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Spatial Evidence from the Pili R&D Center

Ivan Harris Tanyag

Higher Education Research and Policy Reform Program

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"Demonstration of the prototype pili depulping machine at BUCAF, Guinobatan, Albay"

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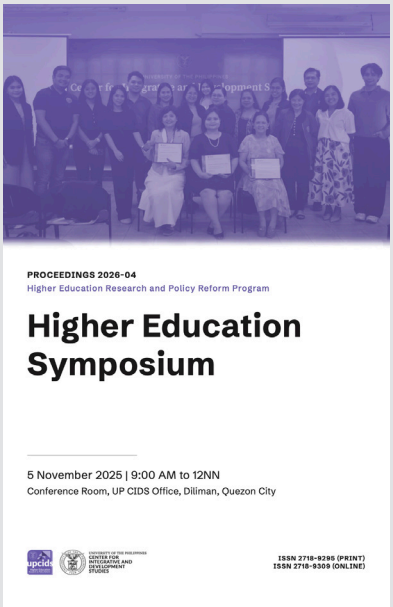

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MONOGRAPH

Developing Regional Economic Complexity through Product Specialization

Do University Research and Development (R&D) Programs Spill Over Locally?

Spatial Evidence from the Pili R&D Center

Ivan Harris Tanyag[1]

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Key Highlights

- The study examines how geographically localized research and development (R&D) initiatives implemented by state universities and colleges (SUCs) generate short-run knowledge spillovers in the Philippines, using the Pili R&D Center in the Bicol Region as an empirical case within the framework of the Harmonized National R&D Agenda (HNRDA).

- The analysis is grounded in product life cycle theory and spatial spillover theory, treating early-stage innovation as spatially concentrated and testing whether such concentration translates into measurable geographic spillovers across local economies.

- Spatial econometric techniques are applied following Anselin's approach, beginning with non-spatial ordinary least squares estimation and subsequent Lagrange Multiplier diagnostics to identify appropriate spatial specifications. Local Moran's I and spatial regression models are used to assess dependence across municipalities.

- Results indicate limited geographic spillovers from the Pili R&D Center beyond host municipalities. Market activity and innovation outcomes remain spatially concentrated, largely driven by established actors with sufficient capital, while smaller producers face persistent information and market-access constraints.

- The findings suggest that R&D funding alone is insufficient to generate broad local spillovers. Complementary, short-term interventions such as targeted transport support, municipal-level extension services, and mechanisms that reduce physical and digital distance between SUCs and markets, are necessary to enhance diffusion, alongside longer-term institutional and infrastructure reforms.

Introduction

The growing influence of higher education institutions (HEIs) on communities has been observed over the last two decades, partly due to the rise of university ranking systems published by consulting firms such as Quacquarelli Symonds (QS). The focus of these rankings has gradually shifted away from traditional subject-based assessments toward measures of universities' global impact. One example is the Times Higher Education Impact Rankings, which measure the performance of higher education institutions in meeting the United Nations' Sustainable Development Goals. As of the writing of this paper, 15 universities in the Philippines were shortlisted in the 2022 list, almost half of which are state universities and colleges (SUCs).[2] While these frameworks emphasize global impact, they often fail to capture local spillovers, such as place-based knowledge transfer, local partnerships, and community-level innovation. This gap provides the rationale for examining localized research and development (R&D) initiatives, including the Pili R&D Center.

Developed countries have allocated large sums of money in the form of grants and scholarships to increase their research activity while positioning themselves as major global development hubs. This approach to R&D has enabled early career researchers to share their expertise while promoting technology transfer at the same time. However, it has limited universities in least-developed countries from pursuing their research agendas, as more professionals leave their home countries to seek better opportunities than ever before. In the absence of responsive political institutions, this trend is expected to continue. The Philippines' experience can attest to this trend, as an OECD (2016) report shows that more than 1.89 million Filipino professionals have decided to migrate for good, with China and India leading the ranking with 3.12 and 2.25 million migrants, respectively. To prevent more scholars from leaving the country, the government has allocated additional funding to several R&D projects, such as the Science for Change Program (S4CP) of the Department of Science and Technology (DOST).

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2 The SUCs included in the list are Mariano Marcos State University (MMSU), Central Luzon State University (CLSU), Tarlac Agricultural University (TAU), Mindanao State University-Iligan Institute of Technology (MSU-IIT), Nueva Ecija University of Science and Technology (NUEST), Visayas State University (VSU), Cebu Technological University (CTU), and Tarlac State University (TSU). Additional information on the ranking is available at https://www.timeshighereducation.com/impactrankings.

The S4CP is composed of four programs that cover seven thematic areas in Science and Technology. These programs are the R&D Leadership Program (RDLead), Collaborative R&D to Leverage PH Economy (CRADLE) for RDIs and Industry Program, Business Innovation through S&T (BIST) for Industry Program, and the Niche Centers in the Regions for R&D (NICER) Program. The S4CP Program Management Office is tasked with ensuring that the goals of these programs are met on time and in a cost-effective manner. It is also responsible for coordinating with DOST Regional Offices, which assist stakeholders such as industry partners and local authorities. While the program has received support from legislators, proposals to institutionalize it as a permanent office within DOST have yet to be enacted. More than two years have passed since the bill failed to reach the President's desk, and it has not been refiled in Congress.

The S4CP is part of the National Integrated Basic Research Agenda (NIBRA), which is a five-year research strategy developed by the National Research Council of the Philippines (NRCP). For the 2017–2022 cohort, the NRCP identified six programs under NIBRA. These are (1) TUBIG Program (Tubig ay Buhayin at Ingatan), (2) SAPAT Program (Saganang Pagkain Para sa Lahat), (3) LIKAS Program (Likas Yaman sa Kalusugan), (4) ALERT Program (Alternative Energy Research Trends), (5) SAKLAW Program (Saklolo sa Lawa), and (6) ATIN Program (Ang Tinig Natin). NIBRA forms part of the Harmonized National R&D Agenda, a multidisciplinary approach to identified key areas that are closely aligned with Ambisyon Natin 2040. In this paper, we focus exclusively on how the NICER Program under S4CP has increased the role of SUCs in the community through localized spillovers, using the Pili R&D Center as a case study.

Geographic and Knowledge Spillovers

Spillovers can be understood as unintended effects caused by an activity. They may be "positive" or "negative" in nature (Frischmann and Lemley 2007). Positive spillovers refer to the benefits that a change in behavior may generate in a system, while negative spillovers refer to the potential harm that a policy change may bring to a community. Economists use this concept to assess how beneficial a project is to the public. The intellectual foundations of the spillover concept can be traced to John Stuart Mill's harm principle, which holds that individual liberty may be restricted when actions impose harm on others. Questions surrounding the appropriate scope of state intervention in individual conduct became especially salient during the period of industrialization, as

factories expanded in scale and intensity prior to the widespread adoption of heavy machinery (Frischmann 2009; Meramveliotakis and Manioudis 2021). Governments during this time intervened in how these firms should conduct their business to ensure healthy competition in the market economy. With pollution levels reaching new heights as a result of increased manufacturing, governments have also imposed a series of environmental regulations.

The question of government intervention has long been debated in economic thought. Classical economists such as Adam Smith (1723-1790) are often associated with arguments favoring limited state involvement in economic activity. However, Smith did not argue for the complete absence of government. In The Wealth of Nations, he explicitly recognized the state's role in protecting property rights, including the granting of patents and copyrights, which provided incentives for innovation and knowledge creation (Hemel and Ouellette 2016). He also identified the provision of public works, such as roads and bridges, as a legitimate government function necessary for facilitating the movement of goods and services. Later economic traditions revisited the scope and form of state intervention. While neoclassical economics generally emphasized market efficiency and restrained public expenditure, John Maynard Keynes (1883-1946) argued that active fiscal policy could stabilize economic fluctuations. Keynes advocated for countercyclical fiscal measures, particularly increased public spending during economic downturns, to support aggregate demand. He also acknowledged the presence of externalities and their effects on prices and resource allocation, recognizing that market outcomes may diverge from socially efficient levels.

This raises the question of whether externalities and spillovers refer to the same concept. They are closely related but not identical. Spillovers describe the transmission of costs or benefits from an economic activity to third parties, while externalities refer to the resulting effects that are not reflected in market prices. Some scholars, such as Clark (2013), do not draw a strict distinction between the two, noting their shared emphasis on unpriced costs and benefits associated with economic activity. Beyond private production costs, economists are also concerned with social costs that are not incorporated into the price of goods and services. In The Economics of Welfare, Arthur Pigou (1877-1959) argued that costs generated in the production process affect the wider community and should therefore be considered in economic decision-making. He proposed taxation as a means of correcting negative externalities by internalizing external costs, particularly in activities involving resource extraction. While such costs are borne by society, Pigou maintained that government intervention may be necessary to address external damages

generated by firms. One policy application of this approach is carbon taxation, which has been adopted in several Western countries to reduce carbon dioxide (CO_2) emissions at relatively low economic cost.

Neoclassical economics has influenced a wide range of academic disciplines by shaping how individuals and their interactions with society are conceptualized. Teraji (2018) notes in his discussion of behavioral economics that, under neoclassical theory, individuals are modeled as possessing preferences that satisfy axioms such as completeness, reflexivity, transitivity, and continuity. On this basis, individuals are assumed to make choices that maximize utility in a consistent manner. Subsequent work has sought to relax or refine these assumptions. Fehr and Schmidt (1999) incorporated psychological considerations into utility functions by allowing individuals to weigh outcomes relative to others, rather than focusing solely on absolute payoffs. Laibson (1997) and O'Donoghue and Rabin (2006) proposed alternative modeling frameworks that account for time inconsistency and self-control problems in decision-making. Drakopoulos (2021) observes that the integration of psychological elements into economic models has facilitated cross-disciplinary applications, including in fields within the physical sciences.

Growing concern over the relationship between economic activity and the natural environment has prompted scholars in geographic and regional science to reassess prevailing economic frameworks. One outcome of this reassessment is the development of New Economic Geography (NEG), which examines the spatial concentration of labor and firms within regional economic and manufacturing zones. Zeng (2015) notes that more than 4,300 industrial zones are distributed across different parts of the world, with their number expected to increase over time. As countries continue to reduce investment and trade barriers, firms are increasingly incentivized to seek lower-cost labor locations in order to reduce production costs. In the Philippines, industrial zones were formally institutionalized following the enactment of the Special Economic Zone Act in February 1995, which established the Philippine Economic Zone Authority (PEZA) to promote investment in export-oriented industries. One of the earliest industrial zones developed under this framework was the First Philippine Industrial Park in Batangas.

NEG theory highlights the role of technological change in shaping patterns of spatial agglomeration (Ottaviano and Thisse 2005; McCann and Van Oort 2019; Gaspar 2020). Unlike earlier approaches in economic geography, NEG explicitly incorporates knowledge flows as spillover parameters that influence

firm location and regional concentration (Garretsen and Martin 2010). These knowledge flows typically involve processes and interactions between firms and organizations that enable the transfer of information, expertise, or technology (Montoro-Sánchez et al. 2011). While there is no single, universally accepted definition of knowledge flows, Karlsson and Johansson (2006) identify several distinct types from the firm's perspective, illustrating the multiple channels through which knowledge may diffuse across economic actors (Table 1).

Table 1. Classification of Knowledge Flows According to Karlsson and Johansson (2006)

Category	Flow Types
Transaction-based flows	1. Flows from knowledge providers that sell knowledge that is used as an input to a firm's R&D activities.
	2. Flows in the form of inventions (innovations) that are sold to a firm (e.g., by licensing a patent).
	3. Knowledge flows between firms that cooperate in an R&D project, where costs and benefits are regulated by an explicit or an implicit contract, which may or may not be associated with unintentional knowledge spillovers.
	4. A firm obtains access to knowledge via a merger or an acquisition.
Transaction-related flows	5. A flow of knowledge that is embodied in the delivery of inputs from an input supplier to a firm.
	6. In the course of supplying inputs to a firm, knowledge from the input supplier spills over unintentionally to the input-buying firm.
	7. In the course of supplying inputs to a firm, knowledge from the input-buying firm spills over unintentionally to the input-selling firm.
Pure spillover flows	8. Unintentionally, knowledge spills over from one firm to a competing firm in the same industry.
	9. Unintentionally, knowledge spills over between firms belonging to different industries.

Beyond categorical distinctions, knowledge flows may also be classified according to their direction of movement. They may occur horizontally or vertically, as well as upward or downward within organizational structures. Horizontal knowledge flows are the exchange of information among units

operating at the same organizational level. Vertical knowledge flows, by contrast, involve interactions across hierarchical levels and often take place through more formalized arrangements. These flows tend to require greater structural coordination, reflecting differences in authority and organizational roles. In their study of the Rabobank Group, Van Wijk and Van den Bosch (2000) show how internal knowledge sharing contributed to improved organizational performance in the Netherlands. Their analysis highlights how changes in organizational structure and management practices facilitated more effective dissemination of knowledge across the institution, enabling the bank to adapt its products while maintaining a competitive position.

Beyond managerial and organizational factors, knowledge flows are also shaped by cultural antecedents (Nissen 2007; Martinkenaite 2011; Mueller 2014). Even where technical and institutional mechanisms for knowledge transfer are available, their effective use often depends on firm-level choices and organizational context (Kostova 1999). Drawing on Hofstede's (1997) cultural framework, Lucas (2006) identifies four dimensions that influence knowledge transfer among subsidiaries of multinational corporations: individualism–collectivism, power distance, uncertainty avoidance, and masculinity–femininity. These cultural dimensions affect how information is interpreted, shared, and transmitted among individuals and organizational units.

These values are particularly relevant for universities, which have long been regarded as key drivers of growth and innovation. However, Geuna and Muscio (2009) raised concerns regarding the funding of university knowledge transfer initiatives, noting that excessive reliance on commercialization may shift academic institutions away from their broader mandate to produce socially oriented research and development outputs. They further argue that the incentive structures governing faculty rewards are often shaped by a university's relationships with third-party funding providers. In the Philippines, this dynamic is evident in the DOST's grants-in-aid program, under which both public and private higher education institutions are eligible to apply for research funding. The Commission on Higher Education (CHED) also collaborates with partner institutions to provide additional support to state universities and colleges in advancing their research and development activities. Beyond externally funded programs, SUCs frequently pursue its research collaboration independently by expanding both local and international linkages. Within the University of the Philippines (UP) System, for example, these efforts are coordinated through the Office of the Vice President for Research and Development (OVPRD).

Methodology

One of the pioneers in the study of geographic spillovers is Luc Anselin. Together with colleagues at the University of Illinois at Urbana-Champaign, he led the development of GeoDa, a free and open-source software designed for spatial data analysis, including global and local measures of spatial autocorrelation. Use of the software requires users to prepare spatial data in advance, typically in the form of shapefiles that link attribute data to geographic units. At the time of writing, GeoDa continues to receive active updates, with version 1.20.0.20 listed as the most recent release in their website. The development team has also announced plans to release updated instructional workbooks to support both current and future users in navigating the software more effectively.

Despite its wide use, GeoDa also presents methodological and technical limitations that may affect the analysis of spatial autocorrelation. In their discussion of spatial econometric implementation, Anselin, Syabri, and Kho (2010) note that heteroskedasticity concerns remain unresolved when users rely on ordinary least squares (OLS) estimation prior to computing spatial autoregressive (SAR) coefficients, reflecting constraints in the software's estimation procedures. Building on this observation, several challenges were associated with GeoDa's use, including restrictions in software architecture, limited availability of integrated open data sources, and constraints on data sharing functions within the platform (Li et al. 2015). A key methodological limitation of GeoDa lies in the range of spatial econometric models available for regression analysis following ordinary least squares estimation. In Appendix A1, Anselin (2004) presents a diagnostic-based decision framework for selecting an appropriate spatial specification after estimating an OLS model in GeoDa, drawing on tests for spatial dependence. Under this framework, users are required to examine post-estimation diagnostics to determine whether a spatially explicit model is warranted and, if so, which specification best captures the spatial structure of the data.

Anselin emphasizes that the OLS specification should be retained only when the diagnostic results fail to indicate statistically significant spatial dependence in the model residuals overall. When such dependence is detected in GeoDa, users must rely on the limited set of spatial models implemented in the software to represent the association, or lack thereof, among observed units.

Another feature of GeoDa employed in this study is its spatial autocorrelation tool. Spatial autocorrelation refers to the extent to which observations located near one another in a defined geographic space exhibit similar or dissimilar values (Griffith 2009). In this paper, spatial dependence is assessed using the local Moran's I statistic, which evaluates the presence and intensity of local spatial clustering or spatial outliers. The local Moran's I is expressed as follows:

$$I_i = \frac{x_i - \underline{X}}{S_i^2} \sum_{j=1}^{n} w_{i,j}\left(x_j - \underline{x}\right)$$

where x_i is the value of the observed variable at location i, x_j is the value of the observed variable at location j, w_i, j as the weight between locations i and j, and I_i as the Moran's statistic for location i. Unlike Global Moran's I, location i receives its own value of I and variance z. These are determined by the Local Indicators of Spatial Autocorrelation (LISA), or the level of variation exists across a given space. The standard deviation, S_i^2, is defined as the variation among values of observed neighbors with mean ($\underline{X}$), and can be expressed with the following equation below:

$$S_i^2 = \frac{\sum_{j=1}^{n}\left(x_j - \underline{X}\right)^2}{n-1}$$

It is important to recognize both the strengths and limitations of the local Moran's I, particularly given its increasing use in regional science research (Brooks 2019). In their spatial analysis of demographic patterns in India, Oliveau and Guilmoto (2005) note the relative simplicity of the statistic, while also acknowledging the need for careful adjustment when assessing the strength of local spatial autocorrelation among observed units. Levine (2013), by contrast, cautions that a positive Moran's I value does not necessarily alone indicate the presence of hotspot clusters. He further argues that the choice of statistical thresholds may substantially influence the interpretation of spatial similarity among neighboring units and recommends the use of a 99 percent confidence interval when applying the local Moran's I to reduce ambiguous results.

This study uses the Cities and Municipalities Competitiveness Index (CMCI) as the primary reference for assessing how the Pili NICER project affects economic dynamism within the municipality and across neighboring localities.

The CMCI was developed by the National Competitiveness Council in collaboration with the United States Agency for International Development (USAID). It draws on Porter's (2004) productivity framework, evaluating economic performance by relating output levels to the inputs available during the production process. The CMCI is released annually by the Department of Trade and Industry (DTI) through its official online platform. The index evaluates local government performance across four pillars—economic dynamism, government efficiency, infrastructure, and resiliency—using a standardized set of indicators. Table 2 presents the indicators associated with each of these pillars.

Table 2. Indicators for Each Pillar in the Cities and Municipalities Competitiveness Index

Pillar	Indicators
Economic Dynamism	1. Size of the Local Economy (as measured through business registrations, capital, revenue, and permits) 2. Growth of the Local Economy (as measured through business registrations, capital, revenue, and permits) 3. Capacity to Generate Employment 4. Cost of Living 5. Cost of Doing Business 6. Financial Deepening 7. Productivity 8. Presence of Business and Professional Organizations
Government Efficiency	1. Capacity of Health Services 2. Capacity of Schools 3. Security 4. Business Registration Efficiency 5. Compliance to BPLS standards 6. Presence of Investment Promotions Unit 7. Compliance to National Directives for LGUs 8. Ratio of LGU collected tax to LGU revenues 9. Most Competitive LGU awardee 10. Social Protection

Pillar	Indicators
Infrastructure	1. Existing Road Network 2. Distance from City/Municipality Center to Major Ports 3. DOT-Accredited Accommodations 4. Availability of Basic Utilities 5. Annual Investments in Infrastructure 6. Connection of ICT 7. Number of Public Transportation Vehicles 8. Health Infrastructure 9. Education Infrastructure 10. Number of ATMs
Resiliency	1. Organization and Coordination: Land Use Plan 2. Organization and Coordination: Disaster Risk Reduction Plan 3. Organization and Coordination: Annual Disaster Drill 4. Organization and Coordination: Early Warning System 5. Resiliency Financing: Budget for DRRMP 6. Resiliency Reports: Local Risk Assessments 7. Resiliency Infrastructure: Emergency Infrastructure 8. Resiliency Infrastructure: Utilities 9. Resilience of System: Employed Population 10. Resilience of System: Sanitary System

Another data source used in this study is the Pili NICER project website, which provides information on key variables, including the number of Pili trees covered by the project and the number of participating local Pili nut retailers in Camarines Sur and Albay. Information on the budget allocated to the Pili NICER project at the time of its inception is drawn from publicly available records published by DOST through the approved General Appropriations Act. For document-based data collection, the study follows the guidance of Bowen (2009), who emphasizes the need to assess the comprehensiveness, balance, original purpose, and intended audience of documents used in research, as these factors may affect the consistency and interpretation of findings. All collected data were compiled into a shapefile covering the relevant

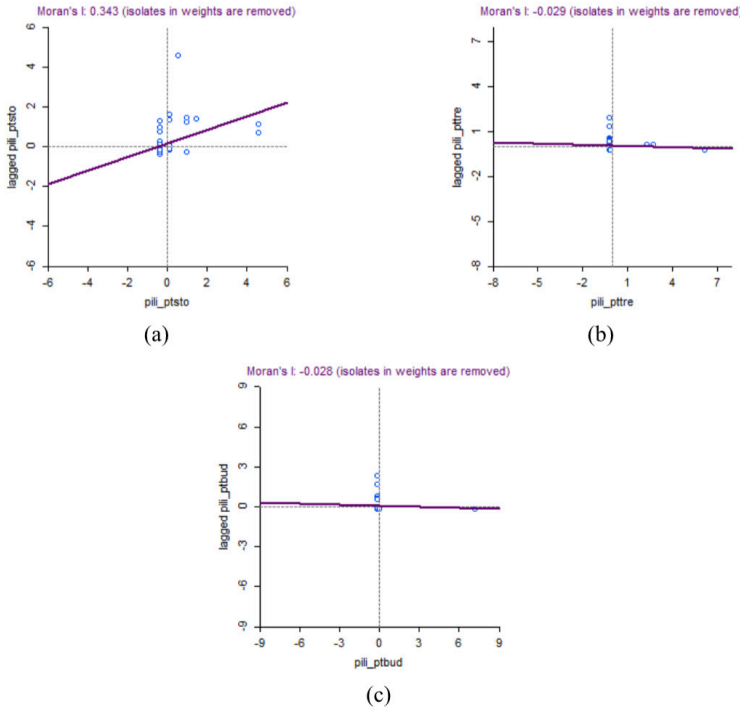
cities and municipalities, based on administrative boundary data prepared by Hijmans and the University of California, Berkeley, Museum of Vertebrate Zoology (2015), and processed using QGIS. Attribute values were adjusted as needed to ensure compatibility and proper recognition within GeoDa.

Results and Analysis

Spatial autocorrelation outcomes are commonly classified into five categories: (1) locations with high values surrounded by similarly high values (High-High), (2) locations with low values surrounded by similarly low values (Low-Low), (3) locations with high values adjacent to low-value neighbors (High-Low), (4) locations with low values adjacent to high-value neighbors (Low-High), and (5) locations exhibiting no statistically significant spatial autocorrelation (Mathur 2015; Cai and Kwan 2022; Zhang, Hou, Duan, and Liu 2023). These classifications indicate whether spatial clustering or spatial outliers are present within a defined geographic area. This study examines 55 municipalities across Camarines Sur and Albay. The selection of these municipalities is based on their geographic proximity to the colleges and universities hosting the Pili NICER project.

Using the spatial autocorrelation tools in GeoDa, this study examines the degree of association among municipalities with respect to the factors discussed in the previous section (Figure 1). The analysis first considers the role of the Pili NICER project in supporting the geographic expansion of its partner retail stores across the province. The local Moran's I value for this variable is estimated at 0.343, which indicates a relatively weak level of spatial association in the analysis. One explanation for this pattern is the limited access to capital faced by small-scale Pili retailers, which constrains their ability to expand operations or establish additional outlets. Among the 40 partner stores observed, only two may be considered relatively well established in terms of market presence and consumer recognition. Drawing on Gu's (2015) analysis of retail spatial concentration in Santa Clara, California, and Durham, North Carolina, the closure or stagnation of small retail outlets may generate negative spillover effects for similar businesses. These include the loss of shared consumer search benefits and reduced opportunities for cost savings in advertising, which may, in turn, affect both market visibility and demand formation.

Figure 1. Neighborhood-level spatial association for (a) the number of participating local Pili nut retailers, (b) the number of Pili trees covered by the project, and (c) the budget allocated to each participating state university and college under the DOST-Pili NICER Project.

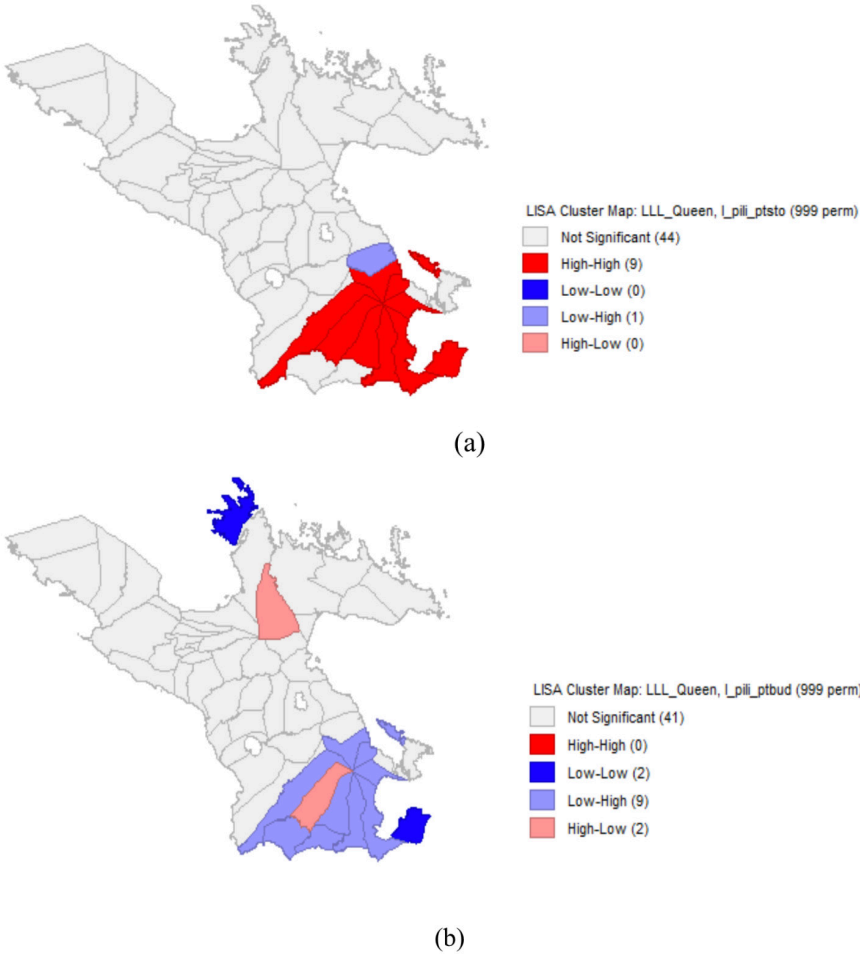


Notes: Spatial weights are constructed using a queen contiguity criterion. All estimates are based on univariate local Moran's I statistics.

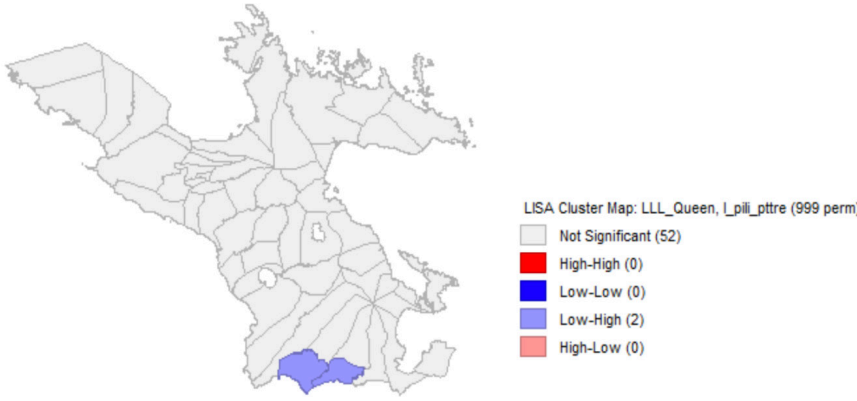
Understanding these externalities enables retail stores to adjust their marketing practices by accounting for changes in consumer behavior and consumer profiles. As Haridasan et al. (2021) note, "information provision strategies with respect to the identified themes may help retailers to reduce consumers' risk perceptions, manage involvement levels, enhance product knowledge, and provide appropriate price information while taking experience-related factors into account." In provinces such as Camarines Sur and Albay, which are widely associated with Pili nut production, the closure of family-owned retail stores may alter public perceptions of local supply and authenticity. This shift may lead consumers to turn to alternative production areas such

as the Eastern Visayas and CARAGA Regions,[3] where Pili nut processing has recently expanded. Figure 2 shows the LISA cluster map for municipalities in Camarines Sur and Albay, indicating the spatial distribution of statistically significant and non-significant local spatial autocorrelation results.

Figure 2. Local Indicators of Spatial Association (LISA) cluster maps for (a) the number of participating local Pili nut retailers, (b) the number of Pili trees covered by the project, and (c) the budget allocated to each participating SUCs under the DOST-Pili NICER Project.



3 CARAGA refers to the Caraga Administrative Region (Region XIII) in the Philippines, located in the northeastern part of Mindanao. The region consists of the provinces of Agusan del Norte, Agusan del Sur, Surigao del Norte, Surigao del Sur, and Dinagat Islands.



(c)

Note: Spatial weights are constructed using a queen contiguity criterion. All results are based on univariate local Moran's I statistics.

The second variable examined is the number of Pili trees included in the study. The Pili NICER initiative extends beyond the marketability of Pili nuts and includes upstream activities related to cultivation and varietal assessment. In this context, the Bicol Consortium for Agriculture, Aquatic and Natural Resources Research and Development (BCAARD), in collaboration with partner state universities and colleges, undertook the planting of Pili trees within selected university campuses. This initiative aims to assess the physiological characteristics of different Pili varieties and their performance under local environmental conditions. As shown in Figure 2(b), the spatial analysis indicates little-to-no observable province-wide effect associated with this activity. This is largely attributable to the concentration of tree planting within the host universities rather than across municipalities. The spatial pattern would likely differ if the initiative were extended to include additional state universities and colleges throughout Camarines Sur and Albay.

A similar pattern is observed for the third variable, which relates to the budget allocation under the Pili NICER program. Because program funding is directed exclusively to partner state universities and colleges, innovation-related activities are largely concentrated within the municipalities hosting these institutions. As a result, spatial knowledge spillovers beyond these localities remain limited. Such spillovers are more likely to emerge when collaborative research arrangements extend beyond host institutions, information barriers between actors are reduced, and transaction costs associated with the transfer and use of knowledge are addressed. An examination of the budget

composition indicates that a substantial share is allocated to Maintenance and Other Operating Expenses (MOOE), covering operational inputs such as supplies and materials, among other things. Consequently, only a portion of total funding is devoted directly to knowledge generation and dissemination activities. This budget structure helps explain the weak spatial effects observed across the Pili industry in Camarines Sur and Albay, as limited resources are channeled toward activities with broader inter-municipal spillover potential.

The regression results indicate that several CMCI indicators are statistically significant. As summarized in Table 3, the diagnostic tests point to a spatial lag specification as the most appropriate model for the observed data.[4] Andersson and Gråsjö (2009) describe the spatial lag model as one in which the dependent variable in each area is influenced by the values of the dependent variable in neighboring areas. This specification is appropriate when the spatial autoregressive coefficient (ρ) is statistically different from zero, while the spatial error coefficient (λ) is not. Under these conditions, spatial dependence operates through the outcome variable itself rather than through the error term. The spatial lag model is expressed as follows:

$$y_i = x_i\beta + \rho w_i y_j + u_i$$

This model is a derivation of the standard linear regression, which is expressed by:

$$y = x\beta + \varepsilon$$

in which it has the spatially lagged dependent variable wiyj, where wi serves as its weights matrix. It is important to note that GeoDa may be sensitive to false positives, particularly when evaluating robust spatial specifications, as the diagnostics for spatial lag and spatial error dependence may yield similar indications. When multiple indicators exhibit statistically significant p-values, the analysis follows the guidance of Anselin (2004), which recommends

4 Anselin and Bera (2018) define the spatial error model as a specification in which spatial dependence operates through the disturbance term rather than the dependent variable itself. In this framework, unobserved factors affecting one spatial unit are correlated with those affecting neighboring units. The model may be written as $y_i = X_i\beta + u_i$, where ui = $\lambda W u_i + \varepsilon_i$. Anselin and Bera identify two situations in which the spatial error model is appropriate. First, when residuals from a standard linear regression exhibit statistically significant spatial autocorrelation. Second, when such spatial correlation in the residuals suggests the omission of relevant spatially structured variables from the model. These conditions indicate that spatial dependence is better captured through the error structure rather than through direct interaction among dependent variables.

selecting the model associated with the smallest p-value among the alternative specifications reported in the regression diagnostics. This approach highlights the need for caution in interpreting the results, as diagnostic sensitivity may affect the robustness of model selection and the reliability of inference.

A closer examination of the spatial diagnostic results in Table 3, however, indicates that the extent and nature of spatial dependence vary across CMCI indicators, suggesting a more differentiated interpretation of the regression outcomes. While several indicators initially register statistically significant Lagrange Multiplier (LM) statistics, the corresponding robust diagnostics largely fail to reject the null hypothesis once competing spatial processes are considered. For most infrastructure, economic dynamism, and government efficiency indicators, neither the robust spatial lag nor the robust spatial error tests remain statistically significant, implying that the apparent spatial dependence detected by the simple LM tests is not sustained under more stringent conditions. This pattern supports the earlier conclusion that the effects associated with these indicators are predominantly localized, reflecting place-specific institutional, economic, or administrative conditions rather than systematic spillovers across neighboring municipalities.

Two partial exceptions merit closer attention. Transportation indicators exhibit limited evidence of spatial lag dependence under the robust specification, which may suggest that the improvements in transport-related conditions in both provinces may be weakly associated with the presence of Pili partner stores in adjacent localities. More notably, the cost-of-living indicator displays statistically significant robust diagnostics for both spatial lag and spatial error dependence, indicating a spatial structure that cannot be attributed solely to residual clustering or model misspecification. This result implies that consumer price dynamics and purchasing power conditions may operate across municipal boundaries in ways that shape the spatial distribution of Pili retail activity. Nevertheless, these findings do not imply large or uniform effects; rather, they point to channels through which spatial interaction may occur, warranting cautious interpretation.

This raises the question of whether the project has generated meaningful local geographic spillovers for the surrounding communities. In terms of economic activity, the participation of partner retail stores has contributed to localized increases in productivity. In parallel, the SUCs involved in the project have addressed information asymmetries that previously constrained Pili nut marketing by developing an online platform that enables partner stores

to present their products at minimal cost. At the same time, the existing Pili Marketplace website requires further updating to reflect recent developments in regional Pili trade and to account for evolving patterns in consumer behavior. Without such adjustments, the platform's capacity to support sustained knowledge diffusion and market expansion across municipalities remains limited.

Table 3. Spatial Dependence Diagnostics for CMCI Indicators and Pili Partner Stores (N=53)

Indicator	Moran's I (Error)	LM (Lag)	Robust LM (Lag)	LM (Error)	Robust LM (Error)
LGU Investment	0.33991	11.92437 (0.00055)	0.20761 (0.64865)	11.92160 (0.00055)	0.20483 (0.65085)
Transportation	0.25671	10.84887 (0.00099)	4.14423 (0.04178)	6.79971 (0.00912)	0.09507 (0.75783)
Road Network	0.33769	11.91584 (0.00056)	0.40225 (0.52593)	11.76696 (0.00060)	0.25336 (0.61472)
Productivity	0.35754	12.92855 (0.00032)	0.29147 (0.58928)	13.19100 (0.00028)	0.55392 (0.45672)
Size of Local Economy	0.31019	9.74835 (0.00179)	0.00746 (0.93118)	9.92828 (0.00163)	0.18739 (0.66510)
Establishments Active in the Locality	0.36179	13.85576 (0.00020)	0.41807 (0.51790)	13.50577 (0.00024)	0.06809 (0.79414)
Capacity to Generate Local Resource	0.33703	11.92357 (0.00055)	0.20426 (0.65130)	11.72074 (0.00062)	0.00144 (0.96977)
Cost of Doing Business	0.33851	11.99554 (0.00053)	0.25203 (0.61565)	11.82403 (0.00058)	0.08051 (0.77661)
Cost of Living	0.21082	6.75822 (0.00933)	9.36875 (0.00221)	4.58593 (0.03224)	7.19646 (0.00730)
Employment Generation	0.38234	14.75324 (0.00012)	1.24437 (0.26463)	15.08381 (0.00010)	1.57494 (0.20949)
Financial Deepening	0.29358	9.67946 (0.00186)	0.98307 (0.32144)	8.89348 (0.00286)	0.19709 (0.65708)
Getting Business Permits	0.33689	12.49707 (0.00041)	1.08264 (0.29811)	11.71130 (0.00062)	0.29687 (0.58585)

These findings should be interpreted in light of several statistical limitations inherent in the empirical design. First, the analysis is based on a relatively small sample of municipalities, which constrains statistical power and increases sensitivity to influential observations, particularly in spatial diagnostic testing where asymptotic properties may not fully hold. Second, the use of bivariate specifications in the diagnostic stage, while consistent with GeoDa conventions, limits the ability to account for joint interactions among CMCI dimensions and may overstate or understate spatial dependence in individual indicators. Third, not all potentially relevant covariates affecting retail participation and market access are observed or reported in the available data, raising the possibility of omitted variable bias that could manifest as residual spatial correlation. Finally, the spatial diagnostics rely on a single contiguity-based weights matrix, and alternative spatial structures may yield different patterns of dependence. Taken together, these constraints suggest that the reported results are indicative at best, rather than exhaustive, highlighting broad spatial tendencies rather than precise estimates of inter-municipal effects.

Conclusion

Universities play an important role in the generation and dissemination of knowledge with potential social and economic relevance. Fulfilling this role, however, requires complementary state action. This includes strengthening the research and development capacity of faculty and staff through sustained training and professional exposure, as well as designing incentive structures that recognize contributions to knowledge production without relying solely on target-driven performance metrics that risk undervaluing academic labor. At the same time, the core mandate of universities remains the education and training of students within their respective fields of specialization. Engagement with broader policy and economic frameworks does not displace this mandate, but instead requires balancing workforce-oriented objectives with disciplinary development and critical inquiry. Collaboration across scientific, technical, and humanistic fields, together with engagement with public and private sector partners, provides a path for supporting skill formation and knowledge exchange across a wider set of actors.

Attention must also be given to factors affecting the relevance of knowledge transfer initiatives to the conditions faced by local communities. As demonstrated in this study, geographic context plays a significant role in shaping how research and development activities translate into local economic outcomes, particularly under conditions of information asymmetry. The

NICER Program was designed to address these asymmetries through collaboration with state universities and colleges, which serve as coordinating institutions for local partners. Evidence from the Pili NICER Program in Camarines Sur and Albay, however, indicate uneven spatial outcomes.

Market activity related to Pili nut processing and retail remains concentrated in some areas, with expansion largely driven by retailers possessing sufficient capital. Smaller actors continue to face constraints in scaling operations and often rely on external assistance from agencies such as the DTI, Department of Agriculture (DA), and Department of Tourism (DOT). While the primary objective of the program is the development of high-yielding Pili nut varieties, its broader aim is to support farmers through decision-support tools that improve risk assessment and production outcomes. The observed spatial concentration suggests that technological gains alone are insufficient without mechanisms that facilitate wider geographic diffusion and market access.

The findings also indicate that additional government intervention is required to address spatial and institutional constraints affecting the effectiveness of the Pili NICER Program. Research initiatives of this scale must consider the socio-economic and geographic characteristics of their implementation sites. Although SUCs play a central role in reducing information asymmetries, they operate within structural limits and cannot independently resolve barriers related to market connectivity and land administration that shape production and distribution decisions.

While land administration reform remains a longer-term national concern, the results point to the need for short-term, locally actionable measures that local government units in the Bicol Region can implement. These include (1) targeted transport subsidies for Pili products, (2) municipal-level extension services focused on post-harvest handling and market linkage, and (3) localized support facilities that reduce the physical and digital distance between universities and retail markets. Such interventions can be embedded within existing local development, agriculture, and enterprise support programs and directly address the spatial constraints identified in the analysis.

Encouraging participation by established private firms in Pili-related research may also help bridge gaps between scientific development and commercial application, provided that such engagement aligns with farmer welfare and local value retention. Local government-led information campaigns may further support consumer awareness and reinforce the association between

Pili production and the regional economy. More broadly, the study highlights how regional economic activity in the Philippines remains shaped by localized production identities. While this structure creates opportunities for place-based development, limited inter-regional coordination constrains market expansion. In a context of economic uncertainty and weakened household purchasing power, the overall effectiveness of the Pili NICER Program depends not only on technological advances it made but also on complementary socio-economic strategies that lower transaction costs, strengthen local market incentives, and support farmer resilience in the short to medium term.

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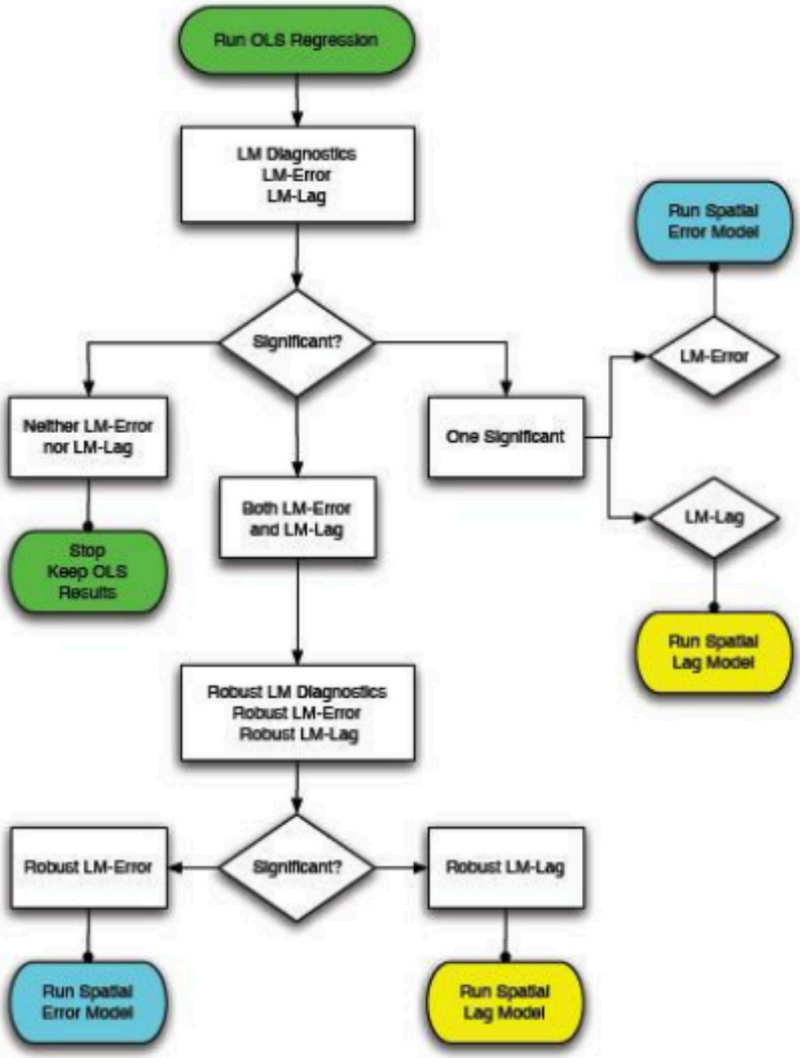
Appendix

Appendix A1. Flowchart developed by Anselin (2004) for interpreting regression diagnostics in GeoDa. The software outlines three spatial model specifications (Spatial Lag, Spatial Error, and SARMA) used to assess spatial dependence and the relationships among observed units.



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