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TECHNICAL EFFICIENCY ANALYSIS OF WHEAT PRODUCERS IN KAZAKHSTAN AND RUSSIA: STOCHASTIC FRONTIER APPROACH

Abstract. Kazakhstan, Russia and Ukraine (KRU) already collectively account for about quarter of the world wheat exports and those countries have still huge unrealized production potential. This production potential can be realized if improvements in production efficiency achieved since an average yields yet are far below compared to the developed countries like US and Canada. Need for efficiency improvements are often mentioned and governments implemented several policy reforms to advance production efficiencies. However, empirical research on the effects of such policy reforms is scarce, particularly in the case of KRU countries. This study aims at filling this gap with using cross-sectional data from wheat producing farms across six regions of Kazakhstan and Russia employing a two-step stochastic frontier production analysis. Analysis suggest that the factors like an access to capital assets, farmer's education and use of crop insurance can improve technical efficiencies of farms. On the other hand, subsidy payments from government seem to have strong negative impact on farm's technical efficiency.

Keywords: technical efficiency, stochastic frontier analysis, food security, KRU countries.

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Аннотация. На Казахстан, Россию и Украину (КРУ) в совокупности приходится около четверти мирового экспорта пшеницы, и эти страны все еще обладают огромным нереализованным производственным потенциалом. Этот производственный потенциал может быть реализован, если будет достигнуто повышение эффективности производства, поскольку средняя урожайность все же намного ниже по сравнению с развитыми странами, такими как США и Канада. В литературе часто упоминается необходимость повышения эффективности зерно производителей, и правительства упомянутых стран реализовали несколько экономических реформ для повышения эффективности производства. Однако эмпирические исследования, изучающие влияние таких экономических реформ немногочисленны, особенно в случае стран КРУ. Данное исследование направлено на восполнение этого пробела за счет использования данных из фермерских хозяйств, производящих пшеницу, из шести регионов Казахстана и России с использованием двухэтапного стохастического пограничного анализа производства. Анализ показывает, что такие факторы, как доступ к капиталу, образование фермеров и страхование урожая, могут повысить техническую эффективность фермерских хозяйств. С другой стороны, выплаты субсидий со стороны государства, по-видимому, оказывают сильное негативное влияние на техническую эффективность хозяйств.

Ключевые слова: техническая эффективность, стохастический пограничный анализ, продовольственная безопасность, страны КРУ.

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Аңдатпа. Әлемдік бидай экспортының шамамен төрттен бір бөлігі Қазақстан, Ресей және Украина (КРУ) елдеріне тиесілі және бұл елдер әлі де пайдаланылмаған орасан зор өндірістік әлеуетке ие. Бұл өндірістік әлеуетті өндіріс тиімділігі жоғарылаған жағдайда іске асыруға болады, өйткені бұл елдерде АҚШ пен Канада сияқты дамыған елдермен салыстырғанда орташа өнімділік әлдеқайда төмен. Астық өндірушілердің тиімділігін арттыру қажеттілігі туралы әдебиеттерде жиі айтылады және осы елдердің үкіметтері өндіріс тиімділігін арттыру үшін бірнеше экономикалық реформалар жүргізуде. Алайда, мұндай экономикалық реформалардың әсерін зерттейтін эмпирикалық зерттеулер, әсіресе КРУ елдерінде өте аз. Бұл зерттеу Қазақстанның және Ресейдің алты аймағындағы бидай өндіретін шаруашылықтардың деректерін пайдалану арқылы өндірістің екі сатылы стохастикалық шекаралық талдауын қолдану арқылы осы олқылықтың орнын толтыруға бағытталған. Талдау көрсеткендей, капиталға қол жетімділік, фермерлерге білім беру және егінді сақтандыру сияқты факторлар шаруа қожалықтарының техникалық тиімділігін арттыра алады. Сонымен қатар, мемлекет тарапынан субсидия төлемдері шаруа қожалықтарының техникалық тиімділігіне қатты кері әсерін тигізетіні анықталды.

Түйін сөздер: техникалық тиімділік, шекараны стохастикалық талдау, азық-түлік қауіпсіздігі, КРУ елдері.

Introduction

The global population is growing at a very high pace, thereby resulting to a significant increase in demand for food worldwide. It is estimated that the population of the earth would exceed 9 billion people by 2050, which would require around 60 percent rise in agricultural production worldwide (FAO, 2013). Kazakhstan and Russia are one of the biggest producers and exporters of wheat globally and therefore have substantial effect on food security worldwide (Figure 1). Kazakhstan, Russia, and Ukraine (KRU) collectively account for nearly a quarter of the wheat exports globally (Liefert and Liefert, 2015).

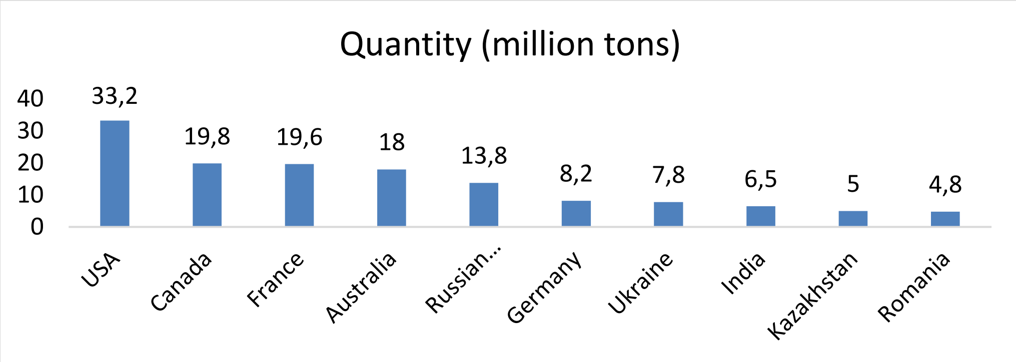

Figure 1: Top 10 wheat exporting countries, 2013
Source: (FAOSTAT, 2013)

The role of countries like Kazakhstan and Russia in meeting the increased demand for food is also high due to their huge unrealized wheat production potential (Glauben *et al.*, 2014). Although KRU countries experienced an increase in wheat yields during the last decade, the values are still far below, compared to European countries, US and Canada. For example, average wheat yields (tons/ha) in Kazakhstan and Russia between 2010 and 2014 were only 1.16 and 2.35 respectively compared to 3.37, 3.38 and 7.58 in US, Canada and France respectively (Figure 2). Thus there are discussions in the existing literature that KRU countries have large potential to boost their production via developments in the productivity and cropland increase (Liefert *et al.*, 2010). The same study projects wheat exports from KRU countries to increase by nearly 50% by 2019, making Russia the largest wheat exporter in the world. Swinnen *et al.* (2017) estimates about 40–110 million tons of wheat could be additionally produced in RUK countries. By increasing the production and export of wheat, Kazakhstan and Russia could potentially contribute to meet the growing global demand for food and prevent from significant increases in the world food prices. However, due to high costs of expanding agricultural land further, improving the productivity levels could be one viable options of bossing export potentials (Liefert *et al.*, 2010; Lioubimtseva and Henebry, 2012; Petrick *et al.*, 2014; Schierhorn *et al.*, 2014b; Fehér *et al.*, 2017; Swinnen *et al.*, 2017). Large areas in KRU countries is still not utilized and remains marginal due to lack of infrastructure and high production costs associated with low efficiencies (Babu and Rhoe, 2001; Liefert *et al.*, 2010; Coulibaly and Thomsen, 2016). Therefore, by improving their production efficiencies, farmers in KRU countries can potentially increase the level of wheat production and export. Furthermore, increased productivity and efficiency is also need to maintain food security not only worldwide but also domestic food security in KRU. Because national governments are very afraid for not being able to meet domestic cereal demand when systemic droughts take place. As a result of drought and harvest failures in several years in the past, governments of Kazakhstan, Russia and Ukraine imposed restrictions on the export of wheat, which resulted to a huge shortage in the world supply of wheat and to the sky-rocketing of world food prices (Götz *et al.*, 2013). Therefore, productivity and efficiency need to be developed to secure national as well as global food security. Being aware of these needs, national governments have implemented several reforms to stabilize and boost productivity. However, there is a scarce studies which investigate the farm level effect of these policy reforms.

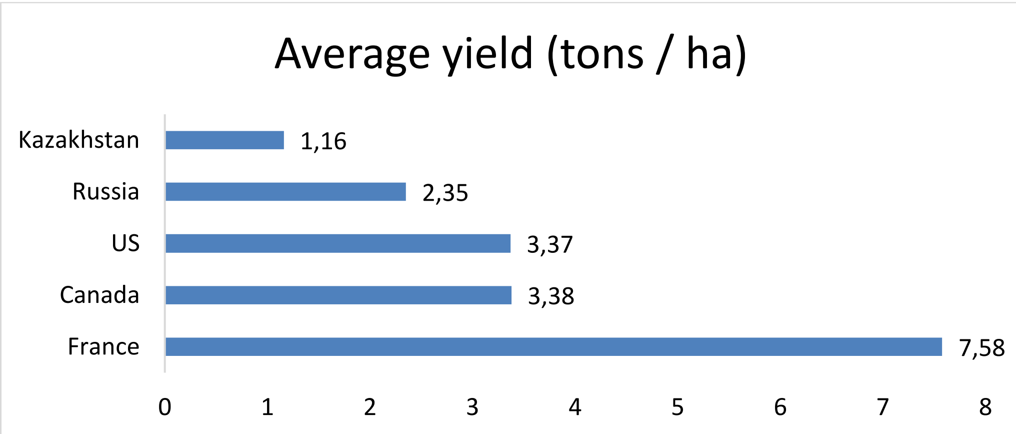

Figure 2: Average wheat yields between 2010 and 2014
Source: (FAOSTAT, 2010-2014)

Therefore, the current study aims to estimate technical efficiencies of wheat producers in Kazakhstan and Russia and to identify the farm-specific characteristics that affect technical efficiencies of farmers. It is very important from policy perspective, as understanding these relationships enables policymakers to implement programs that have positive effect on farms' efficiencies and correspondingly on the agricultural production.

However, so far there is a limited empirical research available on the productivity and efficiency analysis of farmers in the case of transition countries, like Kazakhstan and Russia (Bokhuseva and Hockmann, 2004; Bokusheva and Hockmann, 2006; Svetlov and Hockmann, 2007; Hockmann *et al.*, 2009; Bokusheva *et al.*, 2011; Hahlbrock and Hockmann, 2011). Hence, the effects of such reforms are yet not clear. Therefore, current research aims to fulfil this gap by conducting a two-step stochastic frontier production analysis in the case of the sample of Kazakhstani and Russian farms, thus contributing to the regional literature on agricultural productivity and efficiency.

Conceptual Framework

The backbone of any firm consist of owners, managers and employees who combine their skills and efforts to create added value. While owners bring capital and employees provide their labor and skills, managers on the other hand try to combine all available resources in a most optimal way. Generally speaking, firm is an economic actor that uses inputs to produce some outputs. For the sake of simplicity, assume that firm produces single output (Q) by using single input (L). The amount of output (Q) firm can produce depends on the single input, labor (L). Thus, the production frontier of that firm can be described as F(L) = Q. Consider Firms A and B which are not utilizing their labor inputs efficiently and thus producing at the points lower than their production frontier. Those they are producing less product with available resources than they potentially could do. On the other hand, firms C and B are using resources efficiently and performing at the levels of their maximum production frontier (Figure 3). Inability of firms to reach highest production efficiency can be explained by several factors such as a) lack in quantity and quality of input resources, b) poor access to markets, and c) inefficient management practices (Mathijs and Vranken, 2001). Firms A and C use the same amount of labor, however due to the differences in technical efficiencies, produce different amounts of output. The differences in technical efficiency levels can be explained by human capital, i.e. the quality of labor used. Firms C might be more efficient because it has better educated or better skilled manager compared to firm A and have good knowledge how to allocate resources on the production frontier). The human capital view of Becker (1994) suggest that human capital has direct positive connection to production process. He claims that education improves productivity mainly through providing knowledge, skills and different ways of analyzing problems. In the standard labor economics view, human capital is regarded as the collection of skills and characteristics that improves labor productivity (Acemoglu and Autor, 2011).

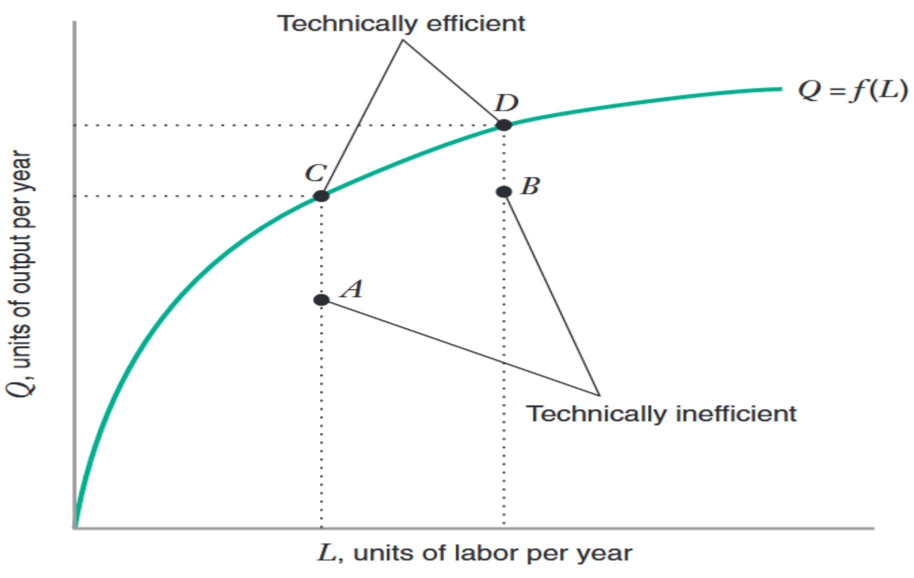

Figure 3: Production Function Frontier

Similarly, inefficiencies may arise because of insufficient quantity of inputs available in the production. Some farms may not have enough resources or may not have available capital to acquire additional resources, which could prevent from reaching their production frontier. Especially the case with farmers that have increasing returns to scale, when one unit increase in input quantity leads to more than one unit increase in output volume (Mathijs and Vranken, 2001).
Manager's ability to better manage uncertainties regarding expected production and thus of expected profit is another crucial factor that can improve farm efficiency. Antle (1983) suggests that risk management in agriculture is important, as production and price uncertainties affect farm's productivity and expected income. In an environment with poor functioning insurance system droughts and harvest failures might lead to a lower application of mineral fertilizers due to high uncertainty of expected profit, which in turn decrease input productivity (Schierhorn *et al.*, 2014a). Several studies in the past have investigated the impact of those factors empirically and following chapter provides short overview of their finding related to the theoretical discussions above.

Results and Discussion

All input variables of the production function have statistically significant, positive effect on output at 1% confidence level (Table 1). The highest elasticity accounts for variable inputs (0.40), followed by capital (0.31), land (0.26) and labor (0.17). The sum of all coefficients equals to 1.15, suggesting an increasing returns to scale. Increase in input quantities lead to a higher total factor productivity, meaning that if a farm increases inputs by one percent, output will increase by more than one percent.

Table 1: Cobb – Douglas Stochastic Production Function Estimates

Ln_revenue *(loutput)*	Coef.	Std. Err.	T-stat	P-values
Constant	4.077618	0.6791172	6	0.000*
Ln_labor *(llabor)*	0.1738904	0.0462332	3.76	0.000*
Ln_land *(lland)*	0.2631805	0.0407061	6.47	0.000*
ln_variable_input *(lvariable_input)*	0.402373	0.042819	9.4	0.000*
ln_capital *(lcapital)*	0.3114349	0.0397619	7.83	0.000*
sigma_v	0.7717493	0.0921065		
sigma_u	0.63565	0.2978551		
lambda	0.8236484	0.3824669		

Notes: *Significant at the 1% level. **Significant at the 5% level. ***Significant at the 10% level.

Table 2: Frequency distribution and summary statistics of efficiency estimates

Efficiency (%)	Number of farms	Percent of farms
>= 80	5	2
>=70<80	70	26
>=60<70	114	42
>=50<60	63	23
<50	18	7
Mean		64
Min		28
Max		83

While the mean TE is around 64 percent, the maximum and minimum TEs are about 83 and 28 percent respectively. Nearly half of all farms utilize between 60 and 70 percent of their full technical potential, whereas only 2 percent of farms use more than 80 percent of their production capacity. Around one-third of the farms have TEs lower than 60 percent (Table 23).

Akmoliskaya oblast, which is the only region representing Kazakhstan in the data, has the highest TE (68.5%) compared to other regions in the model, followed by Ryazan (65.6%) and Belgorod (61.9%) oblasts. The Novosibirsk oblasts shows the lowest performance with TE of 58.4% (Figure 4).

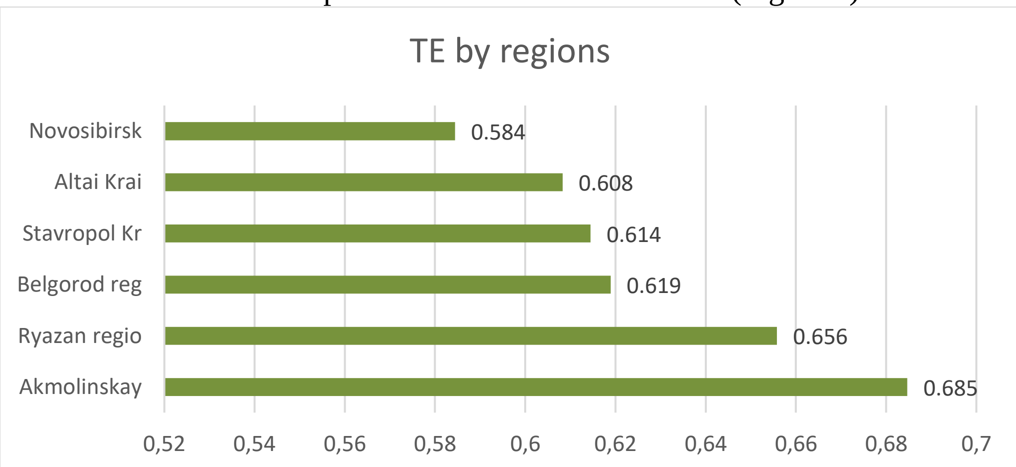

Figure 4: Technical Efficiencies of farms by regions

One of the main issues common to cross sectional model is the presence of heteroscedasticity in the data. Heteroscedasticity occurs when the error terms of all variables are not constant. Regression results of such data could lead to biased results. In current research, two tests for detecting heteroscedasticity were conducted. Figure 5 presents the plotted values of residuals and the straight red line shows that there is no variability in residuals, suggesting for homoscedasticity pattern in the data. White's test for heteroscedasticity shows similar results

(Table 3). The p-value is very large, suggesting that the null hypotheses of homoscedasticity cannot be rejected.

Table 3: Heteroscedasticity Test (White's test)

White's test for Ho: homoskedasticity	
chi2 (22)	9.64
Prob > chi2	0.9893

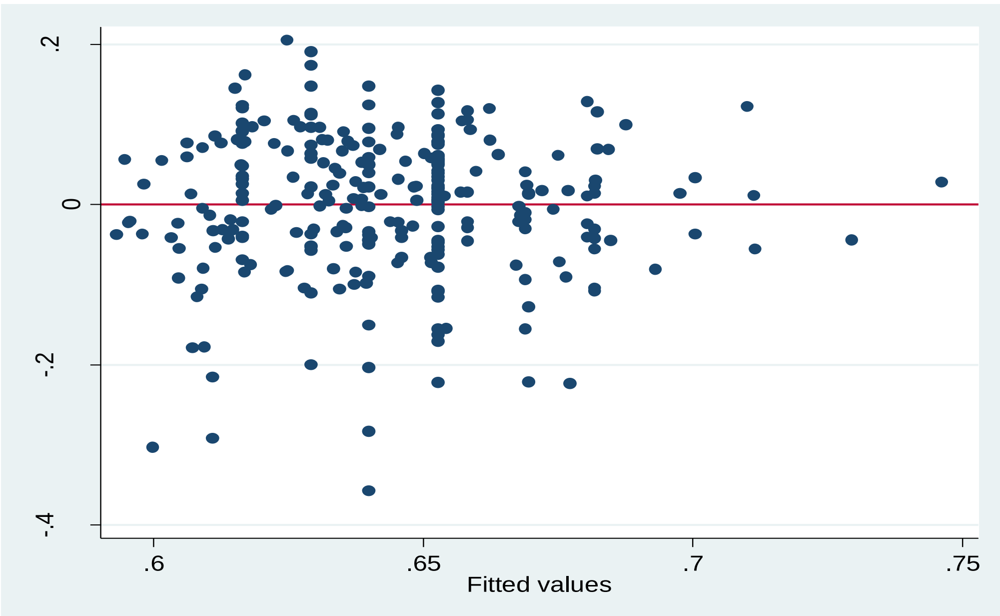

Figure 5: Plot of residuals

None of the tests above showed the presence of heteroscedasticity in the model, which allows to run the ordinary OLS regression for efficiency analysis. The results of both OLS and Tobit regressions (Table 4) indicate almost identical results. All of the variables except for *supplychain*, have statistically significant impact on technical efficiency according to both OLS and Tobit estimates. While variables like *edu*, *cooperation*, *agroholdingmember* and *insurance* positively effect on technical efficiency, *subsidies* on the other hand have a negative impact. The results indicate that both quantity and quality of used input resources can positively influence farm's technical efficiency. Farm manager's education *edu*, which improves the quality of labor force used in the production have statistically significant positive impact on technical efficiency. Farms with better-educated managers on average are more efficient compared to ones with lower level of education. This concept is largely accepted by most scholars in the literature (Battese and Coelli, 1995; Parikh *et al.*, 1995; Alene and Hassan, 2003; Gorton and Davidova, 2004; Asadullah and Rahman, 2009; Karimov, 2014).

Likewise, capital assets access variables like *cooperation* and *agroholdingmembership* show significant positive relationship with technical efficiency. Both variables have statistically significant positive effect on farm's efficiency level. Hahlbrock and Hockmann (2011) have similar results. They studied the impact of agro-holding membership on farm productivity and efficiency in Belgorod region of Russia and found that on average, member farms perform better in terms of productivity compared to non-member farms. An access to the larger quantity of available inputs is particularly important for farms with increasing returns to scale, which is the case in current analysis. Through increasing their input quantities by one unit, farmers can increase their output levels by more than one unit.

Table 4: Efficiency Analysis estimates

	OLS		Tobit	
Variables	Coef.	P-values	Coef.	P-values
Constant	0.5966	0.000*	0.5966	0.000*
Farm managers education *(edu)*	0.0446	0.002*	0.0446	0.002*
Cooperates with other farmers *(cooperation)*	0.0294	0.069***	0.0294	0.066***
Agroholding member *(agroholdingmember)*	0.0536	0.061***	0.0536	0.058***
Market access *supplychain)*	0.0097	0.385	0.0097	0.379
Risk management *(insurance)*	0.0269	0.039**	0.0269	0.036**
Government support *(subsidies)*	-0.0031	0.049**	-0.0031	0.046**

Notes: *Significant at the 1% level. **Significant at the 5% level. ***Significant at the 10% level.

The results of the current study supports the findings of (Hennessy *et al.*, 1997; Di Falco and Chavas, 2006; Agahi *et al.*, 2008; Breker, 2017), where they observe significant positive relationship between risk management and farm efficiency. Better risk management practices *(e.g. insurance)* improve technical efficiencies of farms' on average. The relationship is positive and significant. Agriculture is considered one of the riskiest types of business, due to its high dependence on external factors like weather, irrigation and etc. Huge drops in grain yields in countries like Kazakhstan, Russia and Ukraine as a result of drought in 2007-2008, can be a good example. Farmers can use various insurance schemes to reduce their uncertainties against expected production and profit levels. Having better picture about expected profits, farmers can use mineral fertilizers with more confidence and expect better yields. Therefore, better functioning insurance mechanisms available to farmers can improve their efficiency levels. This mainly explained with allocation of inputs optimally according to technical norms instead of being risk averse. Risk averse farm may spend limited budget to buy variable inputs when no insurance exists. Production efficiency in respect to land and capital is underutilized without proper risk management tools.

Government support in the form of direct subsidy payments *(subsidies)* have significant negative effect on farm technical efficiency. The results are in line with the findings of most articles on farm productivity available in the literature (Kumbhakar and Lien, 2010; Zhu and Lansink, 2010; Bojnec and Latruffe, 2013; Rizov *et al.*, 2013). This variable is very important as subsidy payments play a huge role in both Kazakhstan and Russia as part of their national agricultural support programs. In Kazakhstan alone, for the purposes of Agribusiness 2020 Program, 3.1 trillion KZT (11.5 bln USD) was allocated from the republican budget, of which 42% to be spent on agricultural subsidies of different forms (Petrick and Pomfret, 2016). Thus, the results of this study therefore questions the appropriateness of providing direct subsidies since it has a negative effect on efficiency. Another reason for Kazakhstan to reduce direct subsidy levels is the commitments behind the WTO. Since July 2015, Kazakhstan became the member of the WTO, which implies certain commitments, like keeping support levels for domestic agricultural producers below 8.5% of the year's value of production. Prior to joining the WTO, for many agricultural products domestic support used to be higher than 8.5% (Petrick and Pomfret, 2016).

Finally, having a better access to markets, in terms of direct supply to procurement and agro-processing enterprises *supplychain)* have positive, but not statistically significant effect on farm efficiency.

Conclusion

KRU countries can contribute to the improvement of global food security issue, by partly meeting an increasing demand for food. Although KRU countries already are one of the top wheat producing countries worldwide, they still have huge unrealized production potential. By improving productivity and efficiency, those countries have potential to boost wheat production and potentially be largest wheat exporters in the world. However, current productivity levels are very low compared to internationally leading countries and production efficiencies need to be improved to be competitive in the world market. An obvious need for the improvements in productivity and efficiency in KRU countries was acknowledged by the states and several policy reforms were implemented. However, the effect of implemented policy reforms largely remains unknown due to lack of empirical research in this field. Therefore, this study have analyzed the effect of policy variables on productivity and efficiency using farm level data for the first time. A two-stage stochastic frontier production analysis in the case of wheat producers across six regions of Kazakhstan and Russia was conducted to fill the knowledge gap of the effect of policy instruments.

Using Cobb-Douglas stochastic frontier form, technical efficiencies of farmers are estimated at the first stage of analysis. The second stage involves regressing technical efficiencies against different farm-specific characteristics using a Tobit analysis.

The results of efficiency analysis reveal that both quality and quantity of inputs have significant positive effect on farm's technical efficiency. Farms with better-educated managers, farms who cooperate with each other and farms which are members of agro-holdings tend to be more efficient on average. Similarly, farms using crop insurance to manage their risks are more efficient compared to others. On the other hand, inverse relationship was observed between direct subsidy payments from government and farm's technical efficiency.

The results of current study suggest some guidance for future policy reforms in the field of agricultural support programs. Ensuring better access to education, especially for farmers, as well as promoting cooperation among farmers should be one of the priorities for policy makers to boost productivity and efficiency in these countries. Moreover, the governmental programs related to development of insurance market should be further continued especially in Russia since very limited percent of farms purchase insurance against large about of subsidies from the state. Lastly, current subsidy programs provided by government should be reconsidered and channeled to other support measure as mentioned above since direct subsidies show negative effect on farm efficiency.

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