov Oblast than in the other regions). The weighted average price of fertilizer is 2,619 rubles/ton, higher than the value of marginal product. This indicates that fertilizer is overused given the market prices of inputs and farm products. This is a paradoxical result, because the use of fertilizers has decreased by more than by 50% since the beginning of the 1990s. Perhaps our result does not represent an the equilibrium in the domestic fertilizer market, but instead points to overpricing of fertilizer due to the emphasis of Russian fertilizer manufacturers on exports and the price-boosting impact of input subsidy programs (see Serova and Shick).

The value of marginal product of seeds is 2,239 rubles/ton in the grain model and 3,702 rubles/ton in the total crop production model. This does not mean, however, that the return on seeds for other crop products is higher than for grain. In the grain model the explanatory variable is the quantity of seeds used in tons, whereas in the total crop production model the explanatory variable is the value of purchased seeds. The cost of purchased seeds is only 18% of the total cost of seeds used in the sample. The mean price of purchased seeds is 3,518 rubles/ton, while the mean cost of seeds from own production is 1,500 rubles/ton. Given the estimates for the value of marginal product, it is inefficient to use purchased seeds at the current market price. The most probable explanation of this phenomenon is the almost total absence of a seed market in Russia. Faced with severe working-capital constraints, farms have sharply curtailed their seed purchases and have shifted to seeds from own production. These are lower-quality seeds, but at least their use does not require "ready money". The reduced demand for seeds has led to a sharp contraction of commercial seed production and virtual disappearance of the seed market, which is currently in an inefficient equilibrium characterized by low quantities and high prices.

Estimation of the value of marginal product of labor presents some difficulties. In most commodity models the coefficient of labor is statistically not significant and the value of marginal product of labor cannot be calculated. In total production models (two crop production models, livestock model, and "gross output" model), the coefficient of labor is statistically significant and the value of marginal product varies from 19,000 to 26,000 rubles per year. This is close to the actual level of agricultural wages, and we conclude that the use of labor in Russian agriculture today is allocatively efficient (despite the fact that agricultural wages are less than the minimum standard of living and many farm managers estimate that three-quarters of the employed are redundant).

The value of marginal product of purchased inputs estimated from the aggregated models in money units (total crop production, livestock production, and gross output) is between 0.439 and 0.704 million rubles per each million spent on purchased inputs. This again suggests that purchased inputs are overpriced relative to their marginal product, and the use of purchased inputs is inefficient at the current market prices.

Technical Efficiency Analysis

Table 5 presents the technical efficiency scores (TE) for specific commodities. The mean technical efficiency over all commodities is fairly high (about 0.80), and for more than 50% of corporate farms it is greater than 0.70. These farms are close to the efficiency frontier, where technical efficiency reaches its maximum value 1.

The high mean technical efficiency scores and the high frequency of "best practice" technologies in the sample limit the potential impact that can be expected from the adoption of "best practice" technologies by the inefficient farms. Thus, the adoption of "best practice" technologies will increase the production of beef by 22%-36% (Model 2 and Model 1, respectively). Production gains are obviously desirable, but the magnitude of the potential gains will not be sufficient for Russian agriculture to close the productivity gap relative to developed market economies[4].

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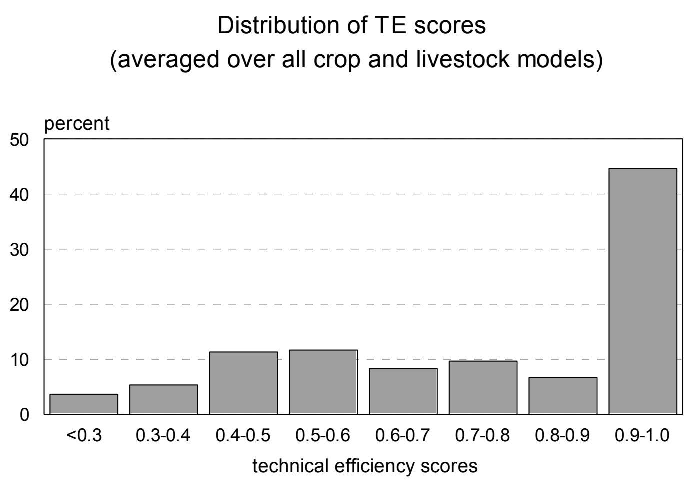
[4] On productivity gaps between Russia and the developed market economies see M. Trueblood and C. Arnade (2001), "Crop yield convergence: How Russia's yield performance has compared to global yield leaders," *Comparative Economic Studies*, 43(2): 59–81.

Table 5. Technical efficiency scores (TE) of corporate farms for selected commodities (estimated by the DEA method)

	TE (mean)	St. dev.	TE > 0.9		TE > 0.7, % of farms	TE< 0.3, % of farms
			% of farms	Number of farms		
Grain	0.77	0.23	39	44	64	2
Sunflower	0.71	0.24	35	17	49	2
Beef 1*	0.64	0.29	31	22	44	17
Beef 2*	0.78	0.26	54	39	64	6
Milk 1*	0.65	0.24	25	19	37	2
Milk 2*	0.82	0.22	55	41	69	1
Beef +milk 1 **	0.78	0.20	42	33	59	0
Beef +milk 2 **	0.88	0.16	65	51	80	0
Pork 1*	0.75	0.28	50	24	63	6
Pork 2*	0.88	0.18	67	32	79	0

*See notes on Models 1 and 2 in Table 3.
**Two-output DEA models (beef and milk). Without fattening operations, the inputs are shared by the two outputs.

Figure 1 shows the distribution of corporate farms by technical efficiency scores



(averaged over all crop and livestock models). The distribution is clearly bimodal. The main mode includes farms that form the efficiency frontier (technical efficiency > 0.9). This mode contains 49% of farms in the sample (averaged over all commodity models). The second mode includes less efficient producers. Their technical efficiency is 0.4-0.6 (23% of farms in the sample). The results of Model 1 for livestock products (in these models, animal feed is expressed in feed units) shed some light on the differences between the farms in the two modes. In corporate farms forming the efficiency frontier (the main mode, TE > 0.9), the share of purchased feed is relatively high. It is 19% for the beef model, 14% for the milk model, and 10% for the pork model. For farms in the second (inefficient) mode, the respective purchased feed shares are 2.6%, 2.0%, and 3.4%. The mean share of purchased feed for all corporate farms in the sample is 7%. Purchased feed is mainly high-quality concentrated feed, whereas feed from own production is basically hay, pasture grasses, or low-quality concentrated feed. The farms at the efficiency frontier, using a high proportion of purchased feed in the ration, probably optimize the ration by analyzing the market price of feed, the cost of on-farm production, and the value of the end product. The inefficient farms, using a small proportion of purchased feed in their ration, probably follow the strategy of cost minimization for purchased inputs because of financial constraints.

Once the technical efficiency scores have been determined by Data Envelopment Analysis, it may be useful to examine their relationship with additional factors, such as farm size, location, or financial conditions. Such a relationship is usually determined by regressing the TE scores on the relevant external factors. Table 6 shows the estimation results for a "second-stage" regression model in which the dependent variable is the TE score and the explanatory variables are various external factors.

Table 6. Factors that influence technical efficiency*

Factor	Grain	Sun-flower	Beef 1	Beef 2	Milk 1	Milk 2	Beef + milk 1	Beef + milk 2	Pork 1	Pork 2
Ivanovo regional factor	-0,134		-0.337	-0.296	-0.279	-0.294			-0.492	-0.284
Distance from oblast capital				0.243			0.134			
Augmentation of farm holdings	0.122			0.321	0.281	0.298		0.167	0.267	
Wage arrears	-0.017				-0.022	-0.017	-0.018			-0.025
Pre-reform status (profitable)		0.298			0.214	0.185		0.171		
Crop specialization			-0.496	-0.613	-0.777	-0.613	-0.533	-0.343	-1.179	-0.485
Controlling packet of shares	-0.175									
Surplus labor								0.002		

* Table 6 shows only the factors that are statistically significant at 10% level in one of the commodity models.

Many factors that a priori were expected to affect the technical efficiency proved to be not statistically significant and are not shown in Table 6. Thus, the farm size (measured by hectares of land used) does not have a statistically significant effect on technical efficiency. State subsidies and borrowing of any kind do not affect technical efficiency (however, very few farms in the sample provided information on these variables). The managerial qualification variable expressing knowledge of tax laws, lease payments, and land allocation procedures is not statistically significant in the model. The land utilization ratio (i.e., the share of land actually used in agricultural production) does not affect technical efficiency. It is quite possible that keeping agricultural land in the farm's possession without cultivating it is the most efficient strategy under the present circumstances because of complex alienation procedures and high transaction costs.

On the other hand, most models show a positive association between enlargement of holdings and technical efficiency. Farm enlargement (a yes/no variable that indicates if the farm has added new agricultural land to its holdings) is statistically significant in both crop and livestock production models. Farm enlargement not only represents expansion of the sown area, but it is also an indicator of management quality.

As suggested by a priori considerations, wage arrears have a negative effect on technical efficiency (in half the commodity models). If this factor is accepted as a proxy for financial health, we conclude that financially ailing farms are less efficient than the rest. This factor is also closely connected with management quality. The absence of wage arrears and good financial health reflect highly qualified management.

The impact of management structure is also reflected by the farms' pre-reform status. Farms that were profitable in the pre-reform period demonstrate higher technical efficiency in some models. The existence of a controlling packet of shares, which a priori led us to expect greater efficiency due to more effective control of the majority owner over management, is not statistically significant in most models, perhaps because of the very small number of farms with a controlling packet in the sample.

Livestock producers that add crops to their product mix are less efficient in all commodities. The regional factor has a statistically significant effect: farms in Ivanovo Oblast are the least efficient and Rostov farms are the most efficient in the sample. Distance from the oblast capital in general does not have a statistically significant effect on technical efficiency. The existence of surplus labor does not affect the technical efficiency of corporate farms either.

Conclusion

Land is unquestionably the cornerstone of agricultural production. Its impact on output is positive and highly significant. However, technical efficiency of corporate farms is not associated with land endowment. The share of idle land is substantial and the price of land is close to the value of marginal product. In order to intensify land use and prevent degradation of land quality (which is typical for unprofitable farms), it is essential to encourage redistribution of land from least efficient to most efficient users. The government should actively move to simplify the procedures for buying, selling, and leasing of land so as to reduce the extremely high transaction costs in the land market.

Efficient production requires purchased inputs. Their positive impact on output is proved by production functions. Nevertheless, the actual use of purchased inputs in Russia is substantially lower than in developed market economies. The analysis of allocative efficiency for purchased inputs produces a mixed picture. However, this analysis is based on actual market prices for products and inputs. Underpricing of farm products combined with overpriced inputs may lead to allocatively efficient use of purchased inputs, but at a very low level of quantities. In medium- and long-term perspective, this may cause degradation of land quality and a range of other negative phenomena.

Price distortions in input markets may be caused by various reasons. Thus, in fertilizer and fuel markets, pervasive monopolization (especially the existence of local monopolies) combined with high export demand strengthens the bargaining power of input manufacturers and leads to overpricing. To correct this distortion, it is necessary to encourage deliveries to the domestic market, while carefully avoiding direct bans that have already demonstrated their absolute inefficiency. Input subsidies do not correct price distortions, and sometimes even aggravate them. The solution of the problem probably requires development of appropriate market institutions that will increase the bargaining power of agricultural producers and at the same time lower the suppliers' risk in dealing with agricultural producers. The most obvious approach is through the creation of farmers' input-supply cooperatives capable of pooling the flows, reducing the risks, and possibly developing short-term credit schemes for input purchases.

The low productivity of Russian agriculture is mainly attributable to management factors, and not to technological or allocative factors. This conclusion is supported by the analysis of external factors that affect technical efficiency. Corporate farms with a proactive management policy (including, for instance, acquisition of additional land) demonstrate higher technical efficiency than others.

Finally, simple extension of "best practice" production will not affect the relatively large contingent of best performers and thus will not eliminate the large productivity gap between Russia and the developed market economies. Growth requires shifting the production frontier outward, which in turn requires the government to develop intelligent long-term policies for agriculture.

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