IMPACT OF INCREASED ENERGY PRICES ON AGRICULTURAL MARKETS IN UKRAINE

by

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Chapter 1

INTRODUCTION

Energy, and fossil fuels in particular, play an important role in agricultural production. It is consumed either directly through combustion of fossil fuels or indirectly through the use of fertilizer or crop protection measures, production of which relies heavily on the natural gas. According to the State Statistics Service of Ukraine (SSSU) 2019 data[1], shares of costs related to direct use of diesel and gasoline varied from 9% to 15% for production of different crops. The shares of inorganic fertilizer costs varied from 26% to 35%. Therefore, agricultural production could be sensitive to changes in energy prices.

On February 24th, Russia conducted a full-scale military invasion to Ukraine, which led to the increase in prices of gasoline, diesel, liquefied petroleum gas, natural gas and inorganic fertilizers on both local Ukrainian and global markets. According to data from the A-95 Consulting Group[2], in December 2022, as compared to the December 2021, prices for gasoline, diesel and liquefied petroleum gas (LPG) have grown by 65%, 120% and 50%, respectively. Natural gas prices have been increasing since the beginning of 2020, and peaked at June 2022. At the same time, export complications led to the significant decrease in corn and wheat farm-gate prices. These combined effects have resulted in profit losses for agricultural producers. As a consequence, producers needed to adapt, choosing between crops substitution, adoption of new production approaches or technologies, exiting the market or incurring the losses.

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[1] SSSU. Costs of agricultural production in enterprises in 2019. - https://www.ukrstat.gov.ua/operativ/operativ2018/sg/vytr_na%20ver_sg_prod/vytr_na%20vyr_sg_prod_2019.xlsx

[2] Minfin Media. Ціни на бензин, дизпаливо, газ на АЗС України. За інформацією Консалтингової групи А-95. - https://index.minfin.com.ua/ua/markets/fuel/a95/

The ongoing war in Ukraine has inflicted severe damage on the agricultural sector, resulting in significant economic losses. According to recent assessment (Neyter et al., 2024), by February 2024, the total damages to Ukrainian agriculture amounted to approximately $10.3 billion, with $5.8 billion attributed to the destruction of agricultural machinery and $1.8 billion to storage facilities. Additionally, the sector has incurred losses of about $69.8 billion due to decreased crop and livestock production, lower domestic prices, and increased production costs. Specifically, annual crop production losses are estimated at $34.3 billion, while livestock production losses are around $5.6 billion. These losses underscore the immense impact of the conflict on Ukraine's food security and agricultural economy.

Agricultural production is one of the largest sectors in Ukrainian economy, on which the local food security and the well-being of rural communities depends heavily. Besides that, Ukraine is one of the world's major wheat, corn, barley and sunflower exporters, so the disruption of the local agricultural production might affect the global market and welfare of other countries as well. According to SSSU 2019 data[3], in 2019 average share of fuel in livestock production costs was only 2.01%. For different sub-sectors it ranges from 0.45% for eggs production up to 4.20 % for milk production. Fuel shares in beef, poultry and pork production costs are 4.02%, 0.90%, and 1.52%, respectively. Thus, livestock sub-sector is not included in the analysis, as it is not expected to be affected significantly by increase in energy prices, if we do not account for the logistics costs. There is not enough data available for food processing sector, although in some of its sub-sectors energy makes up a significant share of costs. According to own

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[3] SSSU. Costs of agricultural production in enterprises in 2019. - https://www.ukrstat.gov.ua/operativ/operativ2018/sg/vytr_na%20ver_sg_prod/vytr_na%20vyr_sg_prod_2019.xlsx

calculations based on the SSSU 2012-2020 data[4,5], average share of energy expenditures (including electricity, natural gas and oil products) in sugar production is 19.49%, in bread production is 8.50%, 5.26% in flour production, 5.10% in dairy and cheese production.

Wheat, corn, sunflower, and soybeans are the main export crops. They were selected for the analysis as those, which have the highest sown areas in Ukraine among the cereal, leguminous and industrial crops, according to the SSSU 2021 data. [6]

The topic of the impacts of changing energy prices on agriculture has brought interest of researchers in the past. It was found that the scale of the effects highly differs depending on region and sub-sector studies. No research devoted to this topic was conducted for Ukrainian agriculture previously. Besides that, in this research we will undertake a first attempt to estimate both short- and long-run demand for energy for different crops production separately instead of aggregated crop production sub-sector.

In this study, we aim to answer the question of how Ukrainian agricultural production is affected by changes in prices of energy and energy-related production inputs, and whether this impact is the same for different crops. To achieve that, short- and long-run cost functions for each crop type is estimated. Its parameters allow to obtain own- and cross-price elasticities of demand for fuel (primarily diesel) and mineral fertilizers and the elasticities of substitution

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[4] SSSU. Purchases of energy products and payments to subcontractors by type of economic activity in 2012−2020. - https://www.ukrstat.gov.ua/operativ/operativ2021/fin/pdp/pdp_ue/vvp_ek_2012_2020_ue.xlsx

[5] SSSU. Costs of agricultural animal production by type in enterprises in 2019. - https://www.ukrstat.gov.ua/operativ/operativ2021/fin/pdp/pdp_ue/vvp_ek_2012_2020_ue.xlsx

[6] SSSU. Areas, gross harvest and yields of agricultural crops by their species. - https://www.ukrstat.gov.ua/operativ/operativ2017/sg/pvzu/arch_pvxu_e.htm

between the production inputs. These parameters would allow to assess the magnitude of the impact on the production technology, costs and their structure and to identify possible adaptation strategies of Ukrainian farmers.

The thesis is structured in the following way. In the second chapter a literature review on the estimation of the impacts of changes in energy prices on agricultural production is conducted. The third chapter describes the methodology used in this thesis. The fourth chapter is devoted to the data description. The fifth chapter discusses the empirical results. The last chapter summarizes the core findings and provides policy implications.

Chapter 2

LITERATURE REVIEW

Considering the fact that energy resources are an important production factor in agriculture, numerous research devoted to the impact of energy prices on agricultural industry have been conducted. There is empirical evidence of the negative effect of increase in oil and natural gas prices on agricultural production. Regarding this topic, there are three main directions of research.

The first group is the analysis of relationship between energy resources' prices and agricultural commodities' prices or production technology. Koirala et al. (2015) examines relationship between energy prices and agricultural commodity prices using the Clayton model and daily 2011-2012 US prices. Relationship was found to be high for all three sub-sectors studied – corn, soybeans and cattle production. However, there are studies which suggest different results. Tyner (2010) used 1982-2007 crude oil and corn futures prices and observed much weaker relationship between them (correlation coefficient of about 0.16). A study by Hertel and Beckman (2012) has found the evidence of significant increase of the abovementioned relationship between 2001 and 2008 (from 0.32 to 0.92). Thus, the impact of oil and natural gas prices depends highly depending on production technology and market conditions, which differ substantially across the time, location and sub-sector.

Another perspective is the relationship between oil and natural gas prices and agricultural production itself. There is empirical evidence of negative effect of increased oil prices on agricultural employment, meaning energy and labor inputs being complementary in agricultural production (Uri 1996). Agricultural productivity is less affected by the shocks in energy prices, Binuomote and

Odeniyi (2013) have found no significant long-term relationship between them, and negative, but weak (-0.04), relationship in the short-term.

The second group of studies is represented by modelling of the impacts of increased energy prices using partial equilibrium models. Most studies focus on the country- or region-level effects. A study by Sands et al. (2011) models the impacts on production of 8 most popular crops in the US. The most significant impact was found to be on acreage and farmers' profits. Impact on prices was found to be around 1% per 6.6%, 13.4% and 14.0% increase in the prices of diesel, natural gas and electricity, respectively. Increase in the price of natural gas has the highest negative impact on the production of fertilizer-intensive crops, like cotton. Uri and Boyd (1997) have obtained similar effects on the aggregated price level of agricultural goods using general equilibrium model of the Mexican economy. For 26.2% gasoline price increase no significant change in equilibrium price and 0.22% decrease in equilibrium quantity was found. Earlier study by Tewari and Kulshreshtha (1988), which used the price-endogenous partial equilibrium model have found the effect on prices to be more substantial for crops production sub-sector of agriculture. Under the doubled crude oil and natural gas prices scenario, prices for crops and livestock increase by 20% and 10%, respectively. Besides that, fertilizer consumption was found to be less elastic than fuel, leading to a higher decrease in its consumption. Adams et al. (1976) has found that in the short-run diesel and natural gas consumption in response to increased energy prices would change very little, with the most significant impact on the net revenues of farmers (16% decrease).

The third category of research is the analysis of demand for agricultural inputs. Studies mostly review aggregated agricultural production of a given country, only differentiating crops and livestock production. The scale of the effects is found to be differ by country and period. Own-price elasticities of demand for energy range from -0.17 (crop production demand for diesel) (Adeleja and Hoque 1986) up to fairly high -0.64 (aggregated agriculture demand for energy) (Gopalakrishnan et al. 1989), with majority of estimates being between -0.3 and -0.4. One of the few studies, in which short-term price elasticities of input demand were estimated along with the long-term ones, is Lambert and Gong (2010). The author uses dynamic translog cost function to differentiate between long- and short-run adjustments to energy price changes. Both short- and long-term elasticities are found to be similar, with short-run being only slightly lower than the long-run ones, such that own-price elasticity of demand for energy is -0.176 in the short run and -0.181 in the long run. All papers of this group focus on American agriculture, with the only exception being Turkekul and Unakıtan (2011), which studies Turkey. Its results differ highly from the estimates obtained by Lambert and Gong (2010) for US agriculture. Demand for diesel is found to be more elastic in the short-run than in the long-run, with own-price elasticities being -0.79 and -0.38, respectively. Demand for electricity is much less elastic in the short-run than in the long-run (own-price elasticities of -0.19 and -0.72, respectively). There are only a few studies, which estimate price elasticities of demand for different kinds of energy inputs simultaneously and none of them differentiates by crops at the same time.

In terms of methodological approaches, most of the studies of demand for production inputs estimating translog cost function as Seemingly Unrelated Regression (SUR) (Adelaja and Hoque, 1986; Lambert and Gong, 2010; LeBlanc, 1985) or 3-Stage Least Squares (3SLS) (Gopalakrishnan et al., 1989). A study that stands out in terms of methodological approach is the one by Turkekul and Unakıtan (2011), which applies an error-correction model to estimate elasticities of demand for fuel with the time series data covering 1970-2008.

In conclusion, this review of the literature has revealed the multifaceted nature of research on relationship between the prices of energy resources and parameters of agricultural production. While existing studies have shed light on numerous dimensions of the topic, there persists a discernible gap related to Ukrainian agriculture in particular, given that the estimated impacts of changes in energy prices on agriculture noticeably differ across the regions. Thus, the present study aims to cover this gap, while at the same time providing valuable insights into characteristics of Ukrainian agricultural production, which are of even more importance in the context of war and war-caused crises and disruptions. Additionally, the findings about long- and short-run own-price elasticity of demand for fuel by agriculture are scarce and contradictory at the same time. In our research we try to offer a new perspective on this aspect by estimating the short-run variable cost function. Thus, by situating our analysis within the broader context of existing scholarship, we aim to contribute meaningfully to the ongoing discourse on the topic and pave the way for future research.

Chapter 3

METHODOLOGY

Methodology is based on the study by Gopalakrishnan et al. (1989), which uses pooled cross-section data to estimate price elasticities of demand for production inputs. System of cost share equations is estimated as seemingly unrelated regressions. From obtained regression coefficients, own- and cross-price elasticities of input demand, as well as substitution elasticities are estimated. Berndt (1996) argues that a combination of cost and cost share functions in regression can reduce the possible multicollinearity problem, so the cost function equation is added to the system.

Studies by Gopalakrishnan et al. (1989), Adelaja and Hoque (1986), Lambert and Gong (2010) and Fei et al. (2022) estimate both, the price elasticities of demand and elasticities of substitution (ES). Lambert and Gong (2010) use formulation of ES suggested by Morishima (1967), while the rest of the studies mentioned above use partial Allen-Uzawa formulation of ES. Moss (2010) and Turkekul and Unakıtan (2011) estimate only own-price elasticities.

In our case, we are aiming to estimate short-run elasticities in addition to the long-run ones. Dynamic cost function used by Lambert and Gong (2010) and ECM model used by Turkekul and Unakıtan (2011) were estimated with time-series data, which is not applicable in our case because of lack of long historical time-series data. To estimate the short-run parameters of demand for energy using pooled cross-section data, short-run variable costs function (SRVC) is added to the previously adopted methodology and is estimated separately from the long-run costs function. Translog formulation of SRVC is used according to Berndt (1996), as well as the cost share equations.

It is needed to estimate short-run variable costs function, which, to our knowledge, was not done in the past research dedicated to the energy demand analysis in agriculture.

The long-term cost function mentioned above is estimated econometrically. It's translog expansion is given as follows:

$$\ln C = \alpha_0 + \sum_{i=1}^{N} \alpha_i \ln w_i + \alpha_y \ln y + \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \alpha_{ij} \ln w_i \ln w_j + \frac{1}{2} \alpha_{yy} (\ln y)^2 + \sum_{i=1}^{N} \alpha_{iy} \ln w_i \ln y + u \quad (1)$$

Where w_i, w_j denote prices of respective inputs i and j, and y denotes output. For the homogeneity in prices assumption to hold, the following restrictions should be imposed on the coefficients:

$$\sum_{i=1}^{N} \alpha_i = 1 \,; \sum_{i=1}^{N} \alpha_{ij} = 0 \,; \sum_{i=1}^{N} \alpha_{iy} = 0; \quad (2)$$

Further, Shephard's lemma allows to derive cost share functions of each input as:

$$S_i = \frac{x_i w_i}{C} = \frac{\partial \ln C}{\partial \ln w_i} = \alpha_i + \sum_{i=1}^{N} \alpha_{ij} w_j + \sum_{i=1}^{N} \alpha_{iy} \ln y + u_i \quad (3)$$

From the input cost share functions, Allen-Uzawa elasticity of substitution is obtained as (Thompson, 1997):

$$\sigma_{ij} = \frac{\alpha_{ij} + S_i S_j}{S_i S_j} \; for\ all\ i\ and\ j, i \neq j;\ \sigma_{ii} = \frac{\alpha_{ii} + {S_i}^2 - S_i}{{S_i}^2} \; for\ all\ i \tag{4}$$

From the elasticity of substitution, the price elasticity of demand for inputs is obtained as (Thompson, 1997):

$$\varepsilon_{ij} = S_j \sigma_{ij} \; for\ all\ i\ and\ j, i \neq j;\ \varepsilon_{ii} = S_i \sigma_{ii} \; for\ all\ i \tag{5}$$

Morishima elasticities of substitution are estimated as (Koizumi, 1976):

$$\sigma_{ij}{}^{M} = \varepsilon_{ij} - \varepsilon_{jj} \tag{6}$$

To estimate all the coefficients of the cost function, cost share equations given in (3) and cost function equation given in (1) are estimated simultaneously as seemingly unrelated regressions.

Short-term cost function differs from the long-term such that the firm is considered to be in the equilibrium in variable costs conditional on non-adjustable quasi-fixed costs, instead of full equilibrium. It is estimated separately from the long-run cost function described above, as the reformulation of cost-function is required. Translog expansion of the short-run variable costs is given as follows:

$$
\begin{aligned}
\ln C_v = \ & \alpha_0 + \sum_{i=1}^{N} \alpha_i \ln w_i + \alpha_y \ln y + \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \alpha_{ij} \ln w_i \ln w_j \\
& + \frac{1}{2} \alpha_{yy} (\ln y)^2 + \sum_{i=1}^{N} \alpha_{iy} \ln w_i \ln y + \sum_{k=1}^{M} \alpha_k \ln x_k \\
& + \frac{1}{2} \sum_{k=1}^{M} \sum_{l=1}^{M} \alpha_{kl} \ln x_k \ln x_l + \sum_{k=1}^{M} \alpha_{ky} \ln x_k \ln y \\
& + \sum_{i=1}^{N} \sum_{k=1}^{M} \alpha_{ik} \ln w_i \ln x_k + u
\end{aligned} \qquad (7)
$$

where w denotes prices of corresponding variable inputs i and j, x denotes quantities of corresponding quasi-fixed inputs k and l, and y denotes output. In order to ensure homogeneity in input prices, restrictions from (2) and $\sum_k^M \alpha_{ik} = 0$ should hold. In the short-run, cost shares of inputs become:

$$
S_{vi} = \frac{x_i w_i}{C} = \frac{\partial \ln C}{\partial \ln w_i} = \alpha_i + \sum_{j=1}^{N} \alpha_{ij} w_j + \alpha_{iy} \ln y + \sum_{k=1}^{M} \alpha_{ik} x_k + u_i \qquad (8)
$$

Allen-Uzawa and Morishima elasticities of substitution and price elasticities of demand for inputs are obtained as given in the equations (6), (4) and (5). To estimate all the coefficients of the cost function, cost share equations given in (8) and short-run variable cost function equation given in (7) are estimated simultaneously as seemingly unrelated regressions.

To assess the statistical significance of the values of obtained own- and cross-price elasticities of demand for inputs, and elasticities of substitution we apply the approach, commonly known as "delta method". As given by Casella & Berger (2001), variance of a function of random variable could be approximated as:

$$Var\big(f(\alpha)\big) = [f'(\alpha)]^2 * Var(\alpha) \tag{9}$$

where α is a random variable. Thus, a standard error of the function $f(\alpha)$ is derived as:

$$SE\big(f(\alpha)\big) = \sqrt{[f'(\alpha)]^2 * Var(\alpha)} = f'(\alpha) * SE(\alpha) \tag{10}$$

The obtained formula is used to calculate the standard errors of elasticities and test for their respective statistical significance. Null hypothesis in case of own-price elasticities of demand for inputs is:

$$H_0: |\varepsilon_{ii}| = 1, \tag{11}$$

implying that the demand is unit-elastic. And in case of cross-price elasticities of demand for inputs and elasticities of substitution:

$$H_0: \left|\varepsilon_{ij}\right| = 0, \text{ and } H_0: \left|\sigma_{ij}\right| = 0, \tag{12}$$

implying no cross-price effect and no substitutability or complementarity between the inputs.

Chapter 4

DATA DESCRIPTION

The data used to estimate the cost function of Ukrainian agricultural producers includes cost shares, prices, and production quantities. Separate datasets for wheat, corn, sunflower, and soybeans producers were constructed. All four datasets follow the same structure and include inputs cost shares, input prices and production quantities.

Input costs shares were calculated based on production costs data obtained from the 50-SH statistical forms, submitted by farmers to the State Statistics Service of Ukraine.

Production expenditures of agricultural producers were obtained from Section 1 of the 50-SH statistical form, submitted by farmers to the State Statistical Service of Ukraine. It includes the following expenditure categories:

- social security contributions;
- depreciation and amortization;
- electricity;
- fuel (coal, wood, natural gas);
- fuel (oil and gas for machinery);
- fertilizer;
- labor;
- land;
- other agriculture goods purchased for production;
- seeds and planting material, mineral fertilizers;
- spare parts and materials for repairs.

Spare parts and materials for repairs, seeds and planting material, and other agriculture goods purchased for production were grouped into a single materials expenditures category. Contributions for social purposes, depreciation and amortization, electricity and fuel (coal, wood, natural gas) were dropped from the dataset because of high number of missing (non-reported) values and low average share in total costs (<2% on average). Thus, cost shares were calculated for the following categories: fuel, fertilizer, labor, land, materials. Observations with costs values equal to zero in two or more categories are considered outliers and are dropped from the dataset

Prices of fuel and fertilizer were calculated based on data from the section 4 of the 50-SH statistical forms, where farmers' materials purchases are reported. Prices of land are calculated as land expenditures divided by total sowed area of each respective farmer. Average yearly salaries in agriculture for each of the regions are obtained from the SSSU and are used as labor price values. Materials price is challenging to estimate due to heterogeneity of materials purchased by different farmers. Thus, the average prices of seeds and repair parts were used, calculated based on the data from section 4 of 50-SH statistical forms mentioned above.

From the 50-SH and 29-SH data we construct four datasets of wheat, corn, sunflower, and soybeans producers. Type of producer is determined based on the share of sown areas. Producers which had >50% of total area sown with wheat, corn, or sunflower were categorized as the respective crop producers. There are 854, 917, 960, and 503 observations in wheat, corn sunflower, and soybeans datasets, respectively.

Descriptive statistics of core variables used for cost function estimation is provided in the Tables 1-4 below.

Table 1: Descriptive statistics of core variables in the wheat dataset.

	Mean	Median	SD	Min	Max
Share of labor costs	0.14	0.13	0.08	0.02	0.39
Share of fuel costs	0.17	0.16	0.06	0.04	0.35
Share of fertilizer costs	0.27	0.26	0.10	0.04	0.52
Share of land costs	0.21	0.21	0.08	0.02	0.43
Share of other material costs	0.21	0.20	0.07	0.07	0.43
Price of labor, UAH per month	4588	4558	548	3550	7100
Price of fuel, UAH per ton	16606	17548	2958	11749	27133
Price of fertilizer, thousand UAH per 100 kg	597	600	105	415	1000
Price of land, UAH per hectare	1.44	1.49	0.68	0.55	4.08
Price of other material expenditures, UAH, aggregated	230.21	229.72	106.77	98.65	701.33
Total output, tons	24112	24923	55114	648	461400

Table 2: Descriptive statistics of core variables in the corn dataset.

	Mean	Median	SD	Min	Max
Share of labor costs	0.21	0.21	0.11	0.02	0.55
Share of fuel costs	0.13	0.12	0.05	0.01	0.34
Share of fertilizer costs	0.21	0.21	0.08	0.04	0.50
Share of land costs	0.20	0.20	0.08	0.04	0.43
Share of other material costs	0.25	0.23	0.08	0.07	0.50
Price of labor, UAH per month	6976	7084	848	4447	8961
Price of fuel, UAH per ton	20073	19752	2026	15941	26010
Price of fertilizer, UAH per 100 kg	800	822	106	520	1141
Price of land, thousand UAH per hectare	2.54	2.77	0.85	0.88	4.87
Price of other material expenditures, UAH, aggregated	12524	4578	146267	1727	591592
Total output, tons	63066	70076	149922	545	777671

Table 3: Descriptive statistics of core variables in the sunflower dataset.

	Mean	Median	SD	Min	Max
Share of labor costs	0.15	0.13	0.09	0.02	0.54
Share of fuel costs	0.17	0.16	0.06	0.01	0.35
Share of fertilizer costs	0.23	0.22	0.10	0.04	0.53
Share of land costs	0.20	0.20	0.09	0.03	0.43
Share of other material costs	0.25	0.25	0.08	0.07	0.48
Price of labor, UAH per month	5967	5839	821	4447	8464
Price of fuel, UAH per ton	20382	20049	2170	15894	27700
Price of fertilizer, UAH per 100 kg	782	779	107	509	1174
Price of land, thousand UAH per hectare	1.72	1.74	0.78	0.76	4.40
Price of other material expenditures, UAH, aggregated	12972	5389	116172	1445	641306
Total output, tons	12510	13161	36835	573	624888

Table 4: Descriptive statistics of core variables in the soybeans dataset.

	Mean	Median	SD	Min	Max
Share of labor costs	0.25	0.27	0.12	0.02	0.56
Share of fuel costs	0.14	0.13	0.05	0.01	0.34
Share of fertilizer costs	0.20	0.21	0.08	0.04	0.51
Share of land costs	0.21	0.22	0.08	0.02	0.44
Share of other material costs	0.20	0.17	0.07	0.08	0.50
Price of labor, UAH per month	6581	6792	999	4592	8961
Price of fuel, UAH per ton	19269	18556	2420	13677	26103
Price of fertilizer, UAH per 100 kg	804	841	102	508	1154
Price of land, thousand UAH per hectare	2.18	2.16	0.78	0.62	4.75
Price of other material expenditures, UAH, aggregated	7607	3692	106132	1418	441858
Total output, tons	16717	12001	128504	560	621180

Energy-related production inputs – fertilizer and fuel – are constituting a significant part of total production costs. The most energy-intensive being wheat production with a 43.4% energy-related costs share. Sunflower and corn production have 39.9% and 34.1% of expenditures devoted to fuel and fertilizer. While it is the least energy-intensive, corn production has a higher share of labor costs (22%, as compared to 15.2%). Expenditures on land are approximately 20% for all producer types.

Prices for fuel and fertilizer are similar for all types of producers. Average price of diesel fuel is 22900 UAH per 1 ton and ranges from 19000 to 37097.86. Average price of fertilizer is 890 UAH per ton and ranges from 600.25 to 1199.78. Land and labor prices are similar for wheat and sunflower producers, with the average monthly salary being 6750 UAH and price of land being 2150 per hectare. For corn producers, these prices are consistent with the cost shares data. Average salary is 8016 UAH per month and per hectare price of land is 2999.72 UAH.

There is an issue that stems from the definition of the "other material expenditures category". As it includes all the material expenditures on various inputs, which do not fall into the categories of fuel, fertilizer, land, and labor, it causes "price of other material expenditures" variable to become basically meaningless, incorporating all of the residual price information, not reflected in other price variables. To calculate this variable, we used the data on expenditures and quantities of purchased miscellaneous material inputs which was reported by farmers in 50-SH forms.

Data covers the period of 2017-2019. There are farmers which appear twice and thrice in the dataset, having observations from 2 or 3 different years. However, the majority of farmers appear only once. Thus, the data is treated as pooled cross-section.

Chapter 5

ESTIMATION RESULTS

This chapter describes the estimation results of the long-run and short-run models defined in the Chapter 3. System of cost share equations is estimated simultaneously as Zellner's (1962) Seemingly Unrelated Regressions model with symmetry and linear homogeneity restrictions imposed. Price elasticities of demand for production inputs and substitution elasticities were calculated based on the estimated regression coefficients. Full regression estimation results are provided in the appendix on the tables 15-16.

Long-run own-price elasticities of demand for production inputs in wheat, corn, sunflower and soybeans production are presented on the Tables 5. As expected, demand for both, fuel and fertilizer, is found to be inelastic in the long run. Demand for fertilizer is found to be the least elastic for the production of sunflower (-0.39) and is the most elastic for production of soybeans (-0.79). Own-price elasticity of demand for fuel ranges from -0.44 (corn production) to -0.61 (wheat production). These results are consistent with the past findings by Turkekul and Unakıtan (2011) and Gopalakrishnan et al. (1989).

Consequently, it implies that as the fuel prices go up, their consumption does not fall proportionally, leading to higher production costs, ceteris paribus. Similar situation is observed for fertilizer as well. Among the crops studied, own-price effect on production of wheat (own-price elasticities of demand equal to -0.61 and -0.57, for fuel and fertilizer, respectively) and soybeans (elasticities equal to -0.47 and -0.79, for fuel and fertilizer, respectively) is slightly less pronounced, as compared to corn and sunflower.

Table 5: Long run own-price elasticities of demand for inputs for production of wheat, corn, sunflower and soybeans

	Wheat	Corn	Sunflower	Soybeans
Labor	-1.19	-0.90	-0.54	-0.79
	(0.12)	(0.10)	(0.12)***	(0.10)**
Fuel	-0.61	-0.44	-0.51	-0.47
	(0.09)***	(0.08)***	(0.07)***	(0.09)***
Fertilizer	-0.57	-0.51	-0.39	-0.79
	(0.09)***	(0.07)***	(0.08)***	(0.11)*
Land	-0.18	-0.18	-0.14	-0.16
	(0.02)***	(0.02)***	(0.02)***	(0.04)***
Materials	-0.73	-0.76	-0.79	-0.76
	(0.23)	(0.21)	(0.21)	(0.26)

Note: standard errors are provided in the brackets. Statistical significance (for $H_0: |\varepsilon_{ii}| = 1$) is indicated as: *** - 0.01 level, ** - 0.05 level, * - 0.1 level.

Source: own elaboration

Long run cross-price elasticities of demand for production inputs are presented in Tables 6-9, for wheat, corn, sunflower, and soybeans, respectively. Most of the cross-price elasticities with respect to fuel and fertilizer prices are fairly low indicating relatively small response of other production input consumption to changes in fuel or fertilizer. The highest change in use is observed for labor in response to fertilizer price in production of corn and soybeans, with a their cross-price elasticities equal to 0.44 and 0.47, respectively. On the other hand, labor-fertilizer cross price elasticity for wheat and sunflower is approx. two times lower, with respective values equal to 0.26 and 0.21. Additionally, for wheat production, the labor-fuel cross-price elasticity is found to be 0.38. For sunflower production neither of the cross-price elasticities exceed 0.25, indicating the lowest cross-price relationship, as compared to other studied crops.

Table 6: Long-run cross-price elasticities of demand for inputs for production of wheat.

Change with respect to price of:	Labor	Fuel	Fertilizer	Land	Materials
Labor	-	0.33	0.14	0.10	0.27
	-	(0.07)***	(0.06)**	(0.03)***	(0.013)**
Fuel	0.38	-	0.13	-0.08	0.15
	(0.08)***	-	(0.05)**	(0.02)***	(0.11)
Fertilizer	0.26	0.21	-	0.11	0.26
	(0.11)**	(0.08)**	-	(0.03)***	(0.15)*
Land	0.15	-0.11	0.09	-	0.05
	(0.03)***	(0.03)***	(0.03)***	-	(0.05)
Materials	0.40	0.18	0.21	0.05	-
	(0.19)**	(0.12)*	(0.12)*	(0.05)	-

Note: standard errors are provided in the brackets. Statistical significance (for $H_0: \left|\varepsilon_{ij}\right| = 0$) is indicated as: *** - 0.01 level, ** - 0.05 level, * - 0.1 level.

Source: own calculations

Table 7: Long-run cross-price elasticities of demand for inputs for production of corn.

Change with respect to price of:	Labor	Fuel	Fertilizer	Land	Materials
Labor	-	0.30	0.43	0.06	0.21
	-	(0.08)***	(0.07)***	(0.03)**	(0.15)
Fuel	0.19	-	-0.05	0.01	0.13
	(0.05)***	-	(0.04)	(0.02)	(0.09)
Fertilizer	0.44	-0.08	-	-0.06	0.22
	(0.07)***	(0.07)	-	(0.02)***	(0.12)*
Land	0.08	0.02	-0.07	-	0.21
	(0.04)**	(0.03)	(0.02)***	-	(0.06)***
Materials	0.20	0.20	0.20	0.17	-
	(0.14)	(0.14)	(0.05)***	(0.05)***	-

Note: standard errors are provided in the brackets. Statistical significance (for $H_0: \left|\varepsilon_{ij}\right| = 0$) is indicated as: *** - 0.01 level, ** - 0.05 level, * - 0.1 level.

Source: own calculations

Table 8: Long-run cross-price elasticities of demand for inputs for production of sunflower.

Change with respect to price of:	Labor	Fuel	Fertilizer	Land	Materials
Labor	-	0.13	0.13	0.01	0.12
	-	(0.06)**	(0.06)**	(0.02)	(0.12)
Fuel	0.15	-	0.12	0.00	0.18
	(0.07)**	-	(0.05)**	(0.02)	(0.10)*
Fertilizer	0.21	0.16	-	-0.07	0.25
	(0.10)**	(0.07)**	-	(0.02)***	(0.13)*
Land	0.02	0.01	-0.08	-	0.25
	(0.04)	(0.03)	(0.03)***	-	(0.05)***
Materials	0.16	0.21	0.21	0.20	-
	(0.17)	(0.12)*	(0.11)*	(0.04)***	-

Note: standard errors are provided in the brackets. Statistical significance (for $H_0: |\varepsilon_{ij}| = 0$) is indicated as: *** - 0.01 level, ** - 0.05 level, * - 0.1 level.

Source: own calculations

Table 9: Long-run cross-price elasticities of demand for inputs for production of soybeans.

Change with respect to price of:	Labor	Fuel	Fertilizer	Land	Materials
Labor	-	0.19	0.60	0.05	0.20
	-	(0.09)**	(0.10)***	(0.05)	(0.17)
Fuel	0.10	-	0.04	-0.02	0.15
	(0.05)**	-	(0.06)	(0.03)	(0.10)
Fertilizer	0.47	0.06	-	-0.07	0.22
	(0.08)***	(0.09)	-	(0.04)*	(0.15)
Land	0.04	-0.02	-0.07	-	0.20
	(0.04)	(0.04)	(0.04)*	-	(0.07)***
Materials	0.17	0.23	0.23	0.20	-
	(0.14)	(0.16)	(0.16)	(0.08)***	-

Note: standard errors are provided in the brackets. Statistical significance (for $H_0: |\varepsilon_{ij}| = 0$) is indicated as: *** - 0.01 level, ** - 0.05 level, * - 0.1 level.

Source: own calculations

Elasticity of substitution, which measures a change in relative input use induced by the change in their relative prices, provides a better picture of substitutability and complementarity between the inputs. Following the pattern observed in cross-price elasticities, the most pronounced of substitutability is observed for labor-fertilizer pair, with values of it equal to 0.97, 2.05, 0.92, and 2.37 for production of wheat, corn, sunflower, and soybeans, respectively. Another pair of inputs worth mentioning is labor and fuel. In case of it, values of substitution elasticity is the highest for wheat and corn (2.27 and 1.43, respectively). For sunflower and soybeans production such relationship is not observed (substitution elasticities between labor and fuel are 0.89 and 0.76, respectively). In general, corn has the highest values of substitution elasticities for input pairs with fuel and fertilizer, while for sunflower it is found to be the opposite.

It is important to mention that values of substitution elasticity do not imply that fuel and labor, or fertilizer and labor, could be used interchangeably in agricultural production. Instead, it highlights the fact that for certain crops production becomes more labor intensive, when price of fuel or fertilizer grows, holding everything else constant. Values of the long run substitution elasticities for wheat, corn, sunflower, and soybeans are presented on the Tables 10-13.

Table 10: Long-run substitution elasticities for production of wheat.

	Labor	Fuel	Fertilizer	Land	Materials
Labor	-	2.27 (0.47)***	0.97 (0.42)**	0.71 (0.19)***	1.91 (0.89)**
Fuel		-	0.78 (0.31)**	-0.50 (0.12)***	0.87 (0.67)
Fertilizer			-	0.43 (0.13)***	0.98 (0.57)*
Land				-	0.25 (0.25)

Note: standard errors are provided in the brackets. Statistical significance (for $H_0: |\sigma_{ij}| = 0$) is indicated as: *** - 0.01 level, ** - 0.05 level, * - 0.1 level.

Source: own calculations

Table 11: Long-run substitution elasticities for production of corn.

	Labor	Fuel	Fertilizer	Land	Materials
Labor	-	1.43 (0.38)***	2.05 (0.32)***	0.31 (0.15)**	0.99 (0.69)
Fuel		-	-0.37 (0.32)	0.09 (0.13)	1.01 (0.68)
Fertilizer			-	-0.30 (0.08)***	1.02 (0.55)*
Land				-	0.85 (0.23)***

Note: standard errors are provided in the brackets. Statistical significance (for $H_0: |\sigma_{ij}| = 0$) is indicated as: *** - 0.01 level, ** - 0.05 level, * - 0.1 level.

Source: own calculations

Table 12: Long-run substitution elasticities for production of sunflower.

	Labor	Fuel	Fertilizer	Land	Materials
Labor	-	0.89 (0.43)**	0.92 (0.42)**	0.08 (0.16)	0.81 (0.85)
Fuel		-	0.70 (0.28)**	0.02 (0.10)	1.07 (0.59)*
Fertilizer			-	-0.32 (0.10)***	1.07 (0.55)*
Land				-	0.99 (0.21)***

Note: standard errors are provided in the brackets. Statistical significance (for $H_0: |\sigma_{ij}| = 0$) is indicated as: *** - 0.01 level, ** - 0.05 level, * - 0.1 level.

Source: own calculations

Table 13: Long-run substitution elasticities for production of soybeans.

	Labor	Fuel	Fertilizer	Land	Materials
Labor	-	0.76 (0.34)**	2.37 (0.38)***	0.19 (0.19)	0.80 (0.66)
Fuel		-	0.32 (0.44)	-0.12 (0.19)	1.11 (0.74)
Fertilizer			-	-0.37 (0.20)*	1.08 (0.76)
Land				-	0.98 (0.36)***

Note: standard errors are provided in the brackets. Statistical significance (for $H_0: |\sigma_{ij}| = 0$) is indicated as: *** - 0.01 level, ** - 0.05 level, * - 0.1 level.

Source: own calculations

Table 14 presents the estimated short run own-price elasticities for production inputs for 4 studied crops. In this case, the elasticities are derived from the short-run variable costs function, in which land is treated as a quasi-fixed input. Thus, the short-term is defined as a period in which sown area could not be changed – time between sowing season and harvest. Values of own-price elasticities of demand for fuel and fertilizer are found to be higher in their absolute values, as compared to the long-term ones. Consequently, the demand for them becomes more elastic if sown area could not be changed. Demand for fuel is found to be close to unit-elastic, with values of -1.09, -1.27, -1.12, -1.38 for wheat, corn, sunflower, and soybeans production, respectively. Demand for fertilizer remains inelastic ($|\varepsilon_{ii}|$<1), however the elasticity is higher in its absolute value, as compared to the long-term estimates (-0.70, -0.91, -0.75, -0.87 for production of wheat, corn, sunflower, and soybeans, respectively). This difference between long- and short-term elasticities is more pronounced for production of crops, which had a less elastic demand for fuel and fertilizer in the long run.

Table 14: Short run own-price elasticities of demand for inputs for production of wheat, corn, sunflower and soybeans

	Wheat	Corn	Sunflower	Soybeans
Labor	-1.05	-0.90	-0.61	-0.96
	(0.14)	(0.11)	(0.14)***	(0.10)
Fuel	-1.09	-1.27	-1.12	-1.38
	(0.17)	(0.13)**	(0.12)	(0.17)**
Fertilizer	-0.70	-0.91	-0.75	-0.87
	(0.07)***	(0.06)	(0.07)***	(0.09)
Materials	-0.73	-0.68	-0.68	-0.73
	(0.28)	(0.24)	(0.24)	(0.27)

Note: standard errors are provided in the brackets. Statistical significance (for $H_0: |\varepsilon_{ii}| = 1$) is indicated as: *** - 0.01 level, ** - 0.05 level, * - 0.1 level.

Source: own calculations

These results are different from the findings by Lambert and Gong (2010), who the own-price elasticity of demand for fuel by agricultural producers to be almost unchanged in the short run, as compared to the long run. However, these findings are consistent with the results presented in a study by Turkekul and Unakıtan (2011), as described in Chapter 2. Possible interpretation for these counterintuitive findings could be the lack of financing options for farmers, so they choose to sacrifice additional yield by reducing their use of fertilizer and machinery if they cannot afford it in the face of growing prices. Then, when the next sowing season comes, they adjust the sown area so they could afford to apply optimal amount of fertilizer and machinery tillage. These intriguing results highlight the need for further research for a more complete understanding of this relationship and its verification.

Chapter 6

CONCLUSIONS AND POLICY IMPLICATIONS

The full-scale war in Ukraine has caused a dramatic rise in the prices of essential agricultural inputs, especially fuel (petrol and diesel) and nitrogen fertilizer. This spike in costs, coupled with a drop in domestic agricultural commodity prices, has severely affected Ukrainian farmers' profitability. This analysis highlights how crucial fuel and fertilizer are in agricultural production, emphasizing the significant challenges the sector faces in recovering from the war. These challenges are worsened by the reduced financial capacity of farmers to reinvest in their operations.

In this research the price elasticities of demand for production inputs across four major crops (wheat, corn, sunflower, and soybeans) were explored. Both long-run and short-run elasticities were estimated, revealing key insights into how Ukrainian agriculture reacts to changes in input prices. In the long run, the demand for both fuel and fertilizer was found to be inelastic across all four crops, meaning that consumption does not decrease proportionately with price increases: the long-run own-price elasticity of demand for fuel ranges from -0.44 (corn) to -0.61 (wheat), while for fertilizer, it ranges from -0.39 (sunflower) to -0.79 (soybeans). These values indicate that farmers continue to use these inputs despite rising costs, which drives up production expenses.

In the short run, the demand for fuel becomes nearly unit-elastic, especially for soybeans (-1.38) and corn (-1.27). This suggests that farmers are somewhat more responsive to price changes within a single growing season when land area is fixed. However, fertilizer demand remains inelastic even in the short run, with the highest elasticity observed in corn production (-0.91). The study also looked at how changes in the price of one input affect the demand for others. The cross-price elasticity between labor and fertilizer was relatively high for corn (0.44) and soybeans (0.47), indicating some level of substitutability. Substitution elasticities showed that labor and fertilizer, as well as labor and fuel, have the highest degree of substitutability in corn production, with elasticities of 2.05 and 1.43, respectively.

Our study shows that different crops have varying sensitivities to input price changes. Specifically, sunflower production is the most vulnerable to increases in fuel and fertilizer prices. This heightened sensitivity leads to a more pronounced negative effects on sunflower producers, as compared to other crops. Conversely, wheat and soybean producers are less affected due to their more elastic demand for these inputs. Nevertheless, the differences in sensitivity among the crops, while present, are not substantial. For sunflower production, the own-price elasticity for fuel is -0.51 and for fertilizer -0.39, indicating substantial cost increases with rising input prices. In contrast, wheat production, with an own-price elasticity for fuel of -0.61 and for fertilizer of -0.57, shows slightly better resilience, though still significant.

Estimating the short-run variable cost function provides important insights for further research. There is a need for more detailed analyses of short-run responses of agricultural producers to changes in input prices. Understanding these dynamics is vital for developing effective adaptation strategies and policy measures to mitigate the adverse effects of price volatility on the agricultural sector. In the short run, the demand for fuel becomes more elastic, implying that farmers might reduce fuel usage or find temporary substitutes during a growing season when faced with high prices.

Given the current complicated economic situation in Ukraine, providing policy recommendations becomes challenging due to highly limited resources of the government and further focus on the post-war recovery. However, several strategic considerations can guide policy development. Encouraging the adoption of organic farming practices and technologies that minimize the use of mineral fertilizers can reduce farmers' dependency on volatile and imported inputs. This shift would not only enhance the sustainability of agricultural practices but also align with the European Union's stringent crop production standards, which Ukraine aims to meet as part of its EU accession efforts.

Promoting the production and use of biofuels can reduce the agricultural sector's reliance on oil-based fuels. This approach not only diversifies the energy sources available to farmers but also stimulates domestic demand for crops suitable for biofuel production, creating new economic opportunities within the agricultural sector. While direct subsidies for fertilizer and fuel can offer immediate relief during periods of rapid price increases, such measures are inherently short-term and unsustainable. Instead, a more strategic approach involving targeted subsidies during critical periods can help stabilize the sector while longer-term solutions are developed.

The research highlights the critical role of fuel and fertilizer in maintaining agricultural productivity. The inelastic nature of demand for these inputs means that price increases lead to disproportionately higher production costs, which can erode profitability and hinder the sector's recovery. Policymakers must consider these dynamics when designing interventions to support the agricultural sector through periods of economic instability. Moreover, the differential impact on various crops suggests that policy measures should be crop-specific to address the unique challenges faced by producers of wheat, corn, sunflower, and soybeans. Tailored support can enhance the resilience of each crop sub-sector, ensuring a more balanced and effective response to input price volatility.

The war-induced increase in input prices presents a significant challenge to Ukrainian agriculture. The sector's recovery will depend on strategic policy interventions that promote sustainable farming practices, support alternative energy sources, and provide targeted relief during critical periods. By addressing the specific needs of different crops and leveraging adaptive strategies, Ukraine can navigate the complexities of the current economic landscape and build a more resilient agricultural sector for the future. These findings and recommendations underscore the need for a holistic approach to agricultural policy, one that balances immediate relief with long-term sustainability. As Ukraine continues its journey towards recovery and EU integration, the agricultural sector's resilience will be a cornerstone of national economic stability and growth.

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APPENDIX

Table 15: Long-run cost function estimation results for production of wheat, corn, sunflower, and soybeans

Coefficient	Wheat	Corn	Sunflower	Soybeans
eq1: (Intercept)	0.036	-0.071	-0.181 ***	-0.077
	(0.065)	(0.075)	(0.065)	(0.094)
eq1: lplabor	-0.048 ***	-0.022	0.045 ***	-0.009
	(0.017)	(0.021)	(0.017)	(0.025)
eq1: lpfuel	0.030 ***	0.012	-0.003	-0.008
	(0.011)	(0.010)	(0.010)	(0.012)
eq1: lpfert	-0.001	0.047 ***	-0.003	0.069 ***
	(0.016)	(0.014)	(0.014)	(0.019)
eq1: lpland	-0.009	-0.036 ***	-0.034 ***	-0.041 ***
	(0.006)	(0.008)	(0.006)	(0.010)
eq1: lq	0.008 ***	0.008 ***	0.006 **	0.016 ***
	(0.002)	(0.003)	(0.003)	(0.003)
eq2: (Intercept)	-0.289 ***	-0.178 ***	-0.196 ***	-0.151 ***
	(0.059)	(0.044)	(0.055)	(0.057)
eq2: lplabor	0.030 ***	0.012	-0.003	-0.008
	(0.011)	(0.010)	(0.010)	(0.012)
eq2: lpfuel	0.037 **	0.055 ***	0.054 ***	0.055 ***
	(0.015)	(0.010)	(0.012)	(0.012)

Table 15 – continued

Coefficient	Wheat	Corn	Sunflower	Soybeans
eq2: lpfert	-0.010	-0.038 ***	-0.012	-0.019
	(0.014)	(0.009)	(0.011)	(0.012)
eq2: lpland	-0.053 ***	-0.029 ***	-0.041 ***	-0.031 ***
	(0.004)	(0.004)	(0.004)	(0.005)
eq2: lq	-0.006 ***	-0.006 ***	-0.007 ***	-0.006 ***
	(0.002)	(0.001)	(0.002)	(0.001)
eq3: (Intercept)	0.098	-0.182 ***	-0.290 ***	-0.255 ***
	(0.079)	(0.056)	(0.067)	(0.080)
eq3: lplabor	-0.001	0.047 ***	-0.003	0.069 ***
	(0.016)	(0.014)	(0.014)	(0.019)
eq3: lpfuel	-0.010	-0.038 ***	-0.012	-0.019
	(0.014)	(0.009)	(0.011)	(0.012)
eq3: lpfert	0.044 *	0.059 ***	0.089 ***	0.002
	(0.023)	(0.015)	(0.017)	(0.021)
eq3: lpland	-0.033 ***	-0.068 ***	-0.077 ***	-0.055 ***
	(0.007)	(0.006)	(0.006)	(0.008)
eq3: lq	0.001	0.002	0.009 ***	0.004
	(0.003)	(0.002)	(0.003)	(0.002)
eq4: (Intercept)	1.134 ***	1.251 ***	1.391 ***	1.200 ***
	(0.042)	(0.041)	(0.041)	(0.058)

Table 15 – continued

Coefficient	Wheat	Corn	Sunflower	Soybeans
eq4: lplabor	-0.009	-0.036 ***	-0.034 ***	-0.041 ***
	(0.006)	(0.008)	(0.006)	(0.010)
eq4: lpfuel	-0.053 ***	-0.029 ***	-0.041 ***	-0.031 ***
	(0.004)	(0.004)	(0.004)	(0.005)
eq4: lpfert	-0.033 ***	-0.068 ***	-0.077 ***	-0.055 ***
	(0.007)	(0.006)	(0.006)	(0.008)
eq4: lpland	0.129 ***	0.141 ***	0.153 ***	0.128 ***
	(0.005)	(0.005)	(0.005)	(0.007)
eq4: lq	0.002	-0.004 ***	-0.005 ***	-0.005 ***
	(0.002)	(0.001)	(0.002)	(0.002)
OLS R^2	0.149	0.153	0.185	0.164
McElroy R^2	0.233	0.244	0.245	0.189
Num. obs. (total of 4 equations)	3416	3668	3840	2012
DF	3398	3650	3822	1994

Note: standard errors are provided in the brackets. Statistical significance is indicated as: *** - 0.01 level, ** - 0.05 level, * - 0.1 level.
Source: own estimation

Table 16: Short cost function estimation results for production of wheat, corn, sunflower, and soybeans

Coefficient	Wheat	Corn	Sunflower	Soybeans
eq1: (Intercept)	0.056	0.127 ***	0.018	-0.068

Table 16 - continued

Coefficient	Wheat	Corn	Sunflower	Soybeans
	(0.060)	(0.049)	(0.049)	(0.056)
eq1: lplabor2	-0.043 **	-0.042 *	0.038 *	-0.085 ***
	(0.021)	(0.024)	(0.021)	(0.026)
eq1: lpfuel2	0.033	0.034 *	0.014	0.079 ***
	(0.020)	(0.017)	(0.017)	(0.021)
eq1: lpfert2	-0.017	0.010	-0.045 ***	0.010
	(0.015)	(0.013)	(0.013)	(0.016)
eq1: ltotarea	0.022 ***	0.016 ***	0.003	0.042 ***
	(0.003)	(0.003)	(0.006)	(0.004)
eq1: lq	-0.003	-0.001	0.005	-0.002
	(0.003)	(0.004)	(0.005)	(0.004)
eq2: (Intercept)	0.467 ***	0.429 ***	0.422 ***	0.410 ***
	(0.089)	(0.046)	(0.058)	(0.063)
eq2: lplabor2	0.033	0.034 *	0.014	0.079 ***
	(0.020)	(0.017)	(0.017)	(0.021)
eq2: lpfuel2	-0.064 **	-0.071 ***	-0.071 ***	-0.098 ***
	(0.029)	(0.017)	(0.020)	(0.023)
eq2: lpfert2	0.045 **	0.039 ***	0.053 ***	0.019
	(0.018)	(0.012)	(0.014)	(0.015)
eq2: ltotarea	-0.011 ***	-0.001	-0.009	-0.011 ***
	(0.004)	(0.002)	(0.006)	(0.003)

Table 16 - continued

Coefficient	Wheat	Corn	Sunflower	Soybeans
eq2: lq	0.009 **	0.000	0.013 **	0.008 **
	(0.004)	(0.003)	(0.005)	(0.003)
eq3: (Intercept)	0.166 **	0.133 ***	0.220 ***	0.221 ***
	(0.066)	(0.042)	(0.049)	(0.057)
eq2: lplabor2	0.033	0.034 *	0.014	0.079 ***
	(0.020)	(0.017)	(0.017)	(0.021)
eq2: lpfuel2	-0.064 **	-0.071 ***	-0.071 ***	-0.098 ***
	(0.029)	(0.017)	(0.020)	(0.023)
eq2: lpfert2	0.045 **	0.039 ***	0.053 ***	0.019
	(0.018)	(0.012)	(0.014)	(0.015)
eq2: ltotarea	-0.011 ***	-0.001	-0.009	-0.011 ***
	(0.004)	(0.002)	(0.006)	(0.003)
eq2: lq	0.009 **	0.000	0.013 **	0.008 **
eq3: lplabor2	-0.017	0.010	-0.045 ***	0.010
	(0.015)	(0.013)	(0.013)	(0.016)
eq3: lpfuel2	0.045 **	0.039 ***	0.053 ***	0.019
	(0.018)	(0.012)	(0.014)	(0.015)
eq3: lpfert2	-0.012	-0.046 ***	-0.011	-0.030
	(0.020)	(0.014)	(0.016)	(0.019)
eq3: ltotarea	-0.003	-0.009 ***	0.000	-0.012 ***
	(0.002)	(0.001)	(0.004)	(0.002)

Table 16 - continued

Coefficient	Wheat	Corn	Sunflower	Soybeans
eq3: lq	-0.006 **	-0.003 *	-0.011 ***	-0.003
	(0.003)	(0.002)	(0.003)	(0.002)
OLS R^2	0.045	0.046	0.028	0.188
McElroy R^2	0.038	0.045	0.023	0.143
Num. obs. (total)	2562	2751	2880	1509
DF	2547	2736	2865	1494

Note: standard errors are provided in the brackets. Statistical significance is indicated as: *** - 0.01 level, ** - 0.05 level, * - 0.1 level.

Source: own estimation