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The Structure of Ukrainian Agriculture:  
Comparative Efficiency with International Agriculture and  
Implications for Policy Reform

Volume I  
Final Report  
to  
The National Council for Soviet and East European Research  
Contract No. 807-07

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Acknowledgments

This work constitutes the first installment in a series of analyses of the structure, trends and dynamics of the agricultural sector in Ukraine.

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Joseph Herriges, associate professor in the Department of Economics contributed valuable suggestions on modeling and variable definitions in the early stages of the project. We also acknowledge the contribution of several research assistants and other staff at various times in the project: Stephen Holland, Arturas Kaslauskas, P.G. Lakshminarayan, Dan Phaneuf, Mohammed Taha and Lyubov Kurkalova contributed greatly to the organization of the data and all computational issues; Selahattin Dibooglu assisted with literature review and modeling. Karleen Gillen worked long hours typing and assembling this report.

Most of all we acknowledge the help of Dr. Peter Sabluk, Director of the Institute of Agrarian Economy, who provided us with the data, access to his researchers, and comments on earlier versions of this report.

Finally, a sincere appreciation goes to Stan Johnson, CARD Director.
In this report we provide an overview of Ukraine’s agricultural sector and its resources. Most of the analysis is based on official records of state, collective and interfarms for the period 1986-1991, obtained with the assistance of Ukraine’s Institute of Agrarian Economics. We also compared relevant indicators from our data set to other recent reports, in particular the 1993 Food and Agriculture Sector Review by the World Bank and a 1992 report on agriculture by the Ukrainian Institute of Agrarian Economics. Overall, the data were comparable and we believe both reports mentioned used the same national statistical database. However, in some cases important discrepancies exist. In part, the differences stem from adjustments made by the national statistics office to achieve "national estimates" for the total agricultural sector. We have made no adjustments to the individual farm survey data we obtained. Two important factors may explain the differences between the national statistics estimates and our numbers. The analysis we present is exclusively concerned with the public sector based on state-owned, collective, and interfarms. We refer to the private sector to explain some discrepancies. Also, of the nearly 12,000 farms reporting, our data set contains 59 less collective farms, 26 less state farms, and 2,075 less interfarms than those the World Bank report mentions. Thus, we expect our total numbers to be smaller than those reported in the other two reports. We have included the number of farms with each indicator presented.

This report is divided in two parts. Volume I is the main report and contains the results of the research. Volume II is a handbook of all the data that is referenced throughout Volume I. Three tables, summarizing model results, are included directly in Volume I and are numbered I-1 through I-3. The two volumes may be read independently.

Volume II is available from the National Council For Soviet and East European Research upon request [Tel. (202) 387-0168, FAX (202) 387-1608].
Executive Summary

Production data on over 11,000 state and collective farms in the Ukraine were obtained through the VASKhNIL Research Agreement* between the Center for Agricultural and Rural Development (CARD) at Iowa State University and the Ukrainian Institute of Agrarian Economics. Of particular interest to this study are data on input use, resource endowments, cost of production, output, prices, and labor. The major objectives of the study were to: (1) organize, develop, and provide descriptive analysis of data from state and collective farms in the Ukraine, (2) summarize and analyze major trends and economic indicators for Ukrainian agriculture, (3) analyze the technical efficiency of Ukraine's agricultural sector using frontier production function estimation and (4) provide policy assessments and dissemination of research results.

The first phase of the project was to describe the data available and to provide background analysis of economic indicators of the agricultural sector of the Ukraine. The second phase analyzed technical efficiency in agriculture. Measures of technical efficiency give an indication of the potential gains in output of major agricultural products without absorbing further resources. A second type of efficiency, allocative efficiency, which measures the amount by which the input mix chosen by the firm between factors of production exceeds the cost minimizing potential, was not addressed directly due to difficulties in observing the true cost of inputs to the farms.

The focal point of the project was the study of efficiency of production and input use. Based on the farm data, it becomes quite apparent that the state and collective farms differed in asset allocation, types of product produced, yields, and wage fund. Overall for both, the crop and livestock sectors, production is at relatively constant returns of scale, and labor's share of total cost is relatively
constant, except for the smallest firms. There is greater variability in costs and yields in vegetables and livestock production compared to other specific food, feed, and industrial crops.

Based on analysis of technical efficiencies, major inefficiencies appear to be present, and result in levels of productivity lower than those observed in comparable market economies. The inefficiency in most cases, has increased over the period 1986-1991.

Based on the initial analysis presented in this report, Ukraine has the opportunity to increase production in the agricultural sector through improved technology. This is evident by the distribution of technical efficiency measures for farms producing specific output. While many firms achieve production near "best practice" levels, for several crops (e.g. corn, potatoes, and sugar beets in the mixed region), there are many farms which produce far from this level. There were a considerable number of farms producing hogs with technology that indicated inefficiencies. It appears that the productivity of labor, particularly for most crops (except potatoes) is low. And, improved production practices, appropriate capital choices, reallocation of labor out of some agricultural activities, and specialization of farm activities (so that not all products were produced in all agroclimatic zones) would improve the overall efficiency in the sector. This, of course, will place greater demands for improvements in the trade and distribution channels for agricultural outputs.

*Research Agreement between Iowa State University (ISU) and the USSR Lenin All-Union Academy of Agricultural Sciences (VASKhNIL). In 1991, a new agreement was signed between Iowa State University and Ukraine’s Academy of Agricultural Sciences. Ukraine’s Institute of Agrarian Economics participates in the agreement.*
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I. GENERAL INTRODUCTION

One of the most important questions facing researchers and policy makers ever since the emergence of the Soviet-type system of economic organization is the quantification of comparative efficiency and trends in performance of Soviet agriculture. These questions are even more important today now that the Soviet system collapsed. Newly created states are aggressively moving ahead with political and institutional reforms that will eventually lead them to market economies fully integrated with the international global economy. The Ukraine is typical of such new countries.

The profound changes in formerly planned economies (FPE), including the former Soviet Union, Eastern Europe and some developing countries, are bringing about an economic transition of unprecedented proportions. In the past, these economies were planned in physical terms using normative models and a central decision maker (the state). Resources were centrally allocated and production decisions made by firms were based on an assortment of prescribed plans, within resource and administrative constraints. In the agricultural sector, the closed nature of these economies with state ownership of the means of production generally gave rise to concentrated, often single-firm (sovkhоз and kolkhoz) or state enterprise industries with little specialization. In most of these countries, soil and water resources were severely affected by the location and intensity of industrial production and by the large-scale projects of drainage, land reclamation, irrigation, and deforestation. In addition, the farms assumed responsibility for providing social services and support for often a large number of pensioners.

In a recent World Bank report (1993a), Ukrainian agriculture was characterized as having suffered severe structural problems due to central planning. Manifestations of these problems include low yields for principal products in agriculture, increasing importance of family plot production, distortion in the mix of crops and livestock production, and high losses in the production and distribution system. The report identifies "high inflation, worsening terms of trade for agriculture, reduced availability of vital inputs, falling real wages and domestic demand and the collapse of intraregional trade" as contributing factors to the decline in agricultural output.

Western economists do not have a good understanding—and certainly no simple recipes for—designing efficient and equitable transition policies (Csáki 1990). The distortions and inefficiencies created by a command and control economic organization have been the subject of extensive writing (e.g., Kornai 1980, Stuart 1984). However, the move from one stable form of economic system, based on administrative allocation of resources, to another one driven by market forces and government policy is by no means obvious: major discontinuities occur and adjustments by economic agents (firms and households) take different forms with varying results in the short and long runs.
In agriculture, the sharp rise in input prices (for energy, chemicals, seeds, and machinery), accompanied by a less rapid increase in commodity prices, has initially resulted in lower yields and planted areas, declining commodity outputs, worsening of the terms of trade, and a fall in real farm income. Input prices typically rose two to four times faster than output prices (Economic Research Service 1992). In addition, high interest rates and depressed farm income have led to a fall in investment for farm production. Producers of agricultural inputs have responded to the changes in the economic environment by increasing prices to maintain revenues rather than cutting production cost, a trend that is not consistent with being competitive in free international markets. Governments are trying to grapple with the new realities and respond with policies aimed at stabilizing farm income (e.g., price support and input subsidies in the Ukraine) while trying to address the major questions of privatization of state farms and agro-industrial complexes, land development, input and commodity markets, and the realities of international markets.

Ukrainian agriculture, considered as a model of Soviet agriculture, now faces restructuring that involves defining new property rights for agricultural resources and their distribution among economic agents, including the state. Clearly economic efficiency is not the only objective of current Ukrainian policy makers; the former type of organization of farm enterprises had major social, political, and cultural objectives as well. The farm was not only the center of economic activity, but also provided housing, education, health care, and cultural activities for an entire community. In addition, because of perceived economies of scale, farm enterprises were often highly vertically integrated, producing part of their inputs (mostly feed and seeds) and processing part of their outputs (mostly meat) and even directly marketing production in excess of planned objectives.

By studying production efficiency of the agricultural sector at the farm level, this work provides information useful in many regards. First, it provides information using farm level data to check previous findings about the overall efficiency of the agricultural sector in the former Soviet Union (e.g., Johnson and Brooks 1983; Hayami and Ruttan 1985; Koopman 1989); second, it helps identify specific types of farms, regions, or production sectors to be targeted for reforms because of relatively large inefficiencies in production; and third, it provides information for evaluating the need for major infusion of technology.

It is important to note several limitations of this study. First, the study period is 1986 through 1991. Data for 1992 have recently become available but they are not included. This has been, and continues to be, a period of rapid and comprehensive change in Ukraine. The increasing number of
new, private farms (recent estimates are of 20,000 new farms) are not included in our analysis and, when operating, are likely to effect changes in technical efficiency (both positively and negatively).

Second, we focus on the production and production technology of the agricultural sector at the farm level, and the technology of production for specific agricultural products. Joint production of products (e.g., crops, feed, and livestock complementarities) is more difficult to identify and evaluate in comparison among farms. Identified constant returns to scale in production of single products may not fully identify, and hence evaluate, other activities of processing or vertical linkages that exist on farm.

Finally, our report conveys findings based on the data from individual public sector farms, as reported by farm managers. We made no adjustment for potential over- or under-reporting of data. Given varying and complex incentives to over- or under-report, and how this is reflected in the data, it is difficult to evaluate the extent of potential bias. A major issue in misreporting of the data is whether or not the misreporting occurs systematically with characteristics of the farm or over time. This may be verified by additional survey work in the future. In addition, several values were reported only in ruble amounts which could include subsidies, bonuses, etc., varying by farm or region. To the extent possible, we used measures in physical terms, but this was not always the case. We also provide analysis of trends and technical efficiency results in both constant and nominal terms.

The report is organized into three major sections in addition to an introduction and conclusion. A section on the structure of Ukrainian agriculture provides a descriptive summary of key indicators from the data set. The next section contains results from a stochastic frontier analysis of technical efficiency. The last section will present a discussion of implications for policy reform.

II. STRUCTURE OF UKRAINIAN AGRICULTURE

1. Introduction

With a share of territory of only 2.7 percent, Ukraine contributed 18 percent (52 million) of the population and 16 percent of gross domestic product (GDP) to the former Soviet Union (Geets 1992). Thirty one percent of its population lives in rural areas.

Agriculture in Ukraine accounts for about 30 percent of the Ukrainian net material product and employs about 20 percent of the labor force. Its growth patterns reflect those of the former Soviet system, with about 2 percent annual growth in agricultural output in the first half of the 1980s and a slow down and decline in the early 1990s (World Bank 1993a).
The Ukraine is divided into three agroclimatic (or soil-climatic) zones running parallel to latitudinal lines. The forest zone has acid podsolic soils developed under forest with an annual precipitation of 600 to 700 mm. The mixed (forest-steppe) zone has 45 percent of its soils classified as chernozem (black earths) and an average precipitation between 450 and 600 mm. The steppe zone is 82 percent chernozem developed under grassland and has an average annual precipitation between 350 and 450 mm.

With some of the most productive land resources in the former Soviet Union and Europe, and with only 15 percent of the total arable farm land resources, during the period 1986-1990, the Ukraine accounted 24 percent of all grain, 22 percent of all meat, and 44 percent of all sunflower production in the USSR.

Despite great natural resource potential, productivity of Ukrainian agriculture has been below standards in some countries with developed and formerly planned economies (see Tables 25 and 26). Farm inputs, including chemical inputs, animal feed, veterinary supplies, and machinery have regularly been either in short supplies or inefficient in their make and application. For this reason, yields of cereals, while above average among former Soviet counties and comparable to Eastern Europe, are less than half of yield levels in West European and some Asian and African countries. Livestock feeding efficiency (measured in terms of meat-to-feed conversion ratios) is about half of that in West Europe (World Bank 1992), primarily due to shortages in protein and feed additives, and to herd genetics. Other factors associated with management and distribution may also limit productivity.

2. Indicators of Performance of the Ukrainian Agricultural Sector

Data from 11,440 farms covering the entire state sector and 99 percent of agricultural production in the Ukraine were obtained through a cooperative agreement with the Ukrainian Institute of Agrarian Economics. These data are the basis for the analysis presented in the report. In this section the data will be briefly described and the main indicators of agriculture production will be presented for 1991. A summary and discussion of trends over time and specialization will also be provided. All tables and graphs are numbered sequentially in an accompanying Volume II. Three tables, included directly in Volume I are numbered using roman numeral I to distinguish them from all the tables in Volume II. Unless otherwise specified, the term "farm sector" and "agricultural sector" will be used interchangeably to refer to the farm enterprises covered by the analysis.
2.1 Description of the Data Set

The data set consists of six years (1986-1991) of data collected by the national Statistics Office through a standard questionnaire that changed very little over the years. State and collective farms were required to provide detailed data on their operations. These data were transmitted to the national level through nearly 400 districts and then 26 regional (oblast) statistical offices. These data were used to assess performance of the farm sector and used for all levels of economic planning purposes.

For each of the 11,440 farms, 467 indicators were recorded for the six years of analysis with a few changes from year to year. An important feature of the data set is that it contains a large number of financial indicators (in nominal rubles) but a lack of detail on input use. The main categories of indicators involve production and main assets (in value), labor (in number of workers and hours) and wages, production cost, and marketing of agricultural production (quantity and value) for grain, sunflower, potatoes, sugar beet, cotton, vegetables, fruit, grapes, cattle, hogs, sheep and goats, poultry, milk, wool, and eggs. In addition, for crop production, the data include for each crop, area planted, yield, labor use, and total cost. For each livestock type, herd size, labor, and total production cost were given. Fertilizer cost, petroleum and energy products cost, and machinery were provided for both all crop and also livestock production in 1991 only.

2.2 Ukrainian Agricultural Structure: Indicators and Trends

2.2.1 General Indicators

With over 11,000 state and collective enterprises farming over 35 million hectares, Ukrainian agriculture is characterized by the predominance of collective farms (76 percent of the total number) and land holdings between one and five thousand hectares. Table 1 and Figures 1 and 2 summarize farm distribution by organizational management type (state or sovkhoz, collective or kolkhoz, and interfarm), farm size, oblast (region), and agroclimatic zone. Interfarms represent less than ten percent of the public sector farms and are special services units rather than mainstream production farms; for this reason, our subsequent analysis will only focus on collective and state farms. As expected and indicated in Table 2, about half of the land is in the Steppe agroclimatic zone.

About 4.8 million workers make up the labor force in agriculture, 84 percent of whom are directly engaged in agricultural production, 4 percent are seasonal workers, and less than 3 percent are engaged in management (Table 3). Average farm employment is about 380 workers (Table 4). Our data did not include any employment information related to gender. State farms average more
tractors and consumption of electrical power compared to collective farms, both indicators of greater capital usage (Table 6).

In 1991 the farm sector grossed 69.3 billion rubles (about 2-3 billion 1991 US dollars), 66 percent of which came from the collective sector (Table 5). Total revenue structure (Figure 3) shows that livestock contributes 62 percent to gross revenue, with 27 percent from cattle, 19 percent from milk, and 9 percent from hog production. Of the 38 percent share of crops sector revenue, grains and sugar beets are the dominant contributors with 14 percent and 7 percent, respectively. The differences in crop mix and specialization between management structures are reflected in revenue shares, with collective farms drawing relatively more revenue from cattle, milk, grains and industrial crops, and state farms drawing more revenue from hogs, poultry, and fruits and vegetables (Figure 4).

An analysis of the cost structure in Ukrainian agriculture, excluding land, reveals that labor and feed are the dominant inputs, with a share of 43 percent and 24 percent, respectively. A miscellaneous category has a 15 percent share and accounts for spare parts, construction material for current repair, insurance payments, and other input expenditures (Figure 5). In terms of cost share differences between management structures, we note the higher shares for feed and miscellaneous in state farms and the higher shares of labor, fertilizer, and seeds in collective farms (Figure 6).

Table 5 shows that, on average, state farms hold 34 percent more assets, gross 36 percent more, and pay workers 22 percent more than do collective farms. However, production cost in collective farms is only 33 percent of that in state farms. This is consistent with the fact that state enterprises have always been favored by the state planners (this difference may be partly due to differences in cost accounting, available subsidies, and product mix between management structures). Additional indication is given by the degree of mechanization as represented by tractor and horsepower; in collective farms the ratio of arable land to number of tractors is 75.5 compared to 64.7 for state farms (Table 24). Evidence from Table 24 suggests that there is little difference in capital to labor use between management structures.

An analysis of average production cost per acre reveals some interesting findings. Overall, the data do not indicate major economies of scale, particularly for farms of size higher than 1,000 hectares in production of agricultural products. It appears however, that for farms with less than 500 hectares average production cost is at least twice that of bigger farms (Figure 7). Caution should be taken in interpreting data for the smaller farms: more smaller farms belong to the specialized "Interfarm" category, and therefore need to be treated differently. This conclusion is also supported
by an analysis of the share of labor cost as a function of farm size (Figure 8). The "flatness" of the overall average cost curve is corroborated by the stochastic frontier analysis, with some differences between production sector. For example, there seems to be no cost advantage in milk production for herds with more than 300 cows (Figure 10). While more variability is observed in the hog sector (Figure 9), some economies of scale may be observed.

These findings suggest that policies aimed at restructuring the farm sector through privatization and breaking up of the large farms need to consider the issue of scale efficiency differences between small and large farms.

2.2.2 Indicators of Crop Production

Crop production contributes about 45 percent to agricultural GDP. During the period 1986-90, estimates of grain production, which is the major contributor to livestock and human consumption, were as high as 49 million tons per year. Industrial crops averaged 43 million tons per year, vegetables averaged 17 million tons per year, and fruits averaged below 2 million tons per year (World Bank 1993a).

Grain (or cereals) in the Ukraine is predominantly produced by collective farms (76 percent of total land) and on farms of large size (between one and ten thousand hectares). Only 12 percent of grain was produced under irrigated farming. In addition, about half of the grain production and the best yields (2.7 tons per hectare) are concentrated in the "steppe" agroclimatic zone considered to be a high risk production zone because of climatic vagaries (Table 7 and Figure 11.A). The mixed and forest zones contribute about 35 percent and 15 percent, respectively, to total production.

One limitation of the farm survey data is that they do not provide detail on specific grains, except for corn. Other sources indicate that, in 1991, total grain output was made up of winter wheat (54.6%), winter barley (5.2%), spring barley (15.5%), corn (12.3%), leguminous (5.1%), rye (2.5%), oats (2.4%), buckwheat (1.0%), millet (0.9%), and rice (0.3%) (Ukrainian Institute of Agrarian Economics 1992). Estimates of total grains production range from 32.8 million tons, estimated from our data set (corresponding to 12.8 million hectares), to about 38.7 million tons (Ukrainian Institute of Agrarian Economics 1992). Part of the difference here may be attributed to personal plot farmers who produced 1.4 million tons of grains (World Bank 1993a).

Grain yield averaged 2.5 tons per hectare in 1991 (Table 7), almost 0.7 tons lower than the yearly average for the period 1986-90 based on World Bank estimates. The World Bank (1993a) reports winter wheat yields ranging from 3.3 to 4.2 tons per hectare for 1986-1990 and 3.1 tons per hectare for 1991. In addition, it is estimated that about 50 percent of grain production was processed
on the farm mostly for livestock production. From Table 8 and Figure 11.B we observe that corn yield is about 3 tons per hectare with very little difference between collective and state farms; important differences exist between agroclimatic zones. While the steppe zone has higher overall grain yield due mainly to the predominance of nonirrigated wheat, for which it has a natural comparative advantage, the forest zone has an important yield advantage in corn production. The best corn yields come from small farms (less than 500 hectares) and particular oblasts (e.g., Lvovskaya and Zakarpatskaya).

**Industrial (or technical) crops** constitute the second major group of crops with about 11 percent of cropland. These crops include sugar beet, sunflower, soybeans, fiber flax, rapeseed, tobacco, and other oils. Collective farms have 87 percent of the industrial crops area (World Bank 1993a). Sugar beet is the main crop in this group with a total production of 36.1 million tons and a yield of 23.2 tons per hectare in 1991. (Table 9 and Figure 12.A). The 1991 production level is considerably lower than the average for the period 1986-1990 reported by the World Bank data. The lower fertilizer application (only 42 percent of the sugar beet area received any commercial fertilizer in 1991 according to the Ukrainian Institute of Agrarian Economics) is a major reason for the drop in yields. Other reasons, like harvesting efficiency, field storage and transportation have had an impact. Even though 94 percent of the sugar beet production comes from collective farms, state farms have a slight yield advantage and the best yields are obtained in the forest zone.

Sunflower is the second largest industrial crop with a total production of 2.2 million tons and an average yield of 1.44 tons per hectare (Table 10 and Figure 13.A). Sunflower also occupies over 90 percent of all oil crops area. With this level of production, it is anticipated that the Ukraine should be able to at least meet its domestic vegetable oil needs. Unlike sugar beet, collective farms have a distinct yield advantage in sunflower production. We note that while 70.5 percent of sugar beet hectares are in the mixed agroclimatic zone, almost 80 percent of sunflower hectares are located in the steppe zone. However, the best yields are obtained in other zones with less production. Other industrial crops are significantly less important, with soybeans and rapeseed grown on less than 100,000 hectares each.

For vegetable production, particularly potatoes, large differences exist among data sources, most likely because of the important role of the private sector in vegetable production. For 1991, over 80 percent of public sector farms in our data report vegetable production (excluding potatoes) on a total area of 284,000 hectares with a total production of 3.4 million tons and an average farm yield of 9.4 tons per hectare (Table 11 and Figure 13.B). For the same year, the Ukrainian Institute of Agrarian
Economics reports a total vegetable production (excluding potatoes) of 5.9 tons from 477,000 hectares and an average yield of 11.9 tons per hectare. The difference is very likely due to the contribution of the private sector. Indeed, World Bank (1993a) data show that in 1991, the private sector produced 2.2 million tons of vegetables on 187,000 hectares with an average yield of 12.3 tons per hectare.

Potato production reported by 80 percent of the public sector farms reporting in 1991, was 3.2 million tons on a total land area of 365,000 hectares and an average farm yield of 6.3 tons per hectare, well below African and Asian yields (Table 12 and Figure 12.B). For the same year both the World Bank and the Ukrainian Institute of Agrarian Economics report exactly the same figures: total area 1.53 million hectares; total yield 14.5 million tons; and yield per hectare 9.4 tons per hectare.

Private sector data reported by the World Bank show a contribution of 11.2 million tons of potatoes on 1.2 million hectares from the private sector with an average yield of 9.6 tons per hectare.

Vegetable and potato production have declined substantially during 1991 compared to the previous five years, even though total planted area did not change much; lower yields overall are due likely to cuts in input use and inefficiencies in harvesting, transportation, and storing.

2.2.3 Indicators of Livestock Production

Livestock production in the Ukraine contributed 62 percent of the total agricultural revenue in 1991 (Figure 3). The priorities given to the increasing per capita consumption of livestock products in the 1980s were reflected in major investments and subsidies to the sector and consequently improvements in production. One important characteristic of livestock production is that it is present in every region and all agroclimatic zones.

In 1991, over 95 percent of the public sector farms had a total of 6.1 million dairy cows with an average herd size of 564 and 13.6 million beef cattle with an average herd size of 1,213. Over 75 percent of the dairy and beef herds were on collective farms and about 80 percent were concentrated in the mixed and steppe agroclimatic zones; overall, state farms tend to have larger herds (Table 13 and 14).

In the pork sector, 70 percent of a total of 10.7 million animals were concentrated in collective farms, although on average, state farms had nearly 50 percent more animals than did collective farms (Table 15). Unlike dairy and beef where herd size increases directly with farm size, average pork

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1 The discrepancy between the potato yield from our data set and the one reported by the World Bank (1993a) also may be due to adjustments made to the data or reporting errors. Another possible explanation could be differences in the definition of yield, based on marketing versus production (a substantial amount of perishable products are usually lost due to inefficiencies in harvesting, storage, and distribution).
herd size on farms with less than 500 hectares is the same as for farms with 5,000 to 10,000 hectares (Table 15). This is due to the fact that confined operations are the predominant technology in pork production.

Even though present in every oblast, sheep production is concentrated on large state farms (more than 5,000 hectares) located in the steppe zone. Overall only 44 percent of the farms in the public sector engaged in sheep production (Table 16).

Poultry production is reported by only 33 percent of the public sector farms. Of a total of over 139 million birds, state farms account for 74 percent with an average flock size of more than fourteen times that of collective farms (Table 17).

Milk production yield, based on dairy cow inventories at the beginning of the year, is around 2,000 liters per cow with the yield in state farms three times as high as in collective farms and yields in the mixed and steppe zones twice the milk yield in the forest zone. We caution, however, that changes in herd size during the year, due to culling, disease or purchasing, may be an important factor to consider.

Indicators of production from the livestock sector for 1991 are summarized in Tables 18 to 23. Our data set shows a total marketed meat production of 4,036 thousand tons with beef accounting for 68.6 percent, pork 24.8 percent, mutton 1.2 percent, and poultry 5.4 percent. Some discrepancies with World Bank figures need to be pointed out, particularly for beef and mutton production. Note in the table below that our data shows marketed and not total production.

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<tr>
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<th>Our data</th>
<th>World Bank (1991)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(figures are in 1,000 tons except for eggs*)</td>
<td></td>
</tr>
<tr>
<td>Beef</td>
<td>2,770</td>
<td>1,878</td>
</tr>
<tr>
<td>Pork</td>
<td>1,000</td>
<td>1,421</td>
</tr>
<tr>
<td>Poultry</td>
<td>219</td>
<td>654</td>
</tr>
<tr>
<td>Mutton</td>
<td>47</td>
<td>40</td>
</tr>
<tr>
<td>Milk</td>
<td>15,283</td>
<td>22,409</td>
</tr>
<tr>
<td>Eggs</td>
<td>8,450</td>
<td>15,188</td>
</tr>
</tbody>
</table>

* Eggs in million pieces.

Overall, yield per animal for beef, mutton, milk, and poultry is low even when compared to the former USSR; pork production yields are relatively better than other meats (Table 26). This lower productivity in the livestock sector has been attributed in part to lower quality feed and animal husbandry technologies. According to a World Bank report (1993a), lower fertility rates, mortality rates, shortage of medication and vaccines, high cow replacement rates and extremely high culling
rates in layers, are some of the factors contributing to low efficiency levels in the livestock sector. Also, the predominance of winter wheat in feed rations, which has lower efficiency than corn, barley, oats, sorghum, and grain forage crops, reduces feed efficiency ratios. This problem is more pronounced in cattle production relative to pig production. Poor quality feed stuffs, including hay, haylage, stovers, and silage, contribute to the deficit in energy and protein.

2.2.4 Indicators of Specialization

Farm-level data show not much specialization on most of Ukraine’s farms. One way to evaluate the degree of specialization is through analysis of farm by type of products produced. Ukrainian farms were classified into groups which contain farms of similar production lines and methods. A standard clustering technique was used to group the farms into nine clusters according to indicator ratios such as number of animals per worker and percentage of land used for each crop. The clusters were then evaluated by various indicators to find similarities and differences among the clusters.

The clustering was done on the basis of nine ratios: 1) head of cattle per worker; 2) percentage of land for fruit; 3) percentage of land for grain and corn; 4) head of hogs per worker; 5) head of milk cows per worker; 6) number of poultry per worker; 7) head of sheep and goats per worker; 8) percentage of land in sugar beets; and 9) percentage of land for vegetables and potatoes. Nine clusters were chosen since nine seemed to statistically fit the data reasonably well without being too unwieldy. The distribution of farms and production is shown by cluster in Table 27.

The first three clusters, Clusters A, B, and C, together account for approximately 84 percent of all the farms and 90 percent of the total land. These farms tend to be large and diverse with significant production of grain, cattle, and milk. The farms are differentiated by other factors:

- Cluster A farms account for approximately 80 percent of all sugar beet production.
- Cluster B farms account for approximately 65 percent of all hog production.
- Cluster C farms account for approximately 50 percent of all vegetable and potato production.

Clusters D, E, F, G, and H are much smaller and together account for only about 15 percent of the farms. These farms are highly specialized and often contain a significant proportion of the production of a certain commodity.

- Cluster D is a small cluster. These farms specialize in the production of cattle.
- Cluster E is small and contains only 2 percent of the farms; these farms account for over 60 percent of all poultry production.
- Cluster F contains only 2 percent of the farms; these farms account for around 30 percent of the sheep and goat production.
\begin{itemize}
  \item Cluster G contains about 6 percent of the farms, however, they account for 25 percent of all the fruit production.
  \item Cluster H contains only 2 percent of the farms, however, they account for approximately 30 percent of the fruit, grape, and berry production.
  \item Cluster I has 2 percent of the farms. These farms are primarily inter-farm operations and account for only a small percentage of production.
\end{itemize}

\textbf{2.2.5 Indicators of Agroclimatic Differences}

There are some major differences among the agroclimatic zones. The natural resource base has important productivity impacts. In the past, because of the need to continually increase food production, in addition to regional development and other strategic objectives, many areas were brought into production to meet local population demand irrespective of comparative advantage in natural capital. This is clearly illustrated by the extent of diversification in the farm sector, and lack of specialization among the state and collective farms.

As was mentioned at the beginning of this report, agroclimatic zones are based on soil and climatic considerations and provide some degree of homogeneity for agricultural production within zone. Average farm size for the two management types is similar across agroclimatic zones, with farms being larger moving from north to south (Figure 14 and 16). The mixed zone has 42 percent of all the public sector farms, followed by 32 percent for the steppe zone, and 26 percent for forest zone. Almost half of the farms in the range 1,000-5,000 hectares are in the mixed zone, and 78 percent of the farms in the range 5,000-10,000 hectares are in the steppe zone. The forest zone is characterized by more farms in the range 500-1,000 hectares (Figure 14). In addition, land distribution between arable, grass, and pasture lands is similar, with the forest zone having the lowest proportion of arable land (74 percent) and the steppe zone having relatively more pasture than grasslands (Figure 15).

In crop production, important differences among the zones are observed (Figure 17). The forest zone, with the highest precipitation amount and less fertile soils, has a yield advantage in the production of corn (7 to 21 percent), potatoes (21 to 52 percent), sugar beet (14 to 19 percent), and vegetables (11 to 15 percent). The steppe zone, drier but with the more naturally fertile black soils, has a yield advantage in the production of cereals (7 to 11 percent). The mixed zone, with intermediate soil and climatic features, has a yield advantage only in sunflower production.

We note that crop yield differences are less pronounced between management structures, particularly in the grain sector. State farms have some advantage in the production of vegetables and
sugar beets and collective farms have a slight advantage in potato and sunflower production (Figure 18).

Productivity differences among zones can also be ascertained from differences in output per worker. For grain, production per worker (expressed as production per worker hour) is 31 and 44 percent higher in the steppe zone for collective farms, and 34 and 48 percent higher in the steppe zone for state farms than in the mixed and forest zones, respectively (Figure 19). Overall, output per worker hour is higher in collective farms (about 18 percent in both the forest and steppe zones), even though output per hectare is the same as that for state farms, as was pointed out previously (Figure 18). In the milk sector, production per worker hour is higher in the state sector across agroclimatic zones (Figure 20).

We use a wage fund indicator, which includes salaries and bonuses, as a proxy for agricultural worker wage (Figure 21). On this basis, some important wage differences are worth noting. Collective farm wages are 12 to 26 percent lower than state farm wages across agroclimatic zones; in addition, the wage differences among zones are more pronounced for collective farms (23 percent) than for state farms (8 percent). Overall, wages are much higher in the steppe zone, where average farm size is higher, for all management types.

Another partial productivity indicator, marketed revenue per worker (Figure 22), shows that state farms market more per worker than collective farms, with the difference being as much as 40 percent in the forest and mixed zones. These differences may be due to product mix and specialization both on the input and output sides.

2.2.6 Trend Indicators

All the previous analysis was based on the performance of the Ukrainian agricultural sector in 1991. In this section we present a summary of trends of major indicators for the period 1986-91.

The total number of collective farms has increased markedly (Figure 23), while the number of state farms has not gone down, indicating that new cooperatives were most likely formed from existing ones and not around newly acquired land. This is because on the one hand, both agricultural land and planted acres have gone down since 1988 (Figure 24), and on the other hand, average farm size has also decreased during the same period (Figure 25).

Financial indicators like assets and marketed revenue (adjusted for price changes) have decreased especially after 1990 (Figure 26); part of the marked decrease in total assets may be explained by little or no new investment and changes in asset valuation. The total number of workers in agriculture has gone down (Figure 27) both on state and collective farms. At the farm level this trend
is led by changes in the number of agricultural workers (Figure 28). This may be explained in part by the policies of "perestroika," that allowed more labor mobility between rural and urban areas. Real agricultural wages declined between 1987 and 1989 (Figure 29).

Finally, we note that total marketed revenue to state has decreased (Figure 30), especially since 1989. The decreases in agricultural land and labor in public sector farms suggest that there were fewer resources devoted to production through state and collective (public sector farms). Also, more production may have been sold outside of the state procurement system. Total production less that marketed to the state has not fallen significantly (Figure 31).

In the crop production sector, we observe a steady decrease in yields since 1989, in sugar beets, vegetables, potatoes, and corn. Sunflower yield has held steady and grain cereals yield increased from 1988 through 1990 (Figure 32). The decline in crop production is due to many factors, including organization problems, reduction in area planted, and input availability and allocation, particularly fertilizer and pesticides.

In the livestock sector, total herd sizes, except for poultry, have decreased since 1986 (Figure 33), but total meat marketed to the state has held steady, suggesting liquidation of herds and possibly some improvements in productivity (Figure 34). Average farm milk output has remained relatively steady; average farm egg production marketed to the state fell in 1991 (Figure 35).

3. Comparative Efficiency: Partial Productivity Indices

In this section we contrast indicators of performance of Ukrainian agriculture with other countries, particularly in the West. An indication of capital endowment and technology is given by agricultural assets, not including land, in the public farm sector. From our 1991 data, the average level of agricultural assets per worker is 16,440 rubles, between $548 and $822 (1991 US dollars). On a per hectare basis, the level of agricultural assets is 4,730 rubles, between $158 and $236 (1991 US dollars) (Table 24). The low level of assets is accompanied by a very low ratio of land to labor force (overall, 7.43 hectares of agricultural land per worker). Furthermore, on average, there are 29 workers for 100 hectares of agricultural land and only 23 of them are involved in agricultural production. By developed country standards, the asset level is extremely low and the work force levels are extremely high. The result of this allocation configuration translates into very low revenue levels. On average, farm revenue is 1,900 rubles per hectare (between $63 and $95) and 1,440

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2 A non-official exchange rate range between 20 and 30 rubles to the dollar for 1991 is used throughout, for illustration purposes.
rubles per worker (between $48 and $72) (Table 24). All things not being equal, it is interesting to contrast this performance to that of a private mixed crop and livestock farm in the midwestern United States with 200 hectares and two operators. Such a farm would have a minimum of $100,000 invested in agricultural assets, excluding land, a workforce of 2 to 4 people, including seasonal labor, and would gross $400 to $800 per hectare, translating into $20,000 to $40,000 per worker.

Even though this characterization holds for the Ukrainian agricultural sector as a whole, some important differences between management type and agroclimatic zones are worth mentioning. On average, state farms have 21 percent more assets per worker, 77 percent more assets per hectare, and 55 percent more agricultural workers per hectare, than is the case for collective farms. This factor endowment advantage in the state sector translates into higher revenue levels: 29 percent more per hectare and 26 percent more per worker.

Overall productivity in Ukrainian agriculture falls within the range of international performance (Tables 25 and 26). In cereal production, yield is almost half the yield in Western Europe and the United States but similar to the Canadian yields. Compared to the former communist world, Ukrainian cereal yield is more than 30 percent higher than that of the USSR but only 45 percent of the Hungarian level and 79 percent of the Polish level. Yields of industrial crops are somewhat better than those of the USSR, except for sugar beets, but much lower than those of the western world and Eastern Europe. Finally, it is in potato production the Ukraine seems to have a major disadvantage as yields are 40 percent lower than in the USSR, and are one-third of the yields in western and eastern Europe, and one-fifth of the yields in the United States. We think that in addition to inefficiencies in production, these very low potato yields reflect omission of private sector potato production, and inefficiencies in harvesting, storage, transportation, and organization. The World Bank reports private sector yield twice the level of the public sector farms.

In the livestock sector, Ukrainian productivity is again within the range of international performance as indicated by beef and pork production (Table 26). The only area where a large productivity gap is observed is in milk production.

III. TECHNICAL EFFICIENCY: A STOCHASTIC FRONTIER ANALYSIS

1. Introduction

The econometric modeling of production and the estimation of technical efficiency of firms make an important contribution to measuring the relative ability of firms to produce maximum output from its resources. Technical efficiency, a relative measure, is the ability of the firm to obtain maximum
output from its resources or inputs. Measures of technical efficiency provide indicators of potential gains in output available if the inefficiencies in production were to be eliminated.

This section is organized in three parts: first is an overview of the literature on modeling production efficiency and estimation of technical efficiency; the second part specifies the data and model used in panel estimations based on the farm-level data for the Ukraine; and finally, the results of the analysis.

2. Efficiency in Production: An Overview of Frontier Model and the Applications

A simple definition of "production function" holds that it is the locus of maximum outputs associated with different combinations of inputs. Fitted by standard econometric techniques, the production function will give the mean level of output rather than maximum output, because the regression equation will have positive as well as negative residuals. From an economic point of view, however, the maximum possible output (statistically the maximum of the distribution rather the mean) is the standard by which the efficiency of an individual firm is measured. Thus the concept of frontier arises because the function sets a limit to the range of possible observations.

2.1 The Concept of Efficiency

There is an ample literature on measuring efficiency through "frontier methodology", the earliest work being Farrell (1957). In this influential work, Farrell proposed specific measures of technical and allocative efficiency and suggested that the production function should be estimated as an envelope function associated with different combinations of observed inputs. Accordingly, technical inefficiency is defined to be the proportion by which excessive input usage could be reduced -given the input ratio- without reducing output. That is, technical efficiency of a given firm in some time period, is the ratio of the firm's mean production, given firm effects and input levels, to the corresponding mean production if the firm were to use its levels of inputs most efficiently. Technical efficiency is estimated through the specification and estimation of the appropriate frontier (or envelope) production functions. In contrast, allocative inefficiency is due to employing inputs in the "wrong" proportions and it measures the possible reduction in cost from using the correct input proportions. These measures do not generalize usually to complicated technologies.

3 For comprehensive surveys of the frontier literature, see Forsund, Lovell, and Schmidt (1980); Schmidt (1985/86); Bauer (1990); and Färe, Groskopf and Lovell (1994).
2.2 Empirical Applications

There have been numerous applications of the stochastic frontier approach in the literature. Aigner, Lovell, and Schmidt (1977) (U.S. primary metals) and Meeusen and van den Broeck (1977) (French Manufacturing) both developed the stochastic frontier production function which contains a composite error structure, allowing for variation across firms due both to random factors and to technical inefficiencies which pull the firm's production below the "best practice" frontier.

Although most of the applications are motivated by a desire to measure efficiency, some studies have used these techniques to find out how efficiency is related to observable characteristics associated with the production unit. As an example of this second type is, Pitt and Lee (1981) which analyzes the effects of foreign ownership, age and size on the efficiency of Indonesian weaving firms, or Battese, Coelli, and Colby (1989), and Battese and Coelli (1991), which study Indian farms.

A brief review of some of the studies which use the frontier methodology to measure efficiency is useful. Our examples will be restricted to those dealing with agriculture in general, and with Eastern European and the former Soviet Union's agriculture in particular.

A major study that tried to assess the efficiency of Soviet agriculture is Koopman (1989). Because there is an enormous growth differential between western agriculture and agriculture in the ex-Soviet Union, the study sets out to explain this growth differential in terms of technical efficiency. The author uses two different data sets collected independently; the first he constructs from official Soviet statistics, the other is collected by Johnson and Brooks (1983) and covers 15 ex-Soviet Republics, 4 Canadian provinces, 10 U.S. states, and Finland. In the first part of the study, a translog production function with Hicks-neutral technical change is fit to the first data set assuming that the 15 republics possess the same production technology. The inputs are fertilizer, livestock, machinery, land, and labor. A linear time trend is included in the production function to capture technological progress. The mean level of inefficiency is found to be 6.79 percent (mean efficiency 93.4 percent), while the ratio of the standard error of the inefficiency term to the standard error of the two-sided disturbance term is 1.75. This implies that a greater portion of the variation in output is due to change in efficiency than random events.

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4 Other motivations include, analyzing the same data set with different frontier techniques, different distributions, different functional forms to see how the results are sensitive to such specifications.

5 The author does not explain the way the variables are measured.
The distribution of efficiency across republics reveals that the most efficient republics are the Baltic Republics (Lithuania ranking the first, with 95.7 percent efficiency level), Transcaucasian republics are average, and Central Asian republics are the least efficient. Ukraine ranks the ninth with 93.2 percent, slightly below the average level of efficiency. The author characterizes the efficiency in Ukraine as "unexpectedly low".

One identified pattern is that the relatively efficient republics have specialization in production. The other pattern is that relatively efficient republics have greater than average output per input ratios, and higher input per input (capital per labor) ratios except for labor inputs per hectare. Ukraine seems to confirm these patterns, having a nonspecialized agricultural production, and lower output per input ratios.

The second part of the study uses the Johnson-Brooks data set. Koopman pools the data set and tests whether the overall sample with Soviet and non-Soviet components has the same technology. The test indicates separate technologies; the author fits a translog production function to each data set. The comparative efficiency analysis reveals interesting results: the Soviet sample has slightly lower inefficiency levels than the non-Soviet sample (7.7 percent as compared to 8.9 percent). In comparative ranking, Soviet Georgia ranks first with 95.07 percent efficiency level, and Ukraine ranks the sixth (93.51 percent), the least efficient "regions" being Saskatchewan (88.14 percent) and Azerbaijan (87.15 percent). The ratio of standard error of the efficiency term to that of random term is 2.03 for the Soviet sample and 1.90 for the non-Soviet sample indicating that more variation is attributable to the variation in efficiency in the Soviet sample. Also, the range in level of efficiency is greater in the Soviet sample as compared to the non-Soviet sample (8 percent as compared to 5.3 percent etc.). In terms of identifying patterns, the same patterns emerge for the Soviet sample as before, but there is no clear pattern for the non-Soviet sample.

Koopman concludes that the planners are effective in attaining production levels suggested by the frontier. He further asserts that in the static environment where prices are fixed, machines are the same, planners’ preferences are the same, and no macroeconomic fluctuations take place, it is easier to operate close to the frontier. While this is true in a static sense, it does not mean the system is dynamically efficient, and the Soviets have paid the cost in terms of lacking technological innovations and growth in agriculture.

Skold and Popov (1990) studied the technical efficiency of 115 state and collective farms in the Stavropol region of the ex-USSR. They fit the stochastic frontier model to five crops: grain, corn for grain, sunflowers, sugar beets, and vegetables. In this study, the production function has one output
(measured in centners) and four inputs: sown area (hectares), capital, cost of depreciation and machinery technical repairs (000 rubles), direct labor applied (man-hours), and mineral fertilizer nutrients applied (centners). The flow of capital services proxies capital and is calculated as follows: for each crop, percentage of cost due to depreciation and technical repairs is multiplied by total cost of production to give total capital services.

The authors fit either a Cobb-Douglas or a translog production function depending on which one fits the data better. Consequently, translog production function is fit to grain, corn for grain, and vegetables, and Cobb-Douglas is fit to sunflowers, and sugar beets. Mean efficiency levels and standard error ratios are: grain (82.7 percent and 1.28), corn for grain (66.6 percent and 4.48), vegetables (54.9 percent and 3.07), sunflowers (67.7 percent and 5.25), and sugar beets (75.1 percent and 0.89). Notice that the efficiency levels are lower than those levels estimated from aggregate data found by Koopman. Also the standard error ratios are higher with the exception of sugar beets.

Brada and King (1992) estimated a Cobb-Douglas type stochastic frontier model for Polish agriculture. The study uses county level aggregate data for the years 1978, 1980, and 1982. In the study, the output is measured in 1977 prices. The inputs are land (hectares of arable land adjusted for quality), labor (man-years adjusted to reflect age and gender composition), machinery (tractor horsepower), livestock (aggregated for various types of animals), and chemical fertilizers (tons). Also a linear time trend is included in the production function to capture technological progress. The mean levels of efficiency for state and private farms are 66 and 50 percent for 1978, 63 and 68 percent for 1980, and 66 and 72 percent for 1982 respectively. The coefficient for the time trend is negative indicating no technical progress. According to the results, the efficiency level for private farms is in a steady increase. The authors emphasize greater incentives for private farms as a possible explanation.

3. The Model and Econometric Estimation

3.1 The Model

There are two alternative and competing paradigms of constructing frontiers: a non-parametric approach which uses mathematical programming techniques (also known as Data Envelopment Analysis (DEA)), and a fully parametric approach. The parametric approach allows for statistical noise but it imposes a functional form for technology, and unless panel data are available, one also

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6The standard error ratio is the ratio of the standard error of the inefficiency disturbance term to the standard error of the two-sided random disturbance term.
has to make distributional assumptions regarding the efficiency term. As always, trade-offs are involved when a structure is imposed, since the assumed structure may not hold. In this work we have adopted the fully parametric, stochastic frontier approach similar to that proposed by Aigner, Lovell and Schmidt (1977), Meeusen, van den Broeck (1977), and Battese and Corra (1977). The estimation of the frontier allows for statistical noise as well as inefficiency to cause deviations from the frontier. The stochastic frontier involves two random disturbances. One is associated with the presence of technical inefficiency and is generally assumed to be distributed as a truncated normal random variable. The second part represents inefficiency and is assumed to be the usual Gaussian error. More specifically, a stochastic production frontier model can be written as

\[ y_i = f(x_i) \exp(e_i); \quad e_i = v_i - u_i \]  

where \( y_i \) is output, \( x_i \) is a vector of inputs, \( v_i \) is statistical noise, and \( u_i \geq 0 \) represents the shortfall of output from the frontier.

The distribution of the statistical error term \( v_i \) is assumed to be independent and identically distributed (iid) normal while the most commonly used distribution for \( u_i \) is half-normal (truncated from above at zero). If \( u_i \) and \( v_i \) are independent of each other and of the inputs, the likelihood function can be defined for certain distributions of \( u_i \) and \( v_i \). Maximum likelihood (ML) estimates of the parameters can be obtained using numerical optimization methods.

The most commonly used functional form has been the Cobb-Douglas, although more general functional forms such as CES, translog, generalized quadratic, generalized Leontief, and Box-Cox have been introduced in recent years. As in any parametric approach, the choice of the functional form depends on the presumed theory as well as which functional form fits the data best.

3.2 Econometric Specification

Stochastic frontiers can be estimated either from cross-sectional or from panel data. If panel data are available, several restrictive assumptions of the conventional frontier models can be relaxed and the model can take into account that technical efficiency for a firm may change over time. In this case, one still has to model efficiency over time.

The general form of the time-varying model we used to obtain the results presented in this report is the following:
\[ Y_{it} = f(x_{it}; \beta) \exp\{\nu_{it} - u_{it}\}, \]
\[ u_{it} = \eta_t \mu_t = (\exp\{-\eta(t - T)\}) \ u_t, \]  

where \( Y_{it} \) represents the production of the \( it \)th firm on the \( tt \)th time period, \( f(x_{it}; \beta) \) is an appropriate production function relating inputs \( x_{it} \) to output levels through a set of unknown (fixed) parameters \( \beta \), and \( T \) is the number of time periods considered. There are two random disturbances in (1). The random noise variables \( \nu_{it} \) are assumed to be normally distributed with mean 0 and variance \( \sigma^2 \), and are taken to be independent for all firms and time periods. The second random disturbance terms \( u_{it} \) are associated with the firm’s inefficiencies, and are assumed to be nonnegative truncated normal random variables from a distribution with mean \( \mu \) and variance \( \sigma^2 \).

According to the model, the stochastic term \( u_{it} \) is an exponential function of time, where the unknown, fixed, scalar parameter \( \eta_t \) gives the rate of growth (or decay) of efficiency over time. Therefore, \( \eta_t \) will be positive for firms that increase their technical efficiency over time, will be negative when the level of technical efficiency of firms is decreasing, and will be 0 when technical efficiency for a set of firms is constant over time.

When a stochastic frontier model is to be estimated from cross-sectional data, a model similar to (1) can be used. Clearly, when \( T = 1 \), \( t - T = 0 \) in model (1), and therefore \( \eta_{it} = 1 \) and \( u_{it} = u_t \). That is, the time-varying model for panel data can be applied to cross-sectional data by restricting the parameter \( \eta_t \) to be equal to 0.

The technical efficiency \( T E_{it} = \exp\{-u_{it}\} \) for the \( it \)th firm at the \( tt \)th time can be estimated as is described in Battese and Coelli (1991). The mean technical efficiency of all firms at time \( t \) is given by

\[ T E_t = E[\exp\{-\eta_t \mu_t\}], \]  

where \( \eta_t = \exp\{-\eta(t-T)\} \). Estimators for firm technical efficiency and for mean technical efficiency can be obtained via the method of maximum likelihood (ML). These ML estimates are computed by iteratively maximizing a nonlinear function of the unknown parameters in the model subject to constraints, and software to carry out the computations is available. We used a program developed by Coelli (1991) called FRONTIER (Version 2.0).

The model described in (1) and the predictors presented in the text and in (2) allow for the estimation of a firm’s technical efficiency at each time period considered. In what follows, we describe an application of the stochastic frontier model presented above to selected crop and livestock
subsectors for Ukrainian state and collective farms. Because of important differences indicated by the analysis in the previous section, the models are estimated separately for farms in different agro-climatic zones. It will be shown that there exists large variation among farms regarding the efficiency with which they utilize their inputs.

3.3 Data and Estimated Model

The data used to estimate technical efficiency for Ukrainian farms were described in detail in Section II. The estimation and analysis were conducted by agroclimatic zone and only included collective and state farms. In addition, technical efficiency was estimated for the crop and livestock sectors separately.

Within the crop sector, we investigated the use of inputs in the production of potatoes, grain, corn, sugar beets, and sunflower. Considering the volume of wheat production in the Ukraine, it would have been very useful to estimate technical efficiency for wheat production as well. The production data, however, are aggregated over all grains (except corn) and it was therefore not possible to estimate frontiers for wheat from the data available. The crop sector data were taken as a panel data set for each of the crops with six time periods starting in 1986. For the livestock sector, panel data for frontier estimation of hog production include four periods beginning in 1989. We did not use data for 1986, 1987 and 1988 in the analysis because between 1988 and 1989 information collected from farms on livestock activities underwent significant changes.

Farm production data in the Ukraine have been collected through comprehensive farm surveys. In 1991, the survey instrument was significantly modified, and the amount of information in the data collected as of 1991 is much larger than that from previous years. For example, for 1991 there is detailed information available on farm input use by crop and livestock activity. For earlier years, however, detailed input data were aggregated over all activities in each sector, and thus it is not possible to obtain, from these data, the amount of, for example, fuel that was used to produce a given crop in a farm. Since we were interested in estimating, among other things the changes in farm technical efficiency over time, we decided to use the panel data with less detailed information about input use per activity.

The functional form of the model estimated was a Cobb-Douglas function with the two stochastic disturbances described in (1). The general form of the Cobb-Douglas function used for activities in the crop and livestock sectors is

\[
\text{where the number and type of inputs were different for activities in the two sectors, where the subscripts } i \text{ and } t \text{ refer to the } i^{th} \text{ farm and the } t^{th} \text{ observation respectively, and there are } j = 1, \ldots, p
\]
\[
\log Y_{it} = \beta_0 + \sum_{j=1}^K \beta_j \log X_{jit} + \beta_{d+1} d + \nu_{it} - u_{it},
\] (4)

independent variables. In (4), the variable \(d (d=1, 2, \ldots, T)\) represents the linear effect of year, and \(T\) equals 6 or 3 for crop and livestock activities, respectively.

For all activities, the dependent variable was the log of total output marketed for the farm (crop yield for activities in the crop sector, and meat yield for hogs), and the input variables considered were slightly different for the crop and the livestock sector models.

For models in the crops sector, inputs included in the model were the following:
- Area planted in hectares
- Labor, measured in thousands of hours
- Cost of production net of labor, in rubles. This was calculated from the data, by subtracting wages from the total cost of production entry for each farm.
- Year, included in linear form in the Cobb-Douglas equation. This term was included in the model to account for possible reductions (or increases) in production technology, independent of changes in technical efficiency.

The model used for hog production in the livestock sector included the following inputs.\(^7\)
- Average (over the year) size of the breeding herd (sows and boars)
- Labor, in thousands of hours
- Cost of production net of labor costs
- Year, as defined above.

The parameters in the models were estimated using FRONTIER Version 2.0. Parameter estimates are approximate ML estimates. Tables I-1 and I-2 in this volume provide the estimated coefficients for the specific crop products and hogs, for nominal (Table I-1) and deflated (Table I-2) ruble values. Parameters of interest in the models are the input coefficients or elasticities, the parameter \(\eta\) that indicates whether technical efficiency is in fact changing over time for those farms considered, the mean technical efficiency for farms considered for each period, and of course, the individual technical efficiencies for each firm in each time period. The sum of the estimated coefficients of variable inputs given is an indication of whether firms are operating at constant, increasing or decreasing return to scale. The parameter in the table denoted by the \(\Gamma\) represents the proportion of the total variance that is attributable to the efficiency term, and is computed as

\(^7\) There was not enough information in the data to identify a proper proxy variable for feed.
The potential problem of multicollinearity among the input variables in each of the models was considered, and the correlation coefficients among the input variables were estimated. As expected from this type of data, there was some degree of correlation among the input variables. However, the degree of multicollinearity presented in the data was considered to be acceptable. As more input information becomes available for these farms, however, it will be possible to make a more judicious choice of input variables or proxies, thereby avoiding multicollinearity problems.

3.4 Results

Results obtained for the different activities in the crop and livestock sectors are given in Tables I-1 and I-2, and in Table 28 in volume II. Those results are described below. Models fit using nominal or deflated values for those variables reported in rubles resulted in similar parameter estimates for most activities. Therefore, we will restrict our comments to those results obtained when monetary amounts were deflated (Table I-2).

3.4.1 Potato Production

Most state and collective farms in Ukraine produce potatoes. There were a total of 6,036 farms reporting potato yields in the 1986-1991 period, where 2,172, 3,025, and 839 farms were located in the forest, mixed, and steppe agroclimatic zones, respectively.

Coefficient (elasticity) estimates for land, labor and costs net of labor for potato production in the mixed agroclimatic zone for 1991 are given in Table I-2. These elasticity estimates are very similar for land and labor, and are higher for cost net of labor. There is some evidence for farms in the mixed zone that they are operating at increasing returns to scale (the sum of factor coefficients is 1.14, see Table I-2) in potato production. This, as will be shown, differs from most activities and agroclimatic zones, where it was found that farms operate at approximately constant returns to scale.

Mean technical efficiency of potato production (η) decreased over the study period. Production of potatoes decreased as a result of factors other than inefficiencies in the use of inputs. There is no evidence of improvements of technology for farms in the mixed zone over time. The regression coefficient associated to the year effect (d) was estimated to be negative (and significantly different from zero). As indicated in Table I-2 and Figure 37 in Volume 2, individual firms' technical efficiency estimates were highly variable, showing the potential for some farms to dramatically

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8 Output, capital, and other variables reported in rubles were deflated using implicit price deflators for net agricultural products (1983 = 100); World Bank (1993b).
improve their potato yield by simply improving upon their input use. During the last period considered (1991), the most inefficient farm was operating at 11 percent of its potential, while the most efficient farm had an estimated technical efficiency of 95 percent.

Results obtained for farms located in the forest zone were somewhat different from those in the mixed zone. Estimated elasticities for land, labor, and cost net of labor were 0.35, 0.16, and 0.56, respectively. While these firms are still operating under nearly constant returns to scale, the coefficient for labor shows that percentage change in this input has a very different effect on output than it did in farms in the mixed zone. Note that labor elasticity was about 50 percent lower when
Table 1-1. Stochastic frontier analysis of farm level production with nominal cost, Ukraine 1986-91

<table>
<thead>
<tr>
<th>Crop/Agro-climatic zone</th>
<th>Intercept</th>
<th>Land/Herd Size*</th>
<th>Labor</th>
<th>Cost*</th>
<th>Time trend</th>
<th>η</th>
<th>Γ</th>
<th>No. of farms*</th>
<th>Mean technical efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1986</td>
</tr>
<tr>
<td><strong>Potatoes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>4.906</td>
<td>0.478</td>
<td>0.171</td>
<td>0.428</td>
<td>-0.147</td>
<td>-0.22</td>
<td>0.74</td>
<td>2,172</td>
<td>.85</td>
</tr>
<tr>
<td>Mixed</td>
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<td>0.424</td>
<td>0.406</td>
<td>0.368</td>
<td>-0.099</td>
<td>-0.16</td>
<td>0.39</td>
<td>3,025</td>
<td>.69</td>
</tr>
<tr>
<td>Steppe</td>
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<td>0.383</td>
<td>0.365</td>
<td>-0.132*</td>
<td>-0.05*</td>
<td>0.56</td>
<td>839</td>
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<tr>
<td><strong>Corn</strong></td>
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<tr>
<td>Forest</td>
<td>4.410</td>
<td>0.648</td>
<td>0.048</td>
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<td>-0.23</td>
<td>0.58</td>
<td>274</td>
<td>.77</td>
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<tr>
<td>Mixed</td>
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<td>0.056</td>
<td>0.413</td>
<td>0.052</td>
<td>-0.29</td>
<td>0.82</td>
<td>2,302</td>
<td>.87</td>
</tr>
<tr>
<td>Steppe</td>
<td>4.246</td>
<td>0.485</td>
<td>0.090</td>
<td>0.510</td>
<td>0.002*</td>
<td>-0.20</td>
<td>0.67</td>
<td>1,629</td>
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</tr>
<tr>
<td><strong>Grains</strong></td>
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<tr>
<td>Forest</td>
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<td>0.618</td>
<td>0.091</td>
<td>0.348</td>
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<td>-0.04*</td>
<td>0.66</td>
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<td>.64</td>
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<tr>
<td>Mixed</td>
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<td>0.709</td>
<td>0.063</td>
<td>0.255</td>
<td>-0.013*</td>
<td>-0.03*</td>
<td>0.63</td>
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<td>0.084*</td>
<td>-0.05</td>
<td>0.41</td>
<td>3244</td>
<td>.87</td>
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<tr>
<td><strong>Sugar Beets</strong></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>5.920</td>
<td>0.696</td>
<td>0.062</td>
<td>0.290</td>
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<td>994</td>
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<tr>
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<td>0.576</td>
<td>0.064</td>
<td>0.449</td>
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<tr>
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<td>0.557</td>
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<td>0.197</td>
<td>-0.10</td>
<td>0.48</td>
<td>855</td>
<td>.71</td>
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</tbody>
</table>

* ** Explanation at the end of the table
Table I-1. Continued.

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<tr>
<th>Crop/Agro-climatic zone</th>
<th>Intercept</th>
<th>Land/Herd Size</th>
<th>Labor</th>
<th>Cost</th>
<th>Time trend</th>
<th>η</th>
<th>Γ</th>
<th>No. of farms</th>
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<th>1989</th>
<th>1991</th>
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<td>0.88</td>
<td>2,849</td>
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<td>.72</td>
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</tr>
<tr>
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<td>1458</td>
<td>.54</td>
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<tr>
<td>Steppe</td>
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<td>0.199</td>
<td>0.270</td>
<td>0.547</td>
<td>-0.132</td>
<td>0.00*</td>
<td>0.97</td>
<td>322</td>
<td>.66</td>
<td>.66</td>
<td></td>
</tr>
</tbody>
</table>

* "Land" is used in the crop models and "herd size" is used in the hogs model.
* Total cost of production net of labor.
* Number of firms in the panel per year.
* The panel starts from 1989 only.

Note: Coefficients are all significant at the 5 percent level, except those marked "ns".
Table 1-2. Stochastic frontier analysis of farm level production with deflated cost, Ukraine 1986-91

<table>
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<tr>
<th>Crop/Agro-climatic zone</th>
<th>Intercept</th>
<th>Land/Herd Size*</th>
<th>Labor</th>
<th>Cost</th>
<th>Time trend</th>
<th>( \eta )</th>
<th>( \Gamma )</th>
<th>No. of farms*</th>
<th>Mean technical efficiency</th>
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<td></td>
<td>1986</td>
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<td><strong>Potatoes</strong></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Forest</td>
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<td>0.350</td>
<td>0.161</td>
<td>0.560</td>
<td>-0.053</td>
<td>-0.14</td>
<td>0.73</td>
<td>2,172</td>
<td>.72</td>
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<td>0.317</td>
<td>0.508</td>
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<td>-0.07</td>
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<td>3,025</td>
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<td>0.334</td>
<td>0.471</td>
<td>-0.017*</td>
<td>-0.05*</td>
<td>0.62</td>
<td>839</td>
<td>.65</td>
</tr>
<tr>
<td><strong>Corn</strong></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
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<td>0.594</td>
<td>0.049</td>
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<td>-0.08</td>
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<td>274</td>
<td>.70</td>
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<td>0.473</td>
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<td>0.214*</td>
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<tr>
<td><strong>Grains</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>3.760</td>
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<td>0.071</td>
<td>0.520</td>
<td>0.089*</td>
<td>-0.01*</td>
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<td>2289</td>
<td>.71</td>
</tr>
<tr>
<td>Mixed</td>
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<td>0.424</td>
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<td><strong>Sugar Beets</strong></td>
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<td>0.76</td>
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<td>0.459</td>
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<td>0.00</td>
<td>0.45</td>
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<td>.68</td>
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* Explanation at the end of the table
Table 1-2, Continued.

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<th>Crop/Agro-climatic zone</th>
<th>Intercept</th>
<th>Land/Herd Size</th>
<th>Labor</th>
<th>Cost</th>
<th>Time trend</th>
<th>η</th>
<th>ι</th>
<th>No. of farms</th>
<th>Mean technical efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunflower</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed</td>
<td>3.995</td>
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<td>0.360</td>
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<td>-0.08</td>
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<td>1,561</td>
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<td>0.076</td>
<td>-0.18</td>
<td>0.86</td>
<td>2,849</td>
<td>.84</td>
</tr>
<tr>
<td>Hogs</td>
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</tr>
<tr>
<td>Forest</td>
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<td>0.317</td>
<td>0.663</td>
<td>-0.079&quot;</td>
<td>0.06&quot;</td>
<td>0.82</td>
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<td>0.00&quot;</td>
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<td>-0.006&quot;</td>
<td>0.18</td>
<td>0.91</td>
<td>322</td>
<td>.61</td>
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</tbody>
</table>

* "Land" is used in the crop models and "herd size" is used in the hogs model.
* Number of firms in the panel per year.
* The panel starts from 1989 only.

Note: Coefficients are all significant at the 5 percent level, except those marked "ns".
comparing the mixed and forest zones. There is a decreasing technical efficiency over time. For firms producing potatoes in the forest zone, mean technical efficiency decreases, and estimated mean technical efficiency over all farms in the zone decreased from 72 percent in 1986 to 53 percent in 1991 (Table I-2) and technical efficiency among farms was quite variable (Figure 36). These results are very similar to those obtained for farms in the mixed agroclimatic region.

Potato farmers in the steppe zone, as opposed to those in the mixed or forest zones, produced at relatively constant mean technical efficiency levels. For the 839 firms, the rate of change in technical efficiency over time was estimated to be not significantly different from zero (although negative again), and therefore the change in mean technical efficiency from 65 percent in 1986 to 59 percent in 1991 is not significantly different from zero either. Individual farm technical efficiency estimates were again highly variable (Figure 38); in 1991, the most efficient farm operated at 93 percent of its capacity, however, the difference between the most and least efficient farms was 87.

3.4.2 Grains

The grains sector included additional variation among farms in the component grains, and the results of the estimated model were not as good as for other crops, although similar to the findings for corn, sugar beets, and sunflowers (Table I-2). In the mixed zone, 3,798 farms reported grains production. The estimated coefficients for inputs are presented in Table I-2. For grains there is less evidence for declining technical efficiency or for change in technology over time; coefficients on time and $\eta$ were estimated to be near zero. The steppe region, with 3,244 farms producing grain showed similar results.

In the forest region, 2,289 farms reported producing grain. As in the mixed region, estimated coefficients for labor are relatively low and are relatively high for land and non labor costs. Again, time-varying change and change in technical efficiency were very small. In all three regions, the variance component associated with the efficiency term was higher than that associated to the random term. Increasing returns to scale in the forest region indicate that there may exist incentives for farmers in the forest region to shift inputs towards grain production.

3.4.3 Corn

There were 2,302 farms in the mixed zone producing corn. Elasticities estimated for the last period (1991) from the panel data are presented in Table I-2. These estimated values for elasticities indicate that farms are producing corn at approximately constant returns to scale. The regression coefficient estimated for the effect of year was 0.14, and was significantly different from zero.
indicating that any decrease in corn production is due to an increase in technical inefficiencies rather than to other factors affecting production technology.

Mean technical efficiency of farms was decreasing over time. In fact, the estimated rate of decrease was -0.15, significantly different from zero. The estimated mean technical efficiency for all 2,302 farms in the mixed agroclimatic zone decreased from 74 percent in 1986 to 54 percent in 1991 (Table I-2).

The range of estimated technical efficiencies in 1991 was 78 percent, where the lowest technical efficiency was 15 percent and the most efficient had an estimate of 93 percent (Table I-2 and Figure 40). The value of $\Gamma$ of 0.53 indicates that the variance in output can be evenly decomposed into variance attributable to the efficiency and to the random terms.

In the forest zone, there were 274 farms with any corn production, and results were similar to those obtained for the farms in the mixed zone. As in the mixed zone, nonlabor cost and land elasticities were much higher than labor elasticity; these farms are operating at near constant returns to scale as well. In contrast to farms in the mixed zone, the effect of year of production was negative and significantly different from zero, indicating that any decrease in corn production may be attributable to factors other than increasing inefficiencies.

Technical efficiency of farms in the forest zone also decreased over time. In fact, the rate of change was estimated to be -0.08, significantly different from zero. The mean technical efficiencies for the region decreased from 70 percent in 1986 to 59 percent in 1991. In the last period considered, the range of individual farm technical efficiencies was 60 percent, with the lowest and the highest values being 31 percent and 91 percent, respectively.

In the steppe agroclimatic zone there were 1,629 firms producing corn. Results were again very similar to those obtained for the other two agroclimatic regions, with farms operating at constant returns to scale and elasticities that are much higher for land and cost net of labor than for labor.

The estimated rate of change of technical efficiency over time for the steppe region, indicates that farms are decreasing their technical efficiency at an even faster pace than farms in other regions. The estimate for $\eta$ obtained for this region was -0.19, and the mean technical efficiency for the region decreased from a high of 82 percent in 1986 to a low of 63 percent in 1991 (Table I-2). Note that the regression coefficient for the year effect is estimated to be positive and significantly different from zero, indicating that corn production would tend to increase over the study period. An increase in technical inefficiencies, however, keeps this improvement from being realized. This observation is consistent with the corn yield figures shown Figure 32. In general, the results for corn indicate
decrease in technical efficiency in production of corn over time. The increasing variability of technical efficiency among farms is most apparent in the forest region (Figure 39). The distribution of farms by technical efficiencies in other zones is less widely dispersed.

3.4.4 Sugar Beets

Results obtained for sugar beet production are, in some ways, strikingly different from those obtained for other crops. There were large differences among firms operating in different agroclimatic zones, and especially in the steppe zone, distribution of technical efficiency among farms was quite variable (Figures 45-47).

The 3,121 farms producing sugar beets in the mixed agroclimatic region were in general most efficient in their use of inputs. Mean technical efficiency, however, decreased over the period 1986-1991, from a high of 90 percent to a low of 73 percent; there does appear to be increasing dispersion in estimated technological efficiencies (Figure 46). In all years, the maximum for estimated technical efficiency was over 98 percent. Estimated elasticities for land, labor, and cost net of labor are reported in Table I-2 and indicate approximately constant returns to scale in farm operations. The estimated labor elasticity, as is the case with other crops, is very low. In 1991, the least efficient firm was operating at 19 percent of its potential, while the most efficient farm reached 99 percent of its potential. A large proportion of the variance of output (76 percent), is attributable to variance of the efficiency term.

For farms producing sugar beets in the forest zone (994 of them) mean technical efficiency remained constant over the study period at an estimated 79 percent. Sugar beet production in this region seems to have declined (albeit only slightly), for factors other than efficiency in the use of inputs; the coefficient associated to the effect of year in the model was estimated to be negative but not significantly different from zero. Elasticities for land, labor, and cost net of labor were estimated to be 0.61, 0.04, and 0.42, respectively (Table I-2). Farms in the forest agroclimatic zone operate at approximately constant returns to scale.

Results obtained for the 855 firms in the steppe agroclimatic region were markedly similar to those obtained for the rest of the country. In this region, the mean technical efficiency of sugar beets products remained constant in the 1986-1991 period, at a 68 percent level. Sugar beet production, in addition, was affected by factors other than efficiency in input use given our model in a positive way; changes in sugar beet production in this region seem to be determined by changes in factors other than technical efficiency alone. The elasticity coefficient for labor was estimated to be 0.12, showing a relatively greater contribution of labor input to output (higher coefficients) in sugar beet production.
than for other crops except potatoes. Returns to scale in sugar beet production in the steppe zone appear to be slightly greater than one. Individual firms technical efficiencies in sugar beet production were highly variable for the whole period in the steppe region (Figure 47). In 1991, the range of individual technical efficiencies was 71 percent, with the most efficient farm operating at 95 percent of its potential.

3.4.5 Sunflower

Frontier production functions were fit to sunflower outputs only for farms producing in the mixed and steppe zones. There were only 7 firms reporting sunflower yields in the forest agroclimatic region, and the small number of observations did not allow for the reliable estimation of the parameters in the nonlinear model.

There were 1,561 firms producing sunflower in the mixed agroclimatic region. Estimated elasticity coefficients for land, labor, and cost net of labor presented in Table I-2 indicate that land inputs contribute the most to output. These firms operate at approximately constant returns to scale. Sunflower production appears to have been a relatively efficient activity in regard to input use, but declining over time (Table I-2). The estimated mean technical efficiency for sunflower, started out at a value of 83 percent in 1986, and by 1991 has decreased to 77 percent. Individual farm estimates were relatively variable, and in 1991 ranged from the lowest value of 37 percent to the highest of 97 percent.

Mean technical efficiency estimated from the 2,849 firms producing sunflower in the steppe agroclimatic region decreased during the study period, and reached a low of 68 percent in 1991. Elasticities for land and labor were similar to those estimated in the mixed region, while that corresponding to nonlabor costs was significantly higher (Table I-2). The sum of the estimated elasticities indicate that firms are operating at nearly constant returns to scale. For the last period, the lowest individual technical efficiency was estimated to be 7 percent while the highest was 96 percent. There were fewer firms producing at the most technically efficient level (Figure 49). The ratio of $\sigma^2$ to the total variance ($\sigma^2 + \sigma^2_v$) was estimated to be 0.86, indicating an over proportional contribution of the variance of the efficiency term to the total variance.

3.4.6 Hogs

The panel for hogs consisted of the period 1989-1991. There were 2,116 enterprises engaged in hog production: 1,458 were located in the mixed agroclimatic zone, 322 were located in the steppe agroclimatic zone, and 336 were located in the forest region. Hog production appears to be mostly concentrated in the mixed region of the Ukraine, and seems to be an inefficient activity in all three
areas (highest mean technical efficiency equals .70 for farms in the steppe zone in 1991 as seen in Table I-2). The data did not contain enough information to identify a proper "feed" variable, but clearly, feed has an important effect on hog output and thus results ought to be interpreted cautiously.

Results obtained from firms operating in the mixed agroclimatic region are summarized in Table I-2 and suggest that farms may be operating at increasing returns to scale. All estimated elasticities were found to be significantly different from zero, as was the coefficient for the effect of technological change. The estimate of the rate of change of mean technical efficiency over the study period was not significantly different from zero. This implies that technical efficiency has remained constant between 1989 and 1991, at a rather low value of approximately 53 percent. A very high value for \( \Gamma \) indicates that most of the variance in output is due to the technical efficiency term.

Individual firms were highly variable in terms of the efficiency with which they utilized their inputs. The range of values for 1991 was at 93 percent, where the least efficient firm had an estimate of only 1.44 percent technical efficiency and the most efficient firm reached a value of 94.4 percent. No significant effect on production (other than input use) was detected.

In the steppe agroclimatic region, results were different regarding mean technical efficiency. In fact, while firms in this region started at a low value of 61 percent in 1989, higher than that for the mixed and forest agroclimatic zones, the estimate for the parameter \( \eta \) indicated that mean technical efficiency significantly increased during the period, to reach a high of 70 percent in 1991. Variability among individual firms, however, was still very high (Figure 51). The lowest individual estimate of technical efficiency for 1991 was 16.0 percent and the highest was estimated at 94.1 percent.

All elasticity coefficients were significantly different from zero. The sum of the estimated elasticities on variable input suggest constant returns to scale. The linear term representing the effect of year on production was estimated to be not significantly different from zero. As in the mixed zone, the variance of the technical efficiency term represented over 90 percent of the total variance in hog production.

For farms in the forest zone, results show the same trends as in the mixed zone with the exception of the elasticity of non labor costs which was about 25 percent lower, and the coefficient of technological change, which was not significantly different from zero.

3.5 Marginal Productivity of Land and Labor Between 1991 and 1992

In 1992 there were significant changes in relative prices in the Ukrainian economy and still more changes in data reporting. Because of these changes and high inflation in 1992, compared with
the previous six years (financial indicators were typically 15 to 20 times greater in magnitude), the model (section 3.3) was separately estimated for 1991 and 1992 and results summarized to give an indication of changes in factor efficiency. The farm average marginal productivities (AMP) of land and labor were calculated using the estimated model coefficients (elasticities) (Table I-3). Overall, the AMP of land was lower than that of labor, except for sugar beets. From 1991 to 1992, AMP of land decreased for all crops, and AMP of labor decreased for corn and grains and increased for potatoes and sugar beets. Added analysis of this type could more fully identify the changes occurring in farm behavior in response to the changed incentives, reform uncertainties, and problems of availability of inputs (in addition to other factors such as weather).

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</thead>
<tbody>
<tr>
<td>Potato</td>
<td>3.5</td>
<td>3.3</td>
<td>-5.7</td>
<td>7.8</td>
<td>8.1</td>
<td>3.8</td>
</tr>
<tr>
<td>Corn</td>
<td>2.0</td>
<td>1.7</td>
<td>-15.0</td>
<td>9.5</td>
<td>4.7</td>
<td>-50.5</td>
</tr>
<tr>
<td>Grains</td>
<td>2.6</td>
<td>2.4</td>
<td>-7.7</td>
<td>8.9</td>
<td>4.8</td>
<td>-46.1</td>
</tr>
<tr>
<td>Sugar Beets</td>
<td>17.9</td>
<td>17.7</td>
<td>-1.1</td>
<td>3.2</td>
<td>9.4</td>
<td>193.8</td>
</tr>
</tbody>
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Note: AMP gives metric tons of commodity per unit of land (ha) and labor (1,000 hours).

IV. CONCLUSIONS AND IMPLICATIONS FOR POLICY REFORM

As was typical of formerly planned economies, agricultural firms in the Ukraine responded to a system of incentive structures determined by two important factors, the production objectives and the system of standards, both set by the central planner. Given an assortment of targets, constraints on input and resource availability, and the wage, management, and price systems, the maximization of physical output provided clear incentive for firms to produce at any (external) cost. The central planner exogenously priced resources very cheaply. At the same time, the public sector in agriculture took the burden of social responsibility for providing employment and social services to workers, and pensioners, on the state and collective farms. The result of such policies, as evidenced by data on
farms in Ukraine, has been productivity often more variable and below standards of comparable market economies and declines in measured technical efficiencies in production of many agricultural products.

It may be no surprise that many studies of socialized agriculture by western economists (e.g., Hayami and Ruttan 1971; Koopman 1989) found no compelling evidence of technical efficiency. Static technical efficiency is independent of input and output prices, and does not take into account changes in the internal organization and incentives of the sector over time. What we find instead, using panel data over several years, is the presence of significant, and increasing technical inefficiencies in the production of specific crops. The reasons for these changes are less obvious.

Comparison of measures of productivity of the agricultural sector (output per unit input) between Ukraine and other countries shows Ukraine to be below East and West European countries, but above the USSR. This finding is more true for crops than for the livestock sector. What may be important to note, however, is that the levels of production are, for the most part, within the range of comparable market economies. The natural resource endowment in Ukraine should make it technically possible to improve productivity in the sector. Instead, it appears to be the limitations of policy, organization, and management that have limited the levels of productivity.

Based on analysis of the farm data, it becomes quite apparent that the state and collective farms differed in asset allocation, types of product produced, yields and wage fund. Farms are of large size, have large amounts of labor, and generally produce a wide range of products. There is little farm specialization. Overall for both the crop and livestock sectors, production is at relatively constant returns of scales, and labor’s share of total cost is relatively constant, except for the smallest firms. Based on analysis of technical efficiencies, major inefficiencies appear to be present, and result in levels of productivity lower than those observed in comparable market economies. The inefficiency in most cases has increased over the period 1986-1991. However, we note that in the hog sector, there seems to be little change, and in the steppe region a slight improvement, in technical efficiency over time, perhaps due to the priority attributed to this sector after "Perestroika."

Based on the initial analysis presented in this report, Ukraine has the opportunity to increase production in the agricultural sector through improved technology. This is evident by the distribution of technical efficiency measures for farms producing specific output. While many firms achieve production near "best practice" levels, for several crops (e.g., corn, potatoes, and sugar beets in the steppe region), there are many farms which produce far from this level. There were a considerable number of farms producing hogs with technology that indicated inefficiencies. It appears, too, that
the productivity of labor, especially, is low in the production of most crops. Improved production practices, likely to occur with increased investment in capital and reallocation of labor out of some agricultural activities, and specialization of farms activities among farms (so that not all products are produced in all agro-climatic zones) would improve the overall efficiency in the sector. This, of course, will place greater demands for improvements on the trade and distribution channels for agricultural outputs.

Finally, as the Ukraine proceeds with a slow restructuring of its agriculture through the reorganization of the state and collective farm system, two new forms of organizations are emerging, joint stock societies and independent private farms. It appears that two major approaches are competing in the ongoing policy reform process. The first approach calls for keeping the current public sector farms intact with some property right adjustments, and directing resources to improving management and technology. The second approach calls for a major land reform and a complete reliance on the market system for the future of agriculture. By pointing to major inefficiencies and low productivity at the farm level, in addition to no compelling evidence of economies of scale, our study points out that perhaps public farms are not technically as efficient as concluded from previous aggregated studies. While for few farms, technical efficiency in production exists, for many farms production occurs with a high degree of inefficiency --lack of production from the given use of inputs. Both improvements in technology and changes in property rights and resource allocation will be required. There is evidence that both factors, firm inefficiencies and agricultural policy are responsible for the overall low performance agriculture in the Ukraine.
Epilogue

Should western economic efficiency be the goal of Ukrainian agriculture? To answer this question one needs to examine economic efficiency of private farms in the west in the context of the overall welfare of society. The current paradigm shift is based on the notion that internalizing external effects of private production and consumption will improve the performance of the market system. And that is perhaps where the Ukraine and all formerly planned economies should aim for. This will imply that efficiency should be measured by a criterion that involves maximizing economic efficiency and minimizing social cost.
References


The Structure of Ukrainian Agriculture:
Comparative Efficiency with International Agriculture and
Implications for Policy Reform

Volume II
Data Handbook

THE PREFACE AND LISTS OF TABLES AND FIGURES, ONLY, FOLLOW. THE FULL
VOLUME II IS AVAILABLE FROM THE NATIONAL COUNCIL UPON
REQUEST [TEL. (202) 387-0168, FAX (202) 387-1608]

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Preface

This data handbook contains selected indicators of Ukrainian's agricultural sector and its resources. The indicators include land and other inputs, total production and yields, cost of production assets, and revenue. The summaries are based on official records of 11,440 public sector farms classified by management structure type, agroclimatic zone, and political districts.

The data were obtained from the Ukrainian Institute of Agrarian Economics. We have made no adjustments to the individual farm survey numbers and included no information on the private sector.

This data handbook is designed to serve two purposes: (i) accompany Volume I, which is the main report on our analysis of Ukrainian agriculture, and (ii) be used as a data source by other researchers interested in working on Ukrainian agriculture.
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