

Rice Straw Bioethanol Market Behavior in Pila, Laguna: Challenges and Efficiency Through Value Chain Analysis and Stochastic Price Simulations



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Date Received: 13 June 2025
Date Revised: 19 November 2025
Date Accepted: 22 December 2025

Abstract

Rice straw, in terms of its chemical composition, is dominated by pentose in its hemicellulose, giving it potential for bioethanol utility. Within the context of the Philippines, rice straws, as a post-harvest waste, are often discarded or burnt in open fields by farmers after the harvesting season. Under the premise of waste commodity frontiers in a circular economy, wastes are seen as a resource that can be reintegrated into the generating capital. Integral to this theme is the waste-to-energy (WTE) approach, which utilizes wastes as a source of energy in the form of electricity, fuel, or heat. This study aims to assess the market efficiency of rice-straw-based bioethanol in Pila, Laguna. Regarding support service providers, the value chain suggests an institutional hybridity, characterized by a conglomerate of government agencies, civil society organizations, and academic institutions. When compared to the prices of existing rice straw-based markets (fodder, mushroom mulch, paper, and *walis tambo*), the Average Variance Ratio (VR) and Granger Causality Count results for rice straw-based bioethanol suggest high levels of market efficiency ($VR = 1.0321$). This is indicative of how rice straw-based bio-ethanol markets are influenced by technology and production costs rather than direct price spillovers for other rice-straw utilities. For integrating rice-straw-based markets into current economic arrangements, incremental niche markets are suggested, acknowledging competition from the established markets of corn silage and sugarcane (for bioethanol production), on which producer and consumer behavior may still be path-dependent.

Keywords: waste commodity frontiers, rice straw, bioethanol, niche markets, value chain analysis

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1. Introduction

Value-added products in agricultural economics refer to alterations in the physical form of a product that both increase its profitability in the market and application towards other industries (such as energy, technology, and manufacturing) (Cornelisse, 2007). Within the context of post-harvest wastes, rice straws are lignocellulose-based remnants often left uncut to be incorporated into the soil for subsequent cropping episodes. It is flagged as a renewable resource and has potential for sugar yield due to its cellulose-based content (Binod et al., 2010). The generation of rice straw wastes is strongly associated with increased rice production to feed a growing population. A classical economic approach to post-harvest wastes would consider rice straws as spoiled and unusable surplus; however, under the premise of waste commodity frontiers in circular economy, wastes are viewed as a resource that can be reintegrated into the process of generating capital. This entails the presence of valorization nodes, which convert wastes into commodities (Doherty, 2022).

Across Southeast Asia and the world, studies have explored the potential of rice straw utilization, focusing on diverse forms of applications, including the development of innovative materials for building and packaging, as well as for bioethanol production and mushroom cultivation (Soam et al., 2017). Islands are geographies constrained by limited and scarce resources. In East Asian countries, such as Japan, which is characterized by its archipelagic nature, the value of frugality is perceived as a response to scarcity and is often reflected in its attitude towards minimizing waste and maximizing resourcefulness. For the Japanese, the virtue of “*montainna*” is described as a cultural rhetoric of regret for wasting the intrinsic value of a resource. It is often derived from Buddhist philosophy, which recognizes the interdependence of all system components, from its conception to its cradle (Taylor, 2011). It can be said that “*montainna*” is an expression of *anima mundi*—“the soul of the world” as it recognizes how one resource can exist in multiple “souls” and life cycles (Sato, 2017). Within Philippine settings, the value of “*pagtitipid*” (frugality) is often celebrated as a virtue in response to constrained budget frontiers and limited income (Dy & Chua, 2020). For instance, the rhetoric for “*pagtitipid*” in the Ilocano context is embedded in the word “*kinasalimetmet*”, which goes beyond the Tagalog approach of being thrifty and saving for the rainy days. For the Ilocanos, “*kinasalimetmet*” involves maximizing the utility of a resource (Tagay & Ballesteros, 2016). This section of the literature review acknowledges that the diverse nature of chain pathways in rice straw products reflects Filipino values and culture. Principal to the theme of waste commodity frontiers is the waste-to-energy (WTE) approach, which utilizes wastes as a source of energy in the form of electricity, fuel, or heat.

As an alternative pathway to traditional waste regimes, the WTE approach has been integrated within institutional arrangements of countries both in the Global North and Global South to address the problem of continuous waste generation; such has been pursued through collaborative networks between government, service providers, civil society, and industry sectors (Gutberlet et al., 2020).

This study aims to assess the market efficiency of rice-straw-based bioethanol in Pila, Laguna. Specifically, it aims to:

- a. Describe the value chain of rice straw-based bioethanol.
- b. Identify the key challenges faced by market stakeholders.
- c. Simulate and model market prices of rice straw-based bioethanol.
- d. Evaluate the market efficiency of rice straw-based bioethanol relative to existing rice straw markets.

2. Materials and Methods

2.1 Research Design

An exploratory sequential research design was employed to elucidate the challenges and bottlenecks to efficiency in the market for rice straw-based bioethanol. Under this research design, qualitative data are collected to understand the phenomenon of interest (thematic analysis of key informant interviews); a subsequent quantitative phase (data analysis of secondary data) is pursued to link the initial findings (Creswell & Creswell, 2018; Subedi, 2016). For the analysis of value chains, collecting both qualitative and quantitative data is considered ideal to grasp the linkages between actors and market behavior (Hellin & Meijer, 2006).

2.2 Conceptual framework

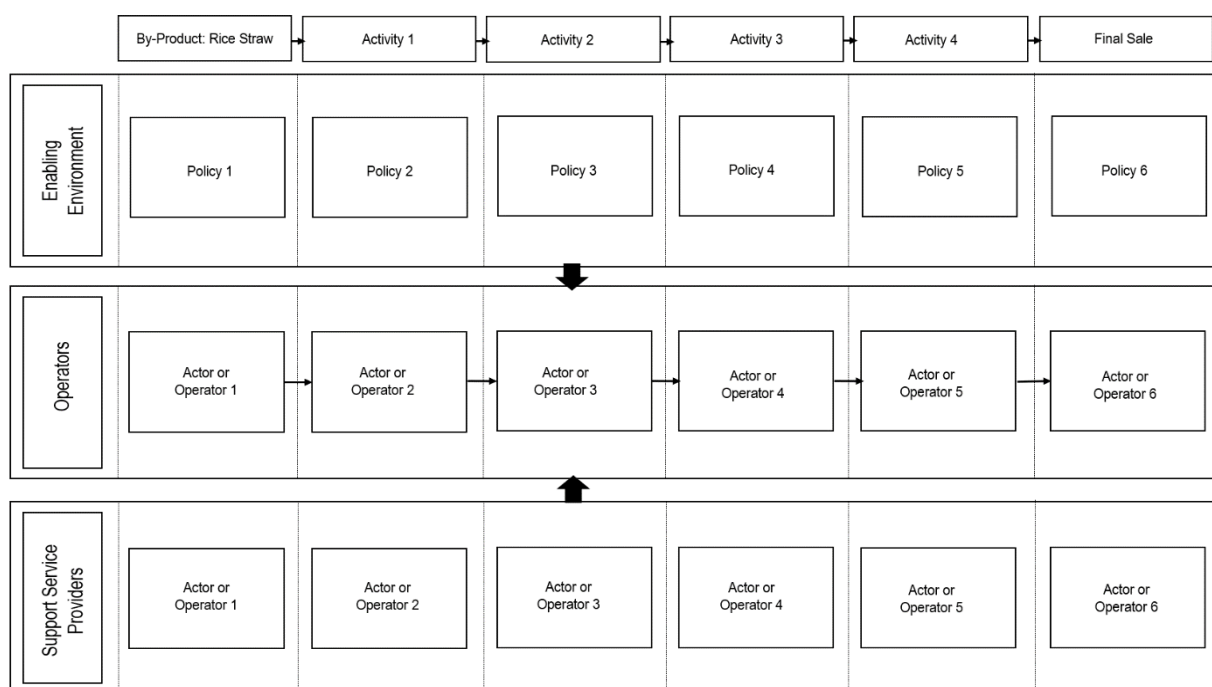


Figure 1. General value chain framework (patterned after the value chain framework prepared by Elca et al. 2020)

Figure 1 shows the conceptual framework for the study, which is based on the value chain developed by Elca et al. (2020). The framework is generally divided into four components. These include the (a) Value chain activities; (b) Enabling Environment; (c) Operators; and (d) Support Service Providers. The group of boxes positioned at the header of the framework represents the sequence of activities along the value chain. On the other hand, the middle box illustrates the line-up and interaction between the different operators or actors that perform different marketing actions for each of the activities enumerated within the value chain. The operators are influenced by *support service providers* (private actors and government-led institutions) that enhance the operations of the actors throughout the steps of the chain. Moreover, the operators are also influenced by an *enabling environment* (existing policies such as laws, resolutions, ordinances, and quality control guidelines) that contributes to the efficient flow of products from the first activity to the final activity in the chain (Elca et al., 2020).



2.3 Locale of the Study

Pila, Laguna is a third-class municipality situated within the eastern fringes of Laguna de Bay's lentic environment. As of 2022, the municipality allocates 42.31% of its 3,120 hectares for agricultural use. Regarding rice production, the average yield is 6.21 metric tons (Castillo, 2022). The municipality of Pila is also home to Straw Innovations Ltd, a United Kingdom-based private company specializing in agricultural residue management. As a research and development company, Straw Innovations Ph Ltd seeks to address the following problems: (i) how to get the straw out of rice fields economically; and (ii) how to upcycle it (rice straw) to make eco-friendly, commercially viable products.

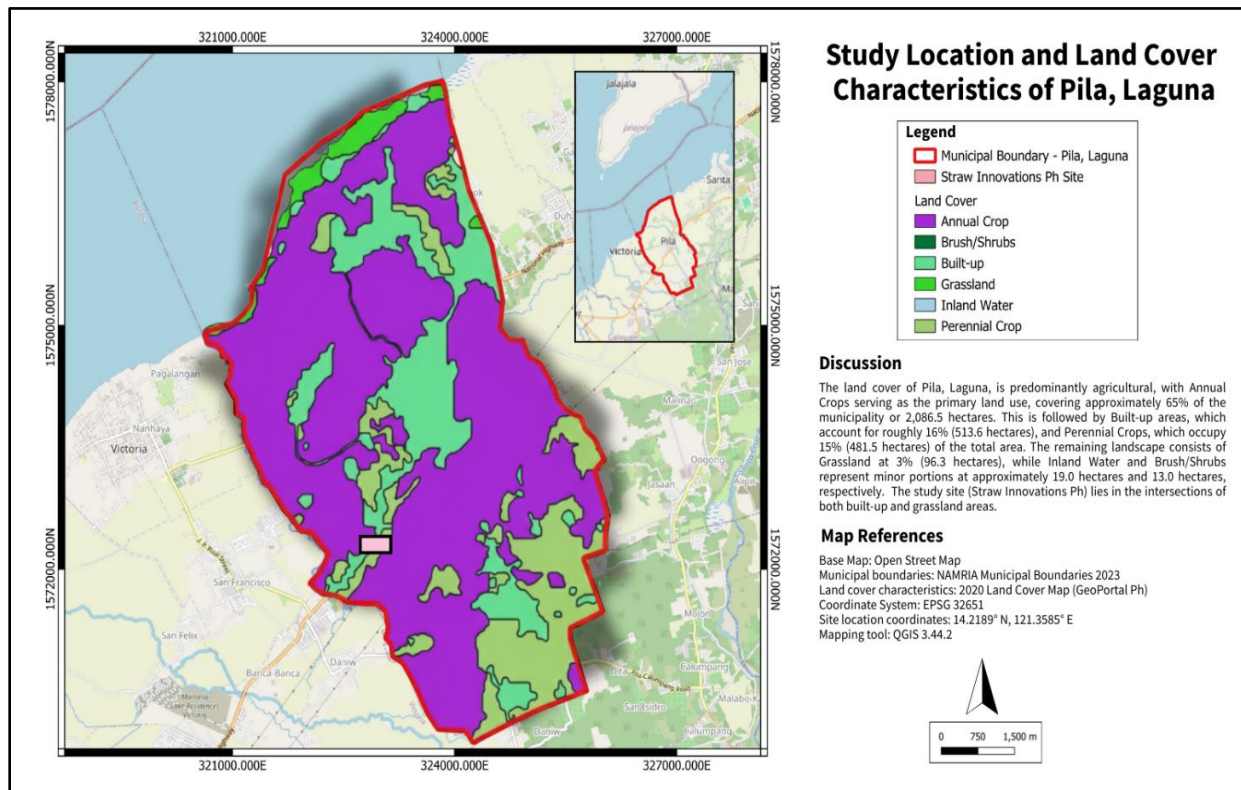


Figure 2. Study location and land cover characteristics of the Municipality of Pila, Laguna

2.4 Sampling design

Purposive sampling is a non-probability sampling technique in which researchers intentionally select participants based on the study's objectives. The rationale for a purposive sampling design is to ensure that the responses obtained are rich and relevant to the research problem (Campbell et al., 2020). Purposively interviewed individuals included a life cycle analyst from Straw Innovations Ltd, two economic anthropologists from the University of the Philippines – Diliman (Department of Anthropology), and three agricultural engineers from the University of the Philippines - Los Baños (Institute of Agricultural and Biosystems Engineering). This results in a total sample size of six respondents, who served as key informants in the study's conduct. Selected individuals had sufficient knowledge of the intersections between rice straw collection, bioethanol production, and challenges faced by stakeholders throughout the value chain.

2.5 Secondary Data Source

Secondary data from government institutions were utilized, namely, farm-gate prices for agricultural commodities from the Philippine Statistics Authority (PSA) and field reports of the Department of Agriculture (DA) Region IV-A. Price monitoring reports of the Department of Trade and Industry (DTI) and the Department of Energy (DOE) were placed into a utility. The following table seeks to summarize the data sets considered per commodity to evaluate market efficiency of the rice straw bioethanol market in Pila, Laguna:

Table 1. Secondary Data Sources for Rice-Straw-Based Commodities

Product	Unit	Secondary Source	Years of data availability
Rice straw fodder	PhP/ kg	Philippine Statistics Authority (PSA) – Farmgate Prices of Agricultural Commodities Department of Agriculture (DA) – Region IV-A Field Offices reports Philippine Carabao Center	1990 – 2024
Walis tambo	PhP/ unit	Department of Trade and Industry (DTI) – Retail Price Monitoring DA – Region IV-A Field Offices reports	1990 – 2024
Rice straw-based paper	PhP/ kg	DOST-FPRDI (Forest Products Research and Development Institute) project reports	2015 - 2024
Rice straw-based bioethanol	PhP/ liter	Department of Energy (DOE) – Biofuels Monthly Price Monitoring Sugar Regulatory Administration (SRA) Ethanol Producers Association of the Philippines Straw Innovations Ph records Prices under the Biofuels Act of 2006 (RA 9367)	1990 – 2024
Rice straw-based mushroom mulch	PhP/ kg	DA – Bureau of Plant Industry (BPI) Mushroom Growers and Traders Association of the Philippines (MGAP)	1990 – 2024
Philippine Consumer Price Index	unitless	Philippine Statistics Authority	1990 – 2024
Brent Crude Oil Price	US Dollars/ barrel	U.S. Energy Information Administration (EIA):	1987 - 2024



2.6 Monte Carlo Simulation

Due to existing gaps in historical data and segmented time series, Monte Carlo simulations were pursued in this research to hypothetically impute and depict the prices of rice straw-based bioethanol. To aid in this process, Geometric Brownian Motion (GBM) equations were used in the conduct of this study. A standard of 10,000 iterations was also pursued to ensure robustness of the mean. GBM analysis is suitable for price simulation, as it accounts for the influence of systematic oscillations (inflation and production) and random shocks (climate events and demand shifts). Results obtained in the Monte Carlo simulation were utilized for determining efficiency in place of other existing rice straw-based markets (rice straw-based fodder, mushroom mulch, paper, and *walis tambo*).

2.7 Econometric Instruments for Market Efficiency

To check on the market efficiency, the Average Variance Ratio (VR) Test and Granger Causality Count were employed in the conduct of the study. It is crucial to note that the Average Variance Ratio Test is a statistical tool used to determine whether a time series exhibits a random walk. A variance ratio with a value closer to 1 suggests an efficient market, whereas the presence of deviations indicates predictability (market inefficiency). In terms of the Granger Causality Count, it seeks to determine the likelihood of one time series predicting another. In interpreting the results, minimal significant Granger causality relationships are indicative of an efficient market, as prices can integrate information rapidly in the absence of lagged dependencies. The following formulae are pursued in determining market efficiency:

For the Average Variance Ratio Test:

$$VR(k) = \frac{Var(P_t - P_{t-k})/k}{Var(P_t - P_{t-1})}, \text{ under the null hypothesis } VR(k) \approx 1 \quad (1)$$

For the Granger Causality Test:

$$\gamma_t = \alpha + \sum_{i=1}^p \beta_i \gamma_{t-i} + \sum_{i=1}^p \gamma_i X_{t-i} + \epsilon_t \quad (2)$$

Python programming was used to assess the feasibility and determine the results for market efficiency. In implementing the Average Variance Ratio test, log returns are set at $\ln(P_t/P_{t-1})$ to ascertain variance stability, z-scores were also considered to identify variance ratios with statistical significance.

2.8 Ethical Considerations

In this study, informed consent served as a critical pillar, ensuring that all respondents were fully informed about the research objectives, the voluntary nature of their participation, and their right to withdraw at any time. To promote transparency and respect the participants' time, the set of interview questions was sent via email beforehand. Central to this ethical framework is the strict preservation of anonymity and confidentiality. It was assured that no names of the individuals will be released in the final report or any subsequent publications. Instead, data were managed using alphanumeric codes to prevent any link between the responses and the specific identities of the contributors. Regarding the handling of secondary data, the associated agencies were informed that the data utility would be used solely for academic purposes.

3. Results

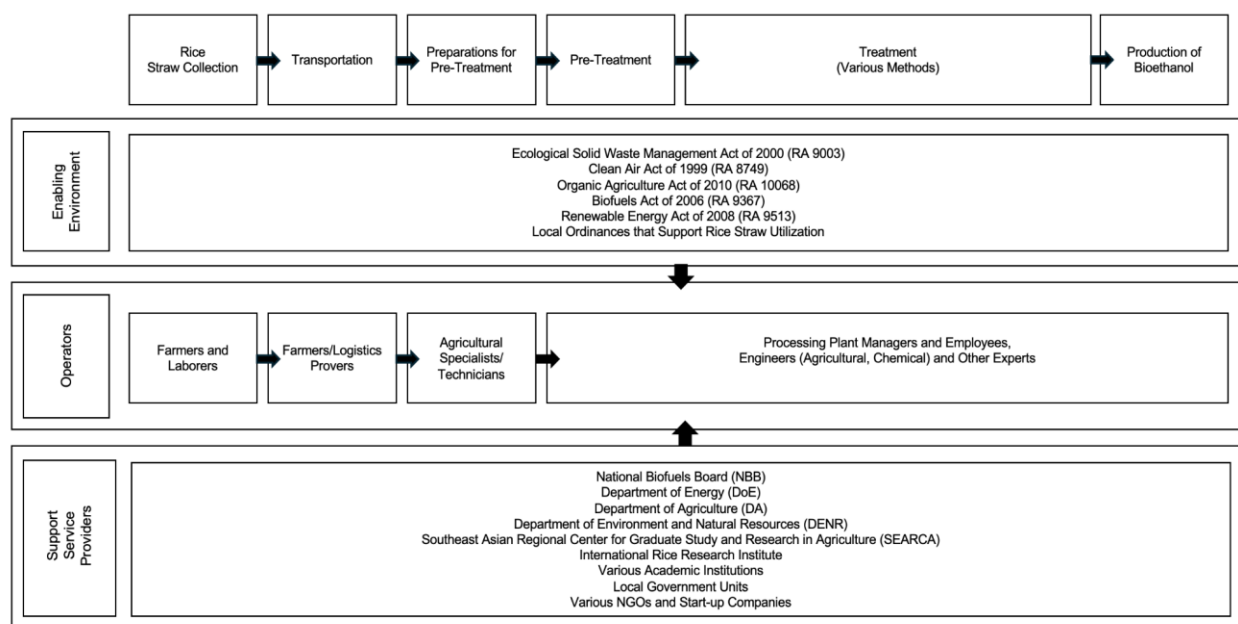


Figure 3. Value-chain for rice straw-based bioethanol

Figure 3 illustrates the standard process of converting rice straw from its raw form into actual bioethanol. The key actors in the rice straw value chain for bioethanol production include rice farmers, logistical personnel who may participate in transporting collected rice straw, and specialists and experts in chemical and agricultural engineering. In the Philippine context, the production of bioethanol is currently encouraged and supported by several laws, such as the Biofuels Act of 2006 (RA 9367) and the Renewable Energy Act of 2008 (RA 9513). Moreover, repurposing rice straw, which is commonly viewed as waste from harvesting rice or other less profitable uses, is also supported by the Ecological Solid Waste Management Act of 2000 (RA 9003), as the law prohibits the burning of solid waste, as stated in Section 48(3). In turn, the prohibition on burning rice straw during the harvest season also supports the Clean Air Act of 1999 (RA 8749), as rice straw incineration releases pollutants such as carbon dioxide, carbon monoxide, and sulfur dioxide (PhilRice, 2016). Moreover, this practice also supports the Organic Agriculture Act of 2010 (RA 10068) by promoting sustainable agricultural practices and encouraging the re-use of post-harvest waste. In support of national laws, various localities around the nation have ordinances that prohibit the burning of rice straw and rice hull (Balingbing et al., 2020), including the Municipality of Pila, Laguna; the Municipality of Getafe and Maribojoc, Bohol; and the Municipality of Tibiao, Antique.

In general, the process for producing bioethanol involves the collection, transportation, pre-treatment, and treatment of rice straw (Devi & Munjam, 2022; Takano & Hoshino, 2018; Wi, 2013). It begins with the collection of rice straw from open fields, a task commonly performed by farmers. After this, the normal practice is to burn the collected rice straw as it is merely regarded as nothing more than agricultural waste. On the other hand, if it were used as a raw material for bioethanol, the collected rice straw would be transported to a facility where its size would be mechanically reduced through cutting, pulverization, or shredding in milling facilities operated by agricultural



technicians and specialists. Once its size is reduced, the raw product will undergo pre-treatment, treatment, and distillation in bioethanol processing plants before being converted into actual bioethanol. This part of the process is usually supervised by experts from the field of Chemical and Agricultural Engineering, with the participation of plant managers and operators. Pretreatment is crucial, as it is necessary to break down the lignin structure and increase the accessibility of the cellulosic complex for hydrolysis (Shukla et al., 2023). Determining the most suitable pre-treatment technique is currently one of the most significant challenges in bioethanol production, as it has implications for whether bioethanol production using rice straw would be economically viable (Ibrahim, 2012). Meanwhile, common treatment methods include alkali pretreatment and enzymatic hydrolysis. The treatment process also includes saccharification, fermentation, distillation, and purification (Singh & Patel, 2022).

National Government Agencies (NGAs) such as the Department of Environment and Natural Resources (DENR), Department of Agriculture (DA), and the Department of Energy (DoE), of which the National Biofuels Board (NBB) is a subsidiary, support the conduct of activities that make up the process of making biofuels using rice straw. In addition to the support of NGAs, research institutions such as the International Rice Research Institute (IRRI) and the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), in tandem with various academic institutions such as UPLB, also contribute to the advancement of technologies and methodologies for bioethanol production and processing using rice straw as input. These institutions have also partnered with various NGOs and startup companies, such as Straw Innovations Ph Ltd., a startup based abroad, which helped kickstart initiatives promoting the upcycling of rice straws in local rice farms. Local Government Units also play a key role in supporting the above-mentioned initiatives by creating and enforcing local ordinances that support the conduct of activities indicated in the value chain.

3.1 Practices and Key Challenges Faced by Market Stakeholders

Table 2. Thematic Analysis on Key Informant Interviews

Theme	Associated words and phrases
Upland and lowland regional variation in the post-harvest rice straw practices	fertilizer, decomposition, <i>mandala</i> , <i>pagpapayao</i> , Laguna, Abra, Cordillera, Southern Tagalog
Challenges	land conversion, information gap, licensed software, royalty fees, generational shift, farming, abandonment

Regional variation is expressed in the post-harvest value of rice straw, particularly between upland and lowland communities. As evident in the key informant interviews on economic anthropologists, the practice of *mandala* is commonly observed among lowland regions, such as in Laguna, where rice straws are clustered in a haystack and are burned to fertilize the soil for the next planting season; the practice of rice straw burning is expressed in the provinces of the Southern Tagalog region. Considering that upland regions, such as in the Cordillera, do not have wet and dry episodes for the rice fields due to the practice of *pagpapayao* (terraces), rice straws are integrated in the *pilapil* to reinforce the terrace. As expressed by the economic anthropologist, the process of *pilapil* integration is typically accomplished by submerging the rice straw in mud. This practice is observed in Tabok, Abra, and in the northeastern provinces of Northern Luzon, such as in the case of Isabela, where rice straw is burned to be incorporated into the *pilapil*.

In terms of challenges to the utility of rice straw, the following obstacles were identified from the key informant interview results: issues with preserving traditional weaving practices, land conversion, generational shifts, licensed software, and the abandonment of farming. Within rural communities, generational shifts among agricultural households are evident, driven by a least-preference for farming as a means of livelihood. Urbanization trends are a challenge, as agricultural household members seek better opportunities in the city, leading to the abandonment of farms.

In the context of the interviewed agricultural engineers, the responses highlighted three key hurdles: information gaps in agricultural communities, the need for licensed software, and the associated royalty fees. As expressed in the collected interviews, farmers face an information gap on the potential of rice straw for bioethanol and biogas: “Farmers would often hand out rice straws for free,” making them prone to exploitation. A life cycle analyst has also pointed out how the software used for data analysis of pyrolysis is licensed. For the bacterial strain and associated organisms serving as enzyme catalysts in bioethanol production, an agricultural engineer has raised concerns about the potential for royalty fees to be imposed for their procurement.

3.2 Rice Straw-Based Bioethanol Price Simulation

Geometric Brownian Motion and Heston models were applied in conducting Monte Carlo Simulations for rice straw-based bioethanol. For the base price, a hypothetical price of PHP 10/L was assumed, since rice straw is considered a low-cost agricultural byproduct of the palay supply chain, relative to sugarcane and corn. The following price drivers were considered in running the simulation: (i) rice straw supply shocks, (ii) production cost, (iii) oil prices, and (iv) policy incentives. Historical data, based on the Philippine Consumer Price Index (CPI) and the Brent crude oil price, were considered for the simulation.

The first assumption regarding rice straw supply shocks recognizes that supply reductions triggered by shocks (such as typhoons, droughts, and El Niño) shift the supply curve to the left, thereby inversely raising prices (while demand remains constant). These adjustments are based on the scarcity of palay and rice straw (as a factor of production) for the bioethanol market.

The Philippines, in terms of its geography, is prone to such climatic shocks. Reports indicate how successive episodes of typhoons have reduced agricultural areas for rice production, resulting in delays to planting and harvesting regimes (Cariaso, 2024; Tabile, 2024). In the context of agricultural economics, these episodes are referred to as negative supply shocks. These shocks are wrought into existence when an exogenous event (such as adverse climate and weather conditions) decreases the productive capacity of an economy (Jo & Adjemian, 2023). These



episodes are anchored in the concept of Keynesian supply shocks, which posit that reductions in potential output in specific sectors (in this case, the sectors of *palay* production affecting the fodder market) lead to an expected decline in aggregate demand across the economy (Guerrieri et al., 2022).

In terms of production costs, a hypothetical base price of PhP 5/L was assumed, reflecting the average 3-5% annual inflation growth during 1990. In terms of oil prices, historical Brent crude oil data was approximated with 30% volatility. Considering the niche of incentives, the Biofuels Act of 2006 was considered in modelling the demand premium: thus, dividing it within the phases of pre-2006 (before the enactment of the Biofuels Act) and post-2006 (after the enactment of the Biofuels Act, on which the context of this simulation is within the interim of 2007 - 2024).

The following Geometric Brownian Motion (GBM) equation with an integrated Heston Model was utilized to simulate price iterations for the utility of rice straw-based bioethanol:

$$S_t = S_{t-1} \cdot \exp[(\mu - \frac{\sigma^2}{2})\Delta t + \sigma\sqrt{\Delta t}Z_t], Z_t \sim N(0,1) \quad (3)$$

Where,

S_t : Price at time (t)

μ : Drift:= 0.05 (from 1990 - 2006) and 0.07 (2007 - 2024)

σ : Volatility := 25% annually, with normal variation (standard deviation = 5%)

Δt : Time step (1 year)

Z : random variable $\sim N(0,1)$

Heston Model:

$$d\sigma_t^2 = \kappa(\theta - \sigma_t^2)dt + \varepsilon\sqrt{\sigma_t^2}dW_t^\sigma \quad (4)$$

Where,

$\kappa = 2$

$\theta = 0.9625$

$\varepsilon = 0.1$

Correlation between price and volatility shocks = -0.5

For the parameters of the third simulation, the drift value was set at a mean of 0.05 (covering the years 1990-2006) and 0.07 (covering the years 2007-2024); the standard deviation was set at less than 1%. Volatility for the GBM equation was set at a mean of 25% and a standard deviation of 5%, in line with the nature of the Heston Model, which evolves according to a stochastic differential equation. The following adjustments were pursued, namely: rice straw cost (1 ton yields ~ 200 L), production cost (adjusted by efficiency range of -2% to 2 %), oil price factor (normalized to 1 in 1990), and the demand premium. In running the Monte Carlo simulation, a base price of PhP 10/ L was pursued; Euler discretization of the Heston standard differential equation was applied to simulate σ^2 .

The generated mean prices from the simulation reveal a rising trend, from PHP 10/L in 1990 to PHP 101.2/L in 2024. Such behavior can be associated with episodes of inflation, oil price hikes,

and policy-driven incentives brought by the enactment of the Biofuels Act of 2006. An expanding 5th-95th percentile range over time could be indicative of compounded uncertainty from such episodes. It can be observed how the pre-2006 phase (1999 - 2006) was characterized by modest bioethanol price growth; the first five years after the implementation of the Biofuels Act of 2006 witnessed eventual price peaks (associated to the Brent crude oil price of \$100 per barrel); eventual declines in bioethanol price are visible on the years 2013 - 2020 such may be associated with the Brent crude oil price placed at \$50 per barrel (during 2015) and the exogenous shocks of the COVID-19 pandemic. Recovery of bioethanol prices in 2021 - 2024 economic arrangements may be associated with elevated oil prices and sustained demand.

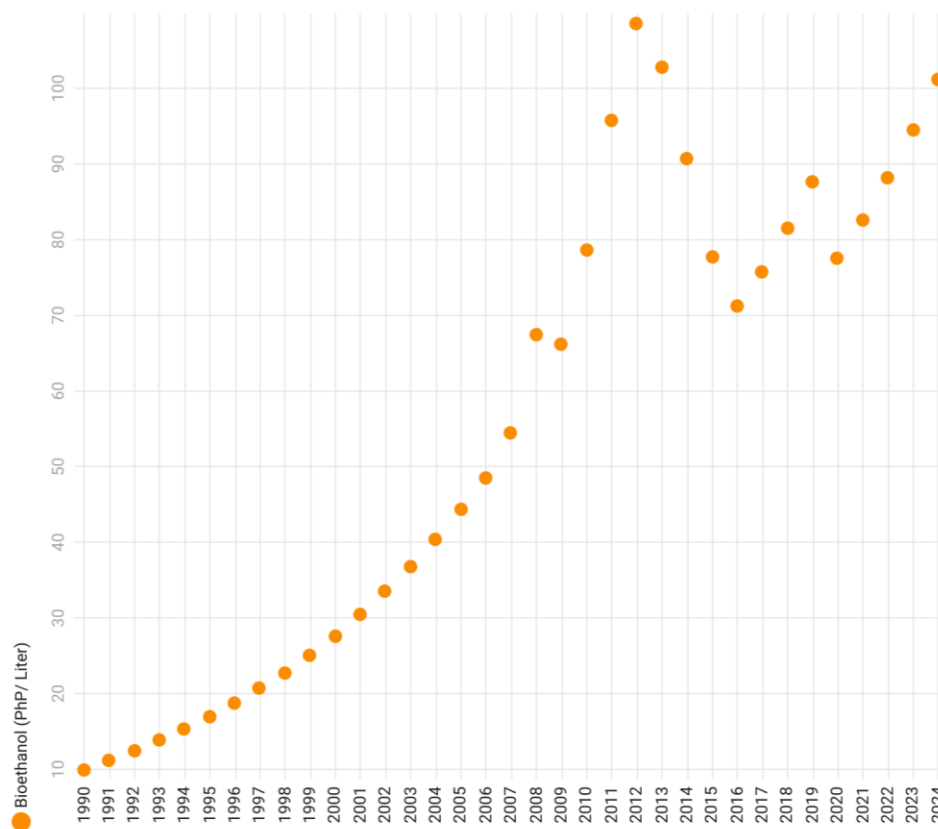


Figure 4. Bioethanol simulation for rice straw-based bioethanol (1990 - 2024)

3.3 Market Efficiency Tests

Referencing the results of the average variance ratio test, it can be observed that *walis tambo* has the average which is closest to 1 (VR = 0.9846) with non-significant z-scores [- 0.1234, - 0.1567, - 0.1890]. This can be indicative of prices closely following a random walk and suggest high market efficiency. Moderate efficiency is expressed for bioethanol (VR = 1.0321) and mushroom mulch (VR = 0.9578) as their values are close to 1; for markets with low efficiency, these are visible for fodder (VR = 0.9213) and paper (VR = 0.8765) since they deviate from 1 and have larger z-scores: [-0.5123, -0.6231, -0.7345] for fodder, and [-0.7890, -0.8567, -0.9234] for paper. The values for fodder and paper are indicative of potential predictability and low market efficiency.



Table 3. Average Variance Ratio Test Results for Existing Rice Straw-Based Markets

Rice straw-based market	Average Variance Ratio	Z-Scores
Fodder	0.9213	[-0.5123, -0.6231, -0.7345]
Walis Tambo	0.9846	[-0.1234, -0.1567, -0.1890]
Bioethanol	1.0321	[0.2345, 0.1987, -0.1890]
Mushroom mulch	0.9578	[-0.3456, -0.4123, -0.4789]
Paper	0.8765	[-0.7890, -0.8567, -0.9234]

For the implementation of the Granger Causality Test, lag orders were considered to count significant causal relationships. The standard $p < 0.05$ was utilized. Under its efficiency criterion, markets with minimal incoming causal relationships are flagged as more efficient, as they are deemed less predictable compared to other markets. Utilizing Python programming, the following table depicts the results of the Granger Causality Test:

Table 4. Granger Causality Counts for Existing Rice Straw-Based Markets

Rice straw-based market	P-value	Granger Causality Count
Fodder	0.0321	1
Walis Tambo	0.0412	2
Bioethanol	0.0289	0
Mushroom mulch	0.0478	1
Paper	0.0261	0

Based on the results from the Average Variance Ratio Test and the Granger Causality Test, it can be concluded that the market for rice straw-based bioethanol is the most efficient in terms of its average variance ratio, which is close to 1 ($VR = 1.0321$) and a Granger Causality Count of 0 (suggesting prices quickly integrate information without lagged dependencies from other markets). Although the variance ratio performance of *walis tambo* is flagged as efficient, such has been offset by its Granger causality links (as its Granger Causality Count is two, suggesting high predictability and low market efficiency).

The Average Variance Ratio and Granger Causality Count of rice-straw-based bioethanol may be associated with its alignment on global energy markets and sustainability measures (as evident in the projects of Straw Innovations Ph) and the policy incentives of the Biofuels Act of 2006. Existing literature suggests that rice-straw-based bioethanol production is feasible (in terms of technology) and efficient (in terms of fermentation process and rice straw availability) (Ningthoujam et al., 2023; Satlewal et al., 2018). This is suggestive how rice-straw based bioethanol are influenced by technology and production costs rather than direct price spillovers for other rice-straw utility (e.g., fodder, mushroom mulch, paper, and *walis tambo*); results from the key informant interview with the agricultural engineers and life cycle analysts emphasized the dire challenges for technology costs associated with rice-straw based bioethanol production including the bacterial strain to catalyze fermentation and the licensed software for detecting biogas shifts.

4. Discussion

It is crucial to understand how market entry is shaped by terrains of risk and uncertainty. The existence of policy constraints and the unpredictability of consumer and retail behavior provide difficulty in securing sustained market life expectancy (Eduardsen & Marinova, 2020). Acting as barriers to entry, established markets whose attributes are defined by a loyal consumer base, robustness, control over distribution pathways, and substantial capital demand lead to the odds of exclusion (Pehrsson, 2009). For integration of rice-straw-based markets in current economic arrangements, incremental niche markets are suggested, acknowledging competition deriving from other substitutes such as corn silage (for fodder), wood pulp (for paper), sugarcane (for bioethanol), and tiger-grass (for *walis tambo*), on which producer-and-consumer behavior may still be path-dependent. The researchers of the study recognize that existing markets and economic institutions may be hesitant to change; therefore, incremental changes are to be pursued to prevent shocks and provide avenues where both producers and consumers can adapt.

A niche approach for existing rice straw-based markets

Framework referenced from Dodd Parrish, Nancy L. Cassill, and William Oxenham (2004)

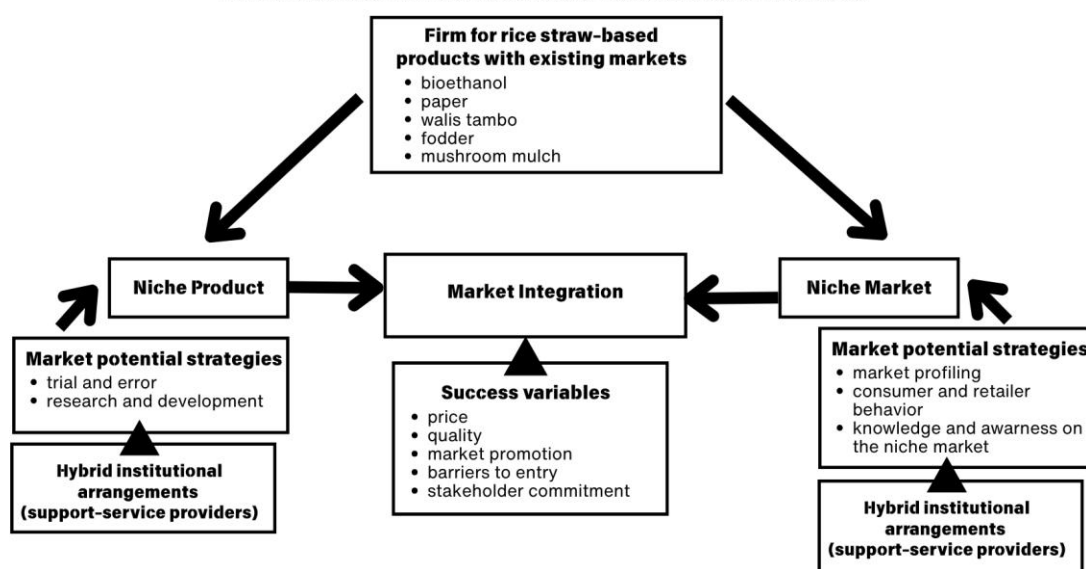


Figure 5. Niche Approach for Existing Rice Straw-Based Markets

The comparative advantage of established markets over new market entrants leads to the development of a niche-based approach for existing rice straw-based markets identified in this study (see Figure 4). Niche markets exist as distinct consumer segments; their channels for ascertaining competitive advantage include differential consumer preferences, innovation, and strong client relationships (Nikmah et al., 2023). Within the context of the identified rice straw-based market for bioethanol in Pila, Laguna, this can be construed as a green fuel alternative.

In microeconomics, market potential is defined as the anticipated maximum sales revenue that a product or service can achieve within a specific geography or market segment at a given time. It exists as an upper limit of demand and the total market width available for allocation to a given



service (Jacks & Novy, 2016). A niche market framework provided by Parrish et al. (2024) identifies the following market potential strategies, namely, (i) a trial-and-error phase, and (ii) research and development (R&D). As explained in the support service providers of the bioethanol value chain, drivers for rice straw-based niche products exist in hybridity (a conglomerate of the market, civil society, and government instrumentalities). Instance, in the case of rice straw-based bioethanol, its permutations occur as a hybrid of academic institutions (Benguet State University, Mariano Marcos State University, and University of the Philippines Los Baños, Los Baños), private non-profit organizations (International Rice Research Institute and Southeast Asian Regional Center for Graduate Study and Research in Agriculture), government agencies (DOST and DA), and market players.

The following variables were considered vital for the success of niche market integration: price, quality, market promotion, barriers to entry, and stakeholder commitment (Parrish et al., 2004). As a determinant of a household's willingness to consume a product, price reflects how markets position themselves and operate under competitive arrangements (Muwanga & Snyder, 1999). Quality assurance assessments on rice-straw-based products with existing markets relative to their commodity counterparts with established markets (such as corn, wood pulp, and tiger grass) may provide a competitive advantage in the long run. Support service providers must ascertain commitment and promotion for these niche markets to thrive; otherwise, reliance solely on the invisible hand may be detrimental, resulting in possible displacement and exclusion.

5. Conclusion and Recommendations

The inputs for the value chain were created by referring to secondary data. To supplement the data collected through literature reviews, it would be ideal to conduct key informant interviews with actors and representatives from involved institutions to gain a deeper insight into the steps and nature of participation of actors involved in the chain. Inputs from key informants can also be useful in highlighting best practices, as well as in identifying the unique challenges and barriers that hinder the promotion and establishment of a stable market for products that can potentially be produced from rice straw. Conducting actual observation studies will also be ideal for validating the supply chain path, as well as the involved actors, for each step in the chain. For further research on the prices of rice straw-based bioethanol, a data gap exists because the simulation considers Brent crude oil price data. Further validation is recommended to find parallels between the simulation results and historical data.

Below are the key recommendations of the study for government agencies, private markets, academic institutions, and civic society actors geared towards:

Government agencies mandated for agricultural sustainability and transition towards alternative fuel utility, such as the Department of Agriculture, the Department of Energy, and the Department of Environment and Natural Resources, should provide grants specifically for the procurement of fermentation catalysts and monitoring software to lower the initial capital burden for local producers. Such a recommendation is based on the key informant interview results, which indicate the high cost of specialized bacterial strains and licensed biogas software. The National Biofuels Board is recommended to coordinate with the Philippine Statistics Authority on initially isolating "rice straw utility" in agricultural statistics as a measure to help investors distinguish between the efficient bioethanol market and less efficient markets, such as the case of *walis tambo*.

Private enterprises and emerging markets, as in the case of Straw Innovations Ph, are suggested to adopt a "niche-first" strategy rather than attempting to immediately displace established

sugarcane-based bioethanol or fossil fuels. Incremental market entry may focus on environmentally conscious consumer segments (through a green fuel lens), where differential preferences can offset initial production costs. Enterprises should form direct contracts with rice farmer cooperatives to secure a stable supply of raw straw, mitigating the risk of "path-dependent" behavior where farmers might otherwise burn straw or sell it for lower-value uses.

Academic institutions are often the primary avenues for innovation. Through research extension programs, priority should be given to developing indigenous bacterial strains for fermentation, directly addressing the "dire challenges" of technology costs identified in the thematic analysis. As emphasized in the institutional hybridity framework of the discussion section, the authors of the study reiterate that research should not be confined to the laboratory; academic institutions should facilitate a hybrid conglomerate, providing pathways for accessible technology to government, the private sector, and civic society actors.

Civic society actors in such an episode of market regime transition towards rice straw-based biofuels must position themselves to bridge the gap between the invisible hand of the market and government regulations, ensuring that market growth remains inclusive and sustainable. Such initiatives can be pursued through capacity-building programs geared towards rice farmers' educational programs on efficient straw collection and storage techniques. This ensures that the feedstock may meet the quality standards required for bioethanol, giving the product a competitive advantage over substitutes, as evident in wood pulp and corn silage.

Acknowledgements

The researchers of the study would like to acknowledge Dr. Caroline D. Piñon from the College of Human Ecology and agricultural economist Dr. Cenon D. Elca for guidance and support in this endeavor.

Declaration of Conflict of Interest

The authors declare that there are no conflicts of interest related to the content of this manuscript. No financial, personal, or professional relationships exist that could influence or bias the work reported in this paper.

Funding

The authors received no financial support from any individuals or groups for the research and/or authorship of this article.

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^a key informant interviews, study site, QGIS mapping, thematic analysis, discussion, and recommendations

^b conceptualization of value chain framework for the rice straw, conclusion

^c introduction section and background of the study

^d simulated models verification

^e simulations, econometric tools utilization