ADB Institute Discussion Paper No. 65

Spatial Effect in the Efficient Access of Rural Development

Erniel B. Barrios

May 2007

Erniel Barrios was a visiting researcher at the Asian Development Bank Institute from July–December 2006. He is also a professor at the School of Statistics, University of the Philippines.

ABSTRACT

The search for an effective policy direction to contribute to the alleviation of rural poverty requires understanding of various socio-economic dynamics affecting the household. The central issue in the economic dimension is inefficiency in production, which may contribute to the widening income gap among rural households. Spatial externalities are introduced into a stochastic frontier model in the analysis of rural households' efficiency in utilizing various factors of production including development interventions (infrastructure and capability-building activities) and other localized endowments. Output is measured in terms of income and perceptions on various aspects of rural development summarized into an index.

Provision of rural roads and other rural infrastructure should be bundled properly with support services and capacity building activities. This can enhance the demand for other infrastructure and services resulting in a dynamic evolution of essential elements in the pursuit of rural development. Bundles of intervention improve production efficiency of rural households at the different stages of production in-farm and/or off-farm.

Spatial indicators illustrate the role of geographical dynamics (physical, social and cultural factors) in rural development, justifying a site-specific, participatory approach in development intervention. Although site-specific interventions may be costly at first, they become more efficient in the long-run. Benefits from an intervention in one community are expected to produce ripple effects that reach its spatial neighbors.

Stakeholders' contribution in maintenance is feasible provided that there is a true sense of ownership of the infrastructure/project, usually evolving through a participatory approach. Public investment in infrastructure and user's fees can complement one another; continuous provision of new infrastructure and maintenance of existing infrastructure can add up to a sustainable track towards rural development. A socialized user's fee system can be used as a vehicle to prevent the potential widening of income disparity in rural areas. It is important however to carefully choose a suitable and acceptable basis for the socialized user's fee rates. An incorrect choice can be perceived as a disincentive for access or might stimulate distrust among the affluent segment of the rural society regarding the sincerity of the government in pushing rural development. An unsuitable basis for user's fee rates could thus eventually lead to more social problems instead of bridging inequality.

Keywords: *rural development, rural infrastructure, household efficiency, spatial autoregression, spatial stochastic frontier*

1 INTRODUCTION

Rural populations live in a simple environment, yet the structure and the dynamics of their day-to-day life are complex. Patterns of social processes vary across countries, and even across regions within a country; these patterns are highly sensitive to cultural differences. The study of rural societies has garnered interest in development economics as well as in many other disciplines. The panoramic view of developing economies is overshadowed by rural societies. Vulnerability, inequity, and deprivation are common issues confronting rural societies, prompting development assistance/interventions slanting in their direction.

Income vulnerability, one major issue confronting rural societies, exhibits strong interdependence with other thematic issues. In their own initiative to avoid exposure to income vulnerability, rural households tend to find ways to augment their livelihoods, which are mainly based on agriculture in a limited parcel of land. Their natural strategy for income augmentation often results to excessive, unsustainable use/harvesting of natural resources. Some examples are clearing of forest for additional agricultural land, logging, over-fishing (even using illegal tools/gear) in inland and coastal water, and intensive crop production resulting in massive environmental degradation. Some rural residents have opted to join the rural-urban labor migration that has been rampant in the rural Philippines for the last three decades. Initially, this process was motivated by conflict and social unrest. Later, and up to the present, poverty and the evolving economic landscape have also contributed to this migration.

The prominence of agriculture among rural communities naturally brings about linkages between rural and agricultural development. The role of agricultural development in fostering rural development cannot be ignored. The engine of agricultural development relies on facilitating production and efficient utilization of resources among the farming households. The study of agricultural development focuses on understanding how factors of production (technology, social and economic support services) are efficiently allocated to optimize output/outcome.

Facilitating non-farm livelihood is one commonly used strategy to complement agricultural development towards rural development. The outcome of this strategy is rural income diversification. Empirical evidence provides crucial inputs; see Barrett, et al. (2002), for instance, on the extraction of policy implications that can enable the diversification of rural income.

How is agricultural development stimulated? This question is best answered when each factor of production is analyzed in the context of production optimization/efficiency. The role of land ownership in agricultural production has long been used as a justification of agrarian reform programs in various countries. Farmers, the argument goes, will be free to choose a resource allocation scheme that will optimize production if they are not entangled in the bondage of the land, when there is no landlord who decides primarily despite lacking direct knowledge of the farming system. Landlords may decide how resources should be allocated only on the basis of their instincts to protect their interests, so their decisions may not necessarily yield optimum production. There is thus inefficiency in production when the farmer does not own the land. The farmer's lower stake means lower effort that will not necessarily involve highly-profitable crops may be provided (Bandiera, 2002). However, a farmer who owns the land may opt to plant high-value crops and exert proportional efforts to enhance productivity. Similar observations were made by Larson and Plessmann (2002) that farming households that differ in their ability or willingness to take on risks are likely to make different decisions when allocating resources and effort among income-producing activities; these decisions have consequences for productivity. Diversification and technology choices do affect efficiency outcomes among farmers, although these effects are not dominant. In a similar context, but on a higher level of empowerment (organized community), Ranis et al. (2001) highlight the linkages between group behavior and economic performance.

Other points of view concerning land ownership differ with the above. Using a modern theory of agrarian organization, Conning and Robinson (2002) offered a reason why tenure improvement, despite its economic advantages, has been so little used in countries where agrarian reform is a salient political issue, explaining the relative failure of land reform in Latin America.

It is also possible that development policies are leading towards the opposite of what has been expected. Boothroyd and Nam (Eds., 2000) observed that in Vietnam, the appropriate balance in agricultural/industrial and rural/urban development occurred, but that industry has been deprived of the necessary endogenous factors for development. Streams of people have surged into towns and cities, crowding into slums, leaving behind a destitute, miserable countryside. Analyses by policymakers and leading scientific researchers have led to a conclusion that because of the small scale of agricultural cooperatives, conditions were not conducive to a re-division of labor in the direction of centralization and specialization that would promote enhanced production.

Development intervention can be broadly classified into four (possibly overlapping) categories: economic infrastructure (e.g., credit, production support); physical infrastructure (e.g., roads, irrigation); capacity building (e.g., training, information dissemination); and support services (e.g., marketing services, facilitation of access to basic social services). Physical and economic infrastructure has been emphasized from the start but it seems that the policies and other implementing guidelines may have not evolved completely to support development. Progress among developing countries, particularly the rural areas, has been slow. The role of infrastructure in development is emphasized in the literature. In most poverty reduction strategy programs (PRSP), financing demands usually focus on infrastructure like roads, potable water systems, and irrigation systems. Some studies that link infrastructure and development are discussed below.

Rural areas are characterized by isolation, lack or inadequate provision of basic amenities, inadequate health and social services, etc. Isolation needs to be resolved before it will be feasible for other issues to be resolved. Farm roads facilitate access to the major supply source and market destinations. Roads are expected to facilitate the reduction of costs for transporting farm inputs and bringing the produce to the supply chains. Although Glaeser and Kohlhase (2003) focused on peri-urban centers, they reported some 90% reduction in the cost of transporting goods through an efficient road system.

Although the economic importance of infrastructure is supported in the literature, there are also some negative externalities to the society. Dams, for example, are perceived to contribute towards sustainability of irrigation. They are also costly and controversial but Dulfo and Pande (2005) emphasized that there is less known about their impact. In an area where dams were constructed in India, production did not increase but poverty did. Among areas benefiting from irrigation, production increased, but those residing in the areas that become flooded due to the dam were vulnerable to substantial economic losses. Thus, dams can lead to widening inequality. It was argued that as a whole, dam construction resulted in aggravating poverty because no safety nets were provided to the disadvantaged segment of the community.

The localization of infrastructure development polices was studied by Demurger et al. (2002) in China with the conclusion that there is geographic inequity of growth. There is a perception that coastal areas in China benefit from preferential policies, but this is actually because of deregulation policies that allow them to link to the international economy. Instead of re-imposing regulations, expanding deregulation to the inner provinces can help quicken growth. Infrastructure development to improve the accessibility of inner provinces is needed along with human capital development towards poverty alleviation.

Countries that use infrastructure inefficiently are effectively paying for growth at a much higher rate than those that use infrastructure more efficiently (Hulten, 1996). Capital stocks (infrastructure) that are not efficiently used would render marginal growth for additional capital formation. This usually happens when infrastructure identification lacks community participation, resulting in supply-demand mismatch. Furthermore, new investments (capital) need not indicate economic growth while efficient use of such translates into real growth. Hence, maintenance and sustainability are more important than putting up more new investments.

The effect of public infrastructure on Philippine agriculture has been established. Teruel and Kurodo (2005) used a trans-log cost function framework augmented with public infrastructure viewed as fixed input. Infrastructure substitutes labor and intermediate inputs. This supports the public capital hypothesis of complementation between public infrastructure and private capital input. The importance of farm roads in altering input demand and enhancing productivity is also established.

We will explore how rural households allocate and utilize factors to optimize production in order to mitigate their vulnerability due to dependence on agriculture, possibly leading them out of poverty. Production output will be measured in terms of income and rural households' perception of the presence of certain attributes of rural development aggregated into an index. Rural infrastructure, other development interventions and local/household endowments will constitute the exogenous determinants of production and efficiency in household production.

2 SOME MODELING STRATEGIES

The usefulness of an econometric model depends on the soundness of the assumptions underlying the mathematical equation. The plausibility of the model to depict reality is crucial in development studies aimed to understand the patterns and the engines that fuel the progress of an economic unit.

Lewis (1984) divided development theory into two categories: that relating to short-run allocation of resources and that relating to long-term growth. In the short-run, the main issues include price that does not equate to real social cost; an unregulated market that constraints productive capacity; and production and exchange not governed by the income maximization objective, but rather by other “non-economic” considerations. Decision making in development economics is not done on the sole basis of economics, but by integrating sociological perspectives as well (social cost, specifically). In long-term growth, two major issues exist: the search for an engine of growth, and the growth pattern. For the rural poor, land reform, infrastructure, production support, capacity building, etc. comprise a typical package serving as the growth engine. Lewis further proposed that the real question is, given an intervention policy, how much change in development indicators do we expect? If so much land will be distributed for tenure improvement, how much increase in rural income is expected? In other words, it is not enough to say that infrastructure leads to income growth; more relevant information is the amount of contribution expected for a unit of infrastructure added.

To determine the impact of policy reforms in rural economies, the reaction of households to policy shocks was modeled by Taylor et al. (2005). The computable general equilibrium (CGE) model was used, and the resulting model accounts for the interaction among sectors, but is not able to assess household behavior as a consequence of the policy shock. The researchers proposed a new methodology that combines the advantages of both approaches (household and CGE models). Simulation was used to illustrate the role of the rural market constraints and the heterogeneity of the households in shaping household behavior.

2.1 STOCHASTIC FRONTIER MODEL

Traditional econometric modeling aims to explain the output indicator **y** in terms of determinants, say **x**. In the event that the predicted value $\hat{y}$ is different from the actual value y, it is often explained in statistics as the amount due to other unaccounted determinants or to random errors that cannot be accounted for by x through the model.

Stochastic frontier analysis (SFA) or the "composed" error model was developed in the late 70's to provide an alternative paradigm to the usually optimizing producer in the standard econometric literature. The stimulus is the observation that some stakeholders in an economy will not be successful enough in their optimization endeavors. In lieu of the optimization target (which cannot be achieved anyway), the aim may be adjusted to at least know how close they are to the optimum. An appropriate measurement of the distance of their actual production from the maximum potentials can push forward their allocative and productive efficiency. The measures of efficiency can then be linked to certain exogenous factors and anybody who is short of the optimum level will now be in the position to strategize towards attainment of that optimum in the future. The exogenous factors will provide guidance in the development of such strategies. SFA offers an alternative to the standard econometric assumption of equilibrium because it allows a certain degree of inefficiency. The SFA then led to a new error structure that is a composite of true error and those factors (presumably heterogeneous and unknown among producers) that contributed to the inefficiency. Fortunately, there is a growing area in statistical science called mixed models that readily supports the estimation and other statistical aspects of stochastic frontier analysis.

Kumbhakar and Lovell (2000) provided a comprehensive account of the developments in SFA. This account provides our major source for subsequent discussions. The cross-sectional production frontier model is given by $y_i = f(x_i;\beta)\exp(v_i)TE_i$ or $TE_i = \frac{y_i}{f(x_i;\beta)\exp(v_i)}$, where y_i is the single output of producer i, x_i is the vector of inputs used in producing y_i, f is a parametric function, TE_i is the output-oriented technical efficiency of producer i, and v_i is a random error. TE=1 implies efficiency, while TE<1 indicates a shortfall (inefficiency) in an environment characterized by $\exp(v_i)$, possibly varying across producers. Let $TE_i = \exp(-u_i)$, then the production stochastic frontier model becomes $y_i = f(x_i;\beta)\exp(v_i)\exp(-u_i)$, the last two factors accounting for two error components.

For the parametric function f, the literature is dominated by those that assume the Cobb-Douglas family. Recently, however, Henderson and Simar (2005) considered a nonparametric specification of f. The nonparametric specification is desirable in cases where the modeler is not willing to risk any parametric functional form because of insufficient knowledge about the phenomenon being modeled. Even a Bayesian formulation of f was considered by Koop and Steel (2004). Contrary to the nonparametric argument, if some prior knowledge about the efficiency of producers being analyzed is available, the Bayesian strategy is the best way to incorporate such knowledge into the model.

The model is usually estimated via the maximum likelihood (MLE) procedure. The quantities v_i, u_i, and x_i are assumed to be independent and v_i is assumed to be normally distributed while u_i is often positive half normal to ensure that $TE \leq 1$. Other combinations of the distribution of v and u include normal-exponential, normal-truncated normal, and normal-gamma. Green (1990) reported that estimates of efficiency vary depending on the distributional assumption on v and u. The nature and relationship between v and u can be enhanced further into the model using mixed models.

Stochastic frontier models for panel data were also postulated. In the time-invariant technical efficiency assumption, the following models were considered: fixed-effects model, random-effects model, or even mixed model (for multiple output case). Kumbhakar and Lovell (2000) warned that the longer the panel, the less likely it becomes that technology remains constant, amounting to a serious violation of the assumption. The learning curve of producers is expected to improve over time. Therefore, any inefficiency realized in the distant past may have been resolved already and that inefficiency will arise from new sources.

The literature on time series data considered time-invariant or time-varying technical efficiency. The error assumptions also considered fixed and random effects. Heteroskedasticity in u and v was also considered, possibly leading to volatility assumption in technical efficiency.

To complement the production frontier, a cost frontier can also be specified so that instead of measuring how close actual production is to optimum production, the distance between lowest cost and realized cost is also compared. In both cases, efficiency is attained through appropriate allocation of resources (input).

The stochastic cost frontier model is given by $E_i \geq c(y_i, w_i : \beta)\exp(v_i)$, $E_i = \sum_n w_{ni} x_{ni}$ is the total cost incurred by producer i, $w_i = \{w_{1i}, w_{2i} ..., w_{Ni}\}$ is the vector of input prices for producer i, $\mathbf{y_i}$ is output of producer i, $x_i = \{x_{1i}, x_{2i}, ..., x_{Ni}\}$ is the vector of inputs incurred by producer i to produce output $\mathbf{y_i}$, β is a vector of technology coefficients, c is the cost function common to all producers, and $\exp(v_i)$ is the producer-specific cost. The cost efficiency (CE) is $CE_i = \frac{c(y_i, w_i : \beta)\exp(v_i)}{E_i}$.

One aim in SFA is to explain inefficiency/efficiency in terms of exogenous determinants. Kumbhakar and Lovell (2000) summarized the commonly used models to account for such.

1. $y_i = f(x_i, z_i; \beta)\exp(v_i)\exp(-u_i)$, the exogenous factor interacts along with the factors of production in the parametric function f.

2. Estimate TE_i first, then regress it on z_i (two-step estimation). The resulting model may be interpreted as the regression of technical efficiency on z, conditioning on the sampling distribution induced by the true error and the causes of inefficiency, $E(u_i / v_i - u_i) = g(z_i ; \lambda) + \varepsilon_i$

3. Assuming a Cobb-Douglas production function, $\ln y_i = \ln f(x_i ; \beta) + v_i - u_i$, $u_i = \gamma' z_i + \varepsilon_i$ => $\ln y_i = \ln f(x_i ; \beta) + v_i - (\gamma' z_i + \varepsilon_i)$ (Kumbhakar et al., 1991). The exogenous determinant is postulated outside the production function. This implies additivity of the effect of factors of production and exogenous factors to actual production.

4. $\ln y_i = \ln f(x_i ; \beta) + v_i - u_i$, $u_i = g(z_i ; \gamma) + \varepsilon_i$ (Reifschneider and Stevenson, 1991). This model is very much like that in (3).

5. $\ln y_i = \ln f(x_i ; \beta) + v_i - [g(z_i ; \gamma) + \varepsilon_i]$. The function g is allowed to include interaction of x_i and z_i (Huang and Liu, 1994).

The choice of the best way to analyze the effect of exogenous factors depends on the adequacy of the underlying assumption associated with the model. For example, if it is theoretically sound that the effect of the exogenous factors and the factors of production are additive, then (3) or (4) can be specified. The resulting estimates of production efficiency, however, are expected to vary according to the postulated model. Some simulation studies may help guide the researchers in the choice of an appropriate form of the way the exogenous factors are introduced into the model.

The use of SFA is not necessarily confined among establishments as producing units. Amos et al. (2004) used SFA in studying productivity and technical efficiency of small-scale farmers in Nigeria, providing empirical evidence of the common assumption that farmers engaged in mixed crops generally achieve higher technical efficiency than do those propagating only one crop at a time. Other demographic factors (exogenous to agricultural production) also affect technical efficiency in addition to cropping patterns.

2.2 SPATIAL CHARACTERISTICS OF DEVELOPMENT

Economic geography or spatial economics studies the location and reason for the choice of location or certain economic activities. The role of space in the dynamics of some phenomena has been acknowledged not just in economics but in many other disciplines as well. In economics, the distribution of economic activities in space is important in facilitating optimization of resource allocation, developing competitive cooperation, zoning, and even in the development of competition policies and many other concerns. In cases where such distribution changes, the impact on individuals and communities will be desirable to know because this knowledge will contribute to understanding overall changes to be expected in the growth patterns of the economy in general. This is contrary to the implicit assumption of neo-classical economics where activities are supposed to be evenly distributed across space. Venables (2006) argued that the neo-classical assumption is not realistic because it boils down to “backyard capitalism” where production is intended primarily for local demand. Plausible explanations for location-dependence of economic activities include, among many, availability of raw materials, accessible natural resources, skill of the labor force, general policies resulting in zoning, socio-cultural aggregation, industrial clustering, cooperation, competition, and demand.

Little importance has been accorded to economic geography, but interest has grown dramatically in recent years (Fujita et al., 1999). This development was paralleled by development in statistics that readily offer modeling tools. Spatial models are available in a longer time period, but in recent years, interest focused more on the space-time interaction of certain phenomena. Spatial economics, especially the issues of economic clustering and integration, will provide an avenue to better understand a more general pattern of economic growth.

Transportation cost has been an important determinant in clustering of economic activities leading to its spatial distribution. The fundamental premise is that geographical distance is a barrier to economic interaction, and time in transit is costly (Venables, 2006). Redding and Venables (2002) used a structural model of economic geography (estimated from cross-country data) and provided empirical evidence that the geography of access to markets and sources of supply explains cross-country variation in per capita income.

The effect of geography on the macroeconomy was analyzed by Gallup et al. (1998). The analysis looked at how location and climate affect (directly and indirectly) income and income growth through transportation cost, disease burdens, and agricultural productivity, among others. They also pointed out that even the choice of policies could also be geography-dependent. For example, if the production area is far from coastal areas, then large transportation cost is expected. As a policy response to this constraint, so that the same goods remain competitive, tariff liberalization can be considered.

A spatio-temporal model for some poverty indicators was postulated and estimated by Barrios and Landagan (2004). The result lends evidence that there is indeed a spatial clustering among the provinces in the Philippines with reference to the poverty indicators used. Provinces within a region exhibit a similar picture of the poverty situation. Thus, a strategy for alleviation may be adopted for a group of provinces rather than tailor-fitting it for individual provinces. The role of targeted intervention is emphasized over universal strategies. The interaction of socio-cultural scenarios would necessarily link and group together adjacent communities, explaining the spatial character of the poverty phenomenon.

3 THEORETICAL FRAMEWORK

The dynamics in a typical rural community are an irony between simplicity in rural life and the complexity of the economic system that is operating. The literature offers diverse theories and perspectives in trying to explain the rural economy. There seems to be a cycle over the years among these theories, postulated, reinvented, reformulated, refuted in some cases, and emerging again in recent literature. Lewis (1984) postulated that in the rural economy, growth is triggered by the initiation of trade. Farmers are producing not just for consumption but also for the demand in other communities. This is a valid assumption once productivity had surpassed the threshold for local needs. Otherwise, if the production level is still below the threshold, marginalization and subsequent exposure to vulnerability will dominate the rural production with growth hardly manifesting if not remaining impossible. Intensive intervention will be needed to push them initially to cross the threshold for growth. Growth will naturally push economic activities towards diversity at the community level and possibly (but not necessarily) specialization at the household level. In a growing rural economy, households cannot be competitive if they refuse to specialize. Given the limited technologies available to them (agriculture and non-agriculture), specialization will help maximize production in the light of economies of scale. As examples, working within a specific industry for microenterprise development (non-agriculture), raising specific crops requiring special farming systems (and technology) for agriculture, or even specialization of services offered in a diversifying economic environment, will continue to raise households' competitive advantage in that area. Specialization will stimulate efficiency in rural production and possibly curtail certain factors of production (in the hope of attaining efficiency). Among the factors of production, labor is easily substituted through the choice of appropriate technology, resulting in displacement of many rural workers. This phenomenon was observed in the rural Philippines, which has continuously been experiencing rural-urban migration for the past three decades or so. A sizeable proportion of labor migration spills over to other countries. In the desire for market efficiency, specialization can actually lead towards inequality because of the unequal utility values placed on different production activities. As Lewis (1984) points out, market efficiency is not the solution towards equilibrium in an agrarian economy; the concept rather equates social cost with the real gains from trade to serve as an engine of growth. The solution proposed then is empowerment of rural communities. Empowerment can include, but is not limited to, the provision of infrastructure and capacity building. The framework that this study is based upon revolves around the complementation of infrastructure and capacity building in forging a path towards rural development.

The initial role of the government is neither regulation nor governance but empowerment of local communities, similar to the paradigm proposed by the World Bank in poverty alleviation. Empowerment is defined in this paradigm as *"the expansion of assets and capabilities of poor people to participate in, negotiate with, influence, control, and hold accountable institutions that affect their lives"* (Narayan, 2002). Focusing on empowerment in the framework, market efficiencies can be gradually attained since this will help in narrowing the information asymmetries among the stakeholders (the suppliers, the traders, the market/retailers, and the producers/farmers). The empowered stakeholders would like to gain access to pertinent information before they take specific decisions. Rural roads, other rural infrastructure, and capacity building activities will enable all the stakeholders to access relevant information of the supply-demand chains for rural/agricultural goods and services. The stakeholders can use such information in the efficient allocation of factors of production.

In the process, the government needs to facilitate the dynamics where the stakeholders interact towards attainment of efficiency. For certain interventions like credit, direct provision of say seed capital may be provided by the government or can be taken from some other forms of development assistance. This is also true for other infrastructure where the initial construction will need money that is beyond the capability of the stakeholders. It is important though to consider that rural infrastructure does not follow similar protocol as in mainstream public economics, where cost and maintenance have to be secured from the beneficiaries through the process of taxation. Many of the rural beneficiaries in developing countries fall short of the cut-off for taxable income brackets. However, direct provision should not be continuously done; the government and donors will have to veer away from direct provision and focus on facilitation to stimulate a participatory environment leading towards sustainability. It is important for the stakeholders to establish ownership. Hence, encouraging them to contribute (in cash or in kind) for maintenance to safeguard the sustainability plan should be part of the design of the intervention. The notion of user's fees is difficult to inculcate among the stakeholders especially because they have limited income and livelihood opportunities. A good advocacy strategy though will help rural stakeholders to eventually accept the concept of user's fees.

Models will be developed to explain the dynamics of the rural economy. The models will consider a household that would like to maximize its welfare function and will take into consideration spatial distribution. The spatial dimension will rationalize site-specific packaging of bundles of intervention. A stochastic frontier model, basically a production frontier, will also be developed with spatial dimensions. Note that the spatial dimension is justified in terms of soil fertility and diversity of economic activities determined by topography, among others. This model will help explain how inequality among rural households can be traced to how efficient/inefficient they are in accessing the factors of production available to them.

The data that will be used in the empirical investigation will be discussed and presented along with the empirical modeling strategies.

3.1 THE ROLE OF RURAL ROADS

A rural road will be defined as an access route from the main road network to the rural communities and/or production areas. It is intended to provide an access path for individuals residing in rural communities and passage for light public vehicles carrying people and/or produce. Such roads allow transportation cost to be reduced because vehicles carrying farm loads are cheaper than the human carriers that are still used where there is no such road in many rural areas of the Philippines.

Farm roads are often constructed as dirt pavement, or are topped with gravel, with asphalt, or very seldom, with concrete (see Figure 4.1). Usually, only people and light vehicles pass through, but during harvest season, the local government or some community organization upgrades it so that haulers can reach as close as possible to the production areas. The roads in the main road network, called national roads in the Philippines, are usually constructed with concrete materials and are wider, thus accommodating heavy-duty haulers that will collect the produce and bring it to the main distribution depot (government or privately owned).

Figure 3.1 Typical Rural Road in the Philippines

The path of rural development from the improvement of accessibility in the rural communities will start from the known direct impact of rural roads. Roads are intended to mitigate an area's state of isolation that otherwise hinders the initiation of various facets of development. Improved access roads among the rural households will lead to increased accessibility and movement because of lower transportation cost, increasing economic activities. The literature documents a wide range of percentages of reduction in transportation cost as a result of establishing new rural roads or improving existing ones. Regardless of the amount of inputs invested, rural roads are expected to contribute to lowering transportation cost.

Improvement in road networks starts up a feedback system of input procurement and marketing of produce. Producers are expected to pay less for the inputs of production because of the improvement in accessibility, so they become more capable of procuring more inputs. The different suppliers of inputs will lose monopoly and be forced to become competitive since the farmers will now have alternative sources. Marketing will also not be limited among a few traders, resulting in a negotiable pricing system since transportation cost reduction will open the ceiling of price negotiations. This is of course based on the assumption that commodity financing (usually associated with price ceilings for goods and not so fair to the farmers) is no longer practiced or that there is a sustainable credit facility in place. Knowledge of marketing avenues and demand for various commodities (to be facilitated by the government) will encourage farmers to diversify crops, and later on, to specialize in high value crops only viable in the production area (efficiency). Thus, increased production and increased gross value coupled with lower input cost will benefit the farmers in terms of increased earnings.

Improved accessibility will also facilitate provision of basic social services like education and health. Even if such services are not brought right into the community, it will be easier for the households to access those from the town centers or in another community. Social services should result in enhancement of human capital and along with other capacity building interventions, should contribute to empowering the rural community.

Rural roads will also generate multiplier effects. Foremost, they serve as catalysts for greater public investment into infrastructure and capacity building. Given that an improved access road will facilitate the construction of a health center (and visits of health professionals), a warehouse for agricultural commodities, and even the conducting of training and other capacity building activities. Provision of other physical infrastructure will be feasible because materials can be easily transported. Then for those manned by personnel from outside the community, or for capacity building where resource persons come from outside, traveling into the community will be viable now, reducing the lost time normally spent traveling to the site.

Because of the improved mobility of the households, they will be exposed to outside communities and may observe prototype development that will serve as a stimulus for their desire to realize similar development in their locality. It will then foster a good motivating factor for them to participate in the process of identification of strategies that can lead towards development. This is the start of community building that will later on evolve into a sustainability backbone.

With the growing demand for infrastructure, demand for support services will also increase, requiring more participation on the part of the household in planning and in sourcing for infrastructure and support services. This will encourage the local government to contribute as well, so sustainability will become clearer. All of this will lead to increased production. Because of the growing demand for infrastructure, there is now a viable input sourcing at reasonable cost (due to reduction in transportation cost). Better post-production handling will result in lower post-production losses, yielding a good profit margin for the farmers.

For the non-agricultural household, the direct impact of roads will be in terms of facilitating the emergence of new investments and new enterprises. Eventually, more diverse choices of livelihood will become available to them, an important manifestation of rural development.

The complementation between increased production among farming households and the non-farming households engaged in microenterprise development are early leads towards rural development. In rural areas where employment opportunities should extend beyond the traditional agriculture basis, the empowered households—a stronger community that participates in intervention programs—will benefit not only the individual households, but the entire community, leading towards sustainability.

3.2 DATA SOURCES

A client satisfaction survey was commissioned by the World Bank in 2005 (NEDA-WB-ASEM, 2005) to develop a perception-based survey that will facilitate the verification of the effect of the outputs of the rural sector agencies (Department of Agriculture, Department of Agrarian Reform, and Department of Environment and Natural Resources) on rural development in the Philippines. A rural development and living condition scale (see Appendices 1 and 2) was developed and pilot-tested several times (see NEDA-WB-ASEM, 2005 and NEDA-WB, 2003). It was concluded that the scale can approximate the constructs of rural development. The survey was implemented in purposively selected *barangays* (villages) where households were then randomly selected. In the purposive selection of the barangays, prototype interventions of the departments were considered, along with an appropriate control group (no known intervention from the government in recent years). For the government interventions, the strata were defined in terms of whether the project is locally funded or with foreign funding for each of the three major departments working within the rural sector (agriculture, agrarian reform, and environment and natural resources). The delineation between local and foreign funding serves as a proximate indicator of the intensity of resources used in implementing the project, where resources from local sources are usually lesser than those coming from foreign sources. The barangays in the control group were also allocated according to expected income level (low, medium, high income), by topography (upland, coastal areas), and to include the KALAHI-CIDSS sites (a government project using an integrated strategy of facilitating rather than direct provisions, and a participatory approach rather than imposition of appropriate interventions). More than 6,000 households were included in the database. Only rural barangays were included.

The Family Income and Expenditures Survey (FIES), conducted every three years by the Philippine National Statistics Office (PNSO), will also provide data analyzed in this paper. It is a probability sample of about 20,000 households with rural-urban areas of the provinces as domains (until 2000). In 2003, the domain was raised to the regions. In return, more detailed information was collected. The units of analysis are also the households, but in contrast to the information from the Client Satisfaction Survey, long-term outcomes are collected. Transportation cost is used as a proxy indicator of road system improvement.

3.3 BACKFITTING ESTIMATION

In a model with several variables including a good number that are dichotomous (dummy) variables, estimation using least squares may be affected because the design-matrix can become ill-conditioned. Estimates may yield reverse signs, so sensitivity analysis on each independent variable may not be feasible. Forecasting/prediction though may still be viable even when the least squares method is used in the presence of ill-conditioning in the design matrix.

To resolve the potential problem caused by ill-conditioning in the design matrix, the backfitting algorithm can be used in the estimation. The algorithm assumes that the postulated model is additive, a generalization of the linear regression model. The model is expressed as a sum of basic functions that can be linear, non-linear, or non-parametric. The additive model is given by

y = α + $\sum_{j=1}^{r} f_j(x_j) + \varepsilon$. The function f can be of the form $f_j(x_i) = \beta_j x_j$, ε are independent of the *x*'s, *E*(ε) = 0 and *var*(ε) = σ^2. The backfitting algorithm described by Hastie and Tibshirani (1990) enables additive model-fitting using any regression-type estimation mechanism, given by:

(i) Initialize: α = ave(y_i), $f_j = f_j^0$, *j = 1,2,…,r*

(ii) Cycle: j = 1,2,...,r

$$\hat{f}_j = S_j\left[\left(y - \sum_{k \neq j} f_k\right) \Big/ x_j\right]$$

(iii) Continue (ii) until the individual functions do not change where S_j denotes a smoothing of the response ***y*** against the predictor $\boldsymbol{x_j}$.

Smoothing may reduce to ordinary least square for simple regressions (one-at-a-time) if the functions are linear.

3.4 EFFICIENCY IN HOUSEHOLD PRODUCTION

Stochastic frontier analysis (SFA) will be used in analyzing efficiency of household production both from farm and non-farm sources. The model will be used in explaining inequality among rural households. It is postulated that inequality among rural households will depend on how efficient they are in utilizing infrastructure facilities towards increasing their income and other benefits in general. This is also affected by the combination of infrastructure and other interventions available and is needed in their production activities. Bundles yield more effect than simply adding the individual effect of each intervention.

It is further assumed that efficiency is also affected by spatial dependence in production/income-generation because of soil fertility that is site-specific, diversity of economic activities influenced by topography, homogeneity of agents of transportation, the source and availability of inputs, and markets in adjacent communities.

Technical efficiency will be computed for farming and non-farming activities of the household. The production function will consider income and the rural development index as the dependent variable.

3.4.1 Specification and Estimation of Production Frontier (Model 1)

Consider a cross-sectional production frontier model $y_i = f(x_i;\beta)\exp(v_i)TE_i$ or $TE_i = \frac{y_i}{f(x_i;\beta)\exp(v_i)}$. $[y_i]$ is the actual production and $[f(x_i;\beta)\exp(v_i)]$ is the theoretical production function. x_i is a vector of production inputs needed to produce y_i while v_i is a random error. Note that the distribution of v_i and the form of the function f will dictate an efficient estimation procedure for the parameters. Assuming that the theoretical production function is correct, the ratio between actual and theoretical production level yields a reasonable account of technical efficiency (TE).

The function f should satisfy the following conditions provided by Kumbhakar and Lovell (2000) summarized in Section 2 above. Let $TE_i = \exp(-u_i)$, then the production stochastic frontier model becomes $y_i = f(x_i;\beta)\exp(v_i)\exp(-u_i)$, yielding two error components v_i and u_i. The negative sign for u_i will ensure that TE≤1. TE=1 implies efficiency, while TE<1 indicates a shortfall (inefficiency) in a stochastic environment characterized by $\exp(v_i)$, varying across households. The variable u_i will be linked to some factors that are postulated to influence production efficiency of rural households. Reifschneider and Stevenson (1991) proposed $\ln y_i = \ln f(x_i;\beta) + v_i - u_i$ and $u_i = g(z_i;\gamma) + \varepsilon_i$. We will imbed a spatial autoregression model or SAR (Pace and Barry, 1997) with a general linear mixed model. Thus, the postulated technical efficiency model is $u = w\varphi + z\phi + \delta D[u - w\varphi - z\phi] + \varepsilon$,

where $u = (u_1,...,u_n)'$, $w = \begin{bmatrix} w_{11} & \dots & w_{1a} \\ \dots & \dots & \dots \\ w_{n1} & \dots & w_{na} \end{bmatrix}$, $z = \begin{bmatrix} z_{11} & \dots & z_{1b} \\ \dots & \dots & \dots \\ z_{n1} & \dots & z_{nb} \end{bmatrix}$ $\varphi = (\varphi_1,...,\varphi_a)'$, $\phi = (\phi_1,...,\phi_a)'$, δ is a spatial parameter, $D = |(d_{ij})|$, the spatial weight matrix where $d_{ij} = \begin{cases} 1, \text{if unit i and unit j are spatially related} \\ 0, \quad \text{otherwise} \end{cases}$. Two households will be considered spatially related if they belong to the same barangay/village. w_i is a vector of fixed factors, z_i is a vector of random factors, and $\varepsilon' = (\varepsilon_1,...,\varepsilon_n)$ is pure error. If the observations are arranged so that households coming from the same barangay are next to each other, then the matrix D is block diagonal. The joint distribution of $z' = (z_{11}, z_{12},..., z_{1n},..., z_{i1},...., z_{ij},..., z_{in},..., z_{k1},..., z_{kn})$ and $\varepsilon' = (\varepsilon_1,...,\varepsilon_n)$ is assumed to be normal with mean $E\begin{bmatrix} \varepsilon \\ z \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$ and variance $V\begin{bmatrix} \varepsilon \\ z \end{bmatrix} = \begin{bmatrix} \Sigma & 0 \\ 0 & \Gamma \end{bmatrix} = \Omega$, where Σ and Γ are not necessarily diagonal. We are assuming a general dependence structure among the elements of z' and ε', but independence of elements of z' from elements of ε' is imposed.

Thus, the production frontier equations can be summarized into $y_i = f(x_i;\beta)\exp(v_i)\exp(-u_i)$ or

$$\ln y_i = \ln f(x_i;\beta) + v_i - u_i \quad (3.1)$$

$$u = w\varphi + z\phi + \delta D[u - w\varphi - z\phi] + \varepsilon, \quad (3.2)$$

where $v_i \sim N(0,\sigma^2)$ and $\varepsilon', z' \sim N(0,\Omega)$. The function f may take the Cobb-Douglas form or a more general exponential or a non-linear function. Since dummy variables will be used in addition to factors of production that are zero for some households, an exponential function f will be used. The location of an exponential function can be adjusted so that the six properties above are satisfied.

Estimation will be done using a modified backfitting algorithm (Landagan and Barrios, 2007), taking advantage of the additive nature of (3.1) and (3.2). The estimation algorithm follows:

1. Depending on the link function f , ignore u_i in (3.1) and estimate β using maximum likelihood estimation (MLE) or least squares estimation (LSE).
2. Compute the residuals from (3.1), $\hat{u}_i = \ln f\left(x_i;\hat{\beta}\right) - \ln y_i$. This now contains information on $\varphi, \phi \text{ and } \delta$.
3. Estimate $\varphi \text{ and } \phi$ from (3.2), setting aside the spatial effect, using the initial estimates of technical efficiency ($\hat{u}_i$). A maximum likelihood estimator for a mixed model can be used.
4. Compute residual technical efficiency $\hat{\hat{u}} = \hat{u} - w\hat{\varphi} - z\hat{\phi}$. This contains information on δ .
5. Estimate δ from $\hat{u} = \delta D\hat{\hat{u}} + \varepsilon$, which is a regression through the origin with a single covariate ($D\hat{\hat{u}}$).
6. Use the estimates derived from (5) in revising the estimates of technical efficiency ($\hat{u}_i^*$) from (3.2).
7. Estimate the overall constant term of (3.1) using a non-negative filter (e.g., logistic function), and deduct this from the revised estimate from (6).

The algorithm is expected to converge after (7), (see Landagan and Barrios, 2007 for details).

3.4.2 Specification and Estimation of Production Frontier (Model 2)

In the second model, spatial dependence is postulated on the production function instead of appearing in the efficiency equation.

$$\ln y_i = \ln f\left(x_i;\beta\right) + \delta D\left[\ln y_i - \ln f\left(x_i;\beta\right)\right] + v_i - u_i \qquad (3.3)$$

A similar argument on spatial dependency can be made whether it is in the production function or in the technical efficiency equation. Estimation can be done using a similar algorithm to that in Model 1 above.

The advantage of simultaneous estimation of parameters through maximum likelihood estimation using a distribution of non-negative values for v (e.g., half-normal, logistic) is that it always produces estimates of technical efficiency ≤ 1. An alternative is to filter u using a function in a non-negative domain, similar to (7) in the algorithm above. Thus, instead of fitting a linear regression of the first residual from (3.3) above, filtering is done, e.g.,

$$u = \frac{1}{1+\exp\left(-w\varphi\right)} + \varepsilon\,. \qquad (3.4)$$

A similar algorithm can be used with (3.4) above, in lieu of the linear regression of u on the determinants of efficiency. A no constant specification of (3.4) would ensure that $\hat{u}$ will always be positive, so that the estimate of technical efficiency will be between 0 and 1.

3.4.3 Specification of Variables

The response variables are total income and the rural development index (standardized so that values will range from 0 to 100). The total income coincides with farm income if the household derives all income from farming, non-farm income if it earns income from non-farm sources, and the aggregate of farm and non-farm income if it derives income from both sources.

The survey design imposes constraints in the choice of inputs of production (farming) among the households. Some proximate indicators were considered in lieu of real production inputs so that the production function becomes comprehensive. This will provide a rationale to the estimates of technical efficiency. The following inputs of production will be considered: area cultivated, access to irrigation, access and utilization of credit (as proximate indicators of procurement of farm inputs or capital availability for non-farm activities, a requirement for the development of small scale industries), whether single or multiple crops are planted (proximate indicator of farming system), health indicator of household members (as proximate indicator of human capital), number of household members with work (non-farm), and tenure of work. Two dummy variables will also be included: $S_1 = \begin{cases} 1, \text{if household derives income from farming activities} \\ 0, \text{otherwise} \end{cases}$ and $S_2 = \begin{cases} 1, \text{if household derives income from non-farming activities} \\ 0, \text{otherwise} \end{cases}$. If the household derived income from both farming and non-farming sources, then S_1=S_2=1. The interaction between S_1 and farming inputs, and S_2 with non-farming inputs, will be included to ensure that causation between output and production inputs are appropriate.

For the efficiency equation, the determinants are classified as fixed or random effects. Fixed effect determinants will register similar results regardless of the household being observed. On the other hand, random effect determinants are those whose effects are governed by a sampling distribution, i.e., one household may react differently from another household. The fixed-effect factors are household demographic characteristics (including dependency ratio), land tenure, female-male headed household, education of household members, and the spatial effect. The weight matrix for the spatial effect will be computed for the barangay (village) and will not differentiate households within the same barangay. The spatial indicator will account for socio-geographic characteristics that will affect production and income, soil fertility, and other site-specific unknown agronomic factors. For non-farming activities, the spatial effect will explain the kind of economic activities viable in the area and other site-specific unknown economic and cultural conditions.

Among the random factors to be included are availability of needed infrastructure or other intervention activities, bundles of such, whether the bundles include roads, membership in organization (as measure of participation), and whether they commit to contribute for maintenance. Since these factors are measured in terms of perception among the households, it is expected that the dichotomous responses will yield varying effects among the households.

4 SPATIAL EFFECT AND EFFICIENCY IN HOUSEHOLD PRODUCTION

Household analysis based on perceptions can provide almost instantaneous feedback on various activities geared towards rural development. Causation is better seen using perceptions instead of income measures that may take a considerable lag time before effects are manifested. Although income manifestation is a long-term outcome, it should also be carefully factored into the analysis as a validation tool and other information it ought to contribute.

Spatial dependence measures are used and explicitly incorporated into the models to generate further evidence on the generation of multiplier effects beyond the direct beneficiaries of various interventions. This will also account for the possible intervention leakage (when non-intended beneficiaries receive the intervention) and the justification of targeted rather than universal intervention for development.

The results of estimation of the spatial autoregression and spatial stochastic frontier models are given in Appendices 3-13.

4.1 EFFICIENCY OF HOUSEHOLD PRODUCTION (INCOME)

In the assessment of household efficiency, the household utility function is indexed both by income and the rural development index. While a production frontier is also fitted in the estimation of technical efficiency, the results are similar to the models presented in Barrios (2007), so only the determinants of efficiency are discussed in this section.

Starting with income as an indicator of household production, some demographics, participation indicators, availability and needs for some development interventions, bundles of interventions, and spatial dependency turned out to significantly contribute to the efficiency of a household's income generation.

Female-headed households are more efficient in income-generation, explained by the way they allocate the limited factors of production. The savings rate among female-headed households is higher, an indication of how they conserve current earnings for possible future use, not excluding investment for future income-generation. They are also efficient if there are few members below 16 years old: the lower dependency rate indicates more members eligible to join the labor force. More members 6–16 years old attending school is also an indicator of household efficiency. Education as part of human capital in rural areas is confirmed here. The nuclear family types are more efficient. Even if the large family size common among extended family types generates more income, these households are not necessarily efficient. Setting aside family structure, large households in general are more efficient. Considering the fact that agricultural sources still dominate the income of rural households, the efficiency of large households can be taken as possible evidence of rural labor migration. There is already a labor shortage in some areas (confirmed in some case studies) and in labor-intensive agricultural production, it is advantageous if one can easily tap family labor, which is abundant among large households.

The continuous provision of services from rural infrastructure indeed stimulates household efficiency. The households who indicated willingness to contribute to the maintenance of water systems and post-harvest facilities are more efficient in income-generation. The water system will have welfare implication affecting the human capital, so a properly maintained system can be expected to contribute towards household members in efficiently generating income. The post-harvest facilities, on the other hand, will ensure that the produce will be efficiently converted into household income.

There a few stand-alone development interventions, mostly infrastructure that contributed to households' efficiency in income generation. The more efficient households were those who perceived availability and believe that roads, bridges and haulers are needed. Note that these are the elements that will facilitate access to and from production areas, thus linking them to the suppliers of inputs as well as the market for their produce. Households who perceived need and believe that credit is available also manifested efficiency. Among trainings, availability and perceived need for training on the use of farm machineries, and care and management of the environment contributed to efficiency. The use of farm machineries can lead to efficiency, especially considering that there are already signs of rural labor shortages as a result of rural-urban migration. Training on care and management of the environment is an important facility for sustainable agriculture.

Perceived availability and need for bundles of training on farm production improvement becomes an efficiency driver for household income generation if it goes with rural roads. These trainings include pest management, planting technologies, use of farm machineries, harvesting methods and use of equipments, use of hybrid varieties, multiple cropping, and crop selection. Individually, the training does not affect efficiency. A training curriculum then among agricultural extension workers would necessitate bundles, rather than small trainings that will have minimal impact. The key for these trainings to yield efficiency in production is the enhancement of accessibility to various agents in the household income generation chain through rural roads.

On the non-agriculture side, availability and perceived needs for training on microenterprise development, in-farm livelihood, with credit for microenterprise development, at the least can contribute to household efficiency in income generation. This bundle, however, along with rural roads, can yield more efficient household income generation. The roads here will have a similar role to that in farm production: accessibility of the outputs of the microenterprise will be linked towards various agents in the production process. Trainings will provide the skill, credit for the capital, and road for input procurement and the marketing of the outputs.

The spatial dimension in the production frontier was introduced as a sparse autoregressive term. Households coming from the same barangay (small village) are treated as neighbors. There is indeed evidence of spatial convergence of efficiency in household production. Neighbors within the barangay exhibit homogeneous efficiency in income generation. This is easily explained by the homogeneity in various factors of production (including soil productivity) and the kind of development intervention or support services they have access to. The implication is that programs that are geared towards enriching households' production efficiency should be site-specific. Many development projects would include social preparation that will accomplish both the advocacy function and the identification of appropriate modalities for a target site.

Accessibility infrastructure has a prominent role in the efficiency of the households in income generation. It should be bundled with other interventions for better benefits, i.e., more efficient income generation.

4.2 EFFICIENCY OF HOUSEHOLD PRODUCTION (RDI)

A similar production frontier was fitted but instead of income, the rural development index (RDI) was used as the indication of production. In the production frontier with income, contribution for the maintenance of various infrastructure projects turned out to affect household efficiency. With RDI, only the contribution for maintenance of the water system is significant. Membership in various organizations (generic farmer's organization, community organization, and credit organization), however, also contributes towards household efficiency in welfare maximization, i.e., perceiving that there is rural development. By interacting with other members of the organization, the household may already imbibe the prospect of development, an important precursor of the manifestation of real rural development. The path towards rural development becomes clear once the stakeholders have a positive view towards rural development.

Efficiency in income generation is affected more by bundles than by single interventions. Perception on rural development, however, is affected by single interventions in addition to the bundles. Availability and perceived need for key physical infrastructure like roads, bridges and irrigation can improve the way households view the presence of rural development. The role of accessibility and other physical infrastructure in household efficiency in perceiving rural development confirms the actual manifestation (income) of rural development discussed in the previous section.

Availability and perceived need for trainings on planting technologies, use of hybrid seeds, and care and management of the environment will at least leave an impression on the empowerment of the stakeholders, resulting in the households efficiently perceiving that there is rural development. This is enhanced further by development of cooperatives, training of off-farm livelihood, and credit. In addition, support for marketing linkages completes the list of individual interventions that can influence how efficiently the households would perceive the presence of rural development.

Among the bundles of intervention that prominently influence households' efficiency of perceiving rural development, training on livelihood and microenterprise development with appropriate credit, with or without road projects, is more important. An effort that will illustrate to the rural stakeholders that the means to expand income sources are available can persuade them to believe that there is indeed rural development. To reiterate a point, non-farm income sources can help alleviate the income vulnerability of rural households. Thus, skills training, credit and roads that provide means of accessing other income sources will motivate the households to believe that there is rural development. These elements will eventually result in actual manifestation of income increases as discussed in the previous section.

In the same way as the households' efficiency in income generation converges spatially (at village level), this is also true for rural development perception. The perception of contentment in a household in the community spreads to other members of the community. This will facilitate the participatory identification of appropriate development interventions in a site since a community level consensus can be generated, as guaranteed by this spatial convergence of their perception on rural development in general.

Bundled interventions and rural roads also encourage households to optimize their utility function efficiently. They are more efficient in raising their rural development index score if roads, trainings, and other support services are bundled and made available to them.

4.3 OTHER SPATIAL EFFECTS IN HOUSEHOLD DYNAMICS

Spatial distance is represented in the model by averaging the rural development index score among all households in the same region. It is then assigned for all households in the region. A linear and a quadratic term for this indicator were included in the model; both are significant. This indicates that there is indeed regional convergence in the rural development index among the households. There is a chance that the perception on rural development of one household can be spread to other households in the same community. This result supports the idea of concentrating the interventions in a few sites rather than spreading it in as many sites as possible. Convergence in perceptions can facilitate the multiplier effect that is expected in limiting the interventions in a few sites. Not only will this strategy generate larger multiplier effects, but is also cost-effective.

Using average farm income among households in the same region as a proximate indicator of spatial distance, regional convergence of farm income is confirmed ($p<0.000$). Farm incomes of households coming from the same region tend to be similar. This can be explained by a variety of reasons, including soil fertility being homogeneous among neighboring areas, uniformity of farming systems among neighboring communities, and similarity in farming cultural practices in a community neighborhood. The regional convergence will have important consequences for the type and nature of policies and interventions in agriculture that are intended to upgrade farm income. A universal policy, though less costly, will not be optimal in terms of income generation among farmers. Culture-specific practices and farming systems should also be taken into consideration in the formulation of strategies in agriculture to at least maximize the potential benefits among farmers, specifically in income generation.

The average non-farm income among households in the same region and in the same strata (project sites) is used as the indicator of spatial distance. There is a regional convergence of non-farm income ($p<0.000$) as well as in the specific strata or intervention sites of the government ($p<0.000$). Regional variation of non-farm livelihood opportunities will explain the regional convergence, while the project menu (of the government intervention sites) and the constraints in resource availability (the control sites) can help explain convergence of non-farm income across strata. The present strategies used by the Departments of Agriculture, Agrarian Reform, and Environment and Natural Resources have varying effects on non-farm income. The programs of these departments are also specialized according to the mandate of the department. In the hope to deliver their mandate, interventions are sometimes provided in a stand-alone fashion. For a more comprehensive strategy towards the pursuit of rural development, these departments can consider combining their strategies and should carefully plan the paradigm shift from direct provision to facilitation of access to certain development interventions to ensure efficiency, effectiveness, and eventually sustainability.

4.4 SPATIAL EFFECTS IN LONG-TERM OUTCOMES

Income is the only indicator of rural development from the Family Income and Expenditures Survey (FIES). The breakdown of farm income and non-farm income will be analyzed separately. Income growth may manifest in the mid- to long-term, but spatial autoregression will help account for the possible lagged effect of the determinants of income. Furthermore, we have filtered households from rural areas only for the analysis.

There is no direct measurement of intensity of accessibility infrastructure because nationwide data is not available at the household or even at the community level. Some measures of expenditures on certain economic activities will be used as proximate indicators. Although reduction in transport cost is not as instantaneous as the provision of rural roads, the fact that we are also using income as indicator of rural development justifies the causative models.

Non-Agriculture Income

The demographic determinants of non-farm income with positive effects include age of the household head ($p<0.000$); whether the head is married ($p<0.000$); and whether the head's education is elementary ($p<0.000$), high school ($p<0.000$), or college ($p<0.000$). There is a premium for age in non-farm income generation since this is usually associated with accumulated experience/skills and rank. Being married could mean that there is a spouse who can also contribute to the household non-farm income. Furthermore, any level of education is an investment in non-farm income; the higher the level of education, the higher the expected income returns.

An agricultural household (income is generated mostly from agriculture) has non-agriculture income that is 53% lower than the non-agriculture household (income derived mostly from non-agriculture sources). Even among households in rural areas alone, the vulnerability of the farmers is very clear. Male-headed households also generate lower non-farm income. This coincides with an earlier analysis on the efficiency of female-headed household in income generation. Nuclear families that usually have smaller sizes and those with more members below 15 years old also have lower non-farm income since there are few members eligible for non-farm employment. Furthermore, the nuclear families have more employed individuals and an employed spouse generating more non-farm income.

Income generated by professional workers is the highest, followed by operators (usually skilled), laborers (usually unskilled), and those in agriculture; animal husbandry and forestry still generate the lowest income from outside the farm. Although there is a gradual diversification of occupation, the goal of alleviating the vulnerability of rural communities is not yet attained since the indicator of employment in a private enterprise is not significant, while employment in a private household is significant. There is not enough income generated from the private enterprises because there are only a few of them operating in rural areas. The rural enterprises have not evolved yet as planned from being micro to medium (or even small) scale.

Higher expenditures on petroleum, telephone, electricity and water are all functions of accessibility of an area. Isolation of a community can raise all these expenditures. All these indicators yield significant, negative coefficients in the regression of non-farm income. Furthermore, expenditure on manufacturing activities also yields a negative regression coefficient. Manufacturing requires transportation of raw materials and finished products. Hence, cost of production is closely associated with transportation cost. Improved accessibility infrastructure can indeed generate more non-farm income among the rural households.

The spatial autoregressive parameter is also significant ($p<0.000$), indicating that non-farm income is significantly affected by the homogeneity of inputs of non-farm production in an area. One simple way of facilitating homogeneity of access to such inputs is the improvement of access and mobility among the stakeholders. If there is a provision for ample mobility among stakeholders in a rural community, non-farm income generation becomes feasible.

Agriculture Income

In as much as agricultural production requires male workers, male-headed households have the advantage of generating more income from agriculture. As strong workers have an advantage in land cultivation, younger people also have natural advantages in agriculture. Education, however, unlike in non-farm income where it has a positive contribution, it is not necessarily needed to cultivate the land. Furthermore, while the younger members of the household (<15 years old) cannot get jobs outside the farm yet, and hence have negative contributions to non-farm income, they can be (and in fact are) used as agriculture labor, doing light jobs like planting, weeding, and harvesting. Thus, they contribute positively to agricultural income generation.

Higher expenditures on electricity, water and land transportation are all proximate indicators of availability of access infrastructure. Expenditures on the wholesale and retail trade are usually dominated by transportation cost, since the activity requires movement of goods from the producers to the consumers. Cost in the operation of a transport business easily increases when the road system is of poor quality. These indicators also generate negative coefficients in the regression of agriculture income, indicating that accessibility infrastructure affects both the farm and non-farm income levels of rural households. Absence of an accessibility network isolates a place or a community, reducing their productive potential from both farm and non-farm sources.

5 CONCLUSIONS AND RECOMMENDATIONS

Microeconometric models were developed with households as unit of analysis. To assess the impact of infrastructure and other development interventions, both the actual income manifestation and perceptions were analyzed. For income, total household income and breakdown by source (farm, off-farm, non-farm) were considered. For perceptions, a scale item that directly inquires whether or not the households believe that there is rural development was considered. Furthermore, an index based on the scale was also considered.

Availability of roads and bridges are indicated by lower transportation cost, lower cost of utilities, and in a mid- to long-term range by diversification of employment opportunities. Electricity and water lines are installed in rural areas along paved road systems. Service cost is expected to be lower if the road system is favorable.

Given roads, investments in microenterprises will move towards rural communities because it will be cost-effective to locate production facilities in areas where the raw materials originate. This will result later in employment/occupation diversification. Change of occupation from farming to non-farming will benefit non-farm income but will be a loss to farm income. However, total income will be expected to post a positive net growth.

The importance of spatial indicators in the different models for various indicators illustrates the role of geographical dynamics in rural development. Various physical, social, and cultural factors play a pivotal role in the rural development dynamics. This also justifies the necessity for development intervention to be site-specific, participatory in approach, and not the universal targeting type. Although site-specific interventions may not be cheaper initially, in the long-run, a site-specific targeting approach may be more efficient. Development in one small community can easily spread to the spatial “neighbors” of the community. Because of the spatial dependence among communities, benefits from an intervention in one community are expected to produce a ripple effect reaching its spatial neighbors.

Provision of rural roads should be the core of rural infrastructure. This provision should be bundled properly with support services and capacity building activities like training to enhance demand for other infrastructure and services, thus resulting in a highly dynamic movement of various elements essential for rural development. Bundles of intervention further improve production efficiency of the rural stakeholders since this will facilitate activities at the different stages of production at or outside the farm.

The gap in rural development strategies can be isolated from the fact that there are fewer employment opportunities from private establishments. It is important to encourage or provide incentives to private establishments to establish operations in rural areas. This incentive should primarily consist of accessibility development to reduce transportation cost. Private investments in rural areas can help mitigate the vulnerability of rural households when they become independent from the limitations inherent in agricultural production. Rural-urban labor migration may also be relieved. This will also serve as the catalyst in the development of sustainable microenterprises. Private establishments with a sound social responsibility program can also contribute to mitigating inequality.

REFERENCES

Amos, T., Chikwendu, D., and Nmadu, J., 2004, Productivity, Technical Efficiency, and Cropping Patterns in the Savanna Zone of Nigeria, *Food, Agriculture and Environment*, 2(2): 173–176.

Bandiera, O., (2002), Land Distribution, Incentives and the Choice of Production Techniques in Nicaragua, *Center for Economic Policy Research (CEPR) Discussion Paper No. 3141*

Barrett, C.B., Reardon, T.A., Webb, P., Nonfarm Income Diversification and Household Livelihood Strategies in Rural Africa: Concepts, Dynamics, and Policy Implications, 2002, *Food Policy*, 26(4): 315–331.

Barrios, E., (2007), Access to Rural Development: Household Perceptions on Rural Development, *Asian Development Bank Institute Discussion Paper No. 61, Tokyo, Japan.*

Barrios, E. and Landagan, O., 2004, Geographic Distribution of the Poor: Is Poverty Contaminating?, proceedings of the 9th National Convention of Statistics, Manila.

Boothroyd P. and Nam, P.X., Eds., 2000, Socioeconomic Renovation in Viet Nam: The Origin, Evolution and Impact of Doi Moi, Singapore: IDRC/ISEAS.

Conning, J.H. and Robinson, J.A., 2002, Land Reform and the Political Organization of Agriculture, *CEPR Discussion Paper No. 3204.*

Demurger, S., Sachs, J., Woo, W., Bao, S., Chang, G., and Mellinger, A., 2002, Geography, Economic Policy, and Regional Development in China, *NBER Working Paper No. 8897*, National Bureau of Economic Research.

Dulfo, E. and Pande, R., 2005, Dams, *NBER Working Paper No. 11711*, National Bureau of Economic Research.

Fujita, M., Krugman, P., and Venables, A., 1999, *The Spatial Economy: Cities, Regions, and International Trade*, MIT Press.

Gallup, J., Sachs, J., and Mellinger, A., 1998, Geography and Economic Development, *NBER Working Paper No. 6849*, National Bureau of Economic Research..

Glaeser, E. and Kohlhase, J., 2003, Cities, Regions and Declines of Transportation Cost, *NBER Working Paper No. 9886*, National Bureau of Economic Research.

Green, W., 1990, A Gamma-Distributed Stochastic Frontier Model, *Journal of Econometrics*, 46(1): 141–164.

Hastie, T.J., and Tibshirani, R.J., 1990, *Generalized Additive Model*, St. Edmundsbury Press.

Henderson, D. and Simar, L., 2005, A Fully Nonparametric Stochastic Frontier Model for Panel Data, paper presented during the *9th European Workshop on Efficiency and Productivity Analysis*, Brussels, Belgium.

Holtz-Eakin, D. and Lovely, M., 1995, Scale Economics, Returns to Variety, and the Productivity of Public Infrastructure, *NBER Working Paper No. 5295*, National Bureau of Economic Research.

Huang, C. and Liu, J., 1994, Estimation of a Non-Neutral Stochastic Frontier Production Function, *Journal of Productivity Analysis*, 5(2): 171–180.

Hulten, C., 1996, Infrastructure Capital and Economic Growth: How Well You Use It Might Be More Important than How Much You Have, *NBER Working Paper No. 5847*, National Bureau of Economic Research.

Koop, G. and Steel, M., 2004, Bayesian Analysis of Stochastic Frontier Models, *ESE Discussion Paper No. 19*, Edinburgh School of Economics, University of Edinburgh.

Kumbhakar, S. and Lovell, C., 2000, *Stochastic Frontier Analysis*, Cambridge University Press.

Kumbhakar, S., Ghosh, S., and McGuckin, J., 1991, A Generalized Production Frontier Approach for Estimating Determinants of Inefficiency in US Dairy Farms, *Journal of Business and Economic Statistics*, 9(3): 279-286.

Larson, D.F., Plessmann, F., 2002, Do Farmers Choose to Be Inefficient? Evidence from Bicol, Philippines, *WB Working Paper 2787*, World Bank.

Landagan, O. and Barrios, E., 2007, An Estimation Procedure for a Spatial-Temporal Model, *Statistics and Probability Letters,* 77(4): 401-406.

Lewis, W.A., 1984, The State of Development Theory, *The American Economic Review*, 74(1): 1–10.

Narayan, D. (Ed.), 2002, *Empowerment and Poverty Reduction: A Sourcebook*, International Bank for Reconstruction and Development, World Bank.

NEDA-WB, 2003, The Dynamics of Rural Development: Implications of the Intervention of the National Government, under the NEDA-WB TA on Capacity Building on Rural Development and Natural Resource Management: Planned Performance Monitoring and Indicator System, Pasig City, Philippines.

NEDA-WB-ASEM, 2005, The Contributions of the Government to the Rural Sector, under *NEDA-WB-ASEM TA on Poverty Monitoring and Analysis*, Pasig City, Philippines.

Pace, R. and Barry, R. (1997), Sparse Spatial Autoregressions, *Statistics and Probability Letters*, 33: 291–297.

Ranis, G., Burmeister, L., Wang, M., 2001, Group Behavior and Development: A Comparison of Farmers' Organization in South Korea and Taiwan, *Yale Economic Growth Center Discussion Paper No. 828*.

Redding, S., and Venables, A., 2002, Economic Geography and International Inequality, *Globalization Programme*, Center for Economic Performance, London School of Economics.

Reifschneider, D. and Stevenson, R., 1991, Systematic Departures from the Frontier: A Framework for the Analysis of Firm Inefficiency, *International Economic Review*, 32(3): 715–723.

Taylor, J.E., Dyer, G., and Yunez-Naude, A., 2005, Disaggregated Rural Economy-wide Models for Policy Analysis, *World Development*, 33(10): 1671–1688.

Teruel, R. and Kuroda, Y., 2005, Public Infrastructure and Productivity Growth in Philippine Agriculture, 1974–2000, *Journal of Asian Economics*, 16: 555–576.

Venables, A., 2006, Economic Geography: Spatial Interactions in the World Economy, in Weingast, B. and Wittman, D., Eds., *The Oxford Handbook of Political Economy*, Oxford University Press, In-Press (2006).

APPENDICES

APPENDIX 1: SELF ASSESSMENT OF LIVING CONDITIONS

The following is the scale used in collecting perceptions on living conditions in rural areas:

Some issues relevant to your community are listed below. We would like to ask your opinion, idea and some recommendations concerning these issues. For each item below, please indicate your agreement/disagreement whenever applicable. Note that NOT APPLICABLE option is included in case the issue is irrelevant to you. Please tell me what number best represents your assessment as I read each statement. (USE SHOWCARD). READ THE STATEMENT ONLY, DO NOT READ THE ANSWERS, HAND DOWN THE SHOWCARD TO THE RESPONDENT WHILE READING THE STATEMENTS.

0 – Not Applicable 1 – Disagree 5 – Agree (1,2 levels of disagreement, 4,5 levels of agreement, 3 about to agree/disagree)

(The showcard will contain 5 varying faces indicating extent of agreement/disagreement to the statement.)

1 Housing unit is comfortable for the family	5	4	3	2	1	0
2 Toilet is hygienic	5	4	3	2	1	0
3 Cost of electricity is reasonable	5	4	3	2	1	0
4 Water source is accessible	5	4	3	2	1	0
5 Water is safe for drinking	5	4	3	2	1	0
6 Water cost is reasonable	5	4	3	2	1	0
7 School is more accessible now	5	4	3	2	1	0
8 There is an improved quality of education	5	4	3	2	1	0
9 Income is more regular	5	4	3	2	1	0
10 Income is sufficient for household needs	5	4	3	2	1	0
11 There are enough jobs available now	5	4	3	2	1	0
12 There is enough training on possible livelihood	5	4	3	2	1	0
13 There is enough training on new farming practices	5	4	3	2	1	0
14 There is enough food for the family	5	4	3	2	1	0
15 It is now easy to take a public transportation	5	4	3	2	1	0
16 There is general feeling of satisfaction in the community.	5	4	3	2	1	0
17 I am contented with the way our needs are met.	5	4	3	2	1	0
18 Our living conditions now are much better than 5 years ago	5	4	3	2	1	0

APPENDIX 2: SELF ASSESSMENT OF RURAL DEVELOPMENT STATUS

The following is the scale used in collecting perceptions on rural development status in rural areas:

Please indicate your agreement on the following issues on rural development and poverty.
0 – Not Applicable 1 – Disagree 5 – Agree (1,2 levels of disagreement, 4,5 levels of agreement, 3 about to agree/disagree)
(The showcard will contain 5 varying faces indicating extent of agreement/disagreement to the statement.)

1 The poverty reduction strategy of the government is effective.	5	4	3	2	1	0
2. There is rural development	5	4	3	2	1	0
3. There are enough programs by local government on agriculture.	5	4	3	2	1	0
4. There are enough employment opportunities.	5	4	3	2	1	0
5. There is equitable access to productive resources.	5	4	3	2	1	0
6. Harvesting of resources is sustainable.	5	4	3	2	1	0
7. There are enough agricultural trainings.	5	4	3	2	1	0
8. The rural sector participates in the discussion on development issues.	5	4	3	2	1	0
9. Government's effort on agricultural research is important.	5	4	3	2	1	0
10. There is enough employment/livelihood in the area.	5	4	3	2	1	0
11. Agrarian reform is properly implemented.	5	4	3	2	1	0
12. The state of environment may cause calamities.	5	4	3	2	1	0
13. Ecological integrity can be maintained while there is development.	5	4	3	2	1	0

APPENDIX 3: SPATIAL ADDITIVE MODEL FOR RDI RESULTS

Source	SS	df	MS
Model	202663.971	7	28951.9959
Residual	2093701.13	5318	393.700852
Total	2296365.1	5325	431.242273

Number of obs =	5326
F(7, 5318) =	73.54
Prob > F =	0.0000
R-squared =	0.0883
Adj R-squared =	0.0871
Root MSE =	19.842

rdi	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
farminc	2.42e-06	9.96e-07	2.43	0.015	4.67e-07	4.37e-06
roadmain	2.000226	.6927994	2.89	0.004	.6420547	3.358396
wrrdi	-2.797715	1.700229	-1.65	0.100	-6.13086	.535431
wsrdi	-2.97547	1.713636	-1.74	0.083	-6.334899	.3839588
w1	.0667817	.0310345	2.15	0.031	.0059414	.1276219
irrmain	1.388528	.6975741	1.99	0.047	.0209971	2.75606
phmain	2.94377	.7279947	4.04	0.000	1.516602	4.370938
_cons	167.5357	93.84975	1.79	0.074	-16.44831	351.5197

Source	SS	df	MS
Model	13415.3942	6	2235.89904
Residual	2080285.74	5319	391.10467
Total	2093701.14	5325	393.183312

Number of obs =	5326
F(6, 5319) =	5.72
Prob > F =	0.0000
R-squared =	0.0064
Adj R-squared =	0.0053
Root MSE =	19.776

rdi1	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
sch6_12	.0172174	.0064104	2.69	0.007	.0046504	.0297844
sch17_21	.0136378	.0077343	1.76	0.078	-.0015247	.0288003
depend12	-.0260411	.0123641	-2.11	0.035	-.0502797	-.0018024
notmigr	1.301375	.5771753	2.25	0.024	.1698751	2.432876
intmigr	1.470534	.7743534	1.90	0.058	-.0475162	2.988584
workover21	.0184567	.0061059	3.02	0.003	.0064867	.0304268
_cons	-3.138566	.8995905	-3.49	0.000	-4.902132	-1.375

Source	SS	df	MS
Model	14360.3731	3	4786.79104
Residual	2065925.37	5322	388.185901
Total	2080285.74	5325	390.663988

Number of obs =	5326
F(3, 5322) =	12.33
Prob > F =	0.0000
R-squared =	0.0069
Adj R-squared =	0.0063
Root MSE =	19.702

rdi2	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
roof	1.424448	.5586398	2.55	0.011	.3292848	2.519611
govthosp	-1.554159	.6968348	-2.23	0.026	-2.92024	-.188077
toilet	2.997115	.7023592	4.27	0.000	1.620203	4.374027
_cons	-2.911548	.6505384	-4.48	0.000	-4.18687	-1.636226

Source	SS	df	MS
Model	7015.12691	2	3507.56346
Residual	1700094.22	4389	387.353434
Total	1707109.35	4391	388.774618

Number of obs =	4392
F(2, 4389) =	9.06
Prob > F =	0.0001
R-squared =	0.0041
Adj R-squared =	0.0037
Root MSE =	19.681

rdi3	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
comorg	2.549524	.7632132	3.34	0.001	1.053241	4.045807
irrigorg	5.539626	2.119422	2.61	0.009	1.38449	9.694763
_cons	-.7497969	.3317722	-2.26	0.024	-1.400238	-.099356

Source	SS	df	MS
Model	1632.23049	1	1632.23049
Residual	2058096.02	5324	386.5695
Total	2059728.25	5325	386.803427

Number of obs =	5326
F(1, 5324) =	4.22
Prob > F =	0.0399
R-squared =	0.0008
Adj R-squared =	0.0006
Root MSE =	19.661

rdi4	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
agri	.0490255	.0238586	2.05	0.040	.0022529	.0957982
_cons	.0049955	.2834337	0.02	0.986	-.5506506	.5606415

Source	SS	df	MS			
Model	12233.1112	4	3058.2778	Number of obs = 5326	F(4, 5321) = 7.95	Prob > F = 0.0000
Residual	2045862.95	5321	384.488433	R-squared = 0.0059	Adj R-squared = 0.0052	
Total	2058096.06	5325	386.496914	Root MSE = 19.608		

rdi5	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
tenant	3.37592	.7869787	4.29	0.000	1.833119	4.918721
own	1.254455	.6166544	2.03	0.042	.04556	2.463351
amortizing	8.36614	3.164095	2.64	0.008	2.163217	14.56906
upland	.4630886	.2330683	1.99	0.047	.0061791	.919998
_cons	-1.1546	.3795538	-3.04	0.002	-1.898681	-.4105192

Source	SS	df	MS			
Model	29315.1102	7	4187.87289	Number of obs = 5326	F(7, 5318) = 11.04	Prob > F = 0.0000
Residual	2016547.81	5318	379.192893	R-squared = 0.0143	Adj R-squared = 0.0130	
Total	2045862.92	5325	384.199609	Root MSE = 19.473		

rdi6	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
creditrepay	2.752348	.6181064	4.45	0.000	1.540606	3.96409
mccoopac	2.33913	.9137023	2.56	0.010	.5478985	4.130361
mcgbankav	2.256361	.9822183	2.30	0.022	.3308107	4.181912
phfacil	5.193719	2.741423	1.89	0.058	-.1805951	10.56803
mcgfiav	9.061952	1.892495	4.79	0.000	5.351885	12.77202
mcgfiac	-13.05389	3.302386	-3.95	0.000	-19.52792	-6.579856
prodloan	-2.47991	1.151964	-2.15	0.031	-4.738232	-.2215878
_cons	-2.587589	.5515059	-4.69	0.000	-3.668766	-1.506411

Source	SS	df	MS			
Model	52592.8721	33	1593.7234	Number of obs = 5283	F(33, 5249) = 4.30	Prob > F = 0.0000
Residual	1943795.47	5249	370.317292	R-squared = 0.0263	Adj R-squared = 0.0202	
Total	1996388.34	5282	377.960685	Root MSE = 19.244		

rdi7	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
areaadj	1.713528	.4512627	3.80	0.000	.8288658	2.598191
i21	.0832391	.0452058	1.84	0.066	-.005383	.1718613
ageadj	-.0482329	.0271912	-1.77	0.076	-.1015389	.0050732
ageadj2	.0022403	.0011392	1.97	0.049	6.93e-06	.0044737
i2_fpi1	-2.480024	1.353856	-1.83	0.067	-5.134145	.1740961
i126	2.25432	.7517844	3.00	0.003	.7805097	3.72813
i123	1.648263	.8724714	1.89	0.059	-.0621438	3.35867
i212	-.0877862	.0502697	-1.75	0.081	-.1863356	.0107633
i3_fpi4	11.1933	4.348552	2.57	0.010	2.668333	19.71827
i3_fpi6	-8.495248	4.7443	-1.79	0.073	-17.79605	.8055538
i2_ph3	4.967488	2.161574	2.30	0.022	.7299047	9.205072
i132	-1.623938	.456063	-3.56	0.000	-2.518011	-.729865
br6	4.117373	1.859797	2.21	0.027	.4713968	7.763349
i121	-1.172574	.4888251	-2.40	0.016	-2.130875	-.2142737
i125	-1.77297	.627896	-2.82	0.005	-3.003907	-.5420328
i2_tft3	-7.709473	2.273298	-3.39	0.001	-12.16608	-3.252865
i2_tft4	4.960242	2.72763	1.82	0.069	-.3870474	10.30753
b3	-4.440714	1.413989	-3.14	0.002	-7.212721	-1.668707
i112	-1.159336	.4563647	-2.54	0.011	-2.054001	-.2646719
i2_tft7	4.839006	2.299451	2.10	0.035	.3311265	9.346886
i116	.8387854	.4968378	1.69	0.091	-.1352233	1.812794
i131	1.115049	.6457493	1.73	0.084	-.150888	2.380986
i221	.2124763	.0612028	3.47	0.001	.0924934	.3324592

```
        i114 |  -1.909885    .563299    -3.39   0.001    -3.014186    -.805585
        i229 |   .0881832   .0525178     1.68   0.093    -.0147736      .19114
          b4 |   2.553285   1.443797     1.77   0.077    -.2771583    5.383729
     i3_ocb1 |  -6.879749   3.507305    -1.96   0.050    -13.75552   -.0039725
         i23 |  -.0907933   .0456153    -1.99   0.047    -.1802182   -.0013683
        i231 |  -.1922895    .072802    -2.64   0.008    -.3350116   -.0495673
          b5 |  -3.328982   1.953244    -1.70   0.088    -7.158152    .5001878
      i3_ph4 |  -7.398437   3.688918    -2.01   0.045    -14.63025    -.166624
        i115 |   1.338683   .5179082     2.58   0.010     .3233676    2.353999
     i3_lti1 |   8.596055      3.306     2.60   0.009     2.114919    15.07719
       _cons |  -.2279601   .3660384    -0.62   0.533    -.9455476    .4896273
------------------------------------------------------------------------------

. predict rdierr, resid
(43 missing values generated)

. gen aperdiadd=abs(rdierr)
(43 missing values generated)

. sum aperdiadd, detail

                          aperdiadd
-------------------------------------------------------------
      Percentiles      Smallest
 1%     .1808723       .0005737
 5%     1.048358       .0033927
10%     2.009198       .0047022       Obs                5283
25%     4.900703       .0058451       Sum of Wgt.        5283

50%     10.17546                      Mean           14.01554
                        Largest       Std. Dev.      13.09699
75%     18.64712       69.82649
90%     30.07888       69.87405       Variance       171.5311
95%     45.30962       70.77287       Skewness       1.732325
99%     60.13055       71.48418       Kurtosis       6.048047
```

APPENDIX 4: SPATIAL ADDITIVE MODEL FOR FARM INCOME RESULTS

Source	SS	df	MS
Model	12691.2383	7	1813.03404
Residual	121423.157	5318	22.8324853
Total	134114.395	5325	25.1858019

Number of obs	= 5326
F(7, 5318)	= 79.41
Prob > F	= 0.0000
R-squared	= 0.0946
Adj R-squared	= 0.0934
Root MSE	= 4.7783

lfarminc	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
wrfarm	9.31e-06	1.84e-06	5.06	0.000	5.70e-06	.0000129
farmerorg	2.056803	.2461888	8.35	0.000	1.574172	2.539434
cooporg	.48237	.1997994	2.41	0.016	.0906812	.8740588
irrmain	1.034425	.1653308	6.26	0.000	.7103091	1.358541
phmain	1.677004	.1644165	10.20	0.000	1.35468	1.999328
irrigorg	2.365613	.4935181	4.79	0.000	1.398115	3.333111
creditorg	1.319596	.346657	3.81	0.000	.6400066	1.999186
_cons	2.424669	.1451744	16.70	0.000	2.140068	2.70927

Source	SS	df	MS
Model	1266.2845	4	316.571125
Residual	120156.872	5321	22.5816336
Total	121423.157	5325	22.8024708

Number of obs	= 5326
F(4, 5321)	= 14.02
Prob > F	= 0.0000
R-squared	= 0.0104
Adj R-squared	= 0.0097
Root MSE	= 4.752

lf1	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
hs	-.5451271	.1478216	-3.69	0.000	-.834918	-.2553363
college	-.5863684	.1721378	-3.41	0.001	-.9238291	-.2489076
nuclearfam	.2562293	.1466451	1.75	0.081	-.0312552	.5437138
workover21	-.008552	.001453	-5.89	0.000	-.0114005	-.0057035
_cons	.4886389	.154825	3.16	0.002	.1851185	.7921593

Source	SS	df	MS
Model	37580.7445	18	2087.81914
Residual	82576.1278	5307	15.5598507
Total	120156.872	5325	22.5646709

Number of obs	= 5326
F(18, 5307)	= 134.18
Prob > F	= 0.0000
R-squared	= 0.3128
Adj R-squared	= 0.3104
Root MSE	= 3.9446

lf2	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
rice	1.362836	.1575751	8.65	0.000	1.053924	1.671748
corn	1.154734	.2185612	5.28	0.000	.7262646	1.583204
coconut	3.523113	.2038196	17.29	0.000	3.123542	3.922683
amortizing	1.170141	.6485395	1.80	0.071	-.1012633	2.441545
industrial	2.885491	.4324953	6.67	0.000	2.037623	3.73336
livestock	3.064782	.233366	13.13	0.000	2.607289	3.522276
inheritten~y	1.787529	.4960865	3.60	0.000	.8149959	2.760063
cash	.9379582	.1906504	4.92	0.000	.5642051	1.311711
tenant	2.344184	.2062378	11.37	0.000	1.939873	2.748494
riceint	.0004329	.0002395	1.81	0.071	-.0000366	.0009024
cornint	.2391876	.0737612	3.24	0.001	.0945852	.3837899
lowirrarea	.3770942	.0712243	5.29	0.000	.2374652	.5167232
lownonarea	.0538082	.0242698	2.22	0.027	.0062294	.101387
upland	.1664961	.0491404	3.39	0.001	.0701607	.2628315
pasture	.4875872	.2911907	1.67	0.094	-.0832663	1.058441
own	2.453647	.1752489	14.00	0.000	2.110087	2.797207
leased	3.536133	.4005222	8.83	0.000	2.750945	4.321321
mortgage	2.919444	.575653	5.07	0.000	1.790928	4.04796
_cons	-2.806318	.0814157	-34.47	0.000	-2.965926	-2.646709

Source	SS	df	MS
Model	660.590634	6	110.098439
Residual	81915.5366	5319	15.4005521
Total	82576.1272	5325	15.5072539

Number of obs	= 5326
F(6, 5319)	= 7.15
Prob > F	= 0.0000
R-squared	= 0.0080
Adj R-squared	= 0.0069
Root MSE	= 3.9244

lf3	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
prodloan	.5357472	.2328978	2.30	0.021	.0791721	.9923223

```
    mccoopac | -.3937065   .1883841    -2.09   0.037    -.7630167   -.0243964
     homefin | -.6443944   .1765078    -3.65   0.000     -.990422   -.2983668
     phfacil |  1.179652   .5528514     2.13   0.033     .0958368    2.263468
     mcgfiav |  .9106685   .3005929     3.03   0.002     .3213831    1.499954
     farmimp |  .4428051   .1989939     2.23   0.026     .0526955    .8329147
       _cons | -.0031789   .0636142    -0.05   0.960    -.1278887     .121531
------------------------------------------------------------------------------

      Source |       SS       df       MS              Number of obs =    5283
-------------+------------------------------           F( 20,  5262) =    5.88
       Model |  1779.66068    20  88.9830342           Prob > F      =  0.0000
    Residual |  79610.9188  5262   15.129403           R-squared     =  0.0219
-------------+------------------------------           Adj R-squared =  0.0181
       Total |  81390.5795  5282  15.4090457           Root MSE      =  3.8897

------------------------------------------------------------------------------
         lf4 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     areaadj | -.0543301   .0226059    -2.40   0.016    -.0986471   -.0100131
        i130 |  .1953823   .0948572     2.06   0.039     .0094227    .3813418
      ageadj | -.0119675   .0038423    -3.11   0.002       -.0195   -.0044351
         i12 |  .1758237   .0673658     2.61   0.009     .0437588    .3078887
     i2_fpi1 |  .7372256   .2831242     2.60   0.009     .1821847    1.292266
     i2_fpi3 | -.8468514   .3510844    -2.41   0.016    -1.535123   -.1585804
         br2 | -.3028512   .1766985    -1.71   0.087    -.6492537    .0435513
        i120 | -.3116621   .1312695    -2.37   0.018    -.5690047   -.0543194
        i114 |  .3781926   .1053129     3.59   0.000     .1717357    .5846495
        i133 | -.3281229   .1082097    -3.03   0.002    -.5402589    -.115987
      i2_ph3 |  1.098663   .4328236     2.54   0.011     .2501494    1.947177
     i3_ocb1 |  1.086488   .6203349     1.75   0.080    -.1296253    2.302602
        i121 |  .3528756    .108392     3.26   0.001     .1403824    .5653688
     i3_tft6 | -1.738982   .5671848    -3.07   0.002    -2.850899   -.6270641
        i118 |  .1508653   .0838389     1.80   0.072    -.0134936    .3152243
        i126 | -.2781655   .1271717    -2.19   0.029    -.5274747   -.0288562
        i134 |  .2514829   .1084677     2.32   0.020     .0388411    .4641246
        i112 | -.2621128   .0789337    -3.32   0.001    -.4168557   -.1073699
         i17 |  .4126705   .1100435     3.75   0.000     .1969395    .6284015
     i2_ocb2 | -.7440646   .3764408    -1.98   0.048    -1.482045   -.0060845
       _cons |  .0645903   .0582138     1.11   0.267    -.0495329    .1787134
------------------------------------------------------------------------------
                         apefarmadd
-------------------------------------------------------------
      Percentiles      Smallest
 1%      .723089       .0672074
 5%     3.245842        .148299
10%     6.197344       .1622212       Obs                2416
25%     15.58593       .1630482       Sum of Wgt.        2416

50%     29.43713                      Mean           33.19672
                        Largest       Std. Dev.      22.82155
75%     46.29243       107.6966
90%      65.1321        107.734       Variance       520.8233
95%     77.36747       107.9066       Skewness       .8068743
99%     97.09464        108.409       Kurtosis       3.235003

. drop apefarmadd
. gen apefarmadd=(100*exp(abs(lferr)))/farminc
(2910 missing values generated)

. sum apefarmadd, detail
                         apefarmadd
-------------------------------------------------------------
      Percentiles      Smallest
 1%     .0012586        .000015
 5%     .0040729       .0001955
10%     .0084841       .0002516       Obs                2416
25%      .027488        .000271       Sum of Wgt.        2416

50%      .104981                      Mean           3.324435
                        Largest       Std. Dev.      16.35675
75%     .5589297       199.1093
90%     3.351768       226.3076       Variance       267.5432
95%     11.67186       235.6032       Skewness        8.86184
99%     72.14625       242.6177       Kurtosis       97.42754
```

APPENDIX 5: SPATIAL ADDITIVE MODEL FOR NONFARM INCOME RESULTS

```
      Source |       SS       df       MS              Number of obs =    3808
-------------+------------------------------           F(  3,  3804) =   78.90
       Model |  207.852799     3  69.2842662           Prob > F      =  0.0000
    Residual |   3340.5148  3804  .878158464           R-squared     =  0.0586
-------------+------------------------------           Adj R-squared =  0.0578
       Total |   3548.3676  3807  .932063987           Root MSE      =   .9371
------------------------------------------------------------------------------
 lnonfarminc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   wrnonfarm |   7.31e-06   5.60e-07    13.06   0.000     6.21e-06    8.41e-06
   wsnonfarm |   6.34e-06   8.32e-07     7.62   0.000     4.71e-06    7.97e-06
     cooporg |   .0835438   .0472579     1.77   0.077    -.0091093     .176197
       _cons |   9.633375    .109615    87.88   0.000     9.418465    9.848285
------------------------------------------------------------------------------
      Source |       SS       df       MS              Number of obs =    3808
-------------+------------------------------           F( 11,  3796) =   56.72
       Model |  471.550391    11  42.8682173           Prob > F      =  0.0000
    Residual |  2868.96442  3796  .755786202           R-squared     =  0.1412
-------------+------------------------------           Adj R-squared =  0.1387
       Total |  3340.51481  3807   .87746646           Root MSE      =  .86936

------------------------------------------------------------------------------
         lnf1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     college |    .339692   .0344922     9.85   0.000      .272067    .4073171
  nuclearfam |   -.102876   .0317016    -3.25   0.001    -.1650299   -.0407222
      hhsize |   .0512437   .0056758     9.03   0.000     .0401158    .0623715
   work17_21 |   .0017759     .00061     2.91   0.004     .0005799    .0029719
  workover21 |    .000656   .0003184     2.06   0.039     .0000317    .0012803
      empfff |  -.1348592   .0334835    -4.03   0.000    -.2005066   -.0692118
      empent |  -.1058995   .0376904    -2.81   0.005     -.179795    -.032004
      empofw |   1.028642   .4364424     2.36   0.018     .1729582    1.884327
        prof |   .0052847    .001277     4.14   0.000      .002781    .0077883
       admin |  -.0201065   .0019484   -10.32   0.000    -.0239266   -.0162865
    fulltime |   .0106979   .0007561    14.15   0.000     .0092154    .0121803
       _cons |  -.4669879   .0548333    -8.52   0.000    -.5744934   -.3594824
------------------------------------------------------------------------------

      Source |       SS       df       MS              Number of obs =    3808
-------------+------------------------------           F(  6,  3801) =    6.38
       Model |  28.6081527     6  4.76802544           Prob > F      =  0.0000
    Residual |  2840.35628  3801  .747265529           R-squared     =  0.0100
-------------+------------------------------           Adj R-squared =  0.0084
       Total |  2868.96443  3807  .753602424           Root MSE      =  .86445

------------------------------------------------------------------------------
        lnf2 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    mccoopav |   .0954696   .0317418     3.01   0.003      .033237    .1577022
     farmimp |  -.2285592   .0606443    -3.77   0.000    -.3474578   -.1096606
    mcgbankav |   .0829429   .0461735     1.80   0.073    -.0075844    .1734702
  creditrepay |   .0748795   .0324781     2.31   0.021     .0112032    .1385557
    prodloan |  -.1231131   .0655043    -1.88   0.060    -.2515401    .0053139
    consloan |   .1549011   .0933371     1.66   0.097    -.0280944    .3378966
       _cons |  -.0764853   .0302456    -2.53   0.011    -.1357844   -.0171862
------------------------------------------------------------------------------

      Source |       SS       df       MS              Number of obs =    3784
-------------+------------------------------           F(  7,  3776) =    2.91
       Model |  15.1649468     7  2.16642098           Prob > F      =  0.0048
    Residual |  2807.14422  3776  .743417432           R-squared     =  0.0054
-------------+------------------------------           Adj R-squared =  0.0035
       Total |  2822.30917  3783  .746050534           Root MSE      =  .86222

------------------------------------------------------------------------------
        lnf3 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        i216 |  -.0086378    .004786    -1.80   0.071    -.0180211    .0007456
         br4 |  -.1371217   .0731037    -1.88   0.061    -.2804483     .006205
     i2_fpi1 |   .1635975   .0682911     2.40   0.017     .0297064    .2974885
          b3 |   .1327432   .0633864     2.09   0.036     .0084683    .2570181
     i3_tft5 |   .2734171   .1553872     1.76   0.079     -.031234    .5780681
      i3_mc1 |  -.2658072   .1485077    -1.79   0.074    -.5569702    .0253558
        i217 |   .0119813   .0047043     2.55   0.011      .002758    .0212046
       _cons |  -.0058404   .0145752    -0.40   0.689    -.0344165    .0227357
------------------------------------------------------------------------------
```

```
                         apenfarmadd
-------------------------------------------------------------
      Percentiles      Smallest
 1%     .0833014       .0001686
 5%     .4210005       .0027407
10%     .8500838       .0032561       Obs                3784
25%     2.129962       .0069774       Sum of Wgt.        3784

50%     4.569485                      Mean           6.034061
                        Largest       Std. Dev.      5.678497
75%     8.057197       44.97093
90%     12.84925        46.9798       Variance       32.24533
95%     16.50062       47.38177       Skewness       2.308739
99%      27.6897       49.23083       Kurtosis       11.45339

. drop apenfarmadd

. gen apenfarmadd=(100*exp(abs(lnferr)))/nonfarminc
(24 missing values generated)

. sum apenfarmadd, detail

                         apenfarmadd
-------------------------------------------------------------
      Percentiles      Smallest
 1%     .0005403       .0003016
 5%     .0007652       .0003576
10%     .0009316       .0003649       Obs                3784
25%     .0013556       .0003704       Sum of Wgt.        3784

50%     .0020768                      Mean           .0136241
                        Largest       Std. Dev.      .0945901
75%      .003983        1.46245
90%     .0131855        2.31804       Variance       .0089473
95%     .0303114       2.385149       Skewness       18.41596
99%     .2339839       2.733538       Kurtosis       425.3251
```

APPENDIX 6: PRODUCTION FRONTIER MODEL (MODEL 1) FOR TOTAL INCOME RESULTS

Source	SS	df	MS
Model	593983.7	26	22845.5269
Residual	38659.7121	5300	7.29428531
Total	632643.412	5326	118.783968

Number of obs	= 5326
F(26, 5300)	= 3131.98
Prob > F	= 0.0000
R-squared	= 0.9389
Adj R-squared	= 0.9386
Root MSE	= 2.7008

ltotalinc	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
area	.0605294	.0165883	3.65	0.000	.0280094	.0930494
lowirrarea	.0701429	.050762	1.38	0.167	-.0293715	.1696572
fulltime	.0254436	.002201	11.56	0.000	.0211288	.0297584
upland	.0036723	.0361175	0.10	0.919	-.0671328	.0744775
pasture	.352242	.1999019	1.76	0.078	-.039648	.744132
industrial	1.344755	.2952606	4.55	0.000	.7659229	1.923588
riceint	.4475129	.0782143	5.72	0.000	.2941807	.6008452
mccoopac	.7117961	.1281763	5.55	0.000	.4605178	.9630743
mcgbankav	.9002543	.1268626	7.10	0.000	.6515514	1.148957
cornint	.5070422	.0666039	7.61	0.000	.3764712	.6376132
farm	1.714419	.1323264	12.96	0.000	1.455005	1.973833
mcgfiac	1.017187	.3808696	2.67	0.008	.2705257	1.763848
nonfarm	5.577375	.0842737	66.18	0.000	5.412164	5.742586
creditrepay	2.454605	.0783181	31.34	0.000	2.301069	2.608141
farmimp	.0174135	.1431171	0.12	0.903	-.2631548	.2979819
banana	-.2133564	.1670462	-1.28	0.202	-.5408356	.1141229
workover21	.0096377	.0008445	11.41	0.000	.0079821	.0112933
phfacil	1.470329	.3882252	3.79	0.000	.7092479	2.23141
comfin	.314071	.1566782	2.00	0.045	.0069172	.6212247
livestock	-.1411877	.1632525	-0.86	0.387	-.4612298	.1788543
empfff	2.081867	.1285742	16.19	0.000	1.829809	2.333926
empent	1.88566	.1057361	17.83	0.000	1.678373	2.092946
rice	.3245987	.1533733	2.12	0.034	.0239239	.6252734
cash	.4651375	.1284085	3.62	0.000	.2134039	.716871
coconut	.8165834	.1371015	5.96	0.000	.547808	1.085359
work17_21	.0024425	.0016819	1.45	0.146	-.0008547	.0057397

. predict u, resid

Random-effects ML regression
Group variable (i): ID

Random effects u_i ~ Gaussian

Log likelihood = -12616.179

Number of obs	= 5326
Number of groups	= 5317
Obs per group: min	= 1
avg	= 1.0
max	= 2
LR chi2(18)	= 159.38
Prob > chi2	= 0.0000

uhat1	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
comorg	.3258437	.0926302	3.52	0.000	.1442918	.5073957
farmerorg	.504598	.1340074	3.77	0.000	.2419484	.7672476
creditorg	.3526925	.1881558	1.87	0.061	-.016086	.721471
irrmain	.2204825	.0967211	2.28	0.023	.0309125	.4100525
phmain	-.1695554	.0967892	-1.75	0.080	-.3592587	.0201479
roadmain	.274929	.1022203	2.69	0.007	.0745809	.475277
watermain	-.2069049	.0995874	-2.08	0.038	-.4020926	-.0117173
i1_fpi1	.3835193	.0799758	4.80	0.000	.2267697	.540269
i1_ph4	-.2735824	.1298783	-2.11	0.035	-.5281392	-.0190256
i1_ph5	.3769297	.0883879	4.26	0.000	.2036925	.5501669
i1_ph6	-.1552989	.088676	-1.75	0.080	-.3291008	.018503

```
      i1_mc1 |   .4830169   .1154152     4.19   0.000     .2568073    .7092265
      i1_ms2 |  -.0982851   .1273144    -0.77   0.440    -.3478167    .1512466
     i1_lti1 |   .2820723   .1175838     2.40   0.016     .0516122    .5125324
      i1_os3 |   -.082044   .1090454    -0.75   0.452    -.2957691    .1316811
         bd5 |  -1.045845   .3493395    -2.99   0.003    -1.730538    -.361152
        bdr3 |  -.2026367   .1650174    -1.23   0.219    -.5260649    .1207915
        bdr6 |   .8097695   .3946969     2.05   0.040     .0361777    1.583361
       _cons |  -1.115835   .0700681   -15.93   0.000    -1.253166   -.9785043
-------------+----------------------------------------------------------------
    /sigma_u |          0   1.926709     0.00   1.000     -3.77628     3.77628
    /sigma_e |   2.585327    .025049   103.21   0.000     2.536232    2.634422
-------------+----------------------------------------------------------------
         rho |          0          .                             .           .
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01)=    0.00 Prob>=chibar2 = 1.000

. predict uhat2, e


      Source |       SS       df       MS              Number of obs =    5326
-------------+------------------------------           F(  2,  5324) =    3.28
       Model |  .071863601     2    .0359318           Prob > F      =  0.0376
    Residual |  58.2696595  5324  .010944714           R-squared     =  0.0012
-------------+------------------------------           Adj R-squared =  0.0009
       Total |  58.3415231  5326  .010954097           Root MSE      =  .10462

------------------------------------------------------------------------------
       uhat2 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
femaleheaded |   .0090221   .0036961     2.44   0.015     .0017762     .016268
      hhsize |  -.0000449   .0002568    -0.17   0.861    -.0005483    .0004586
------------------------------------------------------------------------------

. predict ehat3
.
. regress uhat3 d, noconstant

      Source |       SS       df       MS              Number of obs =    5326
-------------+------------------------------           F(  1,  5325) =    2.68
       Model |  17.9336004     1  17.9336004           Prob > F      =  0.1014
    Residual |  35578.1195  5325  6.68133699           R-squared     =  0.0005
-------------+------------------------------           Adj R-squared =  0.0003
       Total |  35596.0531  5326   6.6834497           Root MSE      =  2.5848

------------------------------------------------------------------------------
       uhat3 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           d |   .0006577   .0004014     1.64   0.101    -.0001293    .0014446
------------------------------------------------------------------------------


Generalized linear models                          No. of obs      =      5326
Optimization     : ML: Newton-Raphson              Residual df     =      5325
                                                   Scale parameter =  .2059193
Deviance         =   1096.52038                    (1/df) Deviance =  .2059193
Pearson          =   1096.52038                    (1/df) Pearson  =  .2059193
Variance function: V(u) = 1                        [Gaussian]
Link function    : g(u) = ln(u/(1-u))              [Logit]
Standard errors  : OIM
Log likelihood   = -3348.505344                    AIC             =  1.257794
BIC              = -44593.87408
------------------------------------------------------------------------------
lfinalteto~c |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |   .2485158   .0252578     9.84   0.000     .1990113    .2980202
------------------------------------------------------------------------------
. gen ffte=exp(lfinaltetotalinc+.2485158)
. gen a=log(ffte)
. glm a, l(logit)
```

```
------------------------------------------------------------------------------
           a |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |   1.452136   .0404559    35.89   0.000     1.372844    1.531428
------------------------------------------------------------------------------
. gen b=exp(a-1.4521)
    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
           b |      5326    .5788204    .2452161   .0927958   3.011428
```

APPENDIX 7: PRODUCTION FRONTIER MODEL (MODEL 1) FOR RDI RESULTS

```
      Source |       SS       df       MS              Number of obs =    5002
-------------+------------------------------           F( 20,  4982) = 1969.28
       Model |  72554.3678    20  3627.71839           Prob > F      =  0.0000
    Residual |  9177.63536  4982  1.84215884           R-squared     =  0.8877
-------------+------------------------------           Adj R-squared =  0.8873
       Total |  81732.0031  5002  16.3398647           Root MSE      =  1.3573

------------------------------------------------------------------------------
        lrdi |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        cash |    .285406   .0663884     4.30   0.000     .1552555    .4155565
  lowirrarea |  -.0455163   .0249923    -1.82   0.069    -.0945122    .0034796
        corn |    .299971   .0584794     5.13   0.000     .1853257    .4146163
      upland |    .028341   .0167654     1.69   0.091    -.0045266    .0612086
   highvalue |   .3187988   .1737627     1.83   0.067    -.0218527    .6594502
     i1_fpi3 |   .6076598   .0433786    14.01   0.000     .5226186    .6927009
     homefin |   .6057857   .0624081     9.71   0.000     .4834384    .7281331
        rice |   .1329359   .0515288     2.58   0.010     .0319167    .2339551
   mcgbankav |   .5094715   .0651348     7.82   0.000     .3817787    .6371644
      banana |   .3860973   .0853127     4.53   0.000     .2188468    .5533478
  industrial |   .5331771   .1520985     3.51   0.000     .2349971    .8313571
  workover21 |   .0073799   .0004248    17.37   0.000     .0065472    .0082126
        live |   .4231314   .0937061     4.52   0.000     .2394262    .6068366
 creditrepay |   1.742027   .0377881    46.10   0.000     1.667945    1.816108
     farmimp |   .0736015   .0733389     1.00   0.316    -.0701749    .2173779
    prodloan |   .0985224   .0862323     1.14   0.253    -.0705309    .2675757
        farm |   1.572874   .0447268    35.17   0.000      1.48519    1.660558
     phfacil |   .5824764   .2035183     2.86   0.004     .1834909    .9814619
   permanent |   .0878108   .1416556     0.62   0.535    -.1898965    .3655181
    fulltime |   .0299464   .0010038    29.83   0.000     .0279784    .0319144
------------------------------------------------------------------------------

. predict u, resid


Random-effects ML regression                    Number of obs      =      5002
Group variable (i): ID                          Number of groups   =      4995

Random effects u_i ~ Gaussian                   Obs per group: min =         1
                                                               avg =       1.0
                                                               max =         2

                                                LR chi2(14)        =     99.55
Log likelihood  = -2296.2373                    Prob > chi2        =    0.0000

------------------------------------------------------------------------------
      comorg |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   farmerorg |  -.0229624   .0208189    -1.10   0.270    -.0637668    .0178419
   creditorg |  -.0048264   .0291862    -0.17   0.869    -.0620304    .0523776
   watermain |   .0256753   .0114305     2.25   0.025     .0032719    .0480786
     i1_fpi1 |   .0316677   .0122089     2.59   0.009     .0077387    .0555967
     i1_fpi3 |  -.0363805   .0127919    -2.84   0.004    -.0614521   -.0113088
      i1_ph5 |   .0338524   .0131409     2.58   0.010     .0080967    .0596082
      i1_ph6 |   .0048062   .0135485     0.35   0.723    -.0217483    .0313607
      i1_tl2 |    .055383   .0154761     3.58   0.000     .0250504    .0857156
      i1_ms2 |  -.0384982   .0191267    -2.01   0.044    -.0759859   -.0010105
     i1_ocb1 |   .0273024   .0129664     2.11   0.035     .0018886    .0527161
         bd4 |   .0276628   .0325462     0.85   0.395    -.0361266    .0914521
         bd5 |  -.0018906   .0569713    -0.03   0.974    -.1135523    .1097712
        bdr3 |   .0089672   .0247878     0.36   0.718     -.039616    .0575503
        bdr6 |   .0679065   .0595668     1.14   0.254    -.0488424    .1846554
       _cons |   .1292147   .0100087    12.91   0.000     .1095981    .1488313
-------------+----------------------------------------------------------------
    /sigma_u |          0   .1336917     0.00   1.000     -.262031     .262031
```

```
    /sigma_e |   .3829409   .0038286   100.02   0.000      .375437    .3904448
-------------+----------------------------------------------------------------
         rho |          0          .                             .           .
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01)=    0.00 Prob>=chibar2 = 1.000

. predict uhat2, e

      Source |       SS       df       MS              Number of obs =    5002
-------------+------------------------------           F(  4,  4998) =    7.01
       Model |  .011721079     4  .00293027            Prob > F      =  0.0000
    Residual |  2.08856862  4998  .000417881           R-squared     =  0.0056
-------------+------------------------------           Adj R-squared =  0.0048
       Total |   2.1002897  5002  .00041989            Root MSE      =  .02044

------------------------------------------------------------------------------
       uhat2 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       islam |   .0079576   .0020205     3.94   0.000     .0039965    .0119186
      single |   .0024523   .0010038     2.44   0.015     .0004845    .0044202
       sales |  -.0000584   .0000309    -1.89   0.058    -.0001189    2.08e-06
      tenant |  -.0014335   .0007337    -1.95   0.051     -.002872    4.96e-06
------------------------------------------------------------------------------

. predict ehat3

.
. regress uhat3 d, noconstant

      Source |       SS       df       MS              Number of obs =    5002
-------------+------------------------------           F(  1,  5001) =  899.38
       Model |  1547.45437     1  1547.45437           Prob > F      =  0.0000
    Residual |  8604.59165  5001  1.72057421           R-squared     =  0.1524
-------------+------------------------------           Adj R-squared =  0.1523
       Total |   10152.046  5002  2.02959736           Root MSE      =  1.3117

------------------------------------------------------------------------------
       uhat3 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           d |   .0004549   .0000152    29.99   0.000     .0004251    .0004846
------------------------------------------------------------------------------

. gen lfinalterdi=log(finalterdi)

Generalized linear models                          No. of obs      =      5002
Optimization     : ML: Newton-Raphson              Residual df     =      5001
                                                   Scale parameter =  .0494573
Deviance         =  247.3357966                    (1/df) Deviance =  .0494573
Pearson          =  247.3357966                    (1/df) Pearson  =  .0494573

Variance function: V(u) = 1                        [Gaussian]
Link function    : g(u) = ln(u/(1-u))              [Logit]
Standard errors  : OIM
Log likelihood   =  422.5917973                    AIC             = -.1685693
BIC              = -42349.14735
------------------------------------------------------------------------------
 lfinalterdi |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |  -.7042495   .0142028   -49.59   0.000    -.7320865   -.6764124
------------------------------------------------------------------------------
. gen ffte=exp(lfinalterdi-.7042495)

. sum ffte
    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
        ffte |      5002    .7045425    .1427215   .3471777   .9351272
```

APPENDIX 8: PRODUCTION FRONTIER MODEL (MODEL 2) FOR INCOME RESULTS

```
      Source |       SS       df       MS              Number of obs =    5326
-------------+------------------------------           F( 34,  5292) = 2584.66
       Model |  596709.769    34  17550.2873           Prob > F      =  0.0000
    Residual |  35933.6435  5292  6.79018206           R-squared     =  0.9432
-------------+------------------------------           Adj R-squared =  0.9428
       Total |  632643.412  5326  118.783968           Root MSE      =  2.6058

------------------------------------------------------------------------------
   ltotalinc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        area |   .0573434   .0144001     3.98   0.000     .0291134    .0855735
     pasture |   .2724178   .1928181     1.41   0.158    -.1055851    .6504207
      i1_fpi3 |   .6022401   .0803514     7.50   0.000     .4447182    .7597621
    mccoopav |     .67189    .083117     8.08   0.000     .5089464    .8348337
   mcgbankav |   .5413176   .1244969     4.35   0.000     .2972523    .7853829
     mcgfiac |   .7693056   .3717522     2.07   0.039     .0405181    1.498093
   creditgov |   1.032905   .0999866    10.33   0.000     .8368905     1.22892
 creditrepay |   1.603965   .1040977    15.41   0.000     1.399891     1.80804
    prodloan |   .2633697    .156125     1.69   0.092    -.0426997    .5694392
   farmequip |   .7109045   .4102669     1.73   0.083    -.0933878    1.515197
     phfacil |   1.586861   .3729696     4.25   0.000     .8556874    2.318036
      comfin |   .3763184   .1509731     2.49   0.013     .0803489    .6722879
    consloan |   .7416051   .2396307     3.09   0.002     .2718302     1.21138
     homefin |   .6483972    .117121     5.54   0.000     .4187918    .8780025
        corn |   .7818903   .1145975     6.82   0.000     .5572319    1.006549
     coconut |   .7392534   .1321736     5.59   0.000     .4801387    .9983681
  industrial |   1.168788   .2863117     4.08   0.000     .6074994    1.730077
        cash |   .3692052   .1262547     2.92   0.003      .121694    .6167164
      banana |   -.431082   .1624925    -2.65   0.008    -.7496342   -.1125297
     riceint |   .4156937   .0513985     8.09   0.000     .3149314     .516456
    work6_12 |    .005843   .0038121     1.53   0.125    -.0016303    .0133162
   work17_21 |   .0025226   .0016306     1.55   0.122    -.0006741    .0057193
  workover21 |   .0084803   .0008157    10.40   0.000     .0068812    .0100795
    fulltime |   .0206289   .0023327     8.84   0.000     .0160558     .025202
        farm |   1.462155   .1299373    11.25   0.000     1.207424    1.716886
     nonfarm |   5.276055   .0856196    61.62   0.000     5.108205    5.443905
      empfff |    1.97632   .1241209    15.92   0.000     1.732992    2.219648
      empent |   1.772595   .1031134    17.19   0.000      1.57045    1.974739
        prof |   .0176714   .0035563     4.97   0.000     .0106995    .0246433
     service |   .0149379   .0030297     4.93   0.000     .0089984    .0208775
        agri |  -.0148921   .0033789    -4.41   0.000    -.0215161    -.008268
         own |   .4103475   .1111938     3.69   0.000     .1923617    .6283333
      leased |   .4239898   .2640287     1.61   0.108    -.0936153    .9415948
      tenant |   .4355807   .1315043     3.31   0.001      .177778    .6933834
------------------------------------------------------------------------------

. predict u1, resid

.
. regress u1 d, noconstant

      Source |       SS       df       MS              Number of obs =    5326
-------------+------------------------------           F(  1,  5325) =  187.94
       Model |   1225.0223     1   1225.0223           Prob > F      =  0.0000
    Residual |  34708.6212  5325  6.51805094           R-squared     =  0.0341
-------------+------------------------------           Adj R-squared =  0.0339
       Total |  35933.6436  5326  6.74683506           Root MSE      =   2.553

------------------------------------------------------------------------------
          u1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           d |   .0004222   .0000308    13.71   0.000     .0003618    .0004826
------------------------------------------------------------------------------

. predict u2, resid
```

```
Generalized linear models                          No. of obs      =      5326
Optimization     : ML: Newton-Raphson              Residual df     =      5309
                                                   Scale parameter =  6.348507
Deviance         =  33704.22144                    (1/df) Deviance =  6.348507
Pearson          =  33704.22144                    (1/df) Pearson  =  6.348507

Variance function: V(u) = 1                        [Gaussian]
Link function    : g(u) = ln(u/(1-u))              [Logit]
Standard errors  : OIM

Log likelihood   = -12470.56183                    AIC             =  4.689283
BIC              = -11848.88732

------------------------------------------------------------------------------
          u2 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
femaleheaded |  -11.41005   6.826552    -1.67   0.095    -24.78984    1.969746
         ink |   12.96357   8.315626     1.56   0.119    -3.334757     29.2619
    depend16 |   1.222137   .6217165     1.97   0.049     .0035947    2.440679
  nuclearfam |  -141.8734   71.14385    -1.99   0.046    -281.3128   -2.434054
     sch6_12 |  -.3960306   .2040984    -1.94   0.052     -.796056    .0039948
    sch13_16 |  -1.517638   .7559284    -2.01   0.045     -2.99923   -.0360455
      i1_ph5 |    -253.21   127.9089    -1.98   0.048    -503.9068   -2.513145
      i1_ph6 |   42.44212   21.73064     1.95   0.051     -.149163    85.03339
     i1_tft4 |   -227.868    115.258    -1.98   0.048    -453.7695   -1.966484
      i1_tl3 |   38.74271   20.68604     1.87   0.061     -1.80117     79.2866
     i1_ocb2 |   4.633387   3.301879     1.40   0.161    -1.838176    11.10495
      i1_ti2 |  -6.989196   4.352563    -1.61   0.108    -15.52006    1.541671
      i1_ti7 |   40.78323   20.69941     1.97   0.049     .2131343    81.35332
         bd5 |   44.69259   24.32985     1.84   0.066    -2.993049    92.37823
        bdr2 |  -90.61268   45.84645    -1.98   0.048    -180.4701   -.7552879
        bdr3 |   318.7326   160.6427     1.98   0.047     3.878677    633.5865
       _cons |   108.1582    54.0603     2.00   0.045     2.201934    214.1144
------------------------------------------------------------------------------

. predict p3
(option mu assumed; predicted mean u2)

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
  tetotalinc |      5326    1.370173     .697646          1   2.718282

.

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
          p3 |      5326    .2175341    .4074387          0          1

. sum tetotalinc

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
  tetotalinc |      5326    .8611859    .2586368   .3678795          1
```

APPENDIX 9: PRODUCTION FRONTIER MODEL (MODEL 2) FOR RDI RESULTS

```
      Source |       SS       df       MS              Number of obs =    5326
-------------+------------------------------           F( 23,  5303) =  196.52
       Model |    52356.62    23  2276.37478           Prob > F      =  0.0000
    Residual |  61425.5237  5303   11.583165           R-squared     =  0.4601
-------------+------------------------------           Adj R-squared =  0.4578
       Total |  113782.144  5326  21.3635268           Root MSE      =  3.4034

------------------------------------------------------------------------------
        lrdi |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     i1_fpi3 |   .3109322   .1042539     2.98   0.003     .1065516    .5153128
   mcgbankav |   .2943851   .1719954     1.71   0.087    -.0427967    .6315669
     mcgfiav |   .6196363    .331687     1.87   0.062    -.0306068    1.269879
     mcgfiac |  -1.987411   .5785247    -3.44   0.001    -3.121557   -.8532647
   creditgov |   .5381102    .130171     4.13   0.000     .2829215    .7932989
 creditrepay |   .6254965   .1354882     4.62   0.000     .3598839    .8911091
    prodloan |  -.6782187   .2022008    -3.35   0.001    -1.074616   -.2818219
    consloan |   .5811354   .3121752     1.86   0.063    -.0308564    1.193127
   permanent |  -.5214483    .340371    -1.53   0.126    -1.188715    .1458188
     riceint |  -.1313839   .0623407    -2.11   0.035    -.2535973   -.0091704
  workover21 |   .0052556   .0010542     4.99   0.000      .003189    .0073222
    fulltime |   .0070556   .0028379     2.49   0.013     .0014922    .0126191
     nonfarm |   1.109664   .1072592    10.35   0.000      .899392    1.319936
      empfff |   .7105169   .1169772     6.07   0.000     .4811935    .9398402
      empent |   .5726917   .1336164     4.29   0.000     .3107487    .8346347
       admin |   .0130627    .007434     1.76   0.079     -.001511    .0276363
     service |   .0081836   .0038056     2.15   0.032     .0007232    .0156441
         own |   .6682702   .1279929     5.22   0.000     .4173515    .9191889
      leased |   .6234476    .340181     1.83   0.067    -.0434471    1.290342
    mortgage |   .9232939   .4937293     1.87   0.062    -.0446186    1.891206
      tenant |   1.061376   .1599086     6.64   0.000     .7478891    1.374862
inheritten~y |   1.057923   .4245387     2.49   0.013     .2256522    1.890193
  amortizing |    .831036   .5578267     1.49   0.136    -.2625338    1.924606
------------------------------------------------------------------------------
. predict p1

      Source |       SS       df       MS              Number of obs =    5326
-------------+------------------------------           F(  1,  5325) =   11.54
       Model |  132.860463     1  132.860463           Prob > F      =  0.0007
    Residual |   61292.663  5325  11.5103593           R-squared     =  0.0022
-------------+------------------------------           Adj R-squared =  0.0020
       Total |  61425.5235  5326  11.5331437           Root MSE      =  3.3927

------------------------------------------------------------------------------
          u1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           d |   .0004526   .0001332     3.40   0.001     .0001914    .0007138
------------------------------------------------------------------------------

. predict u2, resid

Generalized linear models                          No. of obs      =      5326
Optimization     : ML: Newton-Raphson              Residual df     =      5305
                                                   Scale parameter =  11.48695
Deviance         =  60938.26884                    (1/df) Deviance =  11.48695
Pearson          =  60938.26884                    (1/df) Pearson  =  11.48695

Variance function: V(u) = 1                        [Gaussian]
Link function    : g(u) = ln(u/(1-u))              [Logit]
Standard errors  : OIM

Log likelihood   = -14047.69235                    AIC             =  5.283024
BIC              =   15419.4815
```

```
------------------------------------------------------------------------------
          u2 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     i1_fpi1 |  -103.7355   121.3987    -0.85   0.393    -341.6725    134.2015
     i1_fpi6 |   49.02618   56.89279     0.86   0.389    -62.48164     160.534
     i1_lti1 |   13.86375   23.10037     0.60   0.548    -31.41215    59.13965
      i1_mc1 |   -227.584   261.9156    -0.87   0.385    -740.9292    285.7611
      i1_ms1 |   147.5004   170.9743     0.86   0.388    -187.6031    482.6039
      i1_ms2 |   15.67673    28.7194     0.55   0.585    -40.61227    71.96572
     i1_ocb2 |   14.58061   20.58066     0.71   0.479    -25.75675    54.91797
      i1_os1 |   59.07862   72.98629     0.81   0.418    -83.97188    202.1291
      i1_ph4 |   9.063902   17.20784     0.53   0.598    -24.66284    42.79065
      i1_ph5 |  -5.358641    9.34312    -0.57   0.566    -23.67082    12.95354
     i1_tft3 |  -135.0559   159.2869    -0.85   0.397    -447.2524    177.1406
     i1_tft4 |   177.3639   203.1055     0.87   0.383    -220.7157    575.4434
     i1_tft5 |   25.40797   39.28396     0.65   0.518    -51.58718    102.4031
     i1_tft6 |  -115.1525   137.1611    -0.84   0.401    -383.9833    153.6783
      i1_ti7 |  -44.99301   52.95184    -0.85   0.395    -148.7767     58.7907
      i1_tl3 |   69.61159   80.28455     0.87   0.386    -87.74324    226.9664
         bd3 |  -44.29268   1218.404    -0.04   0.971     -2432.32    2343.735
        bdr2 |   59.03838   81.54318     0.72   0.469    -100.7833    218.8601
        bdr3 |   33.72659   50.50306     0.67   0.504     -65.2576    132.7108
        bdr6 |  -92.88356   1224.729    -0.08   0.940    -2493.307     2307.54
       _cons |  -108.1061   123.9657    -0.87   0.383    -351.0744    134.8623
------------------------------------------------------------------------------

. predict p3

. sum terdi

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
       terdi |      5326    .9528485    .1643609   .3678795          1

.
```

APPENDIX 10: PRODUCTION FRONTIER MODEL (HALF-NORMAL) FOR TOTAL INCOME RESULTS

Stoc. frontier normal/truncated-normal model		Number of obs	=	5326
		Wald chi2(26)	=	162033.24
Log likelihood = -608899.22		Prob > chi2	=	0.0000

totalinc	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
totalinc						
area	63628.29	4627.943	13.75	0.000	54557.68	72698.89
lowirrarea	1276494	14162.05	90.13	0.000	1248737	1304251
fulltime	46908.6	614.046	76.39	0.000	45705.09	48112.1
upland	146859.8	10076.34	14.57	0.000	127110.5	166609
pasture	506747.3	55770.18	9.09	0.000	397439.8	616054.8
industrial	905773.9	82374.1	11.00	0.000	744323.7	1067224
riceint	1041186	21820.86	47.72	0.000	998418.3	1083955
mccoopac	-135387.8	35759.6	-3.79	0.000	-205475.3	-65300.23
mcgbankav	449191.6	35393.1	12.69	0.000	379822.4	518560.8
cornint	202063.4	18581.66	10.87	0.000	165644.1	238482.8
farm	299836.9	36917.44	8.12	0.000	227480	372193.7
mcgfiac	423881.7	106257.9	3.99	0.000	215620	632143.4
nonfarm	2898507	23511.59	123.28	0.000	2852425	2944589
creditrepay	99569.44	21849.79	4.56	0.000	56744.64	142394.2
farmimp	66692.91	39927.9	1.67	0.095	-11564.34	144950.1
banana	-433439.8	46603.83	-9.30	0.000	-524781.6	-342098
workover21	-4058.362	235.605	-17.23	0.000	-4520.139	-3596.585
phfacil	5314634	108310.2	49.07	0.000	5102350	5526918
comfin	-716803.3	43711.3	-16.40	0.000	-802475.8	-631130.7
livestock	946833.9	45545.45	20.79	0.000	857566.5	1036101
empfff	-28023.54	35870.62	-0.78	0.435	-98328.66	42281.58
empent	-305930.2	29499.07	-10.37	0.000	-363747.3	-248113.1
rice	-1018055	42789.27	-23.79	0.000	-1101921	-934189.8
cash	-354924.5	35824.4	-9.91	0.000	-425139.1	-284710
coconut	574363.4	38249.63	15.02	0.000	499395.5	649331.3
work17_21	1062.214	469.2241	2.26	0.024	142.5517	1981.876
mu						
phmain	-.0530822	50.31414	-0.00	0.999	-98.66698	98.56081
i1_ph4	-.0181091	127.844	-0.00	1.000	-250.5877	250.5514
i1_ph5	.0316559	.	.	.	.	.
i1_ph6	-.0299874	68.2365	-0.00	1.000	-133.7711	133.7111
i1_mc1	-.0211947	.	.	.	.	.
i1_ms2	.0919498	.	.	.	.	.
i1_lti1	.0257011	.	.	.	.	.
i1_os3	.0729574	.	.	.	.	.
bd5	-.0048892	.	.	.	.	.
bdr3	-.0346499	.	.	.	.	.
bdr6	-.0367729	.	.	.	.	.
femaleheaded	.0682635	.	.	.	.	.
hhsize	-.0073009	4.169869	-0.00	0.999	-8.180094	8.165493
/lnsigma2	27.06494	.0013449	20124.60	0.000	27.0623	27.06757
/ilgtgamma	-30.45448	164.6212	-0.18	0.853	-353.1061	292.1971
sigma2	5.68e+11	7.64e+08			5.66e+11	5.69e+11
gamma	5.94e-14	9.78e-12			4.4e-154	1
sigma_u2	.033724	5.55169			-10.84739	10.91484
sigma_v2	5.68e+11	7.64e+08			5.66e+11	5.69e+11

Variable	Obs	Mean	Std. Dev.	Min	Max
tetotalinc	5326	.8668246	.02009	.7259138	.9369437

APPENDIX 11: PRODUCTION FRONTIER MODEL (HALF-NORMAL) FOR RDI RESULTS

```
Stoc. frontier normal/truncated-normal model      Number of obs   =       5006
                                                  Wald chi2(21)   =   22345.91
Log likelihood = -22946.734                       Prob > chi2     =     0.0000

------------------------------------------------------------------------------
         rdi |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
rdi          |
        cash |   5.763345   1.154591     4.99   0.000     3.500389    8.026301
  lowirrarea |  -.0592454   .4304307    -0.14   0.891     -.902874    .7843833
        corn |   6.958514   1.005725     6.92   0.000      4.98733    8.929699
      upland |   .6536363   .2900032     2.25   0.024     .0852404    1.222032
   highvalue |   7.878869   2.995147     2.63   0.009     2.008488    13.74925
     i1_fpi3 |   11.08926   1.409837     7.87   0.000      8.32603    13.85249
     homefin |   9.488043   1.072172     8.85   0.000     7.386624    11.58946
        rice |   4.420164   .9039765     4.89   0.000     2.648403    6.191926
   mcgbankav |   8.505643   1.123379     7.57   0.000     6.303861    10.70742
      banana |   6.231354   1.463377     4.26   0.000     3.363189     9.09952
  industrial |   11.31061   2.625555     4.31   0.000     6.164612     16.4566
  workover21 |   .1089153   .0073318    14.86   0.000     .0945452    .1232855
        live |    6.50314   1.610951     4.04   0.000     3.345734    9.660546
 creditrepay |   26.00054   .6711601    38.74   0.000     24.68509    27.31599
     farmimp |    3.92222   1.259747     3.11   0.002     1.453161    6.391278
    prodloan |   2.890311   1.482421     1.95   0.051    -.0151807    5.795803
        farm |   23.25332   .7767451    29.94   0.000     21.73092    24.77571
     phfacil |   17.84114   3.516259     5.07   0.000      10.9494    24.73288
   permanent |   4.096333    2.44747     1.67   0.094    -.7006202    8.893285
    fulltime |   .4716197   .0173172    27.23   0.000     .4376786    .5055608
-------------+----------------------------------------------------------------
mu           |
      comorg |  -10.41729   8.392472    -1.24   0.215    -26.86624    6.031649
   farmerorg |   4.100987          .        .       .            .           .
   creditorg |  -1.609262   16.62928    -0.10   0.923    -34.20205    30.98353
   watermain |  -22.91275   7.605384    -3.01   0.003    -37.81903   -8.006472
     i1_fpi1 |   -6.23268   13.66139    -0.46   0.648    -33.00851    20.54315
     i1_fpi3 |    4.50263   15.68513     0.29   0.774    -26.23966    35.24492
      i1_ph5 |  -7.302225          .        .       .            .           .
      i1_ph6 |   -10.4708   9.495631    -1.10   0.270    -29.08189    8.140296
      i1_tl2 |  -20.83305   11.60594    -1.80   0.073    -43.58028    1.914175
      i1_ms2 |  -2.640425    10.6917    -0.25   0.805    -23.59576    18.31491
     i1_ocb1 |  -6.651272   9.251208    -0.72   0.472    -24.78331    11.48076
         bd4 |  -2.368892   27.23924    -0.09   0.931    -55.75683    51.01904
         bd5 |  -33.14655          .        .       .            .           .
        bdr3 |   5.049293   21.99942     0.23   0.818    -38.06877    48.16736
        bdr6 |   47.70626          .        .       .            .           .
       islam |  -1.184846   12.67204    -0.09   0.926    -26.02159    23.65189
      single |  -21.96257   11.44684    -1.92   0.055    -44.39797     .472826
       sales |  -2.125233   1.706647    -1.25   0.213    -5.470199    1.219733
      tenant |   2.523827          .        .       .            .           .
-------------+----------------------------------------------------------------
   /lnsigma2 |   6.378412   .0325874   195.73   0.000     6.314541    6.442282
  /ilgtgamma |  -2.381747   .2329708   -10.22   0.000    -2.838361   -1.925132
-------------+----------------------------------------------------------------
      sigma2 |   588.9914   19.19369                      552.5486    627.8377
       gamma |   .0845752   .0180371                      .0552861    .1272903
    sigma_u2 |   49.81408   11.89472                      26.50085    73.12731
    sigma_v2 |   539.1773    11.8454                      515.9608    562.3939
------------------------------------------------------------------------------
.
. sum terdi

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
       terdi |      5006    .3968948    .1633236          0   .8187075
```

APPENDIX 12: SAR MODEL FOR NON-AGRICULTURE INCOME (USING FIES 2003) RESULTS

```
      Source |       SS       df       MS              Number of obs =   27783
-------------+------------------------------           F( 47, 27735) = 2171.06
       Model |  43608.0533    47  927.830922           Prob > F      =  0.0000
    Residual |  11852.9128 27735  .427362998           R-squared     =  0.7863
-------------+------------------------------           Adj R-squared =  0.7859
       Total |  55460.9661 27782  1.99629134           Root MSE      =  .65373

------------------------------------------------------------------------------
     lnaginc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      agrihh |   -1.53018   .0102068  -149.92   0.000    -1.550186   -1.510174
    malehead |  -.0857743   .0180284    -4.76   0.000    -.1211108   -.0504378
       hhage |    .005431   .0003543    15.33   0.000     .0047365    .0061254
 marriedhead |   .0850989   .0176456     4.82   0.000     .0505128    .1196851
    headelem |    .278743   .0184082    15.14   0.000     .2426621     .314824
     headhs |   .4084108   .0197887    20.64   0.000     .3696239    .4471977
   headunder |   .5276068   .0240045    21.98   0.000     .4805568    .5746568
    headcoll |     .60926    .028348    21.49   0.000     .5536965    .6648235
     mngrgov |   .0065826   .0224266     0.29   0.769    -.0373746    .0505399
        prof |   .1611614   .0438911     3.67   0.000     .0751326    .2471901
 techniaprof |  -.0281913     .03855    -0.73   0.465    -.1037512    .0473685
       clerk |     .01833   .0415811     0.44   0.659    -.0631711    .0998311
     service |   .0504507   .0299037     1.69   0.092    -.0081621    .1090635
      farmer |  -.2626883   .0187186   -14.03   0.000    -.2993777   -.2259989
       trade |    .026351   .0245076     1.08   0.282    -.0216851     .074387
    operator |   .1148352   .0250806     4.58   0.000      .065676    .1639944
     laborer |  -.1660681   .0225895    -7.35   0.000    -.2103447   -.1217914
       spocc |   .1986786   .0571302     3.48   0.001     .0867006    .3106566
       pvthh |   .1123569   .0395229     2.84   0.004       .03489    .1898238
      pvtest |   .0264095   .0143165     1.84   0.065    -.0016516    .0544705
        govt |    .153146   .0223896     6.84   0.000     .1092613    .1970307
         own |   .0618325    .013282     4.66   0.000     .0357991    .0878659
  workpayown |   .0466034   .1006198     0.46   0.643    -.1506165    .2438232
worknopayown |   .0896592   .0493983     1.82   0.070    -.0071638    .1864822
     nuclear |  -.0573938   .0109361    -5.25   0.000    -.0788291   -.0359585
   pemployed |   .0006539   .0002266     2.89   0.004     .0002098     .001098
     pless15 |  -.0009035   .0002336    -3.87   0.000    -.0013613   -.0004457
    spousemp |   .1459247   .0099997    14.59   0.000     .1263248    .1655247
        FOOD |   .0000148   2.78e-07    53.34   0.000     .0000143    .0000154
       FDOUT |  -2.17e-06   8.21e-07    -2.65   0.008    -3.78e-06   -5.65e-07
fuelightwa~r |   .0000629   3.05e-06    20.64   0.000      .000057    .0000689
      petrol |  -.0001152    .000011   -10.46   0.000    -.0001368   -.0000937
     elecexp |  -.0000253   3.70e-06    -6.85   0.000    -.0000326   -.0000181
    waterexp |  -.0000478   5.21e-06    -9.18   0.000    -.0000581   -.0000376
    landfare |   .0000191   1.36e-06    14.04   0.000     .0000164    .0000217
     airfare |   8.35e-06   2.66e-06     3.14   0.002     3.13e-06    .0000136
   waterfare |   .0000157   3.39e-06     4.62   0.000     9.02e-06    .0000223
   gasdiesel |   3.13e-06   1.53e-06     2.05   0.041     1.34e-07    6.13e-06
         tel |  -9.92e-06   2.81e-06    -3.53   0.000    -.0000154   -4.41e-06
       MEDIC |   5.56e-06   5.20e-07    10.70   0.000     4.54e-06    6.58e-06
      excrop |   1.33e-06   2.18e-07     6.09   0.000     9.01e-07    1.76e-06
      exlive |   1.72e-06   3.93e-07     4.39   0.000     9.54e-07    2.49e-06
      exfish |   1.31e-06   2.80e-07     4.67   0.000     7.58e-07    1.86e-06
    exforest |   1.56e-06   1.01e-06     1.55   0.120    -4.09e-07    3.54e-06
exwholeret~l |   9.67e-08   2.02e-08     4.78   0.000     5.70e-08    1.36e-07
     exmanuf |  -2.65e-07   8.19e-08    -3.23   0.001    -4.25e-07   -1.04e-07
    extransp |   8.55e-07   1.81e-07     4.73   0.000     5.01e-07    1.21e-06
       _cons |     9.6132   .0371565   258.72   0.000     9.540371    9.686028
------------------------------------------------------------------------------

. predict pnaginc

      Source |       SS       df       MS              Number of obs =   27783
-------------+------------------------------           F(  1, 27782) = 3660.55
       Model |  1379.91794     1  1379.91794           Prob > F      =  0.0000
```

```
    Residual |  10472.9948 27782  .376970515           R-squared     =  0.1164
-------------+------------------------------           Adj R-squared =  0.1164
       Total |  11852.9128 27783  .426624654           Root MSE      =  .61398

------------------------------------------------------------------------------
          e1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           d |   .0281819   .0004658    60.50   0.000     .0272689    .0290949
------------------------------------------------------------------------------

. predict eh, resid

. sum lnagincmape

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
 lnagincmape |     27783    4.824561    5.005045   .0000251   180.8987


.
```

APPENDIX 13: SAR MODEL FOR AGRICULTURE INCOME (USING FIES 2003) RESULTS

Source	SS	df	MS
Model	25083.5963	46	545.295571
Residual	33859.0104	25445	1.33067441
Total	58942.6067	25491	2.31229087

Number of obs	= 25492
F(46, 25445)	= 409.79
Prob > F	= 0.0000
R-squared	= 0.4256
Adj R-squared	= 0.4245
Root MSE	= 1.1535

laginc	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
malehead	.2480851	.0342241	7.25	0.000	.181004	.3151663
hhage	-.0017967	.0006493	-2.77	0.006	-.0030693	-.0005241
marriedhead	.0402037	.0329344	1.22	0.222	-.0243496	.104757
headelem	-.0792299	.0327309	-2.42	0.016	-.1433844	-.0150754
headhs	-.331673	.03524	-9.41	0.000	-.4007453	-.2626006
headunder	-.5315983	.0440898	-12.06	0.000	-.6180168	-.4451797
headcoll	-.6295256	.0544892	-11.55	0.000	-.7363276	-.5227236
mngrgov	-.143542	.0437666	-3.28	0.001	-.2293271	-.0577569
prof	-.597688	.0913043	-6.55	0.000	-.7766497	-.4187263
techniaprof	-.5137368	.0768281	-6.69	0.000	-.6643242	-.3631493
clerk	-.734333	.0850501	-8.63	0.000	-.9010362	-.5676299
service	-.8044926	.0592729	-13.57	0.000	-.920671	-.6883143
farmer	1.201679	.0347842	34.55	0.000	1.1335	1.269858
trade	-.6552472	.0463711	-14.13	0.000	-.7461373	-.5643571
operator	-.887906	.0480297	-18.49	0.000	-.982047	-.793765
laborer	.5106462	.0429012	11.90	0.000	.4265574	.5947351
spocc	-.6577374	.1136766	-5.79	0.000	-.88055	-.4349247
pvthh	-.2292714	.0741008	-3.09	0.002	-.3745131	-.0840296
pvtest	.3284705	.0271103	12.12	0.000	.2753328	.3816082
govt	.032962	.0438431	0.75	0.452	-.0529731	.118897
own	.1284396	.0238506	5.39	0.000	.0816911	.1751882
workpayown	.3655942	.1820338	2.01	0.045	.0087975	.7223909
worknopayown	.0770633	.0928139	0.83	0.406	-.1048573	.2589839
nuclear	.0125636	.0202315	0.62	0.535	-.0270914	.0522185
pemployed	-.0001039	.0004202	-0.25	0.805	-.0009276	.0007197
pless15	.0018238	.0004306	4.24	0.000	.0009799	.0026678
spousemp	-.029122	.0183898	-1.58	0.113	-.0651671	.0069231
FOOD	.0000137	5.34e-07	25.62	0.000	.0000126	.0000147
FDOUT	-.0000241	1.68e-06	-14.34	0.000	-.0000274	-.0000208
fuelightwa~r	.0000989	5.59e-06	17.70	0.000	.000088	.0001099
petrol	.0001213	.0000212	5.73	0.000	.0000798	.0001627
elecexp	-.0001464	7.13e-06	-20.54	0.000	-.0001604	-.0001325
waterexp	-.0001917	.0000104	-18.38	0.000	-.0002121	-.0001712
landfare	-.0000293	2.84e-06	-10.29	0.000	-.0000349	-.0000237
airfare	-9.85e-06	5.26e-06	-1.87	0.061	-.0000202	4.54e-07
waterfare	-.0000146	7.75e-06	-1.88	0.060	-.0000298	5.98e-07
gasdiesel	3.30e-06	3.51e-06	0.94	0.346	-3.57e-06	.0000102
tel	.0000224	6.36e-06	3.52	0.000	9.96e-06	.0000349
MEDIC	1.36e-06	9.90e-07	1.37	0.171	-5.84e-07	3.30e-06
excrop	.0000126	3.87e-07	32.49	0.000	.0000118	.0000133
exlive	.0000109	7.35e-07	14.76	0.000	9.41e-06	.0000123
exfish	7.25e-06	4.96e-07	14.62	0.000	6.27e-06	8.22e-06
exforest	7.03e-06	1.78e-06	3.96	0.000	3.55e-06	.0000105
exwholeret~l	-4.20e-07	6.53e-08	-6.43	0.000	-5.48e-07	-2.92e-07
exmanuf	6.48e-08	1.59e-07	0.41	0.683	-2.46e-07	3.76e-07
extransp	-9.31e-07	3.33e-07	-2.79	0.005	-1.58e-06	-2.78e-07
_cons	8.292025	.0676764	122.52	0.000	8.159375	8.424674

. predict paginc

Source	SS	df	MS
Model	3366.64946	1	3366.64946
Residual	30492.3609	25491	1.19620105

Number of obs	= 25492
F(1, 25491)	= 2814.45
Prob > F	= 0.0000
R-squared	= 0.0994
Adj R-squared	= 0.0994

```
       Total |  33859.0104 25492  1.32822103           Root MSE      =  1.0937

------------------------------------------------------------------------------
          e1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           d |   .0311404    .000587    53.05   0.000     .0299899     .032291
------------------------------------------------------------------------------

. predict eh, resid


    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
  lagincmape |     25492    9.287714    13.89095   .0003315   344.8743
```