ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume 65 72 Number 2, 2017
https://doi.org/10.11118/actaun201765020679

ASIAN COUNTRIES IN THE GLOBAL RICE MARKET

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Abstract

MILOVANOVIC VLADIMIR, SMUTKA LUBOS. 2017. Asian Countries in the Global Rice Market. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis,* 65(2): 679–688.

Rice is an important Asian commodity, a region with diverse production systems and consumption patterns. With an increasing population leading to an increase in demand, the main drivers which determine rice production need to be identified. The study thus attempts to identify and assess the key drivers of rice production and the future prospects in major rice producing countries within the region using simple and stepwise multiple linear regression. In most of the countries, rice production was found to be determined by indicators such as *yield*, *country consumption* and *country population*, each accounting for about 90 percent of variation in rice production. Among the mentioned indicators, *country population* should be given the most weight to as majority of rice is consumed by humans, thus validating the need to address the necessity to enhance rice production that commensurate with an increasing population.

Keywords: rice production, Asia, determinants of rice production

INTRODUCTION

Rice is one of the most important crops within Asia, grown by almost two billion people and consumed by more than four (FAO, 2016). Asian countries produce 89 percent of world's rice, with China and India alone accounting for 55 percent of the production. Rice, however, is not equally consumed throughout the region, with more urbanized nations such as Japan experiencing per capita consumption of 65 kg, four times less than overpopulated Bangladesh (258 kg). Continent-wide consumption has been on the rise since the early sixties, from 95 kg per capita in 1961 to 107 kg in 2013 (Ibid.). Even though the region has been net rice exporter since 1978, increased yield and area under rice may not be sufficient to match continent's growing appetite, especially considering projected population of 5.3 billion by 2050 (Tab. I) and recently declining yield growth (Li *et al.*, 2016).

Rice is presently grown on 144 million hectares throughout the continent (Tab. II), with China and India dominating with over half of the total area harvested (FAO, 2016). While the area under rice has increased by 35 percent since the 1960s, it is the yield improvement of 143 percent which allowed production to overtake population growth. Progress is particularly pronounced in China where yield has increased by 230 percent, whereas other countries have raised their rice production mostly through area expansion. Consequently, rural population has grown comparatively slower in China than in other Asian countries.

Further land increase, however, is limited by soil salinity, water scarcity and environmental issues caused by extensive farming. Yield and productivity increases through new technologies and production systems are therefore the only viable options (FAO, 2000). Potentially even more limiting will be the effects of climate change. International Food Policy Research Institute predicts a 12–14 percent decline in rice production by 2050 compared to 2000 level, with South Asia being most affected (IFPRI, 2015; Maitah *et al.*, 2016). The consequences of such a scenario would lead to higher food prices, malnutrition and even social disruptions throughout the continent.

China and India as countries most exposed to these stresses (Fig. 1) will have to lead in technological innovation, develop varieties resistant to extreme weather and promote more efficient

I: *Rice statistics for period 1961-2014 (tonnes, kilograms per capita per year)*

Country	Year	Production	% of total[2]	Growth rate	Balance of trade	Consumption[3]	% of total[2]	Consumption per capita[3]
China	1961	53,640,000	26.98	–	–62,400	40,010,358	24.95	61.12
	1971	115,205,008	39.43	114.77	1,510,000	87,281,276	36.29	105.24
	1981	143,955,008	38.64	24.96	320,000	112,165,348	37.41	113.12
	1991	183,380,992	38.59	27.39	546,154	130,271,329	34.92	111.12
	2001	177,580,992	32.52	–3.16	1,578,574	150,911,088	34.80	118.16
	2014	206,507,400	30.95	16.29	–1,785,106	162,400,555	35.29	119.19
India	1961	53,494,496	26.91	–	–736,698	45,902,176	28.63	100.07
	1971	64,602,000	22.11	20.76	–285,360	55,906,056	23.24	98.69
	1981	79,883,008	21.44	23.65	912,386	67,998,031	22.68	95.29
	1991	112,042,000	23.58	40.26	666,124	102,051,559	27.35	114.86
	2001	139,900,000	25.62	24.86	2,193,648	111,917,432	25.81	104.41
	2014	157,200,000	23.56	12.37	11,298,782	130,444,321	28.35	101.95
Other Asian countries[1]	1961	91,643,637	46.11	–	332,626	74,419,018	46.42	130.19
	1971	112,364,655	38.46	22.61	–1,012,714	97,345,444	40.47	133.43
	1981	148,685,748	39.92	32.32	–34,079	119,672,956	39.91	130.73
	1991	179,789,241	37.83	20.92	3,234,439	140,782,718	37.73	124.34
	2001	228,659,639	41.86	27.18	6,074,382	170,785,920	39.39	120.97
	2014	303,550,911	45.49	32.75	3,298,521	167,302,806	36.36	100.60[4]
World	1961	215,417,133	–	–	–	216,648,660	–	71.08
	1971	316,383,426	–	46.87	–	352,152,429	–	94.65
	1981	407,761,231	–	28.88	–	447,045,944	–	100.11
	1991	516,715,186	–	26.72	–	548,875,824	–	103.00
	2001	599,447,397	–	16.01	–	638,417,122	–	104.80
	2014	740,955,972	–	23.61	–	662,012,788	–	140.40

[1]Category includes 49 remaining Asian countries.
[2]Production percentage of all Asian countries.
[3]*Consumption* and *Consumption per capita* data is for 2013.
[4]Data for a number of countries was not available, resulting in artificially lower per capita consumption.
Source: FAO, 2016

management practices such as alternate land wetting and drying methods, land levelling, direct seeding, etc. Moreover, because of crop's strategic and political importance, Asian governments will likely have to intensify their policy measures, including subsidized inputs and guarantied prices. These measures will become even more important as population grows and the shift away from agriculture and towards more urbanized areas intensifies.

Considering the specificities of each country's rice production systems, this study makes use of eight relevant indicators with the aim of uncovering the main drivers of rice production across Asia. The study makes use of simple and later on stepwise multiple linear regression to identify key determinants of rice production within eight countries, representing 91 percent of continent's rice production. The study acknowledges a number of limitations, including (1) lack of data for certain countries and years; (2) inability to account for all drivers, such as government agricultural expenditures, credit to agriculture, development flows to agriculture, foreign direct investments and weather conditions as a key short-term driver; (4) reliability of linear regression and its output; and (5) inclusion of only the most important statistical parameters (N, Pearson correlation, Adjusted R square, ANOVA F, Beta, and 95.0 % confidence interval for Beta), leaving out the significance levels, histograms and scatter plots.

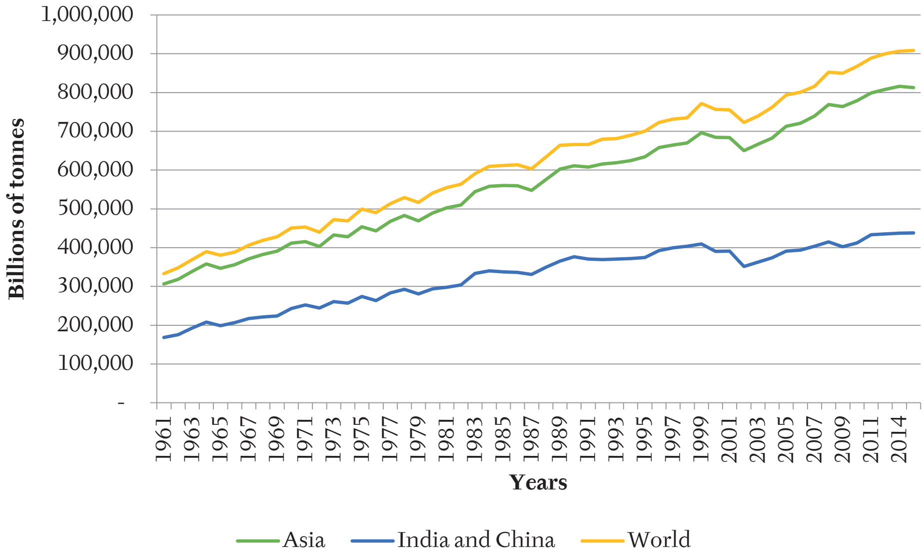
MATERIALS AND METHODS

Based on a list of 48 Asian UN member-states, six non-UN countries and six dependent territories (UN, 2016), the study takes into account China, India, Indonesia, Bangladesh, Viet Nam, Thailand, Philippines and Myanmar as Asia's largest rice producers. The study does not take into consideration remaining countries as aforementioned eight account for roughly 91 percent of region's total rice production. Secondary data from FAO database covering the period between 1961 and 2014 is used in the study.

II: *Rice statistics for period 1961-2014 (hectares, tonnes, kilograms per hectare)*

Country	Year	Area harvested	% of total[2]	Growth rate	Yield	Growth rate	Rural population	% of total[2]	Growth rate
China	1961	26,250,000	24.54	–	2,043	–	550,487,000	41.19	–
	1971	34,883,008	28.43	32.89	3,303	61.67	691,208,000	42.30	25.56
	1981	33,261,008	25.71	–4.65	4,328	31.03	797,279,000	41.69	15.35
	1991	32,590,000	24.77	–2.02	5,627	30.01	859,909,000	39.73	7.86
	2001	28,812,400	21.11	–11.59	6,163	9.53	810,179,000	34.80	–5.78
	2014	30,600,000	21.21	6.20	6,749	9.91	635,424,000	27.89	–21.57
India	1961	34,694,000	32.44	–	1,542	–	375,928,000	28.13	–
	1971	37,757,808	30.77	8.83	1,711	10.96	454,293,000	27.80	20.85
	1981	40,708,400	31.47	7.81	1,962	14.67	547,651,000	28.63	20.55
	1991	42,648,704	32.41	4.77	2,627	33.89	657,861,000	30.40	20.12
	2001	44,900,000	32.90	5.28	3,116	18.61	763,706,000	32.81	16.10
	2014	43,400,000	30.09	–3.34	3,622	16.24	857,198,000	37.63	12.24
Other Asian countries[1]	1961	46,013,677	43.02	–	2,849	–	409,917,000	30.68	–
	1971	50,063,517	40.80	8.80	3,153	10.67	488,747,000	29.90	19.23
	1981	56,713,077	42.82	13.28	3,448	9.36	567,594,000	29.68	16.13
	1991	56,348,672	42.82	–0.64	3,606	4.58	646,426,000	29.87	13.89
	2001	62,768,278	45.99	11.39	3,750	3.99	753,982,000	32.39	16.64
	2014	70,251,532	48.70	11.92	3,977	6.05	785,421,000	34.48	4.17
World	1961	115,247,135	–	–	1,869	–	2,031,780,000	–	–
	1971	134,123,986	–	16.39	2,359	26.22	2,381,742,000	–	17.22
	1981	144,413,250	–	7.67	2,824	19.71	2,728,800,000	–	14.57
	1991	146,121,339	–	0.43	3,536	25.21	3,066,904,000	–	12.39
	2001	151,971,154	–	1.18	3,944	11.54	3,284,185,000	–	7.08
	2014	163,246,747	–	7.42	4,539	15.09	3,363,656,000	–	2.42

[1] Category includes 49 remaining Asian countries.
[2] Production percentage of all Asian countries.
Source: FAO, 2016



1: *Participation of Asia, India and China in global rice production (1961-2014)*
Source: FAO, 2016

III: *Variables used to perform regression analyses*

Variable	Data availability[1]	Unit of measurement	Source
Country production (*paddy rice*)	1961–2014	metric tonne	FAO
Area harvested (*paddy rice*)[1]	1961–2014	hectare	FAO
Yield (*paddy rice*)	1961–2014	kilograms / ha	FAO
Country export (*milled rice*)	1961–2013	metric tonne	FAO
Country import (*milled rice*)	1961–2013	metric tonne	FAO
Country GDP	1961–2013	million USD	FAO
Country consumption (*paddy rice*)	1961–2013	metric tonne	FAO
Arable land (*paddy rice*)	1961–2014	thousand hectares	FAO
Country population	1961–2014	thousand people	FAO

[1] *Area harvested* indicator was omitted due to inconsistent and inflated results for most countries, in spite of being significant predictor.
[2] Data availability may vary from country to country.
Source: FAO, 2016

The analyses relies on nine indicators selected out of approximately 25 plausible measures available through FAO database, on the basis of data availability and reviewed literature on rice production systems within the region (Tab. III). Shortlisted indicators were tested using simple linear regression and significant predictors and their correlation with the response variable revealed, resulting in eight currently used indicators.

Only statistically significant variables (at .05 level) with Adjusted R square of at least 20 percent were reported, along with their Pearson correlation, ANOVA and Beta significance values. Pearson correlation represents linear correlation between two variables, generating values between +1 to −1 inclusive, where 1 signifies positive correlation, 0 implies no correlation, and −1 suggests negative correlation (Stigler, 1989). Similarly, ANOVA is a statistical procedure used to test the degree to which two or more groups vary or differ in an experiment (Rutherford, 2001). In most experiments, a great deal of variance (higher ANOVA F) usually indicates that there is a significant finding from the research. Beta coefficients, also known as standardized regression coefficients, are used to compare the relative strength of various independent variables within the model, and are considered the most useful output of the analysis.

Simple linear regression results are laid down first, covering each predictor variable for each of the eight rice producing countries. In the general regression equation (1), y is the response variable, x is the explanatory variable, β_1 the intercept, β_0 is the slope and u_i is the residual (random error component) that is being minimized. The aforementioned Betas are called regression coefficients and the slope β_0 can be interpreted as the change in the mean value of for a unit change in x.

$$y = \beta_0 + \beta_1 x + u_i \quad (1)$$

Aforementioned indicators were then used in a stepwise multiple regression analysis, a semi-automated process of creating a model by successively adding or removing variables, based only on t-statistics of their estimated coefficients. The aim of the analysis was to include as few variables as possible because each unnecessary regressor decreases the precision of the estimated coefficients and predicted values (NCSS, 2015). Multiple regression equation comes in a similar form as simple regression (2), where y is the value of dependent variable, $x_1, x_2, x_3, \ldots, x_k$ are independent variables, β_0 is the slope, $\beta_1, \beta_2, \beta_3, \ldots, \beta_k$ are regression coefficients analogous to the slope in linear regression equation, while u_i is the residual and assumed to be zero (CSU, 2015):

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k + u_i \quad (2)$$

For multiple linear regression, Durbin-Watson statistic and VIF (Variance Inflation Factor) outputs are included as well to assure that regression assumptions are followed. Durbin-Watson statistic is used to reveal the presence of autocorrelation (relationship between values separated from each other by a given time lag) in the residuals (prediction errors) from a regression analysis (Chatterjee and Simonoff, 2013). The statistic ranges from 0 to 4, where 2 signifies no autocorrelation, values approaching 0 indicate positive autocorrelation, and values leaning towards 4 indicating negative autocorrelation. VIF, on the other hand, is a multicollinearity check, where a value greater than 10 suggests the presence of multicollinearity and requires further investigation (Berry and Feldman, 1985).

RESULTS AND DISCUSSION

The findings suggest a significant relationship among variables from both statistical and economic point of view. Simple linear regression revealed that *yield, country consumption* and *country population* are

IV: *Simple linear regression output for China*

Independent variable	N	Pearson correlation	Adjusted R square	ANOVA F	B	95.0 % confidence interval for B	
Yield	54	.973	.945	909.844	2,844.606	2,655.367	3,033.844
Country import	53	.499	.234	16.878	42.030	21.492	62.569
Country GDP	44	.556	.293	18.835	6.835	3.652	10.017
Country consumption	53	.983	.965	1,420.712	1.195	1.131	1.258
Arable land	53	.673	.442	42.177	2,984.285	2,061.770	3,906.801
Country population	54	.955	.910	536.553	177.920	162.507	193.333

among the most significant predictors for majority of countries, with remaining variables having moderate or high Adjusted R square values. Consumption and population remain the original drivers of rice production as almost all of produced rice is used for human consumption and is consumed domestically. Surprisingly, *area harvested* and *arable land* have not been ranked as highly, suggesting that yield improvements have been crucial for increases in production within mentioned countries. Likewise, *country import* and *county export* as tools for managing and supplementing rice production according to nation's established consumption patterns, did not prove to be great predictors of rice production. *Country GDP* as external factor and also hard to influence, had varying predictive power for different countries.

China is Asia's largest rice producer, accounting for 31 percent of continent's 2014 harvest. The study revealed almost perfect correlation and predictive power for three independent variables, namely *yield*, *country consumption* and *country population*, with remaining predictors explaining around 60 percent of variation in rice production (Tab. IV). Considering country's average yield of 6.7 tonnes per hectare and 30.6 million hectares under rice, predicted rise of 2,845 tonnes with every 1 kg increase in yield per hectare seems realistic enough. The same is valid for *country consumption* indicator which predicts slightly less than 1.2 kg increase in production for every 1 kg increase in *country consumption*. *Country population*'s predicted increase of 178 kg with every additional person, however, is a bit farfetched compared to country's current per capita production of 151 kg. The inaccuracy of prediction can be attributed to relatively small sample size and drastic increase in per capita production during 1960s.

Arable land with its lower predictive power due to competitive land use suggests almost three-tonne increase in production with every additional hectare of land, whereas *country GDP*, which translates to increased purchasing power, assumes growth of 6.8 tonnes with every $1 million increase in country's GDP. The uncertainty of predictive power of these two indicators may be seen in their relatively wide confidence intervals for Betas, implying limited knowledge about the variable effect (Belia *et al.*, 2005). Lastly, *country import* assumes a 42 kg increase in production with each additional imported tonne of rice, a rather mild response.

India is well on the way to overtake China as the world's most populous nation (as early as 2022). It is region's second largest rice producer with 24 percent stake in production during 2014 harvest. Much like for China, it is the three distinguished indicators which explain rice production the best (*yield*, *country consumption* and *country population*) (Tab. V). Predicted increase of 4,953 tonnes with every 1 kg growth in yield is slightly above current figures. Similarly, *country population* shows moderately inflated prediction but still along historical trends, whereas *country consumption* output mimics that of China.

Country export indicator forecasts a dubious ten-tonne increase in rice production with every 1 tonne growth in exports. The prediction, however, may not be farfetched after all considering that India is the single largest rice exporter in the world, even though its pricing is rather non-competitive (Issar and Varma, 2016). Using the same principle, the model suggest a rather steep decrease in

V: *Simple linear regression output for India*

Independent variable	N	Pearson correlation	Adjusted R square	ANOVA F	B	95.0 % confidence interval for B	
Yield	54	.997	.997	9,496.992	4,953.003	4,851.016	5,054.991
Country export	53	.742	.542	62.585	10.046	7.497	12.596
Country import	53	(.710)	.494	51.718	(76.023)	(97.246)	(54.801)
Country GDP	44	.831	.653	79.536	46.561	36.038	57.102
Country consumption	53	.986	.971	1,764.881	1.182	1.126	1.239
Country population	54	.980	.961	1,154.050	132.248	125.448	140.063

VI: *Simple linear regression output for Indonesia*

Independent variable	N	Pearson correlation	Adjusted R square	ANOVA F	B	95.0 % confidence interval for B	
Yield	54	.979	.958	1,179.378	1,572.710	1,480.815	1,664.605
Country GDP	44	.737	.692	97.291	53.082	42.220	63.934
Country consumption	53	.988	.975	2,066.298	1.467	1.399	1.528
Arable land	53	.754	.561	67.379	6,212.917	4,693.393	7,732.440
Country population	54	.992	.983	3,037.997	355.766	342.814	368.718

production due to imports. Lastly, *country GDP* indicator shows a much stronger response to increase in GDP compared to China, with predicted 46.6 tonnes rise with every $1 million growth in GDP. This roughly means that every 1 percent increase in GDP (2014) would lead to 0.52 percent growth in rice production.

Indonesia is the only country within the group with *country population* indicator having the highest predictive power, even though predicted 356 kg increase with every additional person is drastically above the present 278 kg (Tab. VI). Again, as in case of China, the discrepancy can be explained with a two-fold increase in per capita rice production over the past half a century. Connected with it is *country consumption* and its optimistic 0.47 percent rise in production with every 1 percent increase in consumption. Similar trend of higher-than-expected Betas is shown for *yield* (1,573 tonnes predicted vs. 1,380 tonnes in reality) and *arable land* indicators as well (6,213 kg vs. 5,135 kg). Lastly, *country GDP*, as in case of India, shows a rise in rice production of 53 tonnes with every $1 million increase in GDP. The inflated predictions can be attributed to the largest rice production growth amongst the observed countries (486 %), making the regression output slightly skewed.

Bangladesh is by far the most densely populated country within the group. With 11.82 million hectares of arable land, predicted increase in production of 1,228 tonnes with every 1 kg rise in *yield* per hectare seems correct (Tab. VII). As for *country consumption* and *county population* indicators, patterns similar to those of China and India are applicable to Bangladesh as well. *Country GDP*, however, shows significantly higher increase in rice production with growth in GDP compared to other countries, which may be attributed to population pressure that prevents country from replacing cereals with more protein-rich foods as it grows.

Particularly interesting is *arable land* indicator which predicts a decrease in production should more arable land be available. The phenomenon reveals a dangerous trend of decreasing arable land within the country although it also indicates rising yields to compensate for it. The negative correlation is therefore country-specific and result of shrinking land due to flooding, land erosion and lately, climate change.

VII: *Simple linear regression output for Bangladesh*

Independent variable	N	Pearson correlation	Adjusted R square	ANOVA F	B	95.0 % confidence interval for B	
Yield	54	.995	.990	5,397.734	1,228.104	1,194.561	1,261.646
Country GDP	44	.964	.928	553.048	292.929	267.792	318.067
Country consumption	53	.973	.945	897.983	1.184	1.104	1.263
Arable land	53	(.795)	.624	87.401	(16,725.772)	(20,317.492)	(13134.053)
Country population	54	.955	.910	539.852	322.786	294.909	350.663

VIII: *Simple linear regression output for Viet Nam*

Independent variable	N	Pearson correlation	Adjusted R square	ANOVA F	B	95.0 % confidence interval for B	
Yield	54	.996	.993	7,278.069	924.007	902.273	945.741
Country export	53	.955	.911	531.269	4.852	4.430	5.275
Country import	53	(.617)	.380	31.279	(19.178)	(26.062)	(12.294)
Country GDP	44	.854	.724	113.546	221.750	179.753	263.747
Country consumption	53	.967	.934	726.403	2.700	2.499	2.901
Arable land	53	.734	.529	59.519	22,445.773	16,604.881	28,286.665
Country population	54	.952	.905	507.955	622.388	566.974	677.802

IX: *Simple linear regression output for Thailand*

Independent variable	N	Pearson correlation	Adjusted R square	ANOVA F	B	95.0 % confidence interval for B	
Yield	54	.973	.947	939.110	1,582.754	1,479.115	1,686.394
Country export	53	.917	.838	269.672	2.464	2.163	2.765
Country import	53	.699	.478	48.692	928.983	661.711	1,196.255
Country GDP	44	.938	.877	308.072	59.061	52.271	65.852
Country consumption	53	.838	.696	120.966	4.605	3.762	5.448
Arable land	53	.486	.221	15.738	1,667.194	823.489	2,510.899
Country population	54	.919	.841	280.729	563.232	495.777	630.688

Viet Nam is Asia's fifth largest rice producer, with over 6 percent stake in 2014 rice harvest. *Yield* seems to be the best predictor, suggesting 924 tonne increase in rice production with every 1 kg improvement in yield (Tab. VIII). *Country consumption* shows drastically higher prediction compared to other countries, with 2.7 tonnes increase with every 1 tonne rise in consumption. Viet Nam, however, is one of the countries with the highest proportions of exports to production, next to Thailand, which could explain the skewed results of abovementioned indicator. *Country GDP* prediction, on the other hand, is much within the range of that of Bangladesh. *Country export* and *country import* show similar predictions as in case of India, although to a lesser extent. What seems to be out of range though is *country population* indicator with its predicted increase of 622 kg with every additional person (currently 487 kg), attributable to a jump in production during the 1990s.

Thailand, Myanmar and Philippines, as the group's smallest rice producers, account for just over 13 percent of continent's total production (Tabs. IX, X, XI). *Yield* comes on top as the strongest predictor for both Thailand and Myanmar, although the estimate is higher for Thailand due to larger area under rice (60 %). Philippines follows a similar pattern, however, the prediction is roughly half of Myanmar's, again due to smaller area harvested. *Country population* indicator shows similarly high predictions, with Thailand exporting good porting of its production and Myanmar mainly using the produce for domestic consumption, as are Philippines. The skewness in forecasted values for Myanmar also comes from drastic swings in production ranging from just under 450 kg per capita in 2000 to almost 640 in 2008 and then down again to 500 in 2013. *Country consumption* indicator is flawed in a similar way for Myanmar but not for Thailand and Philippines.

Country GDP offers predictions for Thailand and Philippines similar to those of larger countries, such as China and India. Myanmar, on the other hand, shows the same pattern of high increase in rice production with higher GDP as other comparatively smaller rice producing nations, such as Viet Nam and Bangladesh. *Country export* indicator is statistically significant only for Thailand as

X: *Simple linear regression output for Myanmar*

Independent variable	N	Pearson correlation	Adjusted R square	ANOVA F	B	95.0 % confidence interval for B	
Yield	54	.933	.868	250.856	882.626	788.072	877.182
Country import	53	.576	.318	25.290	338.029	203.086	472.973
Country GDP	44	.680	.449	36.076	337.211	223.910	450.512
Country consumption	53	.913	.830	255.582	3.194	2.783	3.595
Arable land	53	.669	.437	41.291	13,251.516	9,111.416	17,391.616
Country population	54	.914	.833	264.838	729.478	639.530	819.426

XI: *Simple linear regression output for Philippines*

Independent variable	N	Pearson correlation	Adjusted R square	ANOVA F	B	95.0 % confidence interval for B	
Yield	54	.972	.943	881.243	494.947	461.490	528.404
Country import	54	.659	.424	39.205	4.068	2.764	5.373
Country GDP	44	.925	.853	250.527	54.044	47.153	60.935
Country consumption	53	.988	.976	2,117.702	.941	.900	.982
Arable land	53	.646	.406	36.553	10,050.977	6,713.471	13,388.483
Country population	54	.979	.959	1,224.023	193.499	182.401	204.597

XII: *Stepwise multiple linear regression output for all eight rice producing countries*

Country	Independent variable	N	Pearson correlation	Adj. R square	ANOVA F	B	Durbin-Watson	VIF
China	Country cons.	53	.983	.965	1,420.712	1.195	.505	1.00
India	Yield	53	.997	.994	9,088.807	4,968.307	NA	1.00
Indonesia	Area harvested	53	.992	.984	3,216.277	8.956	NA	1.00
Bangladesh	Yield	53	.995	.991	5,493.399	1,216.740	NA	1.00
Viet Nam	Yield	53	.996	.992	6,649.064	922.188	NA	1.00
Thailand	Yield	53	.972	.944	878.387	1,584.322	NA	1.00
Myanmar	Country cons.	53	.988	.976	2,117.702	.941	NA	1.00
Philippines	Yield	53	.931	.997	7,911.697	472.220	NA	2.435

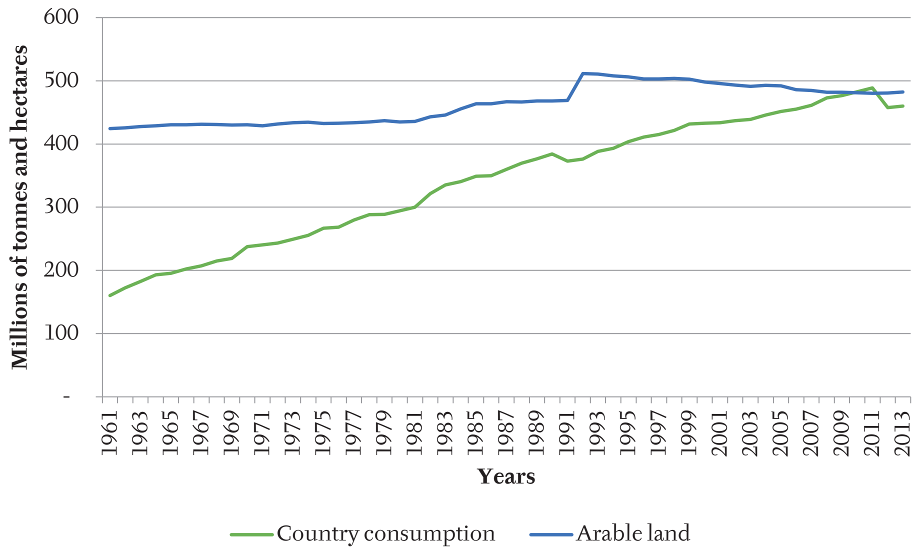
the other two nations are struggling with exporting low quality rice (WB, 2008). *Country import* indicator, on the other hand, reveals a typical pattern where Thailand as one of the largest exporters is predicted to significantly increase its production with every 1 tonne growth in imports (929 tonnes), whereas Myanmar's estimate as a marginal exporter is comparatively lower. Philippines, which have almost no exports, see imports almost favourably. Lastly, *arable land* indicator shows similar low predictive power as in case of China. It should be noted that variation between the countries is only partially consistent with the differences in yield, the other reason being the differences in the overall production growth between 1961 and 2014 (385 % in Philippines versus 321 % in Thailand).

Stepwise multiple regression analysis (Tab. XII) shows that for five out of eight countries, *yield* was the single most important indicator, explaining well above 90 percent of variation in the response variable. The model included *country consumption* and *area harvested* for the remaining three countries, with high predictive power as well. Predicted increases in rice production for each of the independent variables remain more or less unchanged compared to simple linear regression output.

It remains true, however, that population is the sole driver of rice production, which is reflected through rice consumption, and thus on area under rice. It is interesting to note that not a single country had *country population* indicator as the best predictor, with exception if Indonesia. A possible explanation lies within population dynamics and dynamics of country consumption, area harvested and yield. Whereas population grows in a relatively slow and predictive way, the later categories have higher standard deviations. The average intra-year growth difference for population of China, for instance, is –0.02 %, whereas the same figure for yield is –0.27 %. This means that yield, area harvested and country consumption (in that order) better reflect rice production as they fluctuate along with it and are causing it. As such, they come on top as better predictors, even though the true driver remains hidden (country population).

The future prospects of rice production in Asia are function of how well the concerned countries manage their growing populations and whether they assure sufficient arable land is available to future generations (Fig. 2). Moreover, the future of rice is dependent on how well Asian continent adapts to climate change and whether modern technologies succeed in phasing out traditional and inefficient growing methods. The greatest threat to food security and self sufficiency in rice, however, remains the population growth and more recently, population aging. As population continues to develop and demand for rice grows, Asian countries may face significant rice and overall food shortages. In India, the area of arable land per capita has decreased from around 3,800 m^2in 1960s to just below 1,500 m^2today. The situation is even graver in neighbouring Bangladesh, with less than 600 $m^2$of agricultural land available per capita. Fig. 3 shows the demand for rice contrasted with the availability of arable land on Asian continent.

Following the trend of the past 20 years, the region would have to increase production by roughly 39 % in order to keep up with projected consumption of 638 million tonnes by 2050. With limited room for increasing land, productivity and innovative management techniques will have to drive the growth. Asian countries therefore need to be committed to a long-term investment-intensive optimization of their rice production, better population management and phasing out of inefficient growing techniques amongst rural poor. Such measures would not only make the nations food secure in rice but would also create prerequisite environment for departure away from carbohydrate-rich foods and towards protein-rich diets.



2: *Asian rice consumption and arable land (1961-2013)*
Source: FAO, 2016

CONCLUSION

The study revealed that for most countries, rice production is determined by *yield* and *country consumption*, each of which generally explain around 90 % of variation in rice production. Remaining independent variables showed promising predictive power, particularly the *country population* as a long-term driver. This is due to the fact that all rice is used for human consumption and is consumed within the region, making variables such as *area harvested* and *country consumption* a proxy variables. The future of rice production is therefore closely tied to population growth in spite of declining per capita consumption in a number of Asian countries. Aside from population growth, climate change is another challenge requiring attention, whether it be new high yielding varieties resistant to flooding and drought, alternate land wetting and drying methods, or more responsible use of fertilizers and pesticides. In any case, rice demand is bound to continue its upward trend and Asian continent therefore needs to prepare itself for future shock and self-sufficiency in the decades to come.

Acknowledgments

The project was realized with the support of the Internal Grant Agency of the Faculty of Economics and Management, Czech University of Life Sciences Prague (20171018 – Aging in rural India: Implications for agriculture and smallholder farmers).

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