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A SEMI-NOPARAMETRIC APPROACH TO RISK ANALYSIS IN ELECTRICITY MARKETS

AUTHOR

ALFREDO TRESPALACIOS CARRASQUILLA

THESIS SUPERVISORS

JAVIER PEROTE PEÑA

LINA MARCELA CORTÉS DURÁN

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ENFOQUE SEMI-NOPARAMÉTRICO PARA EL ANÁLISIS DE RIESGOS EN MERCADOS DE ELECTRICIDAD

AUTOR

ALFREDO TRESPALACIOS CARRASQUILLA

DIRECTORES DE TESIS

JAVIER PEROTE PEÑA

LINA MARCELA CORTÉS DURÁN

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A la luz interior de cada corazón

Alfredo Trespalacios Carrasquilla

alfredo.trespalacios@gmail.com

alfredotrespalacios@itm.edu.co

Javier Perote Peña

perote@usal.es

Lina Marcela Cortés Durán

lcortesd@eafit.edu.co

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Contents

Summary

This thesis complements the existing literature on risk analysis in electricity markets, proposing the use of a flexible tool that allows capturing skewness, kurtosis and higher order moments in the uncertain components of variables that affect electricity markets. To do so, it is proposed a generalization of the normality assumption, traditionally used to describe the uncertainty of these markets, by means of probability density functions defined in terms of a finite Gram-Charlier expansion. This 'semi-nonparametric approach' (SNP) has been successfully implemented to extend the non-normality of different phenomena, but never before to the description of electricity markets. For this purpose, three applications are proposed to solve risk problems typical of the electricity markets and that will be developed through the three chapters of the thesis: (i) "Uncertainty in Electricity Markets from a semi-nonparametric approach", (ii) “Modeling the electricity spot price with switching regime semi-nonparametric distributions” and (iii) “Hedging in Electricity Markets under skewness and leptokurtosis”. In all three cases, it is found that by means of the SNP approach it is possible not only to better describe the behavior of the variables linked to the electricity markets, but also to use their estimation for issues such as efficient pricing, risk management policies or optimal hedging strategies. From a theoretical point of view, generalizations of SNP distributions are proposed to capture switching regimes and to the multivariate modeling of simultaneous energy price and quantity functions. Thus, establish energy policy recommendations that help companies, investors and regulators to make decisions in the presence of risk and uncertainty in electricity markets.

Resumen

Esta tesis, complementa la literatura existente acerca del análisis de riesgos en mercados de electricidad, proponiendo el uso de una herramienta flexible que permita capturar el sesgo, la curtosis y momentos de orden superior en las componentes inciertas de las variables que afectan a los mercados eléctricos. Para ello se propone generalizar el supuesto de normalidad, tradicionalmente utilizado para describir la incertidumbre propia de estos mercados, por funciones de densidad de probabilidad definidas en términos de una expansión de Gram-Charlier finita. Este 'enfoque semi-noparamétrico' (SNP) se ha utilizado con éxito para extender la no normalidad de numerosos fenómenos, pero nunca a la descripción de los mercados eléctricos. Para ello se proponen tres aplicaciones para resolver problemáticas de riesgo propias de los mercados de energía eléctrica y que se desarrollarán a través de los tres capítulos de la tesis: (i) "Incertidumbre en Mercados de Electricidad: Enfoque semi-noparamétrico", (ii) "Modelo de precio spot de energía eléctrica con cambio de régimen y distribuciones semi-noparamétricas" y (iii) "Cobertura en Mercados de Electricidad ante Condiciones de Sesgo y Leptocurtosis". En los tres casos se encuentra que mediante el enfoque SNP se puede, no solo describir mejor el comportamiento de las variables vinculadas a los mercados de electricidad, sino utilizar su estimación para cuestiones como la fijación eficiente de precios, las políticas de gestión de riesgos o estrategias de cobertura óptimas de los mismos. Desde el punto de vista teórico se plantean generalizaciones de las distribuciones SNP a la captura de cambios de régimen y a la modelización multivariante simultánea de funciones de precio y cantidad de energía. Todo ello para establecer recomendaciones de política energética que ayuden a los empresas, inversores y reguladores a la toma de decisiones en contextos de riesgo e incertidumbre en los mercados eléctricos.

Introduction

The seventh sustainable development goal SDG aims to guarantee access to an affordable, safe, sustainable and modern energy for everyone. Energy is a fundamental part to undertake the great humanity challenges, it contributes to employment, it provides safety, it is essential in food production and its use helps to mitigate the climate change effects, among other aspects. Among those kinds of energy use, electric energy has qualities that are nowadays required to build sustainable environments, allowing not only the movement creation, heating, cooling and transport, but also working as basis for the digital tools growth, in the new environment of industry 4.0. In its final use, electricity is free of greenhouse gas emissions and the new developments regarding renewable sources, such as in the solar or wind energy, allow an energy production that affects the environment less and less, while at the same time, it contributes to the generation of value in companies that participate in this chain.

Furthermore, electricity is the most efficient mean to transform and transport energy. Any kind of primary energy that is used nowadays by mankind can be transformed into electricity, to be carried through long distances, from the production center in great volume to the consumption centers (Stoft, 2002).

When compared to other kinds of energy that have to be transported, like oil, natural gas or coal, the electricity levels of investment in infrastructure are lower and they have lower losses.

These elements make electricity a commodity with no perfect substitutions defined, and it is the type of energy on which higher growth in demand is expected by 2040 (EIA, 2019).

During the 90s, worldwide electricity markets began to be deregulated with aims of turning them into competitive systems that generated the appropriate signals for investors, private or from the state, on the necessary investments in terms of expansion, apart from the management through this policy of keeping the prices prone to marginal cost, (Mayer & Trück, 2018).

This condition encourages the participation of new private actors to compete with already consolidated state-owned enterprises, offering a series of chain value services such as: generation, transmission, distribution and commercialization (Trespalacios et al, 2017). The liberalization process of energy and telecommunication sectors done in Europe and Latin America is analyzed by (Levi-Faur, 2003).

In these liberalized markets, each of the participating agent is responsible for making the investments, getting their return, and keeping healthy risk levels in their operations.

The supply chain of electricity is composed of generation, transmission, distribution and commercialization activites. The generation activity is in charge of energy transformation, from each primary source into electricity: generators transform natural gas, coal, solar radiation or water flow into electric energy.

The transmission activity is in charge of transporting the energy from distant places, where large generators are located, to consumption centers, over hundreds of kilometers away.

The distribution activity on the other hand, is the one delivering the energy to each customer, taking it after the transmission process and adapting it for conditions that can be used by customers. Commercialization activity meanwhile, collects money from all the users and pays the corresponding amount to each of the agents involved in this process.

The final price of electricity is defined by the adequate compensation of operating costs, investment, and opportunity to each one of the agents that interact to provide said service. That requires agents to pay close attention to the availability of energy in the short, medium, and long term due to three conditions: (i) electricity should be produced at the same moments it is demanded; (ii) the availability of primary energy sources limits the production capacity in the short term, depending on external agents such as producers or transporters of fossil fuels or natural agents, e.g., hydrologic inflows; and

(iii) investments in electrical infrastructure are capital intensive and present long capital recovery periods. The regulator of each market is in charge of defining the rules on which all the dynamics in the interaction of supply and demand originate, (Pérez, Watts, & Negrete-Pincetic, 2018).

Energy purchase and sale transactions are hold through the spot market or through financial derivatives that have the spot as underlying. These transactions allow agents to assume or transfer different risk levels in both prices and quanties to be produced or demanded. These markets uncertainty will be marked by the interaction of supply and demand mobiles and the expectations upon them, where weather, according to Pilipovic (2007) is one of the main fundamentals. The winter – summer cycles generate relevant changes in price formation, as well as the medium or long term shocks in macroclimatic phenomena such as *el Niño,* that has an impact on energy demand levels and also determine the maximum amount to be produced from some primary sources, like water, sun or wind. The fuel price, the availability of electrical grid, the regulatory modifications and the economic performance can also influence the risk contidions faced by market agents (Geman & Roncoroni, 2003).

During these uncertain conditions and due to the relevance that risk quantification has for companies, strategies for the modeling of agents cash flow, as well as guidance in decision-making have been designed. It is common to consider the risk hedge decision-making when dealing with the hedge problem in the electrical energy market by assuming normality, either in variables or in the logarithm of the variables involved. Even though that is a common assumption to face the selection of forward contracts appropriate number to cover the risk of transactions in electricity markets, used by Vehviläinen & Keppo (2003) Nässäkkälä & Keppo (2005), Oum & Oren (2010), Pantoja (2012), Trespalacios et al. (2012) and Boroumand R. , Goutte, Porcher, & Porcher (2015), among others; this situation has limitations to face problems related to skewness, and kurtosis cases. In this thesis, the aim is to complement the existent literature on risk analysis in electricity markets, by suggesting the use of a tool that also allows capturing skewness, kurtosis and higher order moments in the uncertain components of variables that can affect the companies' performance.

The treatment of uncertainty and structuring in electricity market portfolios are addressed, in this paper, by evaluating the relevance of the use of semi-nonparametric approach for the description of density distribution of probability in different variables that intervene in an electricity market from the Edgeworth and Gram-Charlier series, explained by (Ullah, 2004), that allows to expand previous papers on the topic when relaxing the assumption of normality; in this regard, (Ichimura & Lee, 1991) make reference when finding that a model in parametric version can also be extended to its semi-nonparametric version.

The semi-nonparametric approach is expected to be applicable when analyzing the variables and the decision-making in electricy markets, since this methodology has managed to improve the results on only parametric approaches into other types of problems that consider heavy -tailed variables in both symmetry or positive asymmetry conditions.

E.g., Cortes, Perote, & Mora (2018) use semi-nonparametric distributions when analyzing the options on the international oil price; Cortés, Perote, & Mora (2016) show how this methodology achieves a better measurement than the assupmtion of log-normality when mesuring worldwide researchers productivity. Similar results, where the semi-nonparametric approach achieves better results than the parametric one, are presented by (Brunner A. D., 1992) for measuring United States gross domestic product, (Gallant, Rossi, & Tauchen, 1992) in prices, and traded volumes in stocks, and (Niguez & Perote, 2012) model heavy- tailed distributions returns.

Although the proposed modeling applies to any type of electricity market, due to the type of literature and the modifications made to the existent models, in this paper, the Colombian electricity market is considered as a case study. The assumptions, methodology and results found are reported in each of the following chapters. The study hypothesis, the objectives and the structure of the document are detailed below. To you, who have decided to honor this paper with your reading, thank you.

Objectives

General Objective:

To propose a semi- nonparametric type treatment to analyze and to measure variables that take part in the electricity markets, taking as case study the Colombian electricity market.

Specific objectives:

To contrast adjustments of electrical energy market series, based on parametric and non-parametric distributions by means of SNP univariate distribution.

To propose a model for the spot price of electricity whose uncertainty dynamics can be captured using the semi-nonparametric approach.

To propose the structuring of portfolios of electrical energy coverage based on price and energy amounts models represented by semi – nonparametric multivariate distributions.

Document Structure

This paper is written as self-contained and autonomous chapters that are divided as follows: in Chapter II, a study is carried out on the adjustment to the probability density distribution of different variables that are part of an electricity market, and it is titled: "Uncertainty in Electricity Markets from a Semi-nonparametric Approach", where the semi-nonparametric SNP approach is studied to describe the uncertainty of different variables of an electricity market, reducing the limitations that parametric density functions impose. In said chapter, the use of the SNP distribution is outlined to model variables in an electricity market, such as the spot price, hydrologic inflows, energy demand and the macro -climatic index ONI. In this chapter, an also in the others, the study case proposed is the Colombian electricity market.

Chapter II aims an exploratory type analysis, which seeks to know if the SNP type distributions manage to measure the shape of the distribution of the data set, better than a normal distribution in the case of typical variables of an electricity market. This first approach has been carried out in terms of the unconditional distribution, without considering the dynamics at the moments, sepecially the variance and the structure of autocorrelation structure, to focus on the adjustment capacity of the distributions nested on the SNP distribution (normal distribution included). This limitation will be addressed in the subsequent chapters, e.g., in Chapter III, a proposal for the spot price is made, where the aim is to improve the level of the estimates made, considering among other aspects, the autocorrelation of the series.

The study done in Chapter II has been published in the journal Energy Policy, (Trespalacios, Cortés & Perote, 2020). There is shown how SNP-type distributions manage to measure the features of the probability density dsitribution better than the normality assumption.

Chapter III aims to study the dynamics of the spot price of electricity considering jump diffussion or regime switches and the use of semi-nonparametric distributions to describe the unexplained components. The study shows how the series of the electricity spot price in Colombia can be represented by a stochastic process with mean reversion and jumps diffusion, that depends on the occurrence of El Niño phenomenon.

The proposed process for the price P_t has three main components: a deterministic one, $F(t)$; and the others are stochastic ones X_t and J_t. X_t which correspond to a process with mean reversion and J_t can be used to represent switching regimes and jumps:

$$P_t = F(t) + X_t + J_t \quad (1)$$

In this case, the pure random components of $X_t \; and \; J_t$ are described by SNP-type distributions, with better adjustment on the residuals of processes than on normal or lognormal distributions. The regime switches of the spot series are also represented with a jumps process, where the probability of appearance or extinction of the regime switch is associated with the occurrence of El Niño phenomenon.

Once the option of representing through SNP distributions some of the variables that intervene in the electricity markets has been identified, Chapter IV expands on decision-making in an environment of uncertainty for electricity generating agents participating in a market, that face uncertainty in the spot price and the quantities to be generated. There, it is considered that agents can cover their uncertainty through the use of electricity forward contracts, looking for the minimization of the variance of their energy sales portfolio, the maximization of the value at risk *-VaR* or the value at conditional risk *-CVaR*. To represent uncertainty, in this investigation, the spot price and the amount of energy generated are represented as a bivariate SNP distribution.

In Chapter IV it is found how the optimal number of forward contracts on electricity to trade depends on the correlation levels between the spot price and the amount generated, as well as the values given to the Hermite coefficients of the bivariate SNP distribution. Likewise, the payed value for the risk on the market, that is measured through the market Forward Risk Premium (FRP), also affects the decisions of the generating agents.

Thanks to the results, some recommendations can be given to the agents that participate in the electricity markets in different parts of the chain, such as generators, distributors, marketers, large consumers, as well as regulators, planning entities and those in charge of surveillance and control. The normality assumption that is typically used to describe the variables behavior in electricity markets cannot capture skewness and kurtosis elements, common in this type of market, causing that the measured risk levels and decision-making considered because of them do not obey the actual dynamics studied. Professionals in this matter should take into account certain conditions for the treatment of deterministic and stochastic projections that can be captured if you start with the assumption of a SNP-type uncertainty, instead of the normality assumption.

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Final Conclusions

This thesis complements the existent literature on risk analysis in electricity markets, by suggesting the use of a flexible tool that allows capturing skewness, kurtosis and higher order moments in the uncertain components of variables that can affect the electricity markets, such as the energy demand, the hydrologic inflows, the electricity generation and the spot price. To do so, it is proposed a generalization of the normality assumption, traditionally used to describe the uncertainty of these markets, by means of probability density functions defined in terms of a finite Gram-Charlier expansion.

This 'semi-nonparametric (SNP) approach' has been successfully implemented to extend the non-normality of different phenomena, but never before to the description of electricity markets. This problem is addressed through chapters: (i) "Uncertainty in Electricity Markets from a semi-nonparametric approach", (ii) “Modeling the electricity spot price with switching regime semi-nonparametric distributions” and (iii) “Hedging in Electricity Markets under skewness and leptokurtosis”. The study case proposed is the Colombian electricity market.

It is found, in a novel way, that a semi-nonparametric -SNP distribution that uses Gram-Charlier expansions achieves a better adjustment for some of the series of the Colombian electricity market with respect to the normal distribution. The variables analyzed are the electricity demand, the spot price, the hydrological inflows added to the system, the Oceanic Niño Index -ONI and the series of hydrological inflows of Nare, Salvajina, Guavio and San Carlos rivers. In these series, there is a generalized condition of leptokurtosis and positive skewness. The normality assumption limits the modeling of uncertainty in the electricity markets. This result makes it convenient for future work to assume that the uncertainty is generated by a probability density function of –SNP type, in which the normal is a particular case.

A stochastic process with mean reversion and regimen switches is proposed to represent the energy spot price dynamics and its logarithmic form. For that purpose, three components were included: a deterministic one, another one of mean reversion, and a third one of regime switching.

The short-term distortion of the mean reversion and regime switching components is represented by semi-nonparametric (SNP) distributions with a probability density function defined by a finite Gram–Charlier expansion, in contrast to previous studies that assume the particular case of the Gaussian process. The greatest contribution of this work to the scientific community corresponds to the conjunction of a modeling with regime switch, not only in terms of the mean and the standard deviation, but also in terms of skewness, kurtosis and moments of higher order. Using the Monte Carlo simulation, it is found that the proposed model manages to measure the moments of the historical spot price series and its performance is more suitable when modeling the natural logarithm of the series.

The proposal of a spot price model considers a binary regime switch component, where the probability of the transition is a function of the time passed in each regime. This representation enables the consideration of events that recurrently change the electricity spot price during one or several consecutive periods, like in the case of El Niño phenomenon occurrence in the Colombian market, where its probability of occurrence after certain number of periods is different from the probability of the phenomenon ending. This switching regime model enables the modification of the spot price in the deterministic and random components, according to the behavior of the sample. Such generalization can be extrapolated in other markets (not only electricity).

In this paper, a static hedging strategy for electricity generators that want to hedge their exposure to market risk, through forward contracts that include a risk premium in their valuation is also proposed.

For this purpose and considering the results found in the course of this thesis, it is considered that the spot price and the generation of energy distribute as a bivariate SNP -Semi-nonparametric function in terms of a Gram-Charlier expansion, allowing the modeling not only from the mean, the variance and their correlation but also the skewness, the kurtosis and the higher order moments. Monte Carlo simulation is used to analyze the effect of three risk indicators: standard deviation, Value-at-Risk (VaR), and Conditional VaR (CVaR). The main contribution of this study to the analysis of electricity markets is the structuring of an energy portfolio that does not impose the assumption of normality in both price and energy generation, which application can be extended to other energy markets and commodities.

The planning, regulation, and control mechanisms and the agents in charge of purchase and sale transactions, can use these results with aim to improve their method when measuring risks, managing their portfolios and determining the system expansion. Activities related to planning must consider the impacts produced by the appearance of extreme events in terms of probability, impact and duration. Besides, it has been found that conclusions under a SNP approach can differ when assuming normality in the uncertain components; keeping the normality paradigm in the electrical industry will lead the market to systematically take wrong decisions when ignoring the conditions of skewness, kurtosis and higher order moments. The electricity markets sustainability will depend on the appropriation of the most suitable methods in decision making. The regulation, supervision and control mechanisms are the ones needed to promote the implementation of the best tools in order to guarantee this sector's sustainability.

If the regime switching (which, in Colombia, is produced by the occurrence of El Niño phenomenon in its different categories) further affects the levels of expectation and uncertainty, the agents involved in short- and long-term price formation should incorporate the assumed risks in the price that users pay. The expansion of systems should not only ensure the supply, long-term prices in accordance with income levels, or the needs of users but also the (systemic and idiosyncratic) risk levels that involve hidden or revealed costs that jeopardize the conditions of return of the invested capital or the objectives of development and social welfare. The model proposed in this study addresses the quantification of the possible impact on the cash flows of all the participants in the market, in the short, medium, and long term.

Professionals in this field should consider certain conditions for the treatment of deterministic and stochastic forecasts that may be captured if they are based on the assumption of an SNP uncertainty: (a) The average of the series is not equal to percentile 50, and bimodality conditions may exist. (b) The volatility and kurtosis in the random variables do not have a symmetrical shape. Therefore, the movements on the right side of the mean should be treated differently from those on the left. (c) Extreme events are not limited to some variables and can be more common than intuition suggests. (d) The SNP assumption does not compete with normality; it completes it. A normal distributed variable should be described by an SNP distribution. And (e) The valuation of derivative products on electricity, as well as their use for the structuring of portfolios, may be more appropriate when considering SNP-type distributions.

Risk management in electricity markets should be able to improve the analysis with the support of tools that are not limited to the assumption of normality. These tools should manage to measure the effects of asymmetry, kurtosis and also higher order moments in in probability distributions. The variables of the electrical market present extreme events in an asymmetrical manner; for that reason, risk indicators that separate positive from negative variations in the series are necessary. The exploration of techniques that have been developed in the SNP statistics field when modeling the electricity markets should keep going.

Conclusiones finales

Esta tesis, complementa la literatura existente acerca del análisis de riesgos en mercados de electricidad, proponiendo el uso de una herramienta flexible que permite capturar el sesgo, la curtosis y momentos de orden superior en las componentes inciertas de las variables que afectan a los mercados eléctricos, como la demanda de energía, los aportes hidrológicos, la generación de electricidad y el precio spot. Para ello se propone generalizar el supuesto de normalidad, tradicionalmente utilizado para describir la incertidumbre propia de estos mercados, por funciones de densidad de probabilidad definidas en términos de una expansión de Gram-Charlier finita. Este 'enfoque semi-noparamétrico' (SNP) se ha utilizado con éxito para extender la no normalidad de numerosos fenómenos, pero nunca a la descripción de los mercados eléctricos. Esta problemática se aborda a través de los capítulos (i) "Incertidumbre en Mercados de Electricidad: Enfoque semi-noparamétrico", (ii) "Modelo de precio spot de energía eléctrica con cambio de régimen y distribuciones semi-noparamétricas" y (iii) "Cobertura en Mercados de Electricidad ante Condiciones de Sesgo y Leptocurtosis". Como caso de estudio, se considera el mercado eléctrico colombiano.

Se encuentra, de forma novedosa, que una distribución semi-noparamética -SNP que utiliza expansiones de Gram-Charlier logra un mejor ajuste para algunas de las series del mercado eléctrico colombiano respecto a la distribución normal. Las variables analizadas son la demanda de energía eléctrica, el precio spot, los aportes hidrológicos agregados del sistema, el índice Niño -ONI y las series de aportes hidrológicos de los ríos: Nare, Salvajina, Guavio y San Carlos. En estas series se presenta de forma generalizada una condición de leptocurtosis y sesgo positvo. El supuesto de normalidad limita la modelización de la incertidumbre en los mercados de energía eléctrica. Este resultado hace conveniente que en trabajos futuros se suponga que la incertidumbre es generada por una función densidad de probabilidad de tipo –SNP, de la cual la normal es un caso particular.

Se propone un proceso estocástico, con componente de reversión a la media y cambios de régimen, para representar la dinámica del precio spot de energía y su forma logarítmica. Se considera para esto la inclusión de tres componentes, una determinística, otra de reversión a la media y otra de cambio de régimen. La distorsión de corto plazo de la componente de reversión a la media y de cambios de régimen, es representada por distribuciones de tipo SNP con una función de densidad de probabilidad en términos de expansiones de Gram-Charlier finitas, a diferencia de trabajos previos donde esta tarea se realiza con procesos gaussianos. La mayor contribución de este trabajo a la comunidad científica corresponde a la conjunción de una modelización con cambio de régimen en términos no solo de media y desviación estándar sino también de sesgo, curtosis y momentos de orden superior. Haciendo uso de simulación de Montecarlo, se encuentra que el modelo propuesto logra capturar los momentos de la serie de precio spot histórica y que su desempeño es más adecuado cuando se modela el logaritmo natural de la serie.

La propuesta de un modelo de precio spot considera una componente de cambios de régimen binaria, donde la probabilidad de transición es función del tiempo transcurrido en cada régimen. Esta representación permite considerar eventos que modifican el precio spot de energía durante uno o varios periodos consecutivos y de forma persistente, como es el caso de la ocurrencia del fenómeno de El Niño en el mercado colombiano, donde la probabilidad de que el fenómeno aparezca luego de un número determinado de periodos es diferente a la probabilidad de que el fenómeno se extinga. Este modelo de cambio de régimen permite la modificación del precio spot en las componentes determinística y aleatoria conforme el comportamiento de la muestra, una generalización tal que puede ser explorada en otros mercados, no solo de electricidad.

En este trabajo, además, se propone una estrategia de cobertura estática para generadores de energía eléctrica que desean cubrir su exposición a riesgo de mercado, mediante el uso de contratos forward que contienen una prima de riesgo en su valoración. Para tal fin y considerando los resultados hallados en el transcurso de esta Tesis, se considera que el precio spot y la generación de energía distribuyen como una función SNP -Semi-noparamétrica bivariada en términos de una expansión Gram-

Charlier, permitiendo la modelación no solo de la media, la varianza y su correlación sino también el sesgo, la curtosis y momentos de orden superior. Se recurre a simulación de Montecarlo para encontrar el comportamiento de los indicadores de riesgo para el ingreso neto de venta de energía: desviación estándar, valor en riesgo -VaR y valor en riesgo condicional -CVaR. El principal aporte de este trabajo al análisis de los mercados de energía eléctrica es la estructuración de un portafolio de energía que no requiere supuesto de normalidad en precio y generación, cuya aplicación puede ser extendida a otros mercados de energía y bienes primarios.

Entes de planeación, regulación, control y agentes que realizan transacciones de compra y venta, pueden utilizar estos resultados con el objetivo de mejorar la forma como miden los riesgos, gestionan su portafolio y definen la expansión del sistema. Las actividades relacionadas con la planeación deben considerar los impactos que produce la aparición de eventos extremos en términos de probabilidad, impacto y duración. Además, se ha encontrado que conclusiones bajo el enfoque SNP pueden diferir al asumir normalidad en las componentes inciertas; mantener el paradigma de la normalidad en la industria eléctrica llevará el mercado a sistemáticamente tomar decisiones erradas, al ignorar condiciones de sesgo, curtosis y momentos de orden superior. La sostenibilidad de los mercados eléctricos dependerá de que se apropien los métodos más adecuados a la toma de decisiones; son los organismos de regulación, supervisión y control los llamados a promover la implementación de las mejores herramientas en aras de garantizar la sostenibilidad de este sector.

En la medida que los cambio de régimen, para el caso de Colombia logrados por la aparición del fenómeno de El Niño en sus diferentes categorías, afecten en mayor medida tanto en niveles de expectativa como e incertidumbre, los agentes que intervienen en la formación de precios de corto y largo plazo deberán involucrar los riesgos asumidos en el precio que se traslada a los usuarios. La expansión de los sistemas no solo debe asegurar el abastecimiento, precios de largo plazo acordes con las capacidades de pago o necesidades de los usuarios sino también los niveles de riesgo, sistemático e idiosincrático, que involucren costos ocultos o revelados que pongan en riesgo las condiciones de recuperación de los capitales invertidos o los objetivos de desarrollo y bienestar social. El modelo acá propuesto aporta a la cuantificación de los posibles impactos sobre los flujo de caja de todos los participantes del mercado, en corto, mediano y largo plazo.

Los profesionales en esta materia deberán tener en cuenta ciertas condiciones para el tratamiento de proyecciones determinísticas y estocásticas que pueden ser capturadas si se parte del supuesto de una incertidumbre de tipo semi-noparamétrica: a) el promedio de las series no es igual al percentil 50 y es posible que se presenten condiciones de bimodalidad; b) la volatilidad y la curtosis en las variables aleatorias no se presentan de forma simétrica. De modo que, los movimientos de la derecha de la media deberán tratarse diferente respecto a los de la izquierda; c) los eventos extremos no son exclusivos de algunas variables y pueden ser más comunes de lo que dicta la intuición; d) el supuesto SNP no compite con la normalidad, la complementa, una variable normal puede ser representada por una distribución de tipo SNP y e) la valoración de productos derivados sobre electricidad, así como su uso para la estructuración de portafolios, pueden ser más adecuados al considerar distribuciones de tipo SNP.

La gestión de riesgos en mercados eléctricos debe procurar mejorar los análisis con el apoyo de herramientas que no se limiten al supuesto de la normalidad. Estas herramientas deben estar en capacidad de capturar los efectos de la asimetría, curtosis e incluso momentos de orden superior en las distribuciones de probabilidad. Las variables de mercado eléctrico evidencian eventos extremos de forma asimétrica por lo que se requieren indicadores de riesgo que separen variaciones en sentido positivo de los negativos de las series. Se debe continuar explorando técnicas que se han desarrollado en el campo de la estadística semi-noparamétrica para la modelización de los mercados de energía eléctrica.