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AGRICULTURAL PRODUCTIVITY GROWTH IN CANADA: CONCEPTS AND EVIDENCES

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Issue

Productivity growth in Canada is a topic of continuing interest to policy makers and researchers who aim to improve on economic efficiency, living standards, economic sustainability of primary agriculture, and international competitiveness. The need to increase productivity growth in Canada has often been cited in federal and provincial budget statements. Economists have also added their voices to the productivity issue and have described a series of obstacles to productivity growth in Canada. These concerns make the measurement of productivity growth a very important issue.

The importance of Global Agriculture productivity with respect to food security and poverty alleviation in the developing world cannot be overemphasized. Since the Second World War, increasing agricultural productivity allowed for food output to more than keep pace with demand. This became possible because of the application of science to agriculture on the biological side in the developed countries and later transferred to less developed countries. By 2050, the world population is expected to grow by 40% and allowing for increased in income and changes in diet global demand for food, feed, and fibre is expected to grow by 70% (Bruinsma 2009). It is therefore imperative to improve productivity growth in agriculture to ensure that supply will keep pace with demand in order to avoid increase in prices and address food security and poverty problems in the developing world. As the developed countries continue to lead in the advancement of technology, there is the need for countries like Canada to find ways to improve on agriculture productivity.

By traditional benchmarks, Canada is not doing well on this front. Current evidence show that since 2000 productivity growth in Canada has been lagging behind that of the United States, its major trading partner, as well as many

OECD countries In addition, the current productivity growth in Canada is below its historical values (Rao *et al* 2008, Agriculture and Agri-Food Canada 2009). It is therefore very important to understand the sources and nature of productivity growth, and to recognize the importance of using the appropriate approach to measure productivity, especially in the agriculture sector. In this policy brief, we discuss the issue of productivity growth and its measures and relate them to innovations, economic growth, living standards and international competitiveness. We also briefly discuss some of the empirical evidence on measures of productivity and efficiency in the Canadian agriculture sector and emphasize the sensitivity of results due to assumptions and methods used. We finally discuss some policy implications.

Concluding Remarks and Policy Implications

Agricultural productivity is important with regards to economic efficiency, living standards, international competitiveness, economic sustainability, and has important policy implications. Canadian productivity growth has been lagging behind that of the United States, and many OECD countries. Moreover, evidence suggests an economically significant slowdown in agricultural productivity growth in Canada. Regarding technical efficiency, evidence suggests that farms are not fully efficient in Canada and hence, there is room for improvement. There are also mixed and sometimes competing evidences regarding agricultural productivity growth in the world, with predominant results that agricultural productivity growth has slowed, especially in the world's richest countries.

Measuring productivity growth is imperative but a very difficult task. The measures used to estimate productivity growth affect the magnitude of the estimates, as well as the direction of effects. Hence, the methodology and assumptions used in measuring productivity growth should be chosen with cautious. Most studies that seek to measure productivity have assumed that all firms are technical efficient. If firms are actually inefficient, then the productivity measure could be misleading. Regarding technical efficiency, it has been shown that methodological characteristics (estimation technique) and other study-specific characteristics (e.g., functional form, sample size, product analysis, dimensionality, geographical region or income level for the region where the farm data was collected) could affect the empirical estimates of technical efficiency indicator and lead to conflicting views or evidences. Therefore, more investigation is need in this area.

There is also the need for government intervention to increase productivity growth. It has been shown that technical change is an important determinant of productivity growth. Increasing funding for agricultural research is essential as it could counter the productivity slowdown in Canada. Private and public investment in agricultural science and technology could improve productivity growth. Furthermore, public sector should focus more on basic innovations, farmer education and R&D infrastructure. For example, government policies that promote the development of institutions, which will improve farmers' education to ensure that they use existing technologies very effectively as well as to introduce new and advanced methods of production.

It is also vital to improve productivity growth in agriculture in order to ensure that supply will keep pace with demand in order to avoid increase in prices and address food security. Furthermore, the ability of Canadian firm to compete with foreign competitors does depend on the dynamics of productivity to improve on the terms of trade. The only way Canadian firms can compete with American firms will be to increase innovative activities in order to close the productivity gap that exists between the two countries.

Productivity, Innovation and Competitiveness

In the neoclassical growth model, capital accumulation can only drive income growth in the short run due to diminishing returns to capital. According to the model, long run productivity growth is entirely due to exogenous technical progress. The new growth model addresses this shortcoming by demonstrating why capital might not suffer from diminishing return and that long run productivity growth could be obtained without exogenous technical progress. One of the important contributions of the new growth model is the broadening of investment to include human capital, public infrastructure and research and development (R&D). Romer (1986) in his pioneer work on the new growth theory demonstrated the possibility of external effects as R&D efforts by one firm spill over to affect the stock of knowledge available to all firms.

The new growth model clearly sets the stage to explicitly examine the relationship between innovation and productivity growth mainly through learning by doing, investment in R&D and human capital. Rao *et al* (2001) define innovation as a continuous process of discovery, learning and application of new technologies and techniques from many sources. For instance, beside internal mechanisms, a firm's technological capacity may be influenced by external factors such as the educational system and research infrastructure. This highlights the importance of massive and sustained public expenditure on research infrastructure, a key component of overall R&D, to promote innovation and growth in productivity. Rao *et al* (2001) classified innovations into two components: fundamental/basic innovations and applied innovation. Fundamental/basic innovation comprises new technological approaches, ideas and processes. It is considered as a small, but important, part of total innovation effort. Applied innovation, the greater part of innovation, occurs when existing technologies are used in a new context or in new ways, or when research that addresses a particular problem is conducted, or when products or processes developed abroad are utilized by firms at home. Both types of innovations are enhanced by investment in human capital and R&D. In a small open economy like Canada, global links and investment in machinery and equipments are important for the adoption and diffusion of new technologies.

Innovation and productivity growth in the agriculture sector depends on many factors such as the accumulation of human and physical capital, geographical constraints, such as soil quality and climate (Gutierrez 2002). It also depends on government policies to promote the development of institutions, which will improve farmers' education to ensure that they use existing technologies very effectively as well as to introduce new and advanced methods of production (Gutierrez 2002). Hence, the need for productivity improvements in the agriculture sector requires collaborative efforts between the public and private sectors with the public sector focusing more on basic innovations, farmer education and R&D infrastructure while the private sector focus on applied/mechanical innovations. The Public investment will promote technology adoption, stimulate complementary on-farm investment and input use and are needed for marketing agriculture products.

The benefits of innovations and productivity growth are numerous. It leads to increase in growth of per capita GDP and improvement of living standards. The phenomenal productivity growth and improvement in living standards in United State in the 1990s has often been attributed to its dynamism and superior innovation record and sustained increases in growth in real GDP per capita (Nanel 2007 and

O'Mahoney 2007). Another benefit of innovations and productivity growth is improvements in international competitiveness and exporting activities of firms. International competitiveness of the Canadian economy has for a long time been a relevant issue for policy and research. In his classical description of capitalist dynamics, Schumpeter demonstrated how innovations in products, production processes, organization and marketing are key factor for shifts in international competitiveness. This implies a strong positive relationship between productivity and exporting activity at the firm level. Bruno *et al* (2010), and Lileeva and Trefler (2007) have explained this pattern as resulting from firms self-selecting exports activities through their investment decision. The ability of Canadian firm to compete with foreign competitors does depend on the dynamics of productivity to improve on the terms of trade. Canadian firms in recent past have relied heavily on price and cost related factors to enhance their international competitiveness especially with American firms, as the Canadian dollar was very low. The recent experience of the rise in the Canadian dollar has showed that these price factors of international competitiveness have only short run effect and that the only way to achieve long run international competitiveness is through innovations and technological advancements. As earlier mentioned, Canada's major trading partner, the US has had phenomenal growth in productivity in recent times. The only way Canadian firms can compete with American firms will be to increase innovative activities in order to close the productivity gap that exists between the two countries.

Measures of Productivity and Efficiency

Measures of productivity and its growth are important concepts for policy development. The measures differ by concept/type of productivity and by approach of measurement. Conceptually, productivity growth can be classified into three components: technical change, scale effects, and changes in the degree of technical efficiency (Coelli *et al* 2005). Technical change refers to technological progress in its broadest sense, including advances in physical technologies and innovations in the knowledge base. Scale effects occur when additional output requires less than proportionate increase in inputs. Technical efficiency occurs when resources are used more efficiently by applying practices from the present stock of knowledge.

In terms of approach, productivity measures are broadly divided into partial and total measures. The most common partial productivity measures for the Canadian agriculture sector are those that refer to the amount of output per unit of a particular input. They are crop yield and labor productivity. Crop yield is a measure of output per unit of land. It is normally used to access the success of new production practices or technology. Labor productivity measures the output per economically active person (EAP). These measures can be misleading as they reflect the joint effect of a host of factors and may not give any clear indication of why they change over time. For instance, land and labour productivities may rise due to increased use of other inputs such as tractors or fertilizers. They may also increase due to a move to high value crops.

The total productivity measures are grouped into: index numbers or growth accounting techniques, econometric estimation of production relationship (Stochastic Frontier Analysis- SFA and the Regression Quintile Production Frontier Analysis) and non-parametric approaches (Data Enveloping Analysis-DEA). Index numbers or growth accounting techniques imposes several strong assumptions about technology and aggregate all inputs and outputs into input and output indices to calculate a total factor productivity (TFP) index. In the 1950s and 60s the approach was used to calculate the Solow residual as a measure of productivity. Based on Tornqvist-Theil index, the growth rate of TFP can be written as:

$\dot{TFP} = \dot{Q} - \dot{X}$, where $\dot{Q}$ is the rate of change of the aggregate output index, and $\dot{X}$ is the rate of change in the aggregate input index. However, this approach does not allow for the decomposition of scale effect and technical change. Stewart e*t al* (2009) and Stewart (2006) have used a complementary econometric technique combined with Tornqvist-Theil indexing procedures (often termed as *superlative index*) to decompose the growth rate of TFP into technical change and scale effects. Another strand of econometric estimation is the following:

(1)

$$\ln y = \alpha_0 + \alpha_1 T + \alpha_2 \ln X + \nu$$

where y is an aggregate output index, T is a time trend, X is an inputs index, and ν is a symmetric error term. From equation (1) α_1 measures technical change over time and α_2 measures the scale effect. With the development of the endogenous growth models in the 1980s and 1990s came the "new growth accounting" as researchers incorporated omitted variables (particularly human capital and R&D expenditures) in the analyses. Both techniques yield measures of technical change while assuming technical efficiency.

Due to the poor performance of the index number approach to measuring productivity, Aigner et al. (1977) and Meeusen and van den Broeck (1977) proposed the stochastic frontier production function approach (SFA) where a non-negative random variable (one-sided error) (μ_t) representing technical inefficiency in production is added to a symmetric error term (ν_t). The idea was to improve on the estimation of productivity growth by using the production function that allows for technical inefficiency while using less restrictive assumptions regarding aggregation and production function They specified a production function (in a log form) for a sample of *N* firms as:

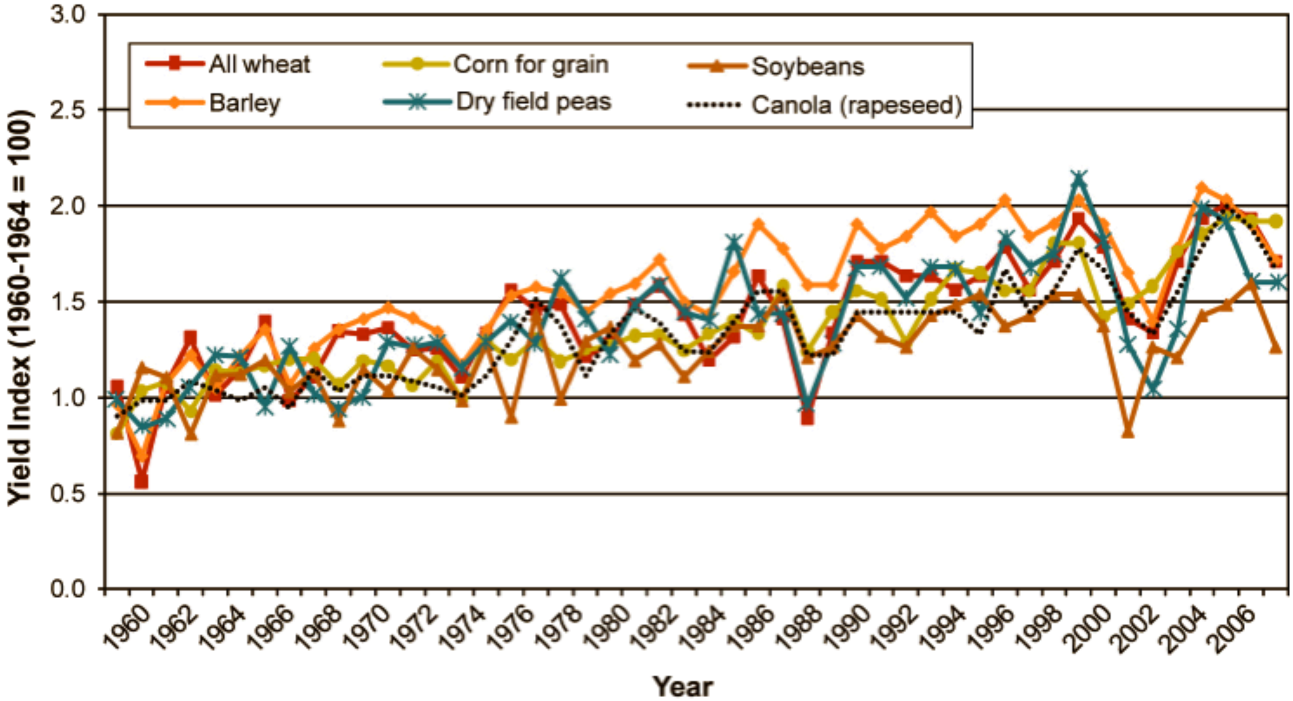
(2) $$\ln(Y_i) = F(X_i, \beta) + \nu_i - \mu_i$$

i= 1,2,…,N

where Y_i is the output of the *i*th firm; X_i is the vector of input quantities used by the *i*th firm; β is a vector of unknown parameters to be estimated. The parameters of the model are estimated by Maximum Likelihood technique given suitable distributional assumptions for the error terms. Subject to the constraints that $(\mu_t) \geq 0$ for all firms, the idea is to minimize the sum of (μ_t) if firms are efficient. The main criticism is that there is not *a priori* justification for the selection of any particular distributional form of the μ_i.

Following the development of quintile regression by Koenker and Basset (1978), researchers have used the method for the estimation of frontier production functions (Behr, 2010). Quintile production frontier function is an econometric approach, which differs from the SFA by not requiring the imposition of a particular form on the distribution of the inefficiency term. The technique estimates the efficiency production frontier by a quintile regression of high percentile, which describes the production process as the obtained regression parameters display the "optimal" technique used by the most efficient farms (farms that produce on the production frontier). Efficiency estimate of all farms are derived by using the obtained coefficients and comparing each farm's factual output with its potential output using the "optimal" technique. An appealing characteristic of the approach is that, it is robust to deviations from distributional assumptions since it imposes asymmetric distribution of the error term. However, quintile regression is not designed

Figure 1. Canadian crop yields, 1960-2007 (base 1960:1964=100)



Source: Veeman and Gray (2010)

for investigation relationship between variables, such as investigating the determinants of technical change or technical efficiency which may be of great interest to policy makers. The choice of the upper quintile for the estimation of the production frontier is arbitral as quintiles differentiation depends on the size of the sample and the amount of information it contains about the upper tail.

The DEA approach to frontier estimation was developed after Charnes *et al* (1978) provided measures of efficiency in production based on the works of Debreu (1951) and Farrell (1957). It was proposed as an alternative to growth accounting approach to calculating TFP prior to the development of the endogenous growth theory. The approach uses lineal programming technique to identify the input-output combinations that define the production frontier (technological efficiency) either overtime or across countries. When applied to time series data, efficiency is defined as the proportion of output not explained by the inputs and is measured relative to other operations in the data set. The calculated efficiency index can be used by itself for comparative purposes or as a dependent variable to examine what factors might affect technological efficiency. The approach shares the advantage of the SFA by not imposing restrictive assumptions on production technology. However, since the model is not statistical, it cannot be statistically tested or evaluated.

Whereas various methods of estimating productivity growth may yield different results due to different assumptions and methodological idiosyncrasies, it is very important to note that the different methods should not be viewed as competitors. For instance, most productivity measures, total or partial, have the underlying assumption that firms are efficient. This may lead to inaccurate estimate of the productivity growth when firms are actually not efficient. Beside these problems, there could be important synergies of methods to generate

Table 1. Average annual compound percentage growth rates for Prairie aggregate agricultural inputs, outputs, and productivity (TFP), 1940-2004

	1940-2004	1940-1959	1960-1979	1980-2004	1990-2004
TFP growth	1.56	1.25	1.48	1.80	1.46
Input growth	0.86	-0.03	1.45	0.57	0.21
Output growth	2.43	1.22	2.95	2.38	1.67

Source: Stewart (2006)

comprehensive results for policy analysis. For instance econometric methods are used to analyse the determinants of TFP obtained by the index method (Stewart *at al* 2009 and Stewart 2006). Future research using Canadian data could also combine the quintile production frontier function to obtain the proportion of inefficient firms and use conventional linear procedure to estimate the probable causes of inefficiencies.

Evidence on Measures of Productivity and Efficiency

Veeman and Gray (2009, 2010) have examined agricultural production and productivity in Canada, and discussed the shifting patterns of agricultural production and productivity overtime. They measured agricultural productivity in terms of partial productivity such as crop yields/land productivity, livestock yield gains and labour productivity, and total factor productivity (TFP). They showed that yield trends for the major field crops grown in Canada (wheat, barley, canola, corn, soybean, peas) exhibits constant absolute growth (about 60%) but, declining proportional growth rate (Figure 1). The yields were based on data from CANSIM and were average actual farm crop yield (yield per seeded acre). They also estimated labour productivity in Canadian crops and animal production based on statistic Canada data. They found that labour productivity grew very rapidly (4.7% per year) from 1961 to 2005, while livestock productivity gains have also been achieved over the period.

Based on Stewart (2006) and Stewart *et al*, (2009) estimations of TFP, Veeman and Gray (2009, 2010) reported on TFP in Canada. Stewart (2006) used a superlative indexing methodology to measure TFP. Specifically, he estimated a three-equation SUR system and total factor productivity measures were based on Tornqvist-Theil indexing procedures. The result of the study indicated that TFP growth for crops and livestock range from 0.6% per year based on gross output to 1.4% per year based on value added. Hence the growth rate has been considerably slower. Moreover, in western Canada's prairie region, productivity grew at a rate of 1.56% a year from 1940 to 2004 (Table 1). In addition, the aggregate output grew by 2.43% over the period, while aggregate input (e.g., land, labor, capital, materials) grew by 0.86% respectively. Historically, crop productivity growth has been higher than productivity growth in livestock but not from 1990 to 2004 period. Stewart (2006) decomposed productivity growth into technical change and scale effect, and found that technical change mainly contributed to productivity growth in crops, while economies of scale were important for generating growth in the livestock sector.

Veeman and Gray (2009) concluded that: "In summary, both the study of Canadian crop yields and the analysis of total factor productivity growth in the crops sector in the prairie region of western Canada indicate a slowdown of productivity growth in crop production since 1990." Furthermore, they suggested that: "Increased funding for agricultural research would help to counter the productivity slow-down in crops and to ensure that future livestock sector productivity growth could be based relatively more on technical change and less on scale economies associated with output expansion. Improved productivity performance, led by increased funding for R & D, is critical to the future competitiveness and economic sustainability of Canada's primary agriculture."

Alston and Pardey (2009) in their synthesis of "Theme Overview: Agricultural Productivity and Global Food Security in the Long Run" based on the papers collected under this Choice theme that explored patents in agricultural productivity growth around the World, summarized the following main results: "…China has had continuing high rates of productivity growth, pulling the global average up, while the countries of the FSU (former Soviet Union) and Eastern Europe have had a dismal record of productivity, especially during the initial years of transition, pulling the global average down... among developed countries generally, agricultural productivity growth appears to have slowed significantly during the most recent 10-20 years, possibly reflecting an earlier slowdown in growth of spending on certain types of productivity enhancing agricultural R&D."

They also concluded that: "If they are sustained for more than a few years, these diverging patterns of productivity growth can be expected to have very significant implications for international competitiveness and comparative advantage in agriculture among nations, and among regions of the world. The long-term outcomes will turn on the influences of determinants of productivity patterns that cannot be controlled in the near term, such as climate change, and other determinants that can, such as private and public investments in agricultural science and technology."

Fuglie (2008, 2010) examined long-run productivity trends in the global agriculture sector using an index number approach. Fuglie (2010) stated that "Contrary to some other authors, I find no evidence of a general slowdown in sector-wide agricultural productivity, at least through 2007. If anything, the growth rate in agricultural TFP accelerated in recent decades, in no small part because of rapid productivity gains in several developing countries, led by Brazil and China, and more recently to a recovery of agricultural growth in the countries of the former Soviet bloc." He also concluded that "it is also clear that agricultural productivity growth has been very uneven. The evidence in this chapter suggests TFP growth may in fact be slowing in developed countries while accelerating in developing countries."

Alston *et al* (2010a) in their analysis of "Global Patterns of Crop Yields and Other Partial Productivity Measures and Prices" used a range of partial productivity measures (such as yield of major crops, measures of aggregate agricultural output per unit of land or labour employed in production) to examine productivity growth. Contrary to Fuglie (2008, 2010), they found evidence of an economically significant slowdown in agricultural productivity growth in most of the world since 1990; with the exception of China and Latin America. They concluded that "In the rest of the world—including both the world's richest countries and the world's poorest countries—the slowdown in agricultural productivity growth has been substantial and widespread."

To sum up, there are mixed and sometimes competing results or evidences regarding

Table 2. Selected overview of empirical studies of technical efficiency in farming

First Author	Year	Country	Product(s)	No. obser.	Mean TE
I. Non-parametric					
Cloutier	1993	Canada	Dairy	187	89.8
Weersink	1990	Canada	Dairy	105	91.8
Mean					*78.3*
II. Parametric					
Deterministic frontier					
Amara	1999	Canada	Potato	82	80.3
Mean					*70.2*
Stochastic frontier					
Giannakas	2001	Canada	Wheat	900	76.9
Mean					*77.3*
Overall mean					**76.6**

Source: Bravo-Ureta *et al* (2007)

agricultural productivity growth in the world, with predominant results that agricultural productivity growth has slowed, especially in the world's richest countries. The measures used to estimate productivity growth could not only affect the magnitude of the estimates, but it could even alter the direction of effects as well. Hence, measuring productivity growth should be with cautious of the methodology and assumption used, as it has very significant policy implications. Alston *et al* (2010b) in their synthesis and collusion chapter, based on the chapters of a book collected under the theme "The Shifting Patterns of Agricultural Production and Productivity Worldwide" stated that: "Agricultural productivity is interesting and important but surprisingly difficult to measure meaningfully and discuss in simple and definitive terms." Lastly, the above mentioned studies assumed that all farms are fully technically efficient. If they are not, then the productivity measures could be misleading. Hence, more investigation is need in this area.

Bravo-Ureta *et al* (2007) collected 167 farm level technical efficient (TE) studies of developed and developing countries and undertook a meta-regression analysis to evaluate the effect of methodological characteristics (estimation technique) and other study-specific characteristics (e.g., functional form, sample size, product analysis, dimensionality, geographical region or income level for the region where the farm data was collected) on empirical estimates of TE indicator. Hence, they examined the impact of various attributes of a study on TE estimates.

An overview of the Canadian papers used in this evaluation is presented in Table 2. All these papers were sorted by the methodology implemented in the studies. Mean TE by study and mean TE by methodology (all studies used) are also presented. The mean TE reported by studies on technical efficiency in Canada range from 76.9 to 91.8, which are not fully efficient and hence, there is a room for improvement in this front.

Based on their analysis they concluded that: "The econometric results suggest that stochastic frontier models generate lower mean TE (MTE) estimates than non-parametric deterministic models, while parametric deterministic frontier models yield lower estimates than the stochastic approach… In addition, frontier models based on cross-sectional data produce lower estimates than those based on panel data whereas the relationship between functional form and MTE is inconclusive."

Based on the results, they also suggested and stated the following: "On average, studies for animal production show a higher MTE than crop farming… the studies for countries in Western Europe and Oceania present, on average, the highest levels of MTE among all regions after accounting for various methodological features. In contrast, studies for Eastern European countries exhibit the lowest estimate followed by those from Asian, African, Latin American, and North American countries. MTEs are positively and significantly related to the average income of the countries in the data set but this pattern is broken by the upper middle income group which displays the lowest MTE."

To sum up, technical efficiency in agriculture is very important and has significant policy implications. For instance, there could be room to increase agricultural output without additional inputs given existing technology. However, methodological characteristics and other study-specific characteristics, or various attributes of a study could affect the empirical estimates of technical efficiency and lead to in mixed results and conflicting views or evidences.

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