The Impact of Trade Openness on Technical Efficiency in U.S. Agriculture

Dragan Miljkovic,* Professor
North Dakota State University
Department of Agribusiness & Applied Economics
614A Barry Hall
NDSU Department 7610
Fargo, ND 58108-6050

and

Saleem Shaik, Assistant Professor
North Dakota State University
Department of Agribusiness & Applied Economics
504 Barry Hall
NDSU Department 7610
Fargo, ND 58108-6050

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Abstract:

This study addresses the impact of trade openness on technical efficiency in the U.S. agricultural sector. The results indicate that trade protectionism illustrated with a decrease in the share of agricultural imports in agricultural GDP led to an increase in technical efficiency. A change in the share of agricultural exports in agricultural GDP had no impact on technical efficiency. These results are partially consistent with the premise of the new trade theory, but also seem to be driven by the intricacies of the agricultural sector and agricultural policy in the US and internationally.

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Introduction

The relationship between free trade on one side and productivity and technical efficiency gains on the other side has been perceived considerably different in the public policy circles than among trade economists. The sentiment often echoed the trade liberalizers is one of the expectation of productivity gains often due to technical efficiency change following trade liberalization. This position is nicely summarized by Daniella Markheim (2007) of the Heritage Foundation: “Free trade allows a country to compete in the global market according to its fundamental economic strengths and to reap the productivity and efficiency gains that promote long-run wealth and prosperity.” (p.3)

Economists, on the other hand, have long realized that this relationship is more complex than what appears at first glance. First, we need to recall that productivity growth is comprised of two mutually exclusive and exhaustive components, technological change (TC) and technical efficiency change (TEC). The TC simply represents a shift of the production possibility frontier (PPF), *i.e.*, it is about changes to the potential output. The TEC indicates a country’s movement towards or away from the PPF, *i.e.*, it is about changes to the gap between the actual and potential outputs. It has been determined that trade openness may not have the same effect on both TC and TEC: trade typically does not lead to negative TC, but it can give rise to either positive or negative TEC (*e.g.*, Iyer, Rambaldi, and Tang, 2008). This in turn makes the impact of trade on productivity uncertain and the relationship between trade openness and technical efficiency especially intriguing.

There is a lack of consensus among economists regarding the impact of trade liberalization on technical efficiency. According to Rodrik (1992), that is the case because there are no systematic theories which link trade policy to technical efficiency. This may be due to great intellectual appeal of the long prevalent Ricardian doctrine of comparative costs which relies on allocative efficiency, *i.e.*, the allocation of domestic resources into sectors where they are most productive. However, one needs to recall that the original case for the gains from trade was developed by Adam Smith (1937) and relied on scale economies via an expanded division of labor within a larger market to lead to overall gains in productivity: "By means of (foreign trade), the narrowness of the home market does not hinder the division of labour in any particular branch of art or manufacture from being carried to the highest perfection. By opening a more extensive market for whatever part of the produce of their labour may exceed the home consumption, it encourages them to improve its productive powers …" (Book IV, Ch. I, p. 415). New trade theorists (Krugman, 1979; 1980) rediscovered scale economies as a rationale for trade, but limited it only to cases of imperfect competition. Under this assumption, "The range of possible outcomes of trade policy then becomes limited only by the analyst's imagination." (Rodrik, 1992, p. 156) Many contributions that followed the original seminal works by Krugman (1979, 1980) strongly support Rodrik's statement (*e.g.*, Helpman and Krugman, 1985; Bernard *et al*., 2003; Melitz, 2003).

Scale economies are not the only argument for trade liberalization made by the pro-liberalizers. Protection is known to lead to higher concentration in the domestic market. Their argument then runs that non-competitive market structures are presumed to not be conducive to improvements in productivity and technical efficiency. On the other hand, liberalization reverses the incentives by creating a more competitive environment. However, this relationship between market structure and innovation is one of the hotly debated and disputed areas in industrial organization. The Schumpeterian prospective, for instance, would be one to strongly disagree with the view that competition is conducive to either innovation or cost reducing investment.

Another argument used by pro-liberalizers is that inward-oriented regimes and macroeconomic instability go hand-in-hand. Macroeconomic instability often leads the output to fall below the full-capacity level which is certainly detrimental to growth in measured productivity. In addition, the overvaluation of domestic currency and shortages of imported inputs discourage domestic firms from trying to benefit from scale economies via foreign markets. Yet these arguments have nothing to do with trade policy per se (Sachs, 1987). The reality is that when technological performance is inferior due to mismanagement of macroeconomic policy, countries should change their exchange rate and fiscal policies. The inclusion of trade liberalization in the policy package is likely to be driven by ideology rather than economics. Indeed, once attention is focused on trade policy, it becomes extremely difficult to sustain the case that liberalization, as a general rule, must have a positive impact on technical efficiency.

The above theoretical uncertainties call for more empirical evidence in order to come to some kind of consensus regarding the relationship between trade liberalization and in turn trade openness and technical efficiency. The introduction of the Malmquist Productivity Index (Caves, Christensen, and Diewert, 1982) and frontier methods from production economics enabled the researchers to isolate TEC from TC. This led to a number of studies examining the effect of outward orientation (trade liberalization) on technical efficiency at industry or national economy level (*e.g.*, Iyer, Rambaldi, and Tang, 2008; Shafaeddin, 2005; Milner and Weyman-Jones, 2003; Lall, Featherstone, and Norman, 2000). Unfortunately their findings varied and did not conclusively lend credibility to either proposition: that trade openness does or does not improve technical efficiency. This study addresses the impact of trade openness on technical efficiency in the U.S. agricultural sector and aims to further contribute to this debate.

Model and Data

Stochastic frontier analysis (SFA) has become a popular tool to estimate the relationship between input and output quantities and has been primarily used to estimate the technical efficiency[1] of firms. This method, first proposed by Aigner et al. (1977) and Meeusen and van den Broeck (1977), has seen a surge in the past decade with extensions to estimate technical change, efficiency change, and productivity change measures using stochastic frontier analysis (*e.g.*, Greene, 1993; Kumbhakar and Lovell, 2000).

Here SFA, used to estimate technical efficiency, is extended to examine the importance of trade openness on technical efficiency for the U.S. agriculture sector. More specifically, the Battese and Coelli (1993) SFA model is used in this research. It allows us to trace the determinants of efficiency using a one-stage approach instead the traditional two-stage approach. The issues with using the two-stage approach and the advantages of using the one-stage approach are discussed in Wang and Schmidt (2002). The SFA model consists of a frontier production function and an efficiency model and,

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[1] Technical efficiency concept introduced by Farrell (1957) is defined as the distance of the observation from the production frontier and measured by the observed output of a firm. In other words, technical efficiency of a firm can be defined as a measure of how well the firm transforms inputs into outputs given technology. Technical efficiency can be estimated by parametric stochastic frontier analysis or non-parametric linear programming approach.

accordingly, the explanatory variables are classified as factor inputs and trade openness variables, respectively. The efficiency determinant variables enter the model in the first lag to minimize endogeneity problems. Recently this model has been used to examine the market structure conduct performance hypothesis and importance of financial ratio on technical efficiency (Shaik et al.).

Specifically, a stochastic frontier production function equation and trade equation is estimated with a firm's output and technical efficiency, respectively as endogenous variables. This can be represented as:

$$(1) \qquad \begin{aligned} y &= f\left(\mathbf{x};\beta\right)\cdot v - u \\ u &= f\left(\mathbf{z};\gamma\right).\varepsilon \end{aligned}$$

where $\mathbf{x}$ is a vector of input variables including t, time trend affecting the output y, β is the input parameter coefficients, $\mathbf{z}$ is a vector of trade openness variables affecting the technical efficiency u; v representing firm or time specific random error which are assumed to be *iid* and normally distributed variable with mean zero and variance σ_V^2; u representing the technical efficiency which must be positive hence an absolutely normally distributed variable with mean zero and variance σ_U^2.; and ε representing random error which is normally distributed with mean zero and variance σ_ε^2.

Equation (1) is used to econometrically estimate two models. The first model uses trade openness as the variable explaining technical efficiency with Hicks-neutral[2] production function. This is represented as:

[2] Hicks-neutral assumption implies a common technology change is associated with the production function. Non Hicks-neutral technical change implies technology is independently associated with each input variable. Ideally, it would be appropriate to statistically test between Hicks-neutral and non-Hicks-neutral change. However due to the degrees of freedom problem we assumed Hicks-neutral.

$$y_t = \alpha_1 + \beta_{1,1}\,Labor_t + \beta_{1,2}\,Capital_t + \beta_{1,3}\,FarmOrigin_t$$
$$(2) \qquad + \beta_{1,4}\,Energy_t + \beta_{1,5}\,Chemicals_t + \beta_{1,6}\,Services_t + \beta_{1,7}\,t + v_t - u_t$$
$$u_t = \alpha_2 + \beta_{2,1}\,TOpen_t + \varepsilon_t$$

In order to differentiate the effect of different components of trade openness, the Hicks-neutral production function along with import and export variables in the technical efficiency equation is estimated. This can be represented as:

$$y_t = \alpha_1 + \beta_{1,1}\,Labor_t + \beta_{1,2}\,Capital_t + \beta_{1,3}\,FarmOrigin_t$$
$$(3) \qquad + \beta_{1,4}\,Energy_t + \beta_{1,5}\,Chemicals_t + \beta_{1,6}\,Services_t + \beta_{1,7}\,t + v_t - u_t$$
$$u_t = \alpha_2 + \beta_{2,1}\,Exports_t + \beta_{2,2}\,Imports_t + \varepsilon_t$$

Factor inputs include standard variables in agricultural growth models such as capital, labor, energy, chemicals, farm-originated inputs, and purchased services. A time trend, *t*, is included to capture shifts in the frontier over time. Capital variables include durable equipment, service buildings, land, and inventories. Labor includes hired and self-employed labor. The farm originated inputs include feed, seed, and livestock inputs from the farm. Energy includes petroleum fuels, natural gas, and electricity used on the farm for agriculture production. Pesticides and fertilizers constitute the chemicals used on the farm. Finally, purchased services include contract labor services, custom machine services, machine and building maintenance and repairs, and irrigation from public sellers of water.

The efficiency effect model contains trade openness (Alcala and Ciccone, 2004) measured as the agricultural exports plus the agricultural imports divided by the agricultural gross domestic product (GDP), or alternatively trade openness divided into two components: agricultural imports divided by the agricultural GDP and agricultural exports divided by the agricultural GDP. All data are collected from the Economic Research Service (ERS) of the United States Department of Agriculture (USDA).

All factor inputs are typically expected to have a positive sign, *i.e.*, additional input quantities are expected to lead to an increased production level or an outward PPF move. There are possible exceptions to this rule and they are typically caused by an "overuse" of some resources where their additional use would not further increase the productivity level. The time variable normally has a positive sign indicating an increase in productivity over time. The efficiency equation, being the main target of our interest, contains the trade openness variable. As it was elaborated previously, the sign on the trade openness variable, based on various trade theory arguments, can be positive or negative.

Table 1 presents the summary statistics along with the units of the variable used in the estimation.

Results

Both variations of the model presented in equation (2), *i.e.*, efficiency equations containing different representations of the trade openness, have been estimated using log-log specification. Hence results are provided in the form of elasticities. The results are presented in Table 2 and 3 respectively for trade openness and export/import models.

(INSERT Table 2 HERE)

The first specification of the model, with trade openness being represented as the agricultural export plus the agricultural import divided by the agricultural GDP, yields some interesting results. A positive and significant coefficient associated with the time trend suggests a technical change in the agricultural sector during the period under consideration led to an increased output quantity index. Based on the parameter coefficient, a change from one year to the next would lead to a 0.02% increase in the output index. The only factor input with significant impact on the productivity is labor: a 10% increase in the use of labor would lead to a 2.23% increase in the output quantity index. This result, coupled with the fact that no increase in other inputs will raise the output quantity index, implies that all other factors have already being optimally used, and that the only increase in output may come from an increase in labor use. While this may sound unusual, US agriculture has been characterized as one of the sectors with the highest productivity within the US economy (Miljkovic, Jin, and Paul, 2008; Stiroh, 2002; Jorgensen and Stiroh, 2000). The substitution of labor for other factor inputs has taken place for several decades in the 20th century. Resulting rural over-depopulation then led to the lack of farm labor in a number of states, in particular where labor intensive agriculture (*e.g.*, vegetable and fruit industries) is dominant.

The efficiency equation of this model specification reveals that trade openness has no impact on technical efficiency. While this result simply states that, for the given data set, a change in agricultural trade openness does not impact the technical efficiency in agriculture, the implications of it are more significant. As it was stated at the very beginning of this paper, one of the key political motives for trade liberalization is an increase in productivity and technical efficiency. Once that rationale is proved to be redundant, it becomes difficult, from a producers point of view, to justify and promote trade liberalization. Hence this result is likely to fuel the usual argument between trade liberalizers and trade protectionists. In order to help resolve this issue, trade openness is divided into import and export shares and their impact on technical efficiency is measured.

(INSERT Table 3 HERE)

The second specification of the model contains agricultural imports divided by the agricultural GDP and agricultural exports divided by the agricultural GDP as the measure of trade openness. This model specification confirms the presence of the Hicks-neutral technical change. However, the factor input coefficients are somewhat different. This model indicates slightly more elastic PPF response to the change in labor use than the first specification, *i.e.*, a 10% increase in labor use leads to an increase in the TFP by 3.20%. Rationalizing the sign of this coefficient is the same as in the first specification of the model. The most significant departure from the results in the first specification is found in the efficiency equation. Unlike the first specification with overall trade openness not being statistically significant, the results here indicate that the share of agricultural imports in agricultural GDP and the technical efficiency move in opposite directions. Figure 1 indicates that the share of agricultural imports in agricultural GDP decreases over time.[3] The elasticity coefficient then may be interpreted more specifically as a 10% decrease in the share of agricultural imports in agricultural GDP leading to a 23.20% increase in technical efficiency suggesting a very elastic response in technical efficiency. This result is significant at a 10% significance level. The change in the share of agricultural exports in agricultural GDP has no significant impact on technical efficiency.

[3] Considering efforts made by GATT, especially during the Uruguay Round, and the WTO to liberalize very sheltered agricultural trade, declining trade openness over time measured as agricultural imports divided by agricultural GDP comes as a surprise considering that the US has always publicly championed free trade.

(Insert Figure 1 Here)

These results are partially consistent with some of the new trade theory premises. Krugman (1984) suggested in his model of "import protection as export promotion" that protectionist policies (assuming that increasing returns to scale takes the form of decreasing marginal costs) allow home firms to increase their domestic sales and therefore to reduce their marginal costs. With lower marginal costs, the home firms can become more competitive in world markets, and therefore increase their exports as well. Our results are obviously consistent with the first premise of Krugman's proposition: more protection yields more efficiency domestically. Indeed, the US has the rich history of protectionist policies, including well documented direct measures such as import tariffs, import quotas, or import licenses (*e.g.* Knutson, Penn, and Flinchbaugh, 1998; Miljkovic, 2004), and indirect measures such as sanitary and phytosanitary regulations (*e.g.*, Miljkovic, 2005). Some of the most recent US trade protectionist policies include side agreements of the North American Free Trade Agreement (NAFTA) to accommodate and protect domestic farmers.[4] Figure 1 clearly shows that protection has been working, *i.e.*, the share of agricultural imports in agricultural GDP decreased substantially over time, while our results suggest that it led to increased technical efficiency over time. The second part of Krugman's proposition about increasing exports could not be confirmed in our analysis. There may be several possible explanations for this outcome. First, the domestic market also grew substantially during this period in

[4] Side agreements following the signing of NAFTA on the imports of tomatoes, orange juice, sugar, or environmental standards are among those illustrating this point. For example, during the heat of the 1996 presidential election, the Clinton administration yielded to the demands of Florida tomato interests by negotiating a floor price on tomatoes imported from Mexico. Mexico's agriculture minister objected to the pact by indicating that this new barrier to trade would damage Mexico's producers and would cost jobs in a country already plagued by unemployment. (Knutson, Penn, and Flinchbaugh, 1998)

terms of its population and purchasing power. Domestic producers may have decided to cater to the needs of the domestic market first. Second, large investments into agricultural research internationally led to a "green revolution" in a number of less developed countries increasing their agricultural productivity manifold (Ruttan, 2002). Since these countries could now be self-sufficient, US exports were marginalized in many of the large less developed country's markets. Moreover, some of the less developed countries such as Brazil, Argentina, or Thailand became US competitors in the international agricultural markets. Third, global trade liberalization as well as a variety of regional trade agreements provided an opportunity to a number of countries to increase their exports. Unlike the United States that has the luxury of having a very large domestic market, most potential exporters of agricultural products in other countries are constrained by the small domestic market size and, naturally, had to turn to the international markets. Thus US producers and exporters may have faced very stiff competition in international markets and preferred to focus on the domestic market. Four, US has always had a conflicting approach to trade policy and farm policy by championing free trade while simultaneously providing significant protection to farmers via both price and income farm policies (Miljkovic, 2004; Knutson, Penn, and Flinchbaugh, 1998). These protectionist farm policies may have ensured comfortable access to domestic markets while at the same time providing disincentives to compete internationally.

Conclusions and Implications

The impact of trade liberalization on productivity and technical efficiency has been a point of scholarly debate for several decades now. The lack of a clear and transparent theory leading to a unique resolution of the issue led the profession down the path of empirical studying of the problem. This study was conducted in that spirit.

The results of this study indicate that overall trade openness does not have an impact on technical efficiency in US agriculture. Results changed when the trade openness was divided into export and import shares. These results indicate that trade protectionism illustrated with a decrease in the share of agricultural imports in agricultural GDP led to an increase in technical efficiency. A change in the share of agricultural exports in agricultural GDP had no impact on technical efficiency at all. These results are partially consistent with the premise of the new trade theory, but also seem to be driven by the intricacies of the agricultural sector and agricultural policy in the US and internationally. The implications of these results are very important.

Substantial resources have been spent in the US throughout the last several decades trying to ensure a barrier free access of domestic producers to international agricultural markets. The Uruguay Round of GATT negotiations and subsequent WTO negotiations are most recent and telling examples of such efforts. The US also engaged in a variety of regional trade agreements such as CUSTA and NAFTA. These negotiations were often motivated by the claim of free trade leading to increased productivity and technical efficiency in US agriculture. Given that this underlying motive for free trade may not exist based on our results, the question becomes: Is the cost of free trade negotiation, from an agricultural producers point of view, justifiable and who should bear it? Moreover, the most obvious question for one to ask is why do policy makers simultaneously engage in trade and farm policies with diametrically opposite interests: free trade policies with the intention of ensuring free access to all producers in all markets and farm policies targeted at protecting domestic producers from external volatilities and competition in the international markets. It seems that political capital is at stake here more than the interests of economic agents and as such begs for a political economy analysis to explain it.

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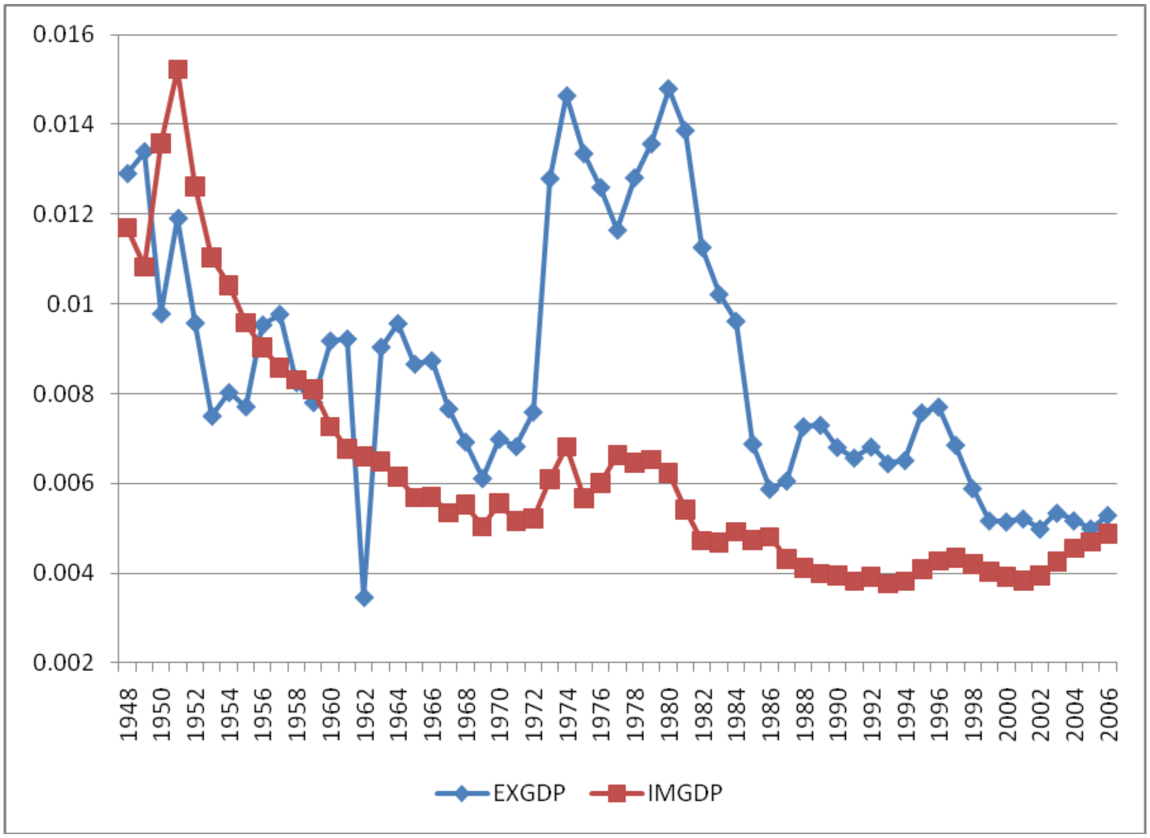

Figure 1. Share of Exports and Imports relative to GDP, 1948-2006

	Units	Mean	Standard Deviation	Minimum	Maximum
Total Output	Index	0.751	0.432	0.432	1.134
Capital	Index	1.155	0.111	0.972	1.353
Labor	Index	1.538	0.690	0.724	3.248
Farm origin	Index	0.917	0.174	0.548	1.164
Energy	Index	0.926	0.117	0.647	1.261
Chemicals	Index	0.722	0.292	0.201	1.145
Purchased Services	Index	0.784	0.197	0.426	1.144
Trade Openness	Ratio	0.015	0.005	0.009	0.027
Exports/GDP	Ratio	0.009	0.003	0.003	0.015
Imports/GDP	Ratio	0.006	0.003	0.004	0.015

Table 1. Summary statistics of the variables, 1948-2006

	Stochastic Frontier Production Function Equation			
	Parameter	Standard Error (SE)	Z-value	P[|Z|>z]
Intercept	-34.653	5.451	-6.35	0.0000
Capital	0.063	0.114	0.54	0.5835
Labor	0.223	0.105	2.11	0.0343
Farm origin	0.044	0.131	0.34	0.7342
Energy	-0.078	0.065	-1.19	0.2311
Chemicals	-0.018	0.029	-.63	0.5237
Purchased Services	0.057	0.083	0.68	0.4923
Year	0.018	0.002	6.54	0.0000
	Trade Openness Equation			
Intercept	-6.180	0.344	-17.93	0.000
Exports+Imports/GDP	-1.074	0.873	-1.23	.2187

Table 2. Parameter coefficients of production function and Trade openness function

	Stochastic Frontier Production Function Equation			
	Parameter	Standard Error (SE)	Z-value	P[|Z|>z]
Intercept	-38.951	6.729	-5.78	0.0000
Capital	0.1211	0.172	0.70	0.4817
Labor	0.3200	0.142	2.24	0.0247
Farm origin	-0.0504	0.126	-0.39	0.6912
Energy	-0.1259	0.123	-1.02	0.3065
Chemicals	0.0356	0.039	0.89	0.3699
Purchased Services	0.0869	0.066	1.31	0.1888
Year	0.0200	0.003	5.94	0.0000
	Trade Openness Equation			
Intercept	-7.766	0.824	-9.42	0.000
Exports/GDP	1.014	1.080	0.94	0.347
Imports/GDP	-2.320	1.332	-1.74	0.081

Table 3. Parameter coefficients of production function and Export/Import function