



Financial Security in the Electricity Market: An Approach to Minimize Commercial Counterparties' Risks

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ABSTRACT

The risk management mechanisms, safeguards, and guarantee schemes adopted in the Brazilian electricity market (BEM) have been insufficient to prevent systemic default. To manage this fragility, this study posits that BEM regulation should be modernized according to the principles of prudential risk that are followed by the world's most critical financial systems (Basel Accord). The study employs a Minskyian approach to identify the financial risks involved in negotiating, registering, and settling contracts in the BEM. We also propose a model to assess and anticipate the evolution of energy trading agents' market risks in Brazil for different forward spot price curves and bilateral trading prices scenarios. The model emulates agents' expected trading behavior referencing historical microdata provided by the regulators for all market participants. We divide the companies into three groups of "personas," based on the observed behavior of market agents to emulate real trading behavior in a virtual environment under simulated bilateral price trajectories and spot price forward curves. The model produces significant results for addressing traders' bilateral risks. From this perspective, we identify previous stress circumstances and increased systemic risk, which can help regulators to prevent "domino effects." The BEM faced credit difficulties at the end of 2000 and the beginning of 2001. We reproduce this real insolvency in the virtual environment, and the results demonstrate that this approach would be an effective tool to predict the situation at least 6 months before the involved agents' default, representing one of the main results of the project: predictability.

Keywords: Financial Security, Electricity Market, Commercial Counterparties' Risks

JEL Classifications: G28, G32

1. INTRODUCTION

Business risk is the financial exposure of a firm to any factor that may negatively affect its profits or lead to insolvency. Some risks may be caused by a company's internal lack of management when navigating adverse circumstances. However, some hard-to-hedge risks may also arise from the external environment, among which financial motives are one of the most significant sources. Most risks will affect an economic unit's cash flow and may jeopardize its capability to pay debts on time.

If market participants can absorb the losses of a particularly severe financial shock, businesses will continue as usual; however,

depending on the de-faulter's economic relevance, a single event could trigger a wave of bankruptcies. This new wave of insolvencies and financial losses may subsequently compromise many other participants' ability to continue paying their obligations on time. If markets stop functioning correctly and liquidity is dramatically reduced, this may lead to a crash, which is the worst-case scenario described by Hyman Minsky's Financial Instability Hypothesis (Minsky, 1986).

The regulation of trading operations in the Brazilian electricity market (BEM) is inefficient and inadequate. The main reason is the absence of a cap on the value of future contracts held by individual firms. Another critical factor is the high electricity spot price

volatility that econometric models set. Therefore, aggressive firms' net exposure may rapidly rise in a very short period, resulting in unexpected defaults and insolvencies (Castro and Brandão, 2019). As individual portfolios are not open to regulators, they are unable to evaluate the risk held by traders and consolidate this data to evaluate the market's systemic risk.

Additionally, the information on some traders' balance sheets is unreliable. The market's stability depends on the credit limits that companies grant to one another to manage their bilateral exposure. Therefore, as happened recently, the default of minor market traders has triggered "domino effects."

Brazilian electricity regulators are aware of these challenges and called a public audience to debate enacting new rules to reduce financial fragility in the BEM (Public Audience 51 from 2022). Their initial proposition is to introduce regulations that financial institutions must follow. The debate was inspired by the prudential regulations applied by central banks worldwide, as systematized by the Basel Accords.

To address the fragility of trading in the BEM, the University of São Paulo, MRTS Engineering Consulting Services, and Navarra Tech, sponsored by CTG Brasil, Câmara de Comercialização de Energia Elétrica (CCEE) (the Brazilian market operator), and Agência Nacional de Energia Elétrica (ANEEL) (the Brazilian regulatory agency) developed a model to simulate the evolution of traders' counterparty risk under current market rules, based on agents' historical behavior, delivered in a "personas" model.

Therefore, we divided agents into three groups according to their risk preferences. The definition of these "personas" references historical data and interviews with CCEE staff. The model projects how the market participants' portfolios interactively react with successive rounds of different short-term price trajectories. In the model, each market participant's exposure changes according to their financial risk preference. The results reveal that the trade behavior trajectory of more aggressive risk-taking firms may trigger a trading path to a systemic crisis in the BEM.

Against this backdrop, this paper has three sections, in addition to this introduction and the conclusions. Section 2 presents the basic concepts of the Minskyian theoretical framework that underpins our investigation of the typical risks of financial transactions' registration, negotiation, and settlement processes.

Section 3 outlines the key characteristics of prudential banking regulations intended to mitigate systemic crises. This can be accomplished by establishing minimum levels of participants' equity proportional to the risks in their portfolios or by defining rigorous criteria for the operation of the so-called Market Infrastructure. These institutions provide services for registering, negotiating, and settling financial assets, enhancing the transparency and security of such transactions.

Section 4 presents the interactive model for market players, discusses the results, and examines the model's application to a real case study based on the real insolvency observed in the

BEM at the end of 2020 and beginning of 2021. We calculate the credit risk of hypothetical portfolios for each participant. The foundational assumption of the model is that traders and regulators can simulate the trajectory of business based on information that companies share with their creditors, and in the case of regulators, on the data of the contracts registered along with the market operator to predict agents' future insolvency that could result in "cascade insolvency effects" in the BEM, and the conclusions are presented in section 5.

This study posits that the BEM's risk management can be enhanced through the gradual adoption of regulations inspired by a framework that is already used in the financial sector. In addition, our results indicate that traders and regulators can use computational models such as that proposed in this study, to assess individual risk strategies and ensure the financial stability of the market.

2. MINSKYIAN APPROACH TO FINANCIAL RISKS: CASH FLOW AND THE SURVIVAL CONSTRAINTS

In a modern economy, all agents must manage money inflow and outflow that is distributed over time. At any given time, each agent has the right to receive cash from other market players in the present and future, based on the credits the agent granted in the past. Agents must also settle payments related to debts owed.

As noted by (Minsky, 2016) "each economic unit, be it a business firm, household, financial institution, or government, is a money-in-money-out device." Therefore, prudent managers continuously make cash flow calculations when faced with uncertain circumstances.

The relevance of cash flow management for modern economies inspired Minsky to introduce the concept of "survival constraint" (Minsky, 2000), which is a calculable limit for each economic agent at any given time, setting a boundary between solvency and insolvency. In this context, the term survival is associated with the severity of the applicable penalties for those who breach this financial restriction (Nielson, 2019; Torres, 2020). From Minsky's perspective, survival constraint is essential for explaining companies' behavior as profit maximization.

The cash flow-based approach has another important implication as it demonstrates that all households, companies, banks, and governments are financially interconnected. Every debt and every payment involve a debtor and a creditor, and a future payer and payee. This interdependence is not the result of the division of labor but inherent to the bilateral nature of payment obligations.

The payment system and the capital market are two vast and relevant networks of people and institutions with bilateral relations that are linked by various "financial pipe-lines" (Manmohan, 2014). Within this vast network, each economic agent manages financial assets and survival constraint, considering different microeconomic risks.

Among the inherent risks, three are the most important (Bank for International Settlements, 2012). The first is credit or counterparty risk, which refers to the possibility that a debtor cannot settle its obligations within the system at maturity or at any future time. The second is market risk, which is the impact of unexpected variation in the value of the underlying asset or index that serves as the reference for one of the counterparties' positions on the value of a financial obligation. In addition, volatility in financial asset and commodity prices and exchange or interest rates may cause this kind of volatility. The third is liquidity risk, which refers to the hypothesis that a counterparty does not settle an obligation on its maturity date but may eventually be able to settle it at some point in the future. This attribute is associated with the satisfactory functioning of specific markets and depends on the secure and stable execution of asset purchases and sales.

In the following section, we briefly present the regulatory framework developed by the Bank of International Settlements to mitigate the risks of systemic crises in the international financial system.

3. PRUDENTIAL REGULATION AND PAYMENT SYSTEMS: LESSONS FOR BRAZIL'S ELECTRICITY SECTOR

Since the liberalization process began in the 1990s, the BEM has faced several financial crises, one of the most significant of which occurred in 2020. This shock was attributable to widespread defaults after unexpectedly high spot prices related to the unusually dry summer season of 2019/2020 when hydropower plants are generally expected to experience the highest inflows of the year. Hydrological risk had been poorly hedged, and weaknesses in the existing contractual mechanisms led to legal disputes. As a result, the energy market froze.

These fragilities are attributable to financial procedures adopted by the industry. First, agents are not required to register their contracts in pre-approved electronic environments when the transactions are closed. In other words, agents purchase and sell electricity, and the respective contracts may remain stored "in drawers," expecting those agents to have the financial capacity to settle them at maturity.

Any agent can unilaterally cancel their operations in the BEM. In contrast, all transactions in the financial markets are irrevocable and non-retractable from the moment they are finalized, whether over the phone, on open electronic platforms, in private trading rooms, or by other means. Conversely, energy purchase and sale contracts are settled bilaterally without the oversight of a central counterparty. Agents establish credit limits for each client and set guarantee levels based on accounting information and abstract knowledge that can be summarized as, "I know who I'm dealing with" (Machayba and Torres, 2019), which raises the question, do you?

In practice, they typically do not as the information required to establish these trading parameters is incomplete. An agent's total

net exposure corresponds to the sum of the bilateral exposures with each counterparty. There is no proportional relationship between each agent's net equity and the risks they assume. Leveraged positions are only known when it is already too late.

In a way, the challenges faced by agents operating in the BEM are like those that plagued the Brazilian financial market until the mid-1990s. However, the modernization of Brazil's Banking and Capital Market regulations completely altered the landscape. Two noteworthy regulatory innovations were introduced into the financial markets: (i) the adherence to the principles of the Basel Accord and (ii) the adoption of principles to build robust payment systems (Zeidan, 2019).

The key perspective in these innovations is that financial transactions represent an interconnected chain of commitments. In this financial network, the effects of one participant's default due to an inability to manage cash flow can be amplified by several other economic agents through payment systems. This infrastructure connects people, companies, banks, and authorities into a single system that provides payments, contract settlements, and asset ownership transfer services.

Contemporary financial safeguards that are intended to prevent market participants from becoming unable to meet their obligations have been gradually implemented in the international financial system, enabling institutions to progressively adapt to new financial, technological, and governance requirements. In this regard, the accumulated experience of central banks from various jurisdictions can inspire the development of a roadmap to regulatory reform that will increase the security of financial transactions conducted by trading agents in the BEM (ANEEL, 2022).

In this context, the computational model that we present in the following section seeks to overcome the lack of information about each agent's exposure. As such, the algorithms used emulate trading agents' (or personas) portfolios based on their performance profiles, which we classify based on information about contracts registered at CCEE, which is responsible for reconciling the differences between each participant's purchased and sold positions.

4. PORTFOLIO SIMULATION: METHODOLOGY AND USE OF RISK ASSESSMENT

This section describes the computational model developed to simulate contract portfolios and assess commercial counterparts and market risks. We explore the model's application within the free-market context and present its methodology in Sections 4.1 and b. Section 0 presents a specific didactic case study to validate the model and make its potential application more understandable. This case study emulates the real situation faced by the Brazilian Electricity Market by 2019, when the default of agents drove the whole market to a "domino effect" and exposed the commercial safeguards fragility in the short-term Brazilian electricity market.

4.1. Motivation

The lack of reliable and detailed information available to market operators about agents' exposure in the BEM significantly limits the transparency and efficiency of negotiations, which increases transactions costs. Because of this information gap, we were motivated to develop a dynamic agent behavior model that simulates interactions and exposures in the BEM in a more realistic way. The model provides a more accurate basis for simulations, accounting, and evaluations of agents' exposure in bilateral transactions and vis-à-vis the centralized clearing of the short-term market driven by the Brazilian market operator (CCEE).

The starting point for the model's development is an empirical survey about the behavior of specific agents in the real market situations. This survey was conducted by the Brazilian market operator (CCEE) that identified the main characteristics of specific energy trading agents, based on their real behavior. Until this survey, no other formal classification or systematic recognition of these agents' profile had been developed in the BEM. The variables observed range from the size and volume of energy traded to structural considerations such as shareholder composition and (short- or long-term) trading profiles.

The lack of transaction public information is a structural problem. Not even CCEE has full access to this sort of information, including historical data, since its accounting system only records contracts with generic volumes of energy between parties and counterparties that are usually defined for long periods, but are not firm (CCEE, 2021). Connections between agents are largely informal and unrepresentative of reality as they are only updated at the time of short-run spot market clearing, with no indication of the bilateral whole market and commercial connections, only indicating trades in which they participated directly, although some trading platforms operate bilateral contracting, they are not used by the whole market (Aneel, 2022; CCEE, 2022).

In the free market each agent considers a different forward price curve to support their own contracting structure. These individual curves are based on an expected spot price forward curve, resulting from the periodic compilation of energy price quotations, which naturally converge toward the difference settlement price (PLD) at the time of de-livery. This convergence stems from the intrinsic nature of forward contracts, which involve future commitments with prices fixed in advance, where uncertainty decreases as the delivery date approaches. Any significant divergence between the forward price and the PLD close to the delivery period raises arbitrage opportunities, generating market pressure for price alignment.

Based on a historical analysis of the trajectories of successive forward market curves, we constructed individualized forward curves for each agent using observed patterns and specific heuristics. These heuristics simulate different levels of knowledge, systematic bias (higher or lower expectations), variations in the speed of response to market changes (anticipation or delay) and include random noise and gradual drifts in future projections. This methodology enables us to capture the diversity of perceptions among agents in a detailed and realistic way, strengthening the analysis of behavior and decisions in different economic scenarios and stress conditions. Moreover, it allows us to generate a consistent set of individualized forward curves from a given reference scenario forecast, which we use later in the case study.

4.2. Methodology

We constructed the model based on a set of personas derived from real agents' historical contracting data as held by the CCEE. Each persona is defined according to real agent characteristics and trading profiles, including typical counterparties, average traded energy volume, social capital, and exposure to the short-term market. This includes whether they buy energy from generators or traders, the usual contract durations (short- or long-term), and their willingness to absorb contract differences settled at the spot price by the market operator.

The combination of these characteristics with attributes of the dynamic agent model such as average traded energy amount from historical observations, financial leverage inferred from social capital, and historical short-term market activity provides insight into whether an agent behaves aggressively or conservatively, acts as a liquidity provider in smaller short-term transactions, or engages in fewer but larger trades with selected counterparties. Table 1 presents the personas defined in this study based on the available BEM dataset from the CCEE.

The interactions between different agents can be observed in Figure 1, which illustrates the configuration of the study case and highlights the actions of the personas constructed to represent the BEM trading system.

The dynamic agent model is the first stage of the risk assessment model, where the characteristics and commercial relationships are parameterized, and the potential trading set among the personas is constructed (Figure 2). Given the amount of social capital (in \$), leverage, which represents how much the agent is willing to commit, is the ceiling for buying and selling energy, and the initial margin corresponds to the percentage of the price difference between the offer and the fair price from the agent's perspective. For each of these characteristics, we added weights

Table 1: Persona definitions

	Social Capital (\$)	Energy Amount (MWavg)	Age	Purchase Portfolio	Sales Portfolio	Short/Long-Term	Connectivity
Big Groups	>15 million	500	5	90% generators	50% consumers	10% ST 90% LT	low (1-10)
Central	>15 million	200	10-20	10% traders	50% traders	60% ST 40% LT	very high (30-100)
Pattern	<5 million	30-50	10	50% generators	50% consumers	50% ST 50% ST	high (10-50)

Figure 1: Didactic case study based on real situation faced by the Brazilian electricity market

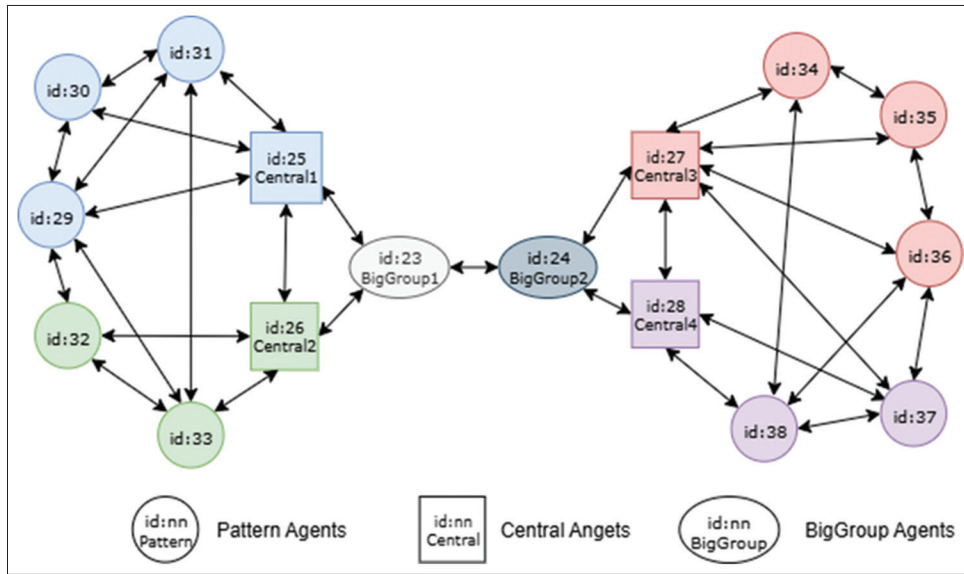
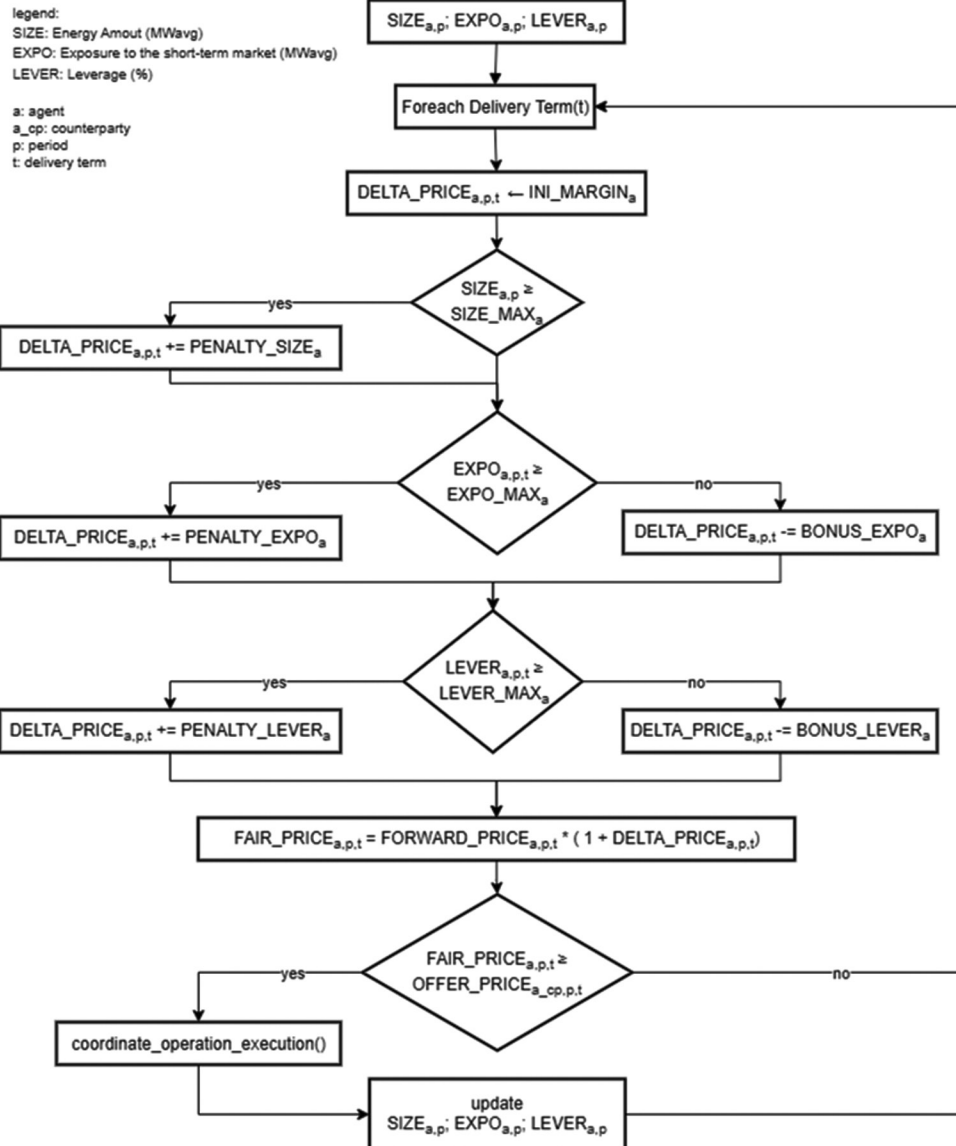


Figure 2: Agent decision make flow



to each control variable representing the real price delta, which sometimes increases the margin the agent imposed to close a deal and sometimes reduces this delta, facilitating the execution of the operation.

Finally, as each agent has their own assumptions regarding future prices based on an expected reference forward curve, scenarios for each agent throughout the simulation are defined based on parameters that translate the agent's possible predictions in terms of bias toward higher or lower prices and whether prices will be delayed or anticipated along the reference curve. The closer an agent's expectation aligns with the "real" forward curve, the more informed that agent is. This dynamic allows us to construct simulations between agents of different sizes, aggressiveness levels, and forecasting capabilities. Despite all favorable characteristics, a 100% success rate is not guaranteed as the randomness of negotiations might cause certain agents to eventually not secure the best deals. This ensures that the computational model is based on the real world.

To simulate a decentralized over-the-counter energy market, we considered a daily trading period or the end of a trading session. At the end of each day, negotiations are processed to obtain the realized bilateral margin up to that day. We calculated the mark-to-market ratio of each contract between agents using the reference forward price. The mark-to-market ratio of contracts enables the calculation of how much financial collateral each agent should allocate at the end of each day, based on the reference forward curve (Figure 3).

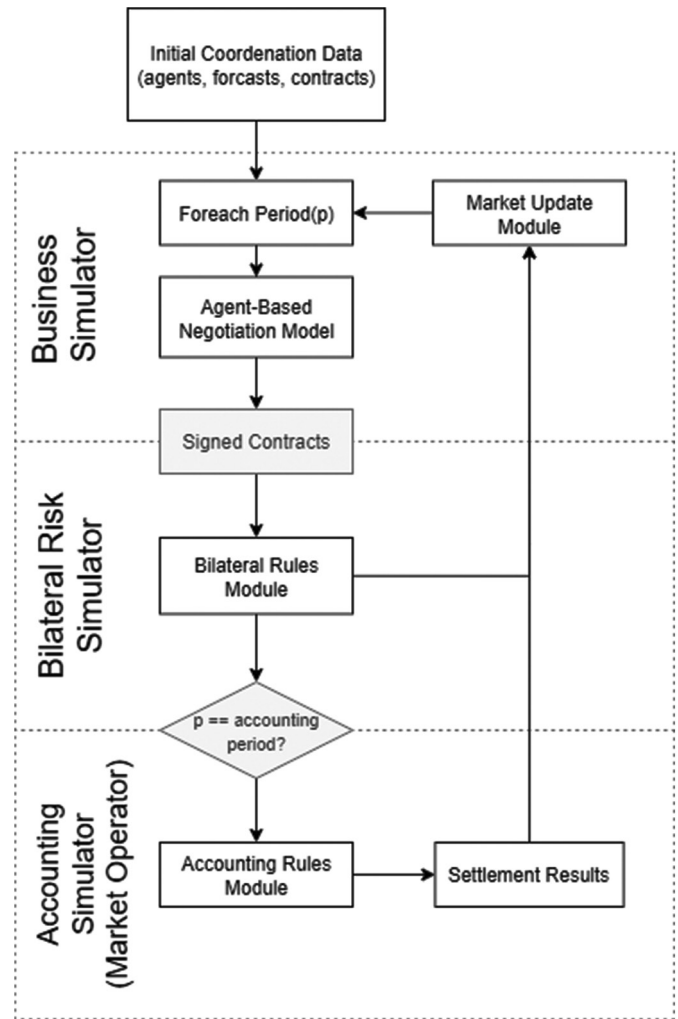
The main problem is that the actual execution of negotiations occurs after the consumption of energy in a monthly cycle, following the delivery of the product in a poorly regulated market. In other words, consumed energy measurement allows the registration of new contracts for the previous period for several business days of the following month. Bilateral payments are made, and records are finalized in the CCEE after verifying the financial transactions between agents.

Once the accounting process for the previous month begins, it is possible to project the financial amount paid or received by each agent based on short-term contractual exposure. The net market position at the end of the trading period is taken as each market agent's initial position in the next trading period. Consequently, the results obtained by each agent over the entire analysis horizon accumulate, reflecting their trading strategies.

For example, in the BEM, the settlement of financial exposure for a given month only occurs in the following month, usually about 1 week after the final accounting, which occurs 20 business days after energy delivery.

To reasonably approximate events, bilateral payments are made at the end of M0, and the financial exposure related to the short-term market in M0 remains open throughout M1. Therefore, for each agent, the open margin in each trading period (p) during M1 carries short-term market exposure from month M0 and does not consider any pending contract settlements in the bilateral market realized up to M0 as follows:

Figure 3: Simulation flow



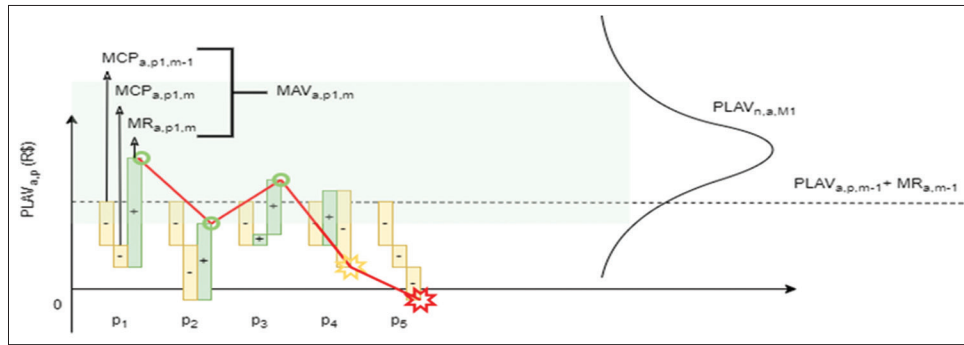
$$MA_{(a,p,m)} = MCP_{(a,p,m-1)} + MCP_{(a,p,m)} + MR_{(a,p,m)} \tag{1}$$

The motivation for this approach stems from directives regarding the creation of a Pre-Established Individual Financial Guarantee, as outlined in Technical Note 6735/21, which foresees the periodic submission of information to the CCEE, which is enough for calculating agents' short-term exposure (MCP).

The proposed approach uses all data beyond the MCP calculation for months M0 and M1, including the realized margin (MR) in monitoring. Without delving into the regulatory and operational considerations, the margin marking between agents also entails financial costs and systemic risk, both of which are considered in the monthly assessments, although they are exogenous to the operations within the chamber. This factor allows the application of financial costs for bilateral collateral contributions and differential risk allocation between agents based on their risk profiles.

The open margin (MA) identifies debtor agents' payment capacity in the MCP by considering bilateral negotiations at the end of the current month (M1). The bilateral negotiations of M1 and the MCP of M0 are settled during the transition from month M1 to M2.

Figure 4: Daily evolution of current adjustment net worth



The MCP of M1 at the end of the month becomes the MCP of M0 for the following month, and so on, chaining the chronology of negotiations and settlements according to the simulated bilateral relationships and resulting exposures in the MCP.

A cash flow adjustment is necessary to accommodate the order of events; therefore, the adjusted net equity (PLA) is obtained using Equation (2). Figure 4 illustrates the evolution of the results for an agent who, following their trading strategies, exhibits negative net equity in the fifth simulation period (p5). Therefore, the proposed methodology enables one agent to preview potential insolvency circumstances by considering their pecuniary obligations in bilateral relationships and short-term markets throughout the analysis horizon. This makes our proposed model a powerful tool for assessing counterparties' market risks.

$$PLA_{(a, m + 1)} = PLA_{(a, p, m)} + MR_{(a, p, m)} + MCP_{(a, p, m-1)}; \{p: \text{last day of } m\} \quad (2)$$

Operationalizing real-time monitoring involves processing information at the end of period p, gathering the new contracts executed in this period over the business days of a specific month. However, the qualification of this monitoring to indicate whether a particular agent is operating as intended and how much risk one agent represents to the market is missing from this model.

We constructed a “what if” scenario for such qualifications. Will the agent survive if the forward curve follows this or another trajectory? This approach eliminates the need to predict future events. Instead, it is possible to recognize the similarity of trends in advance when observing the realized forward curve, which aids in the selection of agents with a higher probability of default if the price curve experiences an abrupt rise or fall.

The intent of this scenario-based analysis is to evaluate agents' default risk if the market trends toward a certain high or low forward price scenario. Therefore, real-time simulation requires a step in which a sample of possible scenarios is simulated (typically around 100 random repetitions) to construct a meaningful result sample. An example of visualizing the distribution of these results is presented in Figure 4, where autonomous agents' simulations are plotted until the end of the monthly cycle, and the day-to-day evolution of negotiations is tracked on the left-hand side.

Notably, negotiations between agents are randomly performed, representing the trading environment among commercial agents. Regardless of each agent's perspective and depending on the order of analysis of a proposal, the decision to close a deal alters the agent's exposure, leverage, and portfolio, thereby affecting the next business decision. We repeated the simulations to obtain more significant results, making the statistical analysis of each agent's financial outcomes more robust at the end of a period.

To align real-time monitoring, we adapted the resultant net equity (PLR) variable to the adjusted net equity (PLA). The same concepts applied to the result distribution were maintained and reorganized within the current M0 + M1 horizon in Equation (3) and subsequent periods M2–M6, as shown in Equation (4).

$$PLAV_{n,a} = PL_a + MR_{n,a,m-1} + MAV_{n,a,m} \quad (3)$$

$$PLAS_{n,a} = \sum_{m=2}^6 PLAS_{n,a,m-1} + MR_{n,a,m-1} + MAV_{n,a,m} \quad (4)$$

4.3. Didactic Specific Case Study Based on a Real Case

This section presents the application of the proposed methodology and related computational model to a specific case study considering the BEM regulatory framework. This case study presents an illustration to make the model more understandable for easing the reproduction of the achieved results and is based upon a real circumstance faced by the BEM at the end of 2020.

To construct a consistent case study, we adopted the combined capacity of all trading agents as 2 times the system demand, simulating a situation in which an exceeding offer to meet the system demand occurs. This circumstance is sometimes encountered in the real operation of the system; for instance, when uncontrollable generation from wind and solar plants exceed expectations (U.S. Department of Energy, 2017). We set a limit of up to 120 MWavg for the monthly growth in each modeled agent's trading capacity. A controlled trading capacity penalty was triggered if the available trading proposal was at least 60% better than the agent's reference price. This penalty simulates agents' aversion to excessive exposure in a single product, particularly if the product is available at an “out of market” price.

It is important to note that we individualized each agent's strategy according to the agent's profile, which was set according to their own related persona. Therefore, an unattractive contract offer for one agent might appeal to another who has different expectations

of the evolution of the forward price curve and differing risk perception.

At the beginning of the simulations, all agents were considered to have zero positions, simulating a scenario with no prior negotiations between any agents. This requires a preparatory simulation to establish a plausible initial condition for starting contracts using observed forward curves as references to construct each agent's individualized forward curves.

For this simulation, zero contracting was assumed from September 15, 2020 to February 28, 2021. The forward curve matrix was based on publicly available data from the Brazilian Energy Trading Exchange (BBCE) website. The final contracting balance for this period was adopted as the initial contract for two subsequent simulations.

The case study configuration focused on simulating March 2021. Using the forward curve from March 1, we constructed two prospective scenarios called Abrupt High and Gentle High. In the first scenario, energy prices increased by \$10.00/MWh in March. In the second scenario, a gradual increase of \$5.00/MWh was set for the same period.

The relationship between the prospective scenarios and the actual prices of forward contracts for the month of March in Figure 5 shows a typical circumstance in the context of high volatility in which abrupt variations at the end of the period significantly impact the average monthly price. Agent 32 represents a standard profile whose perception of forward curves, according to input data, tends to be below the actually observed curve. As the update of individual curves remain below the prospective scenarios, the margin obtained by agent 32 is also lower than expected, which is consistent with the assumptions adopted. The average expected margin values for each prospective scenario are presented above the graph, with a range delimited between the standard deviations of each scenario and with their respective histograms in the graph to the right, which indicates the dispersion of possible margins to be consummated by energy delivery. However, the price jump beyond the established projections has a significant impact on its margin due to $MCP_{a,m}$, as illustrated in Figure 6, which shows the agent's current net equity.

Using daily projected open net equity provides a consistent measure of an agent's financial health, independent of intraday margin fluctuations. This measure normalizes the expected results over the aggregate 5-month net equity (M2–M6) horizon as if a margin call had been triggered (Figure 7). Regardless of the trading strategy, net equity reflects an agent's ability to withstand market stress provided that only a limited portion of the margin is allocated to the short-term market ($MCP_{a,p,m}$) and the bilateral margin ($MR_{a,p,m}$) remains aligned with available resources. While the projected trends indicate a risk of insolvency in the subsequent period, agents benefit from a planning window during which to rebalance their positions; however, temporary liquidity shortages or virtual defaults may occur if market prices follow the projected scenarios. This means the agent's resources are incompatible with the trading volume

Figure 5: Forecasted prices

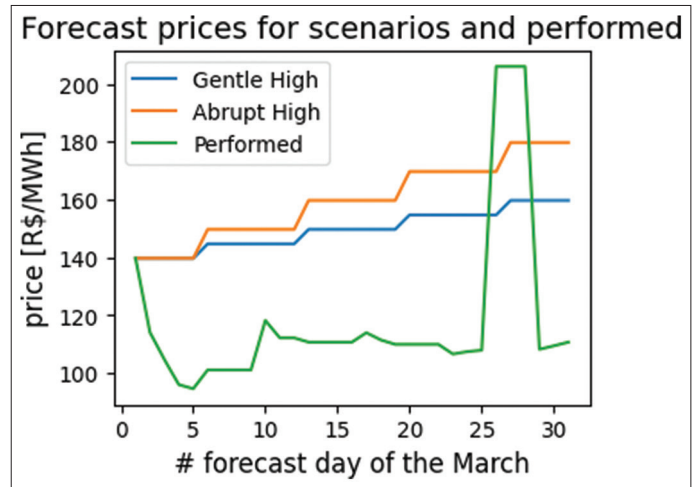


Figure 6: Current adjusted net equity

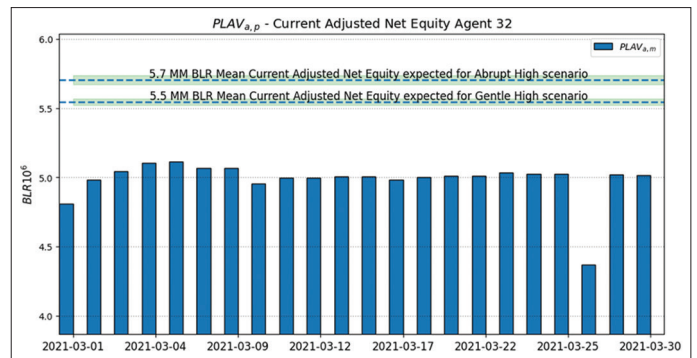
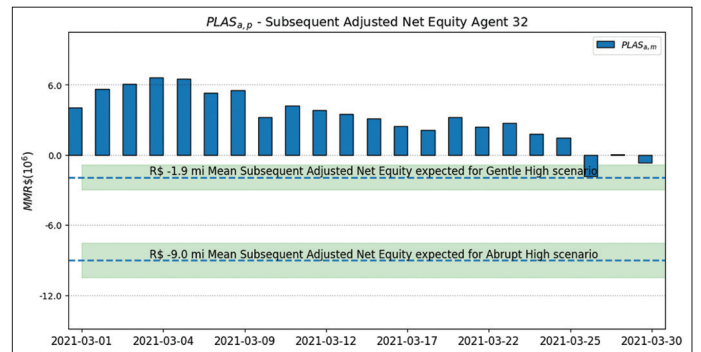


Figure 7: Subsequence adjusted net equity



demanded by the market operator, increased equity, or reduced energy trading volume.

Analysis based on agents' complete monitoring information enables more precise quantification of their behavior and portfolio strategies. Agent 32 has a high degree of exposure to the short-term market, with a disproportionate relationship between the payments to be settled and the bilateral margins contracted, resulting in a significant compression of the final margin. This pattern of action indicates an aggressive profile in which the agent seeks to maximize bilateral margins, deliberately assuming high exposure to the spot price, subject to unmanageable risks. Despite this, the agent in question has sufficient financial support

to absorb any losses, guaranteeing continuity even in ad-verse contexts.

From an operational perspective, implementing the centralized calculation of the monitoring indicators proposed here by a market operator does not necessarily require unrestricted information sharing. Although valid arguments can be made regarding the privacy of trading strategies, contract values, and other sensitive data, the proposed model can be implemented in a decentralized manner. The institutions responsible for registering contracts between counterparties can provide aggregated financial information on bi-lateral margins and partial exposure to the spot price, enabling the CCEE to monitor agents daily using centralized data from these institutions.

In addition to the agents themselves, financial institutions could also access market assessments of registered contracts to periodically update credit limits associated with each agent's portfolio, reducing the need for margin calls. Credit analysis should also consider the effects of margin compression and the potential reduction in contracts between counterparties, which are factors that can influence the requirement of financial guarantees in the system.

5. CONCLUSION

The BEM is expected to adopt some of the Basel Accord principles soon to enhance the security of trading operations as in several other countries where the market players must provide guarantees before registering a bilateral contract and the market operator has full knowledge of the bilateral commercial relations between agents. These principles will guide the registration, negotiation, and settlement processes in the same way as they have been successfully applied to financial sectors and electricity markets worldwide.

The adoption of these principles in the financial market was a lengthy process that entailed reviewing a series of established negotiation practices between institutions during a period marked by recurring economic shocks. Reforms in Brazil's financial system after 1994 introduced greater transparency and security for market participants. While this initially led to some concentration, this phenomenon was gradually offset by the entry of new actors, particularly nonresidents who significantly expanded liquidity in the segment. The BEM is also expected to choose this path, with a prerequisite for gradual implementation of such changes requiring that all operations forming trading agents' portfolios must be

registered in a secure environment at the exact moment they are negotiated. Only using this approach can regulators accurately assess the risk magnitude of each participant's portfolio and adopt measures to prevent the assumption of excessive or financially incompatible risks.

Timely information and systems such as those developed within the scope of this R&D project, are essential for the BEM to adopt practices that bolster greater market resilience and security. The model developed in this study supports the regulatory evolution of Brazil's electricity trading environment by identifying risks that are currently imbedded in negotiations.

This research and proposed model are helpful tools to enhance the BEM security environment for agents' application to emulate unknown bilateral contracting between other agents that may impact their own results. Applying our methodology can reduce agents' market risk.

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