Spatial-Temporal Modeling of Growth in Rice Production in the Philippines

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When the strong El Nino episode in recent history happened in 1998, gross value added of the rice sector in the Philippines declined by as much as 24%, while other crops were able to keep the decline to within single digit level. The convergence hypothesis was verified among the Philippine provinces with reference to rice production. Convergence could mean harmonized efforts among various stakeholders to increase production and hopefully aim for food sufficiency. Divergence, on the other hand, could imply the need for structural assessment of the sector including the goals of various stakeholders, so that an optimal strategy that can stimulate development will be identified. A spatial term is incorporated into the model, providing empirical evidence for the need to localize rice production policy programs across the country. The spatial term also accounts for the natural endowments of the producing provinces that complement those policies in realizing progress in the sector. Rice production among the Philippine provinces diverged in the period 1990-2002. The El Niño episode of 1998 pulled down rice yield by as much as 10% aggravating further the divergence among provinces.

Keywords: spatio-temporal model, backfitting, autoregression, convergence hypothesis, agricultural growth

1. Introduction

From the 2003 estimates based on the Family Income and Expenditures Survey (FIES), 79% of agricultural households fall among the four lowest income deciles (bottom 40% of the population). The nonagricultural households however, only have 30% in the bottom 40% of the population. This is one of the many evidences of vulnerability of those in the agriculture sector not only in the Philippines, but in other developing countries as well. More specifically, within the agriculture sector, those engaged in crops are more disadvantageous with an average income in 2003 of P59,999 compared to the rest in the agriculture sector with an average income of P68,703.

The strong El Niño—a global weather anomaly whose effect to the Philippines is prolonged dryspell—episode of 1998 (NOAA 2007) expectedly affected the agriculture sector the most. The marginalization of the grains farmers, specifically, those planting rice can be gauged from the gross value added (GVA) of the rice sector that declined by as much as 24% while other crops were able to keep the decline to within single digit level. Although majority of agricultural land devoted to rice farming is now reached by irrigation systems—due to the often nonsustainable water source and physical infrastructure—rice farming still maintained the same marginalization due to the volatile weather conditions.

While the world is focusing on productivity growth to fuel agricultural growth, the Medium Term Philippine Development Plan 2004-2010 targets expansion of cultivation area as the source of agricultural growth for the Philippines. Expansion of production areas will only be secondary to a more important tool in policy making in Philippine agriculture – an assessment of the robustness of the sector to internal and external shocks. This assessment shall provide a good instrument in the development of policies and intervention strategies to avert the vulnerability of the rice sector.

The paper proposes a spatio-temporal model in the verification of the convergence hypothesis in rice production among Philippine provinces. The possible role of production area, corn production, and the El Niño phenomenon towards convergence/divergence among Philippine provinces are also explored. Specific focus on the assessment of the structural effect of events associated to the 1998 El Niño episode towards convergence in rice production in the Philippines is made. Rice production is highly vulnerable to weather perturbations hence, the focus on El Niño. Evidence of convergence will also be an evidence of equity among the stakeholders – that there is equity in the distribution of the needed intervention across the provinces, and that the present production areas are indeed suitable for rice production. This could also mean harmonized efforts among various stakeholders in the rice sector towards a common goal of food sufficiency at the least. Divergence, on the other hand, could mean that there is a need for a massive structural assessment of the sector and the goals of the different stakeholders to be able to identify an optimal strategy leading towards development.

2. Rice Production in Philippines

Patterns of rice production in the Philippines vary tremendously across provinces and over different periods. Rice is typically planted twice a year: one cycle during wet months, and one cycle during the dry months. Production cycle varies across provinces, the southern provinces usually planting ahead of the other provinces. In the period 1990-2002, quarterly growth (present quarter relative to same quarter of previous year) averaged 62% across all provinces. The yield has grown at an average of four percent per quarter. For the same reference period, the average yield is 2.78 metric tons per hectare (±0.81). Vulnerability of production to weather conditions is manifested in production area with average quarterly growth rate of 61% (negative for some provinces for certain quarters). Growth in production is the highest during the second quarter coming from a very low (no production in some provinces) production in the fourth and first quarter. Yield has been growing until a decline in 1998 (El Niño year), but it recovered shortly thereafter. Production exhibits similar average pattern across provinces per quarter. See Figures 1 and 2 for details.

Figure 1. Average Yield (metric tons/hectare/quarter) of Rice by Provinces

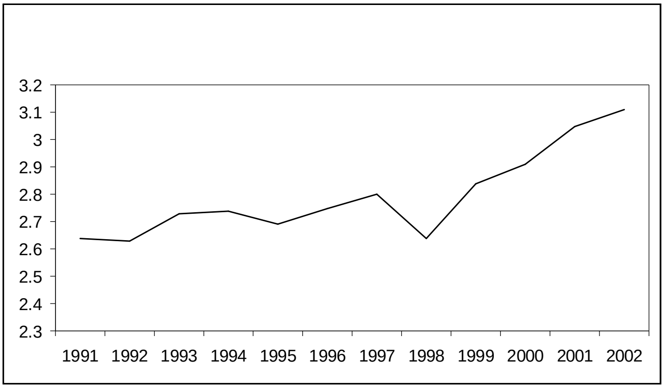
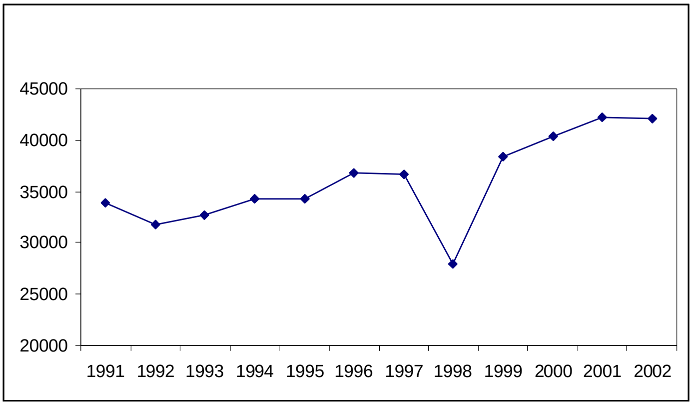


Figure 2. Average Rice Production (metric tons/quarter) by Provinces



3. Convergence and Agricultural Growth

Initially, sprouting from the Solow economic growth model, the concept of convergence has emerged from the literature for a relatively longer period now. As Di Liberto (2005) puts it, the Solow model predicts that economies converge to a steady state, where the key force that underlies the convergence effect is diminishing returns to reproducible capital. Furthermore, steady state growth rate is explained by the model and it is only possible to obtain continued growth in output per head if there is exogenous technical progress.

Several convergence models appear in the literature. As discussed by Barro and Sala-i-Martin (1992) and Sala-i-Martin (1996), there are initially two types of convergence: unconditional or absolute β-convergence and σ-convergence. If there is a tendency for poor economies to grow at a faster rate than the richer ones, then there is absolute β-convergence. Specifically, if $\beta > 0$ in the following regression equation $\gamma_{i,t,t+T} = \alpha - \beta \log(y_{i,t}) + \varepsilon_{i,t}$, where $\gamma_{i,t,t+T}$ is the annual growth rate of GDP of the ith economy between time t and t + T and $\log(y_{i,t})$ be the logarithm of the ith economy's GDP per capita at time t, then there is absolute β-convergence. On the other hand, if $\sigma_{t+T} < \sigma_t$, where σ_t is the standard deviation at time t of log $(y_{i,t})$ across all economies, then the economies are converging. Thus, σ-convergence implies a decreasing trend in the dispersion of per capita GDP or income over time. It refers to the inter-temporal gradual development of the dispersion of world income. These two kinds of convergence are in a way related. Sala-i-Martin (1996) noted that β-convergence is a necessary but insufficient condition for sustained σ-convergence. Dela Fuente (2000) points out that convergence is necessary since the level of inequality will grow indefinitely when β is negative (i.e., when richer economies grow faster than the poorer economies).

Absolute convergence can only be expected or anticipated exclusively among economies which are structurally homogenous and the only difference across economies is in their initial levels of capital. This insight is instrumental in the conception of conditional convergence. This model allows for the differential determinants of the steady state levels (e.g. technological level, propensity to save, or population growth rate) of the economies under study. To verify existence of conditional convergence, one has to estimate the equation

$$\gamma_{i,t,t+T} = a - b\log(y_{i,t}) + \psi X_{i,t} + \varepsilon_{i,t,t+T}$$

where $X_{i,t}$ is a vector of variables that hold constant the steady state of economy i, and $b = (1 - e^{-\beta T})/T$. If the resulting β is positive for $X_{i,t}$ which is held constant, then there is conditional convergence. This seems to be a more realistic model since it is possible for economies to differ in varying technological and behavioral parameters which in turn translates to different levels of equilibrium.

Absolute convergence implies a tendency for differences in per capita income to wear off within the sample over time. In the long run, expected per capita income is the same for all members of the group, independently of its initial value. As explained by Dela Fuente (2000), this does not mean that inequality will disappear completely, for there will be random shocks with uneven effects on the different territories. Such disturbances, however, will only have transitory effects, implying that, in the long run, we should observe a fluid distribution in which the relative positions of the different regions change rapidly. With conditional β-convergence, on the other hand, each economy converges only to its own steady state but these can be very different from each other. Hence, a high degree of inequality could persist—even in the long run—and will be observed high persistence in the relative positions of the different economies. In other words, rich economies will generally remain rich while the poor continue to lag behind.

This leads us to the question of interpretability of the parameter β from the two models. β shows how fast the economies approach their steady state levels. It can help in the analysis of economic growth as it gives the rate or speed of convergence. Dela Fuente (2000) further noted that there is no contradiction between these estimates once it is recognized that they are measuring different things: while the unconditional parameter measures the overall intensity of a process of income convergence which may work in part through changes over time in various structural characteristics, the conditional parameter captures the speed at which the economy would be approaching a "pseudo steady state" whose location is determined by the current values of the conditioning variables.

Agriculture has a vital role to play in contributing to an economy's development. An implication of the model on structural transformation (Gollin et al. 2002) is that agricultural growth is central to development. The model actually shows a connection of agricultural growth to industrial development. Those countries which are experiencing increases in agricultural productivity will have a shift of workers from the agricultural to nonagricultural sector. They concluded that low agricultural productivity can substantially delay industrialization. This delay might result into low per capita income of the country compared to that of the leader. They further noted that a greater understanding of the determinants of agricultural productivity will improve our understanding of the development process among poor nations.

Ruttan (2002) cited that increases in agricultural production, both from crops and animals, initially were attributed to increases in the area cultivated but towards the end of the twentieth century, growth is coming from increases in land productivity – in output per hectare. Growth in total factor productivity in agriculture has made an important contribution to economic growth within rural areas and this has led to poverty reduction. There are several constraints on agricultural productivity: resource and environmental, scientific and technical, and institutional constraints. These will have differential effects on the economies having such constraints. Thus, specific actions can be taken on to facilitate growth in the economy.

4. Methodology

The paper uses quarterly rice production data aggregated at the provincial level for the period 1990 to 2002 in the Philippines. The data is collected from sample farming households by the Bureau of Agricultural Statistics (BAS) of the Department of Agriculture. Rice production is characterized by pronounced seasonality, having only two complete production cycles within a year.

A spatial autoregression term enriches the spatial-temporal growth model postulated as follows:

$$\Delta p_t = \beta_0 + \beta_1 \log(y_t) + \beta_2 \log(a_t) + \beta_3 \log(c_t)$$
$$+ \delta\left(\Delta p_t - \beta_0 - \beta_1 \log(y_t) - \beta_2 \log(a_t) - \beta_3 \log(c_t)\right) D_t + u + e_t$$
$$e_t = \rho e_{t-1} + z_t$$

Where Δp_t is a vector of growth rates in quarterly yield of rice for the provinces at time t, computed both from the original and the deseasonalized data. Deseasonalization is considered to eliminate the effect of strong seasonality in rice production since there are only two distinct cycles of rice production in the Philippines. It can also provide an alternative method of computing growth rates (quarter of the current year relative to the same quarter of the previous year). y_t is the vector of yield of rice for the provinces at time t, a_t is the vector of harvest area for rice, c_t is the vector of harvest area for corn, $D_t = \left[\left(d_{ij}^t\right)\right]$,

$$d_{ij}^t = \begin{cases} \frac{1}{m}, & \text{if province i and j are neighbors (in the same region)} \\ 0, & \text{otherwise} \end{cases}$$

a spatial autoregression indicator matrix, m is the number of provinces in a region, u a random effect component that will account for productivity endowments specific to the provinces and constant over time, e_t the vector of autocorrelated errors for the provinces at time t, and $z_t \sim N\left(0, \sigma^2\right)$. The effect of D_t is to average initial residuals of provinces in the same region. The residuals after accounting for the covariates are attributed to the spatial externalities common among provinces in the same region. The spatial externalities can serve as aggregate proximate indicators of the viability of the area in growing the crop (natural endowments) as well as policies and programs supporting rice production.

The model is estimated using a generalized least squares procedure in two backfitting steps similar to the one proposed by Landagan and Barrios (2007). Step 1 considers a linear model to compute the initial residuals. The residuals are then aggregated with D_t before the second generalized least squares is applied to the whole model with estimated residuals from Step 1. (See Landagan and Barrios 2007 for details of the estimation procedure.)

The effect of El Niño episode of 1998 is assessed by including a dummy variable in the model above, both as a location and scale parameter.

5. Results and Discussion

The random effect model with spatial-temporal autoregression for both the original data and the deseasonalized rice yield data significantly fits the provincial data (see Tables 1 and 2). Parameter estimates for both growth equations (original and deseasonalized) are similar. The possible effect of deseasonalization can be observed only in the magnitude of the spatial parameter.

Adjusting for spatial effect of the regions, the provinces failed to exhibit convergence in rice yield. This can be interpreted in two ways. First, the natural endowments of the provinces are distinctly varied. Even with interventions in farming systems and technological innovations, yield still vary significantly across the provinces in the same region. This means that the zoning of agricultural areas in the Philippines is an important strategy towards the identification of optimal production areas for certain crops, rice most specially. An intensive advocacy campaign among farmers to consider a crop more suitable to their soil is needed, and that rice is not really ideal for all provinces. The second interpretation of divergence is that, it is possible that the agricultural interventions are not tailor-fitted to the needs of the provinces benefiting from such.

The negative effect of area on growth in yield (declining returns to scale) is an indication that the newly developed production areas are not necessarily optimal for rice production. While many arable lands are still available in various parts of the country, it cannot be allocated for rice production. At least for the rice sector, expansion of harvest area seems not to provide support for growth. Corn production area does not significantly contribute to yield of rice. This means that either there is not enough crop rotation between rice and corn, or that rice and corn farmers do not give up production area for the other crops.

The autoregression parameter estimate is only 0.1014. This means that random shocks in yield in the previous quarter influences only about 10% of the random shocks in yield for the present quarter. This means that rice farming has become more intensive, that the present random shocks like technology application, soil, and weather endowments are usually inherited across neighboring quarters.

Table 1. Convergence in Quarterly Growth in Yield of Rice

Random Effect Model

		Determinant	Coefficient	p-value
Overall Fit p-value	0.0000			
ρ	0.1014	Constant	-0.0462	0.166
σ_u	0.0327	Log(Yield)	0.1889	0.000
σ_ε	0.2243	Log(Area)	-0.0107	0.001
$\sigma_u/(\sigma_u+\sigma_\varepsilon)$	0.0208	Log(CornArea)	-0.0010	0.652

Random Effect Model Adjusted with Spatial Autoregression

		Determinant	Coefficient	p-value
Overall Fit p-value	0.0000			
ρ	0.1014	Constant	-0.0503	0.134
σ_u	0.0347	Log(Yield)	0.2629	0.000
σ_ε	0.2216	Log(Area)	-0.0102	0.002
$\sigma_u/(\sigma_u+\sigma_\varepsilon)$	0.0239	Log(CornArea)	-0.0018	0.439
		Spatial Neighborhood	-1.6889	0.000

Table 2. Convergence in Quarterly Growth in Deseasonalized Yield of Rice

Random Effect Model

		Determinant	Coefficient	p-value
Overall Fit p-value	0.0000			
ρ	-0.1557	Constant	-0.1376	0.000
σ_u	0.0294	Log(Yield)	0.2649	0.000
σ_ε	0.2108	Log(Area)	-0.0137	0.000
$\sigma_u/(\sigma_u+\sigma_\varepsilon)$	0.0190	Log(CornArea)	-0.0022	0.341

Random Effect Model Adjusted with Spatial Autoregression

		Determinant	Coefficient	p-value
Overall Fit p-value	0.0000			
ρ	-0.1557	Constant	-0.1766	0.000
σ_u	0.0290	Log(Yield)	0.3285	0.000
σ_ε	0.2079	Log(Area)	-0.0130	0.000
$\sigma_u/(\sigma_u+\sigma_\varepsilon)$	0.0190	Log(CornArea)	-0.0022	0.318
		Spatial Neighborhood	-1.3433	0.000

The random effect due to the provinces accounts for a little more two percent of the aggregate of spatial and temporal variance (excluding the effect of the spatial parameter). This is an indication that spatial dependency is better accounted by the spatial autoregression component than by simply postulating a random component for the provinces. If the average residuals in a neighborhood are positive, then that is deducted (negative sign of coefficient) from the prediction of yield indicating that spatial externalities contributed negatively to yield. On the other hand, if the average initial residuals is negative, then the spatial externalities are meant to contribute positively to yield, hence the spatial effect is added accordingly.

The spatial externalities associated with a region includes, but not limited to, natural endowments due to ideal weather and soil fertility as well as the implementation of programs geared towards enhancing productivity. Majority of the regions yield positive effects for spatial externalities, with Central Luzon and Davao regions benefiting the most from spatial externalities. Davao region benefits from almost uniform distribution of rainfall throughout the year, in addition to the good quality of soil suited for grains production. Central Luzon, on the other hand, includes the most fertile land ideal for crop production (including rice). There are also the most advanced irrigation systems in the region complementing several demonstration farms of different agricultural research institutions. In 2002, of the 16 rice-producing regions, Central Luzon produced 17% of total rice production in the country. Three regions yield negative effect of spatial externalities, including ARMM, Central Visayas, and Eastern Visayas, where some of the lowest rice production can be observed in the period 1990-2002.

The 1998 El Niño episode contributed further in the divergence in rice yield among the provinces. The extent of the effect of drought varies across provinces. The coping mechanism adopted by the farmers to positively mitigate the ill-effects of the weather anomaly also varies across provinces, further spreading away rice yield. Provinces across the country generally experienced 10% reduction in yield as an effect of the drought. The El Niño episode of 1998 does not contribute significantly to the temporal variation as well as the provincial random effects.

6. Conclusion

A spatial-temporal autoregression model with random provincial effect is postulated to explain rice production growth in the Philippines. Growth rate is computed both from the original yield data as well as from the deseasonalized yield data. Parameter estimates for both growth equations (original and deseasonalized) are similar and the possible effect of deaseasonalization can be observed only in the magnitude of the spatial parameter.

Table 3. Convergence in Quarterly Growth in Yield of Rice (Effect of El Niño)

Random Effect Model

		Determinant	Coefficient	p-value
Overall Fit p-value	0.0000			
ρ	0.1009	Constant	-0.0203	0.555
σ_u	0.0310	Y98	-0.0946	0.291
σ_ε	0.2230	Y98*Log(Yield)	-0.1011	0.025
$\sigma_u/(\sigma_u+\sigma_\varepsilon)$	0.0190	Y98*Log(Area)	-0.0191	0.053
		Y98*Log(Corn Area)	0.0109	0.103
		Log(Yield)	0.1684	0.000
		Log(Area)	-0.0093	0.007
		Log(Corn Area)	-0.0024	0.304

Random Effect Model with Spatial Autoregression

		Determinant	Coefficient	p-value
Overall Fit p-value	0.0000			
ρ	0.1009	Constant	-0.0160	0.644
σ_u	0.0331	Y98	-0.1097	0.216
σ_ε	0.2205	Y98*Log(Yield)	-0.0974	0.029
$\sigma_u/(\sigma_u+\sigma_\varepsilon)$	0.0220	Y98*Log(Area)	-0.0102	0.107
		Y98*Log(Corn Area)	0.0102	0.124
		Log(Yield)	0.2414	0.000
		Log(Area)	-0.0094	0.007
		Log(Corn Area)	-0.0033	0.172
		Spatial Effect	-1.7289	0.000

Table 4. Convergence in Quarterly Growth in Yield of Rice (Effect of El Niño With Interaction on Spatial Autoregression)

Random Effect Model with Spatial Autoregression

		Determinant	Coefficient	p-value
Overall Fit p-value	0.0000			
ρ	0.1003	Constant	-0.0160	0.645
σ_u	0.0331	Y98	-0.1052	0.238
σ_ε	0.2205	Y98*Log(Yield)	-0.0838	0.116
$\sigma_u/(\sigma_u+\sigma_\varepsilon)$	0.0220	Y98*Log(Area)	-0.0163	0.098
		Y98*Log(Corn Area)	0.0104	0.117
		Log(Yield)	0.2425	0.000
		Log(Area)	-0.0094	0.007
		Log(Corn Area)	-0.0033	0.170
		Spatial Effect	-1.7515	0.000
		Y98* Spatial Effect	0.2745	0.645

Adjusting for spatial effect of the regions, the provinces failed to exhibit convergence in rice yield. The negative effect of area on growth in yield is an indication that the newly developed production areas are not necessarily optimal for rice production. While many arable lands are still available in various parts of the country, it cannot be allocated for rice production. At least for the rice sector, expansion of harvest area seems not to provide support for growth. Rice farming has become more intensive, that the present random shocks possibly caused by technology application, soil, and weather endowments are usually inherited across neighboring quarters.

A spatial term is incorporated into the model, providing empirical evidence for the need to localize rice production policy programs across the country. The spatial term accounts for the natural endowments of the producing provinces that complement those policies in realizing progress in the sector.

The 1998 El Niño episode contributed further in the divergence in rice yield among the provinces. The extent of the effect of the drought varies across provinces. The coping mechanism adopted by the farmers to positively mitigate the ill-effects of the weather anomaly also varies across provinces, further spreading away rice yield. Provinces across the country generally experienced 10% reduction in yield as an effect of the drought.

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