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A Decade of Applied Quantitative Analytics for Philippine Policy: Forecasting, Statistical Forensics, and Predictive Modeling Across Education, Energy, Agriculture, Health, and Finance

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A Decade of Applied Quantitative Analytics for Philippine Policy: Forecasting, Statistical Forensics, and Predictive Modeling Across Education, Energy, Agriculture, Health, and Finance

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Abstract

Quantitative analytics has assumed a growing role in Philippine policy research as government and sectoral databases have become increasingly central to planning, monitoring, and resource allocation. This review synthesizes recent work in education, energy, agriculture, health, and finance to examine how forecasting, statistical forensics, and predictive modeling have been applied to Philippine policy problems. Across these sectors, the literature shows a clear methodological progression from descriptive diagnostics and classical time-series models toward comparative machine learning, deep learning, explainable artificial intelligence, nonlinear embedding, and Benford-based anomaly detection. Several recurring strengths emerge, particularly the consistent use of official Philippine datasets, transparent model benchmarking, and close alignment with practical policy concerns such as dropout reduction, electricity and crop planning, disease surveillance, and financial forecasting. At the same time, important limitations remain, including limited multivariate and spatial modeling, uneven validation practices, and relatively little attention to uncertainty quantification and operational deployment. In comparison with the broader international literature, the strongest contributions are those that position analytics as a support tool for planning and monitoring, while the main gaps lie in external validation, richer explanatory structures, and decision-oriented system integration. The evidence suggests that the next phase of Philippine policy analytics should move beyond isolated single-series applications toward integrated frameworks that combine forecasting, data-quality assessment, explainable modeling, and sector-specific decision thresholds for routine governance.

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1. Introduction

Quantitative analytics now occupies a central place in public-sector decision-making because governments must allocate scarce resources under uncertainty while responding to nonstationary social, epidemiological, agricultural, and economic conditions. In education, dropout is widely understood as a cumulative process shaped by household, school, and community factors rather than a single event, which makes descriptive profiling and risk monitoring policy-relevant. In energy, forecasting research has moved from classical statistical models toward machine learning and hybrid systems, especially when seasonality, nonlinear demand shifts, and structural breaks matter. In agriculture, forecast quality increasingly depends on whether models can use both conventional time series and richer covariates, while in health surveillance, routine data quality itself has become an analytical object rather than a background assumption. In nonlinear financial forecasting, state-space reconstruction and recurrent models have gained traction because linear specifications often fail under regime shifts and complex temporal dependence (Rumberger & Lim, 2008; Sabates et al., 2010; Ugbehe et al., 2025; van Klompenburg et al., 2020; Deyle & Sugihara, 2011; Ramadevi & Bingi, 2022).

Within the Philippine setting, this shift is particularly important because the country's policy environment depends heavily on official statistical and surveillance systems, including datasets from the Philippine Statistics Authority, Department of Energy, Department of Health, and related repositories. The reviewed corpus captures a coherent research program organized around applied policy problems rather than purely methodological novelty: dropout profiling in education, electricity and coal demand in energy, rice and corn forecasting in agriculture, dengue and measles surveillance in health, anomaly detection in public data, and stock-index prediction in finance. Taken together, these studies make it possible to examine not just model performance, but also how analytical techniques have been translated into policy language across sectors (Parreño, 2019, 2022a, 2022b, 2022c, 2023a, 2023b, 2023c, 2023d, 2024b, 2024c, 2024d, 2024e, 2024f, 2024g; Parreño & Anter, 2024, 2025; Parreño, 2025).

2. Review Method

A structured narrative review was conducted using a core internal corpus of 17 studies spanning 2019 to 2025. Each study was coded on five dimensions: domain, dataset, modeling approach, validation strategy, and policy contribution. The education subset included one SSRN paper on dropout reasons, one journal article using Philippine Statistics Authority data on school non-attendance, and one gender-disparity study based on regional dropout data. The energy subset covered national electricity consumption, Davao del Sur electricity demand, coal production and consumption, national monthly system peak demand, and ASEAN per-capita electricity stationarity. The agriculture subset covered quarterly rice and corn forecasts using classical methods, machine-learning forecasts for the same crops, and a Benford-based audit of crop statistics. The health subset covered dengue-data quality, surveillance anomaly detection, underreporting during the COVID-19 period, measles forecasting, and diabetes-risk prediction. The finance subset consisted of a nonlinear LSTM study of the Philippine Stock Exchange Index (Parreño, 2019, 2022a, 2022b, 2022c, 2023a, 2023b, 2023c, 2023d, 2024b, 2024c, 2024d, 2024e, 2024f, 2024g; Parreño & Anter, 2024, 2025; Parreño, 2025).

External comparison literature was then used to position the corpus against broader developments in dropout research, electricity forecasting, crop-yield analytics, epidemiological surveillance, Benford-based auditing, and nonlinear or explainable machine learning. Priority was given to peer-reviewed reviews, official organizational reports, and major domain studies with clear methodological or policy relevance. This made it possible to distinguish sector-specific findings from broader methodological trends and to identify where the reviewed studies align with, extend, or lag behind the wider literature (David et al., 2018; Idrovo et al., 2011; Guo et al., 2017; Tasin et al., 2023; Misiurek et al., 2025; Morillas-Jurado et al., 2021; World Health Organization, 2021).

3. Results by Sector

3.1. Education

The education studies are descriptive and policy-diagnostic rather than predictive, but they establish an important baseline for Philippine social analytics. The 2019 study used national dropout-related statistics to identify the principal reasons for non-completion. The 2023 journal article drew on Philippine Statistics Authority data on the proportion of 6–24-year-olds not attending school and compared 2008 with 2013 using descriptive statistics and percentage change analysis in R, highlighting cost of schooling and employment-seeking as major drivers. The 2025 gender-focused study used regional dropout rates disaggregated by sex from the Philippine Institute for Development Studies, applying trend analysis and statistical testing to show that male dropout remained systematically higher, with strong regional heterogeneity and especially elevated burdens in historically disadvantaged regions. In domain terms, these studies belong toeducation policy and inequality analysis; in dataset terms, they rely on national and regional administrative statistics; in method terms, they use descriptive profiling, comparative trend analysis, and inferential testing; in validation terms, they rely on internal consistency and statistical significance rather than out-of-

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sample prediction; and in policy terms, they support targeted retention, affordability, and region-specific intervention design (Parreño, 2019, 2023a; Parreño & Anter, 2025).

Compared with the wider literature, these education studies are closely aligned with the view that dropout is multicausal and stratified by gender and disadvantage, but they remain mainly descriptive. Internationally, dropout research often moves beyond pattern description toward multilevel risk modeling, longitudinal event-history analysis, and school-process variables, while Philippine evidence has also emphasized boys' persistent disadvantage in participation and completion (Rumberger & Lim, 2008; Sabates et al., 2010; David et al., 2018). The main strength of the reviewed education work is policy readability: the findings are straightforward, directly interpretable, and anchored in official statistics. The main gap is explanatory depth. There is still substantial room for linking dropout profiles to poverty, labor-market pull factors, school quality, geography, and post-pandemic learning loss through multivariate and spatial models.

3.2. Energy

The energy studies show the clearest progression from classical time-series modeling toward comparative and structural analysis. The national electricity-consumption study used 48 annual observations from 1973 to 2020, split into 43 training points and 5 testing points, and selected an ARIMA specification through a Box–Jenkins procedure using ACF/PACF diagnostics and information criteria. The Davao del Sur study used 22 annual observations, applied Box–Cox transformation and differencing, and selected an ARIMA model through residual diagnostics, but acknowledged the absence of out-of-sample validation because the sample was too short. The coal study forecast both production and consumption using ARIMA, checked residual autocorrelation and normality, and translated the resulting gap between production and consumption into an import-dependence interpretation. These three studies belong to energy planning; their datasets are official historical annual series; their methods are univariate ARIMA-based forecasting; their validation ranges from holdout testing to residual diagnostics only; and their policy contribution lies in long-horizon planning, capacity assessment, and import-dependence awareness (Parreño, 2022a, 2022b, 2022c).

The later energy studies are more comparative and methodologically ambitious. The system-peak-demand paper used monthly Department of Energy data from 2001 to 2020 and compared SARIMA with neural-network forecasting using RMSE, MAE, and MAPE, finding stronger performance from the nonlinear benchmark. The ASEAN stationarity paper moved away from point forecasting and instead asked whether shocks to per-capita electricity consumption are persistent or transitory, applying KPSS-type stationarity testing with structural breaks and finding substantial persistence outside Brunei. In domain terms, these are still energy-policy studies, but their datasets are richer in frequency or cross-country structure; their methods include seasonal time-series models, neural networks, and structural-break stationarity tests; their validation uses error metrics or formal hypothesis testing; and their policy contribution shifts from simple projection toward resilience planning and shock persistence. This pattern matches the broader literature, which now treats electricity forecasting as a spectrum ranging from classical statistical baselines to machine-learning and hybrid systems, especially when nonlinearities, renewables integration, and multiple forecast horizons matter (Parreño, 2023c, 2024g; Kula et al., 2012; Husein & Kara, 2023; Ugbehe et al., 2025; Misiurek et al., 2025).

A recurring strength in this sector is disciplined benchmarking: even when models are simple, they are usually chosen through transparent diagnostics and evaluated with standard forecast errors. A recurring gap is the dominance of univariate modeling. Weather, fuel prices, sectoral demand composition, policy shocks, and macroeconomic drivers are mostly absent, and probabilistic forecasting is not yet routine. The reviewed work is therefore strongest as an operational baseline and weakest where scenario-based or multivariate planning is needed.

3.3. Agriculture

The agriculture studies illustrate a transition from classical seasonal forecasting to machine learning and then to data-quality forensics. The 2023 quarterly rice-and-corn study used Philippine production data from 1987 to 2023 and compared SARIMA with Holt–Winters under additive seasonality, finding lower RMSE and MAPE for Holt–Winters. The 2024 machine-learning study used 145 quarterly observations for rice and corn up to the first quarter of 2023 and compared random forests, echo-state networks, neural network autoregression, and support-vector variants, reporting the best overall performance for random forests. In domain terms, both studies support agricultural planning and food security; in dataset terms, both rely on official quarterly production series; in method terms, the progression is from seasonal exponential smoothing and SARIMA toward machine-learning comparison; in validation terms, both emphasize forecast-error benchmarking; and in policy terms, both support production planning, resource allocation, and import-buffer decisions (Parreño, 2023b; Parreño & Anter, 2024).

The crop-statistics forensic paper adds a distinct contribution by asking whether the agricultural data themselves exhibit expected first-digit patterns under Newcomb–Benford analysis. That moves the discussion from forecast accuracy to statistical reliability. This is important because the broader agricultural forecasting literature increasingly stresses that yield prediction improves when diverse covariates such as temperature, rainfall, soil, and remote sensing are incorporated, but these advances still depend on trustworthy base data (van Klompenburg et al., 2020; Jabed & Azmi Murad, 2024). The strength of the reviewed agricultural work is that it combines forecast comparison with a nascent data-audit perspective. The main gap is that most models still use aggregate time series without climate covariates, subnational spatial detail, or formal uncertainty intervals, which limits their usefulness for adaptive food-security policy.

3.4.Health

The health studies are the most diverse and show the strongest convergence of forecasting and statistical forensics. The dengue-data paper and the broader surveillance-anomaly paper both use Newcomb–Benford analysis as a screening device for epidemiological data quality. In domain terms, they sit at the intersection of public health surveillance and statistical auditing; in dataset terms, they use surveillance counts for dengue or broader communicable disease reporting; in method terms, they apply first-digit conformity testing; in validation terms, they assess consistency with expected digit distributions rather than predictive performance; and in policy terms, they provide a low-cost screening mechanism for identifying unusual reporting behavior that may merit further investigation. This is consistent with the wider literature, where Benford-based methods are treated as early-warning audit tools rather than definitive proof of manipulation or underreporting (Idrovo et al., 2011; Morillas-Jurado et al., 2021).

The forecasting studies deepen this line of work. The underreporting paper used comparative forecast analysis during the COVID-19 period and concluded that significant underreporting of several diseases likely occurred when health-system attention shifted toward the pandemic. The measles study used weekly incidence data from 2017 to late 2023, transformed cumulative counts into weekly differences, imputed missing values, split the data 80:20 into training and validation samples, and compared SARIMA, Holt–Winters, echo-state networks, and NNAR, with NNAR performing best overall. In domain terms, these are outbreak-monitoring and service-disruption studies; in dataset terms, they rely on routine public health surveillance series; in method terms, they combine time-series forecasting, neural network benchmarks, and comparative performance evaluation; in validation terms, they use explicit train–validation designs and error metrics; and in policy terms, they support surge preparedness, immunization planning, and monitoring of silent surveillance deterioration. This aligns with a broader public-health literature that treats routine data as operational intelligence, especially during system shocks, and uses machine learning for dengue and related disease forecasting where seasonality and nonlinear dynamics are strong (World Health Organization, 2021; Guo et al., 2017).

The diabetes study extends the health portfolio from surveillance forecasting to individual-level predictive modeling. It used tabular diabetes data, applied principal component analysis for feature engineering, compared several advanced learners including boosting variants and support-vector machines, tuned hyperparameters by grid search, used an 80:20 train–test split, and employed SHAP values for interpretability. In domain terms, this is clinical risk prediction; in dataset terms, it is patient-level tabular data; in method terms, it uses supervised machine learning, dimensionality reduction, and explainable AI; in validation terms, it uses standard supervised holdout evaluation; and in policy terms, it points toward risk stratification that is more actionable for providers than opaque black-box predictions alone. Relative to the broader literature, the main strength is the explicit inclusion of interpretability. The main gap is external validation and deployment evidence, which remain central concerns in clinical AI (Parreño, 2024f; Tasin et al., 2023).

3.5. Finance

The finance contribution centers on nonlinear time-series prediction of the Philippine Stock Exchange Index. The study used Takens-style embedding to reconstruct the system's dynamics, handled missingness with chained equations, and then estimated an LSTM model on the reconstructed series. In domain terms, this belongs to financial forecasting; in dataset terms, it uses market-index time series; in method terms, it combines chaos-informed phase-space reconstruction with deep learning; in validation terms, it reports training/validation behavior together with actual-versus-predicted comparisons; and in policy terms, the contribution is less about direct regulation than about showing that Philippine financial series may benefit from nonlinear representations when conventional linear models are insufficient. This is consistent with wider work showing that chaotic or nonlinear forecasting frameworks can strengthen machine-learning performance in complex temporal systems, although comparative evidence across asset classes remains mixed (Parreño, 2024c; Deyle & Sugihara, 2011; Ramadevi & Bingi, 2022).

3.6. Cross-Cutting Methodological Trends

Five methodological trends recur across the corpus. First, official Philippine administrative data are the dominant empirical base, which strengthens policy relevance. Second, the early phase of the corpus is dominated by descriptive statistics and classical univariate forecasting, especially ARIMA, SARIMA, and Holt–Winters. Third, later studies increasingly adopt comparative machine learning, including random forests, neural networks, boosted methods, and LSTM. Fourth, a distinct forensics strand emerges through Benford-based anomaly detection, treating data quality as a substantive policy problem. Fifth, interpretability becomes more explicit in the health-prediction work through SHAP and in the stock-index study through theory-guided embedding rather than purely brute-force prediction (Parreño, 2022a, 2022c, 2023b, 2023c, 2023d, 2024c, 2024d, 2024f; Parreño & Anter, 2024).

Validation rigor, however, is uneven. Some studies use explicit holdout sets or train–validation splits and compare models with standard error metrics, while others depend primarily on residual diagnostics or significance testing because samples are short or the goal is descriptive rather than predictive. This unevenness is understandable in applied public-data settings, but it also marks the clearest methodological gap in the corpus. Relative to current best practice, future work would benefit from rolling-origin evaluation, cross-validation adapted to time dependence, external validation across regions or periods, and calibrated uncertainty intervals. That need is visible across energy, agriculture, health, and clinical prediction alike (Ugbehe et al., 2025; Misiurek et al., 2025; van Klompenburg et al., 2020; World Health Organization, 2021).

3.7. Policy Implications

Several policy implications follow directly. In education, descriptive diagnostics already justify more sharply targeted affordability and retention interventions, especially where male dropout is persistently higher and where schooling competes with labor-market entry. In energy, reliable

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baseline forecasting remains essential, but planning agencies would benefit from upgrading from single-model projections to ensemble systems that account for structural breaks and demand nonlinearity. In agriculture, production forecasting should be integrated with data-quality audits and gradually expanded to include climate and spatial covariates. In health, the strongest immediate use case is a dual system in which routine surveillance forecasts are paired with anomaly-screening tools so that unusual patterns trigger investigation before they distort program response (Parreño, 2023a, 2023c, 2023d, 2024d, 2024g; Parreño & Anter, 2025; World Health Organization, 2021).

For the Philippines specifically, the reviewed studies suggest that policy analytics should not treat forecasting, anomaly detection, and explainability as separate agendas. Education systems need predictive risk models built on the descriptive foundations already established. Energy systems need scenario-aware forecasting that incorporates structural persistence. Agricultural planning needs subnational and climate-sensitive modeling. Public health systems need routine-data governance, especially in periods of service disruption and immunization stress. Clinical prediction needs external validation before operational use. The most promising direction is therefore an integrated analytics architecture in which official time series are continuously monitored for quality, forecasted with sector-appropriate models, and interpreted through policy thresholds rather than model accuracy alone.

4. Limitations

The corpus is coherent but heterogeneous. It includes journal articles, a preprint, and SSRN papers, and the studies differ substantially in frequency of data, forecast horizon, sample size, and maturity of validation design. Because the evidence base mixes descriptive, predictive, and forensic studies, direct numerical comparison across sectors is neither appropriate nor intended. In addition, some study characteristics had to be reconstructed from publisher pages, abstracts, or metadata when full texts were not equally accessible. These limitations do not weaken the central conclusion that the corpus documents a meaningful evolution in Philippine applied analytics, but they do caution against overinterpreting performance differences across domains.

5. Conclusions

The reviewed body of work shows a clear maturation in Philippine policy-oriented quantitative analytics. The earliest studies established descriptive and univariate forecasting baselines using official administrative data. Later studies broadened the toolkit to comparative machine learning, structural-break testing, nonlinear embedding, deep learning, explainable AI, and Benford-based statistical forensics. Across education, energy, agriculture, health, and finance, the strongest contributions are transparency, policy relevance, and practical engagement with real Philippine datasets. The main next step is not merely to seek marginal gains in predictive accuracy, but to build integrated sectoral analytics that are multivariate, uncertainty-aware, externally validated, and operationally linked to actual decisions. That is the path by which applied quantitative analytics can move from useful academic exercise to durable policy infrastructure in the Philippines.

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