Agricultural Efficiency in Myanmar Efficiency Differences and Drivers behind them in Myanmar's States and Regions

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ABSTRACT

Efficiency in agricultural production is crucial for developing countries. This statement is particularly true for Myanmar, where more than two-thirds of the population relies on agriculture for their livelihoods. By using a set of four surveys collected by the World Food Program during the period 2012-2015, this paper measures agricultural efficiency in Myanmar's states and regions using both stochastic frontier analysis (SFA) and data envelopment analysis (DEA), while controlling the geographical conditions. Results show that areas that are the traditional focus of agricultural policies (Shan State and the Ayeyarwady river basin) are highly inefficient. To understand this result, the paper analyses how differences in efficiency relate to available capital sources for the farmers, ownership of assets, and crop diversification. This analysis sheds light on the role of monitoring, credit constraints, property rights, and the production of market-oriented crops. Finally, the paper analyses the prevailing conditions in individual regions and states and discusses policy opportunities to increase efficiency in the different administrative units.

Keywords: Myanmar, agriculture, efficiency, data envelopment analysis, stochastic frontier analysis

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INTRODUCTION

In 2011, Myanmar shifted from a military regime to a civilian-led government and started its liberalisation process to join the global economy. The agricultural sector changed production from that defined by the government to production decisions taken at the farmer level. Institutions and legislation on land tenure have been changed to encourage privatisation and exports. Under this new paradigm, efficiency, understood as the capacity of the farmers to maximize their output given a set of inputs, becomes a central indicator to measure agricultural performance and guide the design of public policies. However, due to the large variety of agricultural products, most of the studies of Myanmar have focused on single products (Aung, 2012; Lift, 2019) Different techniques have evolved, that can cover multiple sources of inputs and outputs to measure the efficiency of large agricultural areas (Hossain *et al.,* 2012; Toma *et al*., 2015; Liu *et al*., 2015) Nevertheless, a common assumption on these papers is that all farmers have the same type of asset ownership. This assumption helps to highlight some of the technical elements associated with production inefficiencies, but it shadows important concepts related to the context where production takes place. To illustrate this point, consider agricultural output as a function of assets such as land, capital, and labour. For the case of assets, it is known that ownership share may impact how the farmers use them. Baland and Platteau (2007) have shown that community structures and social norms have a direct effect on the coordination and adequate use of common resources. Thus, the incentives to use a community power tillers and water pumps are different from the incentives of using the same tool but fully owned by the farmer. Furthermore, if the capital is accessed via debt, principal-agent problems can emerge depending on the monitoring capacity of the debtor, and on the regularity of interaction between the debtor and the borrower (Coleman, 1988; Coate and Ravallion, 1993; Udry, 1994). Hence, how inputs are used strongly depends on these tenure and acquisition characteristics, that, at the same time, rely strongly on the social norms and institutions.

The recent and gradual liberalisation of the Myanmar economy has caused substantial heterogeneity in the country, where traditional institutions and social norms clash with market forces. Therefore, using agricultural information from Myanmar after liberalisation and integrating it with the new techniques to measure efficiency, this paper expands the literature on agricultural economics in Myanmar in two aspects. First, it is the first study that covers the whole country and can make the efficiency measure comparable across states and regions. Second, it goes beyond the technical analysis and shed light on how access to capital, ownership of assets, and crop selection are associated with farmers' efficiency. Thereby, this paper identifies the main causes of inefficiencies in the different administrative units of the country and recommend ways to improve the inefficiencies.

MATERIALS AND METHOD

Data sources

The study relies on two sets of data sources: one on the farm information and another on the geographical conditions that can affect the farm production efficiency.

The first data source, outlining farm information, comes from a set of four surveys, under the name of Food Security Surveys (FSS) produced by the World Food Program during the period of 2012-2015. These surveys interviewed 27,000 rural households across Myanmar. The households were randomly selected and stratified at the village tract level (a village tract is an administrative unit in smaller than townships). The number of households used for the study after rural households that are not dedicated to farming activities and registers with a large number of missing values were removed (Table 1). The only division missing the data is Nay Pyi Taw, the country's administrative capital. The reason is that the region is young (established in 2005), and its productive structures are focused on the support of the government structures. The two mid-columns of table 1 show that the sample covered a large share of townships in most states/regions except for some that are impacted by conflict (Rakhine, Shan and Kachin) and highly urbanized areas (Yangon and Mandalay), that for those conditions are not relevant for this study. It is worth noting that the four surveys that comprise this set of data from the World Food Program have some variations on the number of questions used. However, this paper used only common questions from the following sections: household income, expenditures, credits and debts, livestock and other assets, and agricultural production.

Table 1 Sample size statistics by state/region

States /Region	Total Townships	Townships in the sample	Farmers
Ayeyarwady	26	26	182
Bago (East)	14	12	63
Bago (West)	14	14	116
Chin	9	8	107
Kachin	18	13	193
Kayah	7	6	258
Kayin	7	5	159
Magway	25	22	252
Mandalay	28	16	169
Mon	10	9	79
Rakhine	17	15	217
Sagaing	37	36	865
Shan (East)	15	8	162
Shan (North)	45	16	64
Shan (West)	21	19	192
Tanintharyi	10	10	79
Yangon	47	11	102
Total	**350**	**246**	**3,259**

The second set of data sources is compiled from multiple places and aims to capture the geographical factors that affect agriculture. Out of this group, the first variables are temperature and precipitation. These variables were estimated by The Asia Foundation for the project Township Development Indicators (TDI) database using WorldClim Global Data (v1.4). Then, two variables were created to approximate access to water sources.

Data Analysis

First Method

For this purpose, Landsat 7 and 8 images, downloaded via Google Earth Engine, were used to calculate two different Normalized Difference Vegetation Index (NDVI): $NDVI_{(Green, NIR)}$ and $NDVI_{(Green, SWIRI)*}$ To construct these variables, all Landsat available images were collected for the period of 2012-2017. Then, by year, all the rasters were merged into a single raster where the band calculates the average value of the corresponding bands of the rasters from the same year. Then, using the processes suggested in Mcfeeters (1996) and Xu (2006), the indices were calculated for each year. Finally, the six values of each index (one per year during the study period) were averaged at the village track level (administrative unit that is smaller than the township). Finally, two variables were created to estimate the elevation and the slope of the farmland. For this purpose, Shuttle Radar Topography Mission (SRTM) Digital Elevation Data V.4 was downloaded via Google Earth Engine. Then, using the elevation, the slope was estimated using ArcGIS 10.5 default protocols.

In general terms, production (in) efficiency is related to how distant a production unit (in this case, a farmer) is from the production frontier (i.e., if the farmer can use its inputs at its full potential, how much more can it produce). However, due to the diversity of inputs and outputs, there is no definite answer in the best way to estimate the production frontier. The two most popular methods for the estimation of the frontier are the Stochastic Frontier Analysis (SFA) and the Data Envelopment Analysis (DEA) (Coelli, 1995). The methods have different drawbacks and advantages, making them complementary to each other. This paper analyses agricultural efficiency using both methods, similar to work by authors such as Sharma *et al.*, (1997), Tingley *et al.*, (2005), and Theodoridis *et al.*, (2008). Following the notation of Aigner, Lovell, and Schmidt (1977), SFA is stated in equation 1

$$y_i = X_i\beta + v_i - u_i \text{ such that } v_i \sim N(0, \sigma_v^2), u_i \sim \mathcal{F} \quad (1)$$

where i is the production unit, y_i and X_i are the production outcome and a vector of production inputs (adequately transformed), v is a normal error, and U is the inefficiency term that is driven by a distribution F that has positive support[1]. The main advantage of this technique is that it estimates the parameters of the production frontier on a given functional form. Hence, based on the estimated values, it is possible to distinguish effects from additional inputs to general data noise that is captured in the first stochastic term v_i. The main drawback is that the same production function is shared by all the farmers. Since farmers produce different types of crops, the method fails to capture that specific input mixes can be beneficial for production, depending on the crops produced. Table 2 displays the different inputs that are considered for the analysis.

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[1] After different experiments, a truncated normal is chosen due to its data adjustment

Table 2 Average values of the input variables, making up the vector of production inputs for that enters into equation 1 by X_i

States / Region	Townships (Total/sample)	Farmers	Agricultural expenses (log)	Available land area	Livestock assets	Tool Assets	Precipitation	Temperature	Slope	Elevation	$NMDI_{(Green, NIR)}$	$NMDI_{(Green, SWIRI)}$
Unit	Townships	No	MMK_log	Acres	Dimensionless	Dimensionless	Inches	Degree Celsius	Degree	Meters	Dimensionless	Dimensionless
Ayeyarwady	26/26	182	12.70	10.54	-0.08	1.35	243.21	26.82	0.82	20.39	-2.75	0.08
Bago East	14/12	63	12.75	13.21	0.30	1.52	274.22	26.75	1.19	42.82	-1.98	0.10
Bago West	14/14	116	12.28	9.71	0.21	1.57	155.60	26.99	1.13	46.61	-1.73	0.10
Chin	9/8	107	10.11	2.16	-0.30	-0.81	217.15	20.71	20.44	1,040.20	-4.00	0.11
Kachin	18/13	193	12.00	4.82	0.72	0.67	202.96	20.94	12.59	831.43	-3.84	0.10
Kayah	7/6	258	11.24	4.14	0.15	0.41	120.39	22.92	11.45	919.88	-2.59	0.11
Kayin	7/5	159	10.81	5.27	-0.01	-0.07	271.25	26.06	6.62	213.70	-3.38	0.11
Magway	25/22	252	11.32	6.70	0.71	1.00	97.06	26.42	3.80	190.56	-1.91	0.10
Mandalay	28/16	169	11.79	7.63	0.26	0.64	83.18	26.33	2.32	256.43	-1.33	0.10
Mon	10/9	79	12.28	8.08	-0.23	0.47	433.86	26.70	2.85	58.94	-2.64	0.10
Rakhine	17/15	217	11.36	4.83	0.36	-0.14	377.43	25.42	6.36	4,340.87	-3.40	0.09
Sagaing	37/36	865	11.74	5.79	0.60	1.27	155.93	24.08	6.39	338.80	-2.90	0.10
Shan East	15/8	162	10.15	2.64	0.81	0.63	137.07	21.56	15.52	1,088.69	-3.93	0.11
Shan North	45/16	64	11.39	4.83	0.19	0.60	155.75	19.84	11.76	1,036.36	-3.17	0.11
Shan West	21/19	192	11.37	3.93	0.37	0.72	151.57	20.63	9.75	1,127.26	-2.68	0.11
Tanintharyi	10/10	79	11.32	6.45	-0.35	-0.32	327.13	26.05	7.68	124.08	-4.21	0.10
Yangon	47/11	102	12.75	13.91	0.11	1.82	267.73	27.05	0.83	12.54	-1.93	0.08

For the next calculation, the output variable is the logarithm of the income of the household. As input ten variables were used where four are determined by the farmer (agricultural expenditure, livestock assets, tool assets, available land area) and the remaining six are given by the environmental conditions which are divided in topographic characteristics (elevation and slope), hydrographic characteristics (precipitation, NDVI) and weather characteristics (temperature). The first group is referred to as farmer variables, while the second group is denominated environmental variables. It is worth noting that livestock assets and tool assets were constructed from the list of variables associated with the assets of each type owned by the farmer. The reason for this was to create a uniform measurement that weights the various types of assets according to their covariance structure. Finally, due to the need of the production function specification, different functional forms were tested. Out of these calculation, the best functional form was obtained when the quadratic terms of the environmental variables were included. Table 3 shows the estimated coefficients of SFA regression.

Table 3 stochastic frontier analysis regression – estimated coefficients for the input variables

Income Logarithm Frontier	Coefficient	Std. Error	z	P>z	[95% Interval]	Confidence
Livestock assets	0.012836	0.012466	1.03	0.303	-0.0116	0.037269
Tool Assets	0.091282	0.012553	7.27	0	0.066678	0.115885
Agricultural expenses (log)	0.138813	0.015979	8.69	0	0.107495	0.170131
Available land area	0.015409	0.003527	4.37	0	0.008496	0.022322
Precipitation	0.00031	0.001039	0.3	0.765	-0.00173	0.002346
Precipitation (square)	-1.52E-06	1.91E-06	-0.79	0.427	-5.26E-06	2.23E-06
Temperature	0.167411	0.175533	0.95	0.34	-0.17663	0.511449
Temperature (square)	0.003883	0.003739	1.04	0.299	-0.00345	0.01121
Slope	-0.03977	0.017003	-2.34	0.019	-0.07309	-0.00644
Slope (square)	0.000839	0.000681	1.23	0.218	-0.0005	0.002172
Elevation	-6.5E-05	3.03E-05	-2.16	0.031	-0.00012	-6.00E-06
Elevation (square)	2.34E-09	1.47E-09	1.6	0.111	-5.35E-10	5.22E-09
NDVI1	0.114864	0.10334	1.11	0.266	-0.08768	0.317408
NDVI1 (square)	0.037869	0.0184	2.06	0.04	0.001807	0.073932
NDVI2	8.813859	3.770784	2.34	0.019	1.423258	16.20446
NDVI2 (square)	-62.7976	26.27864	-2.39	0.017	-114.303	-11.2925
Constant	8.109225	2.073574	3.91	0	4.045094	12.17336
		μ				
Constant	-994.483	497.3866	-2	0.046	-1969.34	-19.6231
		U_σ				
Constant	6.56864	0.500542	13.12	0	5.587596	7.549684
		V_σ				
Constant	-0.06657	0.037601	-1.77	0.077	-0.14027	0.007124
σ_u	26.69082	6.679936	4	0	16.34297	43.59061
σ_v	0.967261	0.018185	53.19	0	0.932268	1.003568
λ	27.59422	6.680596	4.13	0	14.5005	40.68795

Second method

The second method commonly used to measure efficiency is DEA. DEA is a non-parametric approach to measure efficiency (Charnes *et al*, 1978). Equation 2 and 3 present the main structure of the model. For each individual j,

$$z_j = arg \min_{\beta_j > 0} X_i \beta_j \ \ such\ that\ \forall i\ X_i \beta_j \geq y_i \qquad (2)$$

$$u_j = 1 - \frac{y_j}{z_j} \qquad (3)$$

In contrast to SFA, DEA defines a set of production coefficients for each farmer and uses this data to compare itself against the production coefficients of other farmers. The main advantage of this method is its non-parametric definition of the production function. However, in contrast to SFA, it does not contemplate a stochastic component. Thus, noise in the observations is interpreted as being attributed to inefficiencies.

Statistical comparisons of conceptual difference

Another conceptual difference between the two methods is the construction of statistical comparisons. In the SFA, data from all farmers in the sample is used to obtain the production possibility frontier, and inefficiency is measured as a deviation from the frontier. In contrast, the DEA method measures the inefficiency of a farmer *j* by comparing it to synthetic farmers, defined by the construction of a linear combination of all the farmers that has the same inputs as *j*, but that is maximizing its output. Thus, the inefficiency of is the difference between this ideal value and its realized value. Hence, to be consistent with the conceptual logic, it was not appropriate to include the six environmental variables among the inputs, as they are not defined by the farmer. Therefore, the output variable (logarithm of the income) was adjusted when using the DEA model to remove the fraction of it that was explained by the environmental factors. Equation 4, 5, 6 explain how the adjustment is made.

$$y_i = F\left(X_i^{environmental}\right) + e_i \qquad (4)$$

$$z_j = arg \min_{\beta_j > 0} X_i^{farmer} \beta_j \ \ such\ that\ \forall i\ X_i^{farmer} \beta_j \geq e_i \qquad (5)$$

$$u_j = 1 - \frac{e_i}{z_i} \qquad (6)$$

Hence, the first step, described in equation 4 is the calibration of a model where the logarithm of the income y is a function of the environmental variables and a stochastic error. For consistency with SFA, which was on quadratic form, the adjustment chosen for equation 4 is a linear model where all the terms are also considered in a quadratic form. This regression is displayed in Table 3

A second technical element is that DEA requires the variables to be positive. To achieve this condition, without affecting the linear structure of the method, each of the farmer variables, as well as the regression error, were adjusted by removing its minimum value and dividing it by its range. By making these adjustments, the error identified by this methodology is conceptually consistent, and at the same time, it adjusts by the environmental factors that affect production. After the adjustment, both methods yield comparable results.

Efficiency Levels

After obtaining efficiency measures for farmers using the SFA and DEA methods, the last part of the analysis regresses the estimated efficiency against ownership, credit, and crop diversity variables to understand how these variables related to efficiency. For that purpose, two linear regressions are performed (one for the efficiency level obtained from the SFA model and one from the DEA model), where the dependent variable is efficiency, and the independent variables are divided into five groups. Group one considers ten different sources from where the farmers borrow money. Group two focuses on how the farmers use the credit. Group three contains variables that approximate the ownership share of livestock, tools, and land. Group four controls for the large types of crops. Finally, group five controls for the production scale, and in this case, the variable available land area is used again to understand how the size of the farm relates to efficiency. Finally, these regressions are run without constant term as the set of crops is an exhaustive partition. Thus, without the constant, the coefficients visualize the average efficiency of each group.

RESULT AND DISCUSSION

Efficiency levels

Both methodologies give each farmer an efficiency score between 0% and 100%, where higher percentages indicate higher efficiency levels. As these ranks are built within the sample, a score of 100% does not necessarily mean that the farmer is achieving the highest production given a set of inputs, but that the farmer is the best one in the sample (i.e., that is in the production frontier). (Figure 1)

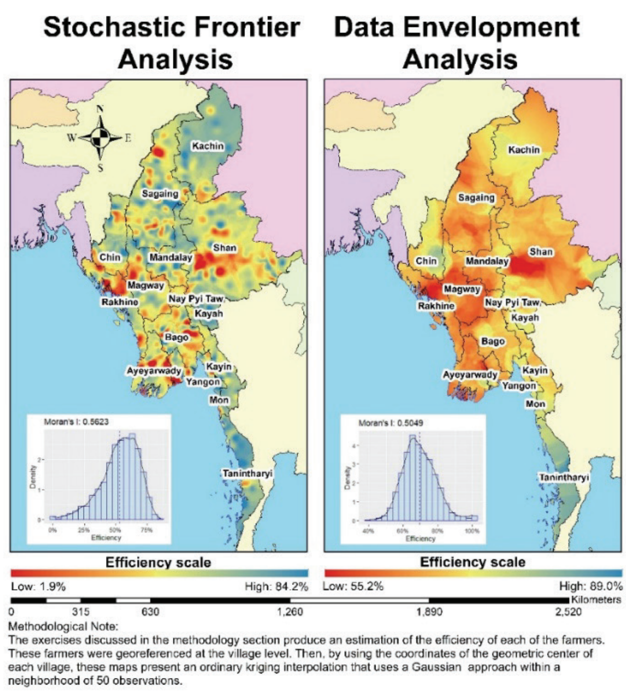

Figure 1 Spatial representation of efficiency results calculated under Stochastic Frontier Analysis and Data Envelopment Analysis methodology.

As expected, the methods produce different ranges of efficiency, which is illustrated by the difference in colouring in the two different maps in Figure 1. However, three results are common between the two methodologies. Firstly, efficiency has a high spatial correlation, reflected in the high values of Moran's I (0.5623 for the SFA model and 0.5049 for the DEA model). This result suggests that spatial factors such as common production styles, attitudes towards markets, and infrastructure could guide productivity. Secondly, both maps indicate low efficiency in northern Rakhine State, which reflect the situation of ethnic conflict in the area. The third shared result is more unexpected: both techniques show that the areas near the basin of the Ayeyarwady river (in Ayeyarwady Region) as well as the centre of Shan State have low levels of efficiency (both maps are coloured red in these areas). This is unexpected since these areas are well-known production areas (DOA, 2018) and suggests that areas that are main agricultural producers are having large inefficiencies once the inputs and natural conditions are considered. In contrast, Tanintharyi region and the frontier between Chin State and Magway region display high efficiency levels using both methods (illustrated by a light blue tone in both maps). Expanding on these maps, Figure 2 contrasts real income against efficiency obtained by the models for all states and regions[1]. Figure 2 highlights that there is no relationship between the real income of the farmer and its efficiency. In other words, these results point to the fact that higher-income does not imply that crops are being produced under a technically efficient regime.

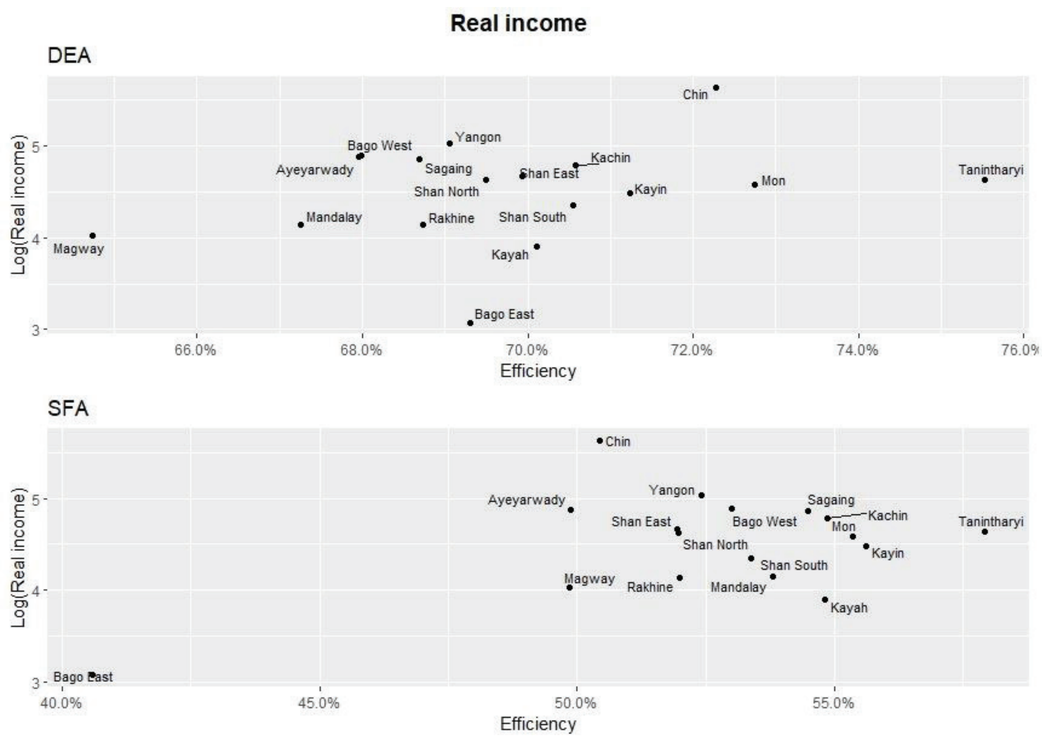

Figure 2 Dispersion of real income against efficiency – figure indicates no relationship

[1] To adjust prices by purchase power, the income produce by the farmer household is divided by the price of a pyi of rice.

Drivers behind efficiency on the national level

Moving on to the second part of the analysis, this section regresses the efficiency measurements over the five groups of variables that were described in the methodology section. Table 4 displays a robust regression that unveils efficiency factors from the perspective of resource ownership, capital sources, and crop diversity. The table's two last columns show the efficiency coefficient obtained from the two different models. These columns show that, except for the production scale, both regressions coincide in the sign of each of the covariates.

The first type of covariates, i.e., debtor type, shows that having debt is associated with more efficient farms. Efficiency increases more when debtors have close relationships with the borrowers (e.g. family, community saving groups, employers, and traders), stressing the role of monitoring capacity to avoid moral hazard. In contrast, debts with government banks and private institutions do not increase efficiency, and, under DEA, government banks have a negative and significant relationship with efficiency. In Myanmar, agricultural government loans are mostly targeted to the production of rice in specific regions along the Ayeyarwady river that traditionally produces rice. Moreover, the government continues creating programs to stimulate this sector in these regions to the point that 88% of the loans of the Myanmar Agricultural Development Bank (MADB) are dedicated to paddy crops in these areas (Myint, 2018). Hence, this study suggests that these loans are either inefficiently targeted, or their monitoring is inadequate. This is supported by the recent reports regarding debt traps that paddy farmers are facing (The Economist, 2017).

The second group of covariates represents the use of the debt, with the aim to investigate whether capital constraints are limiting the farmers' endowment of certain inputs for production. Without credit constraints, farmers can get the best inputs independent of their initial capital, but with credit constraints, farmers must compensate their lack of capital with lower quality inputs (Mukasa, *et. al.*, 2017; Sekyi, *et. al.*, 2017; Lin , *et. al.*, Nguyen, & David, 2019; Ciaian, *et. al.*, 2012). The result in this study show that all the coefficients of this section are positive and, agricultural input loans is significant, which indicate that farmers were initially credit constrained.

The third group of covariates discusses ownership in assets. The data contains information on whether assets like livestock, tools, and land are either owned by the farmer, shared at the community level, or rented. The results show that land ownership is positively correlated with efficiency whereas the relationship is negative for livestock and tools. Since the work of Olson (1971), ownership of productive assets, in particular of land, has been considered as a positive element for the production of goods. However, as suggested by Baland and Platteau (1999), Bardhan (2002), and Bardhan and Dayton

Table 4 Regressing efficiency results against five group of potential efficiency determinants

Regressor	Efficiency	SFA Efficiency	DEA Efficiency
Debtor Type	Borrowed from Family	0.0201***	0.0483***
	Borrowed from Trader	0.0336***	0.0411***
	Borrowed from Money Lender	0.00924	0.0306***
	Borrowed from Microcredit Institution	0.0255*	0.0500***
	Borrowed from Village Saving Group	0.0382***	0.0672***
	Borrowed from Pre-Saling	0.0101	0.00283
	Borrowed from Employer	0.0461**	0.0977***
	Borrowed from Private Bank	0.0134	0.0351
	Borrowed from Government Bank	-0.00404	-0.0197**
	Borrowed from Private Company	-0.0206	-0.000346
Debt Purpose	Loans for Agricultural Inputs	0.0149**	0.0168**
	Loans for Agricultural Labour	0.00325	0.0109
	Loans for Productive Assets	0.0161	0.0204
	Loans for Livestock Breeding	0.0308	0.0195
Ownership	Fraction of Owned Livestock	-0.000994	-0.00307**
	Fraction of Owned Tools	-0.00415***	-0.00300**
	Fraction of Owned Land	0.333***	0.424***
Type of Production	Producers of Cereal Crops Roots and Tubers	0.154***	0.205***
	Producers of Industrial Crops	0.128***	0.142***
	Producers of Oilseed Crops	0.0608***	0.0463***
	Producers of Pulses	0.0385***	0.0358***
	Producers of Vegetables and Aromatic Crops	0.0844***	0.121***
Production Scale	Available Crop Area	-0.000114	0.00122***
Observations		3,213	3,187
R-squared		0.891	0.943
Deg of Freedom		3,190	3,164
Adjusted R Square		0.890	0.943

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

(2002) these statements strongly depend on the type of social structures that foster coordination and promote social capital in the communities. In the context of Myanmar, the negative relationship between ownership of tools and livestock with efficiency is consistent with the fact that the community life in Myanmar's rural areas is still in the core of the social structure. Therefore, the communities have endogenously developed mechanisms to monitor and coordinate the use of these shared items. This justifies the existence of projects that encourage the use of communal use and ownership of farming assets. Land ownership differs from livestock and tools in the way that it has been subject to property rights legislation. During the military regime, land had been nationalized but in 2012, two laws were created that allowed people to hold land property rights (Jepsen *et al,* 2019). This change created uncertainty in land tenure for small farmers (Yeung and Dotto, 2019; Weir, 2017). This uncertainty makes it more beneficial to efficiency to own land rights

The fourth set of covariates present which types of crops that farmers produce. Since farmers can have multiple crops, Table 5 was created to show the average efficiency of different combinations of crops. On average, cereal crop producers (A in the table) increase their efficiency when diversifying their production. In contrast, producers of pulses and vegetable and aromatic crops are, on average, more efficient than other farmers (the letters D and E appear more often in higher positions than A and C). Finally, the most efficient farmers are associated with industrial crops (Table 5).

These results highlight that traditional products such as rice are not generating income as efficiently as other products. Before 2011, the Myanmar Government had a policy of encouraging paddy production in specific regions and therefore farmers could not choose which crops to produce (Raitzer *et al,* 2015). In addition, the production techniques were not optimal due to the institutions involved in the production process (Aung, 2012). Today, farmers are free to choose their crops, but several of the institutions remain and sometimes encourage certain production over others which may affect efficiency. On the other extreme, emerging industrial crops have high efficiency levels. This tendency can be explained due to the market-oriented framework in which these products are embedded (Wiggins *et al,* 2015). Finally, the last factor is the farm scale. The results in the table are inconclusive, suggesting that for Myanmar, large farmers are not necessarily getting the benefits of the economies of scale (Table 5).

Table 5 Average efficiency for different combinations of crops

Crops*	Number of Crops	DEA(%)	SFA(%)	Observations
A, D	2	69.1	50.5	526
A	1	68.9	52.1	2,825
C, D	2	66.0	52.2	239
A, C	2	67.0	52.9	740
A, E	2	70.5	53.2	722
C	1	67.3	53.8	226
D	1	67.3	53.9	116
A, C, E	3	70.5	54.2	131
A, C, D	3	68.6	55.3	403
A, D, E	3	67.8	55.8	106
E	1	74.3	56.6	279
B	1	72.9	56.7	195
A, B	2	73.8	58.1	110
A, B, C, D, E	5	72.7	67.9	219

* The table only presents combinations of crops that have more than 100 farmers producing that specific combination, to avoid conclusions based on noise from specific observations

A = Cereal Crops Roots and Tubers, B = Industrial Crops, C = Oilseed Crops, D = Pulses, E = Vegetables and Aromatic Crops

Figure 3 Agroecological zones.

Drivers behind efficiency on state and regional level:

There are four agroecological zones to be discussed, delta, dry, coastal and hill zone (Figure 3).

Delta zone: where the majority of Myanmar agricultural production takes place; 70% of agricultural land of the country is concentrated in Ayeyarwaddy, Sagaing, Bago, Magway, and Mandalay. Ayeyarwady's land is fertile due to its advantageous location by the Ayeyarwady river. Still, the evidence suggests that, after controlling the geographical advantage, the region is not producing at its full capacity. This issue could be a consequence of the deterioration of the soils due to overexploitation (Myint, 2015) or associated with moral hazard problems linked to the policies implemented by the government to foster paddy that was previously discussed. The geographical location also makes this region prone to natural disasters such as cyclones. These events are occurring more frequently due to climate change (Htwe *et al*, 2015). Hence, this large agricultural provider is having increasing issues affecting its sustainability. Currently, Ayeyarwady is the main rice producer at 28% of Myanmar's total production, followed by Bago (17%) and Sagaing (12%) (DOA, 2018). Diversification of crops in Ayeyarwady is limited to specific districts like Hinthada and Maubin (CSO, 2018). Hence, the previous results encourage policies that push for more diversification and more efficient use of inputs in this region. In that context, diversification policies backed up with programs to improve the use of inputs are strongly recommended to increase the efficiency of the region.

Like Ayeyarwady, Bago is a major rice producer and two thirds of its total agricultural land are dedicated to this commodity. More than 34,000 acres of land (15% of the total annual farming area in the region) has irrigation support, both summer and monsoon rice growing seasons. However, its topography is more varied. Hence, it produces a wider variety of goods, which include corn, groundnut, sesame, monsoon paddy, green gram, soybean, pigeon pea, chill, and vegetables. The efficiency maps created in Figure 1 translate this more considerable diversification into efficiency. Finally, as it is shown in Table 2, the regions of Ayeyarwady, Yangon, and the east of Bago have the largest average farm sizes. However, the current surveys could not provide evidence of economies of scale in agriculture. Hence, more studies are needed in the relationship between productivity and land size on this region as it is a place where potential policies can take place to increase the regional efficiency.

Dry zone: this study shows that it has higher agricultural efficiency than the delta. The dry zone consists of Mandalay, Sagaing and Magway and is known for oilseed crops (nearly 90% of oilseed crops are grown in the central dry zone). Magway is the least efficient in this zone and stands for 34% of the national area used for oilseed production (CSO, 2018). The Myanmar Agriculture Strategy and Investment Plan (2018-2023) noted that sesame is largely produced by smallholder farmers. These farmers are particularly vulnerable to poor agronomic practices and weather-related crop failures, which result in low yields and large pre- and post-harvest losses. According to the Department of Agriculture (DOA) and United States Agency for International Development's Value Chains for Rural Development project, the sesame production fulfils international quality standards. Still, improved access to credit and better crop techniques are required to enable exports (Winrock, 2019). Finally, it is worth highlighting that efficiency in Magway is heterogeneous, and the lowest efficiency is achieved in the flood area where most of the comments made about the delta zone apply.

The second region in the dry zone is Mandalay, it is both a major agricultural producer and a region with high-efficiency levels. Mandalay region is a semi-arid and flat region. Primary crops grown are rice, wheat, maize, peanut, sesame, cotton, legumes, tobacco, and chili and vegetables (Sellamuttu *et al*, 2015; DOA, 2018). Hence, diversification appears to be one explanation behind the efficiency in the region. Another reason could be that the farmers' source of credit is commonly traders and rarely from public institutions. Using traders as the source of credit strategy affects the risk structure of the loan and can be considered a basic form of contract farming. As for example recognised by Kyi (2016), there is an importance of contract farming as a way to increase efficiency among Myanmar farmers. Still, only in the most recent years, the government has taken steps towards formalizing such practices (Thant, 2020).

The last region in the dry zone is Sagaing, where, except for a few specific areas, there are high levels of efficiencies. Like Mandalay, the share of farmers with loans from traders in this region is high, which could be one of the explanations behind the efficiency. Sagaing has rainfed conditions in 87.7% of the region (DALMS, 2018) and has diversified production to both rice, wheat, and pulses (UMFCCI, 2019).

Hill zone: the hill zone is contrasted to the previous zones where the inhabitants are mostly Bamar (the ethnic majority in Myanmar), the states in the hill zone have numerous minority ethnic groups. Therefore, their development has been highly dependent on historical and cultural elements. Kachin State is the most northern state, and despite ongoing conflict, it exhibits relatively high levels of efficiency in both models of this paper. Forested land is predominant, but it is advantageously located by the Chinese border which enables important agricultural inputs to be imported (Dapice, 2016). Recently, agricultural production has benefited by a shift from subsistence-based cultivation systems to cash crop-based systems focused on direct exports to China (Thar, 2018). Moreover, since 2002, the Government of Myanmar has promoted industrial crops in the hill zone, including rubber, coffee, and palm oil in their National Master plan of Agriculture sector, running until 2030 (Woods, 2012). The proximity to China and the shift to cash crops are the two most likely explanations for Kachin's relative efficiency.

The next state in the hill zone is Shan State. It is the geographically largest division in Myanmar, and Figure 1 shows different levels of efficiency within the state, where the west is largely inefficient. Table 1 shows that other parts of Shan State (Shan East and Shan North) have a minimal fraction of the population with access to public loans, while the west has good access to them. In contrast, the relative abundance of community connected loans in Shan State highlights the relevance of community structures in Shan. Besides the incentive roles that has been discussed about the sources of debts, another reason for the low efficiency in western Shan is land degradation, which has been highlighted as a significant problem in the area due to overexploitation of soils (Kyi, 2019). Due to its complex topography and diverse weather conditions, the diversity of crops is common (Corps, 2015). In particular, North and East Shan State occupy more than half of total production in vegetables, which have a higher yield than commodities from the delta and dry zones (Morris and Soe, 2017). Kayah State is the next state in the hill zone. It neighbours Thailand and scores high on agricultural efficiency. Kayah's main crops are rice, maize, and sesame (CSO, 2018; KIC, 2018). Farmers in Kayah State rely on conventional farming methods and have limited access to new technology (KSCCI, 2018). The descriptive statistics revealed that almost half of the farmers have family debts, and more than a third of the debt relates to agricultural inputs. These are probable reasons for the high score in efficiency, combined with the proximity to the strong export market in Thailand. Kayin State is located south of Kayah and has only slightly lower levels of efficiency. It dedicates a major part of its production to paddy and rubber, but also produces sugarcane, coffee, cardamom, and seasonal fruits and vegetables (DOA, 2018). A large share of farmers in this state has loans with both family members and traders, which could be one explanation behind the relatively high efficiency. Another explanation could be that the Kayin government has attempted to increase the production of industrial crops in this state, more specifically rubber, to export it to China.

The last state in the hill agricultural zone is Chin, the poorest division in the country. Despite challenging topography and lack of infrastructure, the evidence shows that agricultural efficiency is relatively high. The state is mountainous, and two-thirds are covered with forest, which makes it more suitable for forestry than agricultural production (BIC, Overview of Chin State, 2018). Most of the rural household farms and are practicing slash-and-burn cultivation (taung yar) on uplands for their food production and income. The current agricultural techniques are known to deteriorate the land quality, and therefore, the government has made attempts to increase awareness about it. Most farmers in Chin State are subsistence farmers, but agricultural production is currently only enough to feed 70% of the population (MIID, 2014). To improve the situation, the government of Chin State has been encouraging farmers to grow permanent crops such as coffee, mulberries, avocado, grape, yam, and apples (MOI, 2019). While conditions are challenging, the statistical results are showing that once the geography is controlled, the farmers are quite efficient, given their limited resources. On a similar note, once prices were adjusted by the purchase parity, Chin farmers earning the highest real income. Therefore, their high productivity can largely be explained by both a price effect and the correction of the geographical conditions. Based on the facts presented, Chin has important potential opportunities, but the improvement of techniques and infrastructure are required to have an absolute efficiency rather than a relative efficiency.

Coastal zone: The last agricultural zone is made up of the coastal areas, Rakhine in the west and Taninthary in the south. However, for the sake of the analysis, Mon State is also included in this group due to its similar efficiency values, its product orientation, and the fact that its population is an ethnic minority. Both Mon and Taninthary show high levels of efficiency. These states mostly produce rice, betel nut, coconut, and rubber. However, crop diversification is good, and several other fruits and nuts are also grown (CSO, 2018). Finally, and especially for Taninthary, palm oil is also becoming a major industrial crop (BIC, 2019). Therefore, in these two states, diversification and the focus on industrial crops are likely drivers behind high efficiency values.

The last state is Rakhine. The areas in the state that display very low efficiency in Figure 1 are specially related to conflict zones in the ongoing ethnic conflict. Another explanation behind the inefficiency is likely that the area has suffered from natural disasters in the past years. The state is mostly dedicated to rice, with 85% of the cultivated agricultural land being used for paddy (LIFT L. , 2016). Pulses, especially black gram, are produced in few specific townships such as Kyauktaw, Mrauk-U, Minbya, and Buthidaung townships, and in some areas, chili and vegetables are important (CSO, 2018). Thus, beyond conflict, the lack of diversity can be an explanatory factor of the inefficiency observed in this area.

CONCLUSION

This paper contributes to the literature by being the first to construct a measurement of agricultural efficiency that is comparable across Myanmar. By using two different methods to model efficiency (the SFA and the DEA), the robustness of results could be assured. The levels of agricultural efficiency were mapped and shows that traditional agricultural production areas (Shan State and the Ayeyarwady river basin) had low levels of efficiency. Next, the paper investigated the drivers behind efficiency by regressing the efficiency measurements on five groups of covariates. This section showed that enhanced efficiency was associated with increased monitoring by debtors, improved access to credit for agricultural inputs, the social norms that coordinate the use of communal assets, increased diversification of crops, and an emphasis on production on industrial crops. Finally, the paper discussed drivers for efficiency by state and region which indicated that there were support for similar trends on sub-national level. Finally, since drivers behind inefficiencies differ between states and regions, agricultural policy would benefit from being geographically targeted.

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