A Blockchain Game in Eurasian Energy Trading

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Outline:

1) Topic & Motivation
2) Research Question (s), Theory, and Research Methods
3) Models & Data
4) Results – Game Theory
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1) Research Motivation

- Topic: Looking at Peer-2-Peer (P2P) Energy Trading in a Macro context via Blockchain Technology using Game Theory to see the strategy choices institutionally of the eventual traders/players
- Initiate a energy trading mechanism on a macro scale with P2P energy trading
- Innovation of a new technology, i.e. Blockchain technology
- Applying the study of New Institutional Economics (NIE) to a new technology
- Probably the first of its kind research looking at P2P energy trading via Blockchain Technology (BCT) using the methods of NIE and game theory

1) Context: Definitions

- Peer-2-Peer (P2P) Energy Trading: Take the macro definition of P2P in energy trading between macro trading partners

- Blockchain Technology (BCT): a decentralized verification system were the “community” validates each transaction; and the record of the transaction can’t be changed once it is added or created. Hence the term “blockchain” in that new information is added to the “chain” by adding another “block” of information

- BCT could be used as a trust mechanism, which in New Institutional Economics (NIE) is a paramount issue

1) Context:

- This has a potential real-world context in the fact that Germany, a major energy buyer in the European Union, buys a large portion of its natural gas from Russia and Ukraine, which is simulated in the 3-Trader, 2-Strategy game. Thus, the game then becomes more complex with adding the sellers of Norway and the United States into the 5-Trader, 4-Strategy game
- In a past real-world context this could have potentially mitigated the 2006 and 2009 Ukrainian Gas Crises
- Also in context to the development of the Nord Stream 2 gas pipeline
- A way for Russia and the West to check and balance each other, which would build trust

2) Research Question, Theory, and Methods

Research Questions:

What does simulating *n*-player games in a game theoretic context do in helping to describe the actual choices made in a P2P energy trading platform via BCT for a multitude of traders involved?

Aims:

The main aim is to prove convergence of 2 algorithms created via the Nash and Stackelberg equilibria, to create game theory simulations and pricing forecasts using real world data that will create P2P trading strategies via BCT that can be used by actual traders within the market place. This work aims to develop a useful tool to aid researchers.

Objectives:

-The creation of a model by applying New Institutional Economics and behavioural aspects to the study of developing institutions around a P2P trading platform via the BCT in the energy trading international market place.

-Using institutional theory to highlight aspects of

- -the current market scenarios and dynamics,
- -the current traders in place in the P2P market place,
- -current laws and legislation, and
- - *n*-player games

2) Research Methods

Methodology and research design will look at the institutional development in context to P2P energy trading via BCT. Empirical methods will be used and analysis of game theory:

-3 Trader, 2 strategy game theory simulation;

-5 Trader, 4 strategy game theory simulation;

-Analysis of firms at the micro-economic level in these new economy communities;

-Analysis of laws and legal instruments available that are advantageous to both industry and governments in the development pathways process;

-Using the economic theory of New Institutional Economics (NIE) and the New Behavioral Institutional Economic (NBIE) model as the methods of analysis, new implications and insights can be made.

Figure 1: New Behavioural Institutional Economic (NBIE) Model

	The Individual (Entrepreneur)	The Institution (The Firm/Government)
Material	Finance Labor Learning	Location – Business Climate Technology and Infrastructure Resource and Time Availability
Social/ Organizational	Values Attitudes	Regulation and Laws Social norms, ties and beliefs Past Economic Performance

Interrelations in initiated P2P energy trading via BCT; National innovation systems and energy intensive manufacturing

3) Game Theory:

Market Model - Overview

Lets see how this works in a 3-player game and 5-player game

First, we need to define game specifics:

1) the traders within the game
2) the strategies given to each player
3) other environmental variables within the game and
4) the payoff to be received by each player for the combination of strategies that could be chosen by each player.

3) Game Theory:

Case 1: 3 trader P2P energy trade – 2 strategies

- 3 different traders have been considered
- Trader 1 = T1 Seller - Russia
- Trader 2 = T2 Seller - Ukraine
- Trader 3 = T3 Buyer - Germany
- Each player has their own parameters of gains and constraints

3) Game Theory

- **Case 2: 5 trader P2P energy trade – 4 strategies**
- 5 different traders have been considered
- Trader 1 = T1 Seller - Russia
- Trader 2 = T2 Seller - Ukraine
- Trader 3 = T3 Seller - Norway
- Trader 4 = T4 Seller - USA
- Trader 5 = T5 Buyer - Germany
- Each player has their own parameters and constraints

3) Game Theory:

Case 1:

$$\boldsymbol{TE_{Tt} = \Sigma_{i=1}^{2} TE_{Tt} = TE_{1t} + TE_{2t}}$$

- The buyer (Trader 3) will be the one who defines the rules of this certain market, given he/she needs the energy at certain times and certain amounts during the given day, meaning he sets the certain reward and bonus structures and penalties that affect each trader's standing. So, the buyer will define:

- → C_l - Penalty for lateness or unreliability
- → C_r - Bonus for reliability, productivity, and efficiency (euros/Mwh) T3 gives a reward to trader that have a strong footprint with in the Blockchain
- → C - Calculated Price at which T3 buys energy from the other traders.

- A static case study has been taken using the 2 time levels of the game evolving and 3 traders (2 sellers and a buyer) The decision controls of the T3 is defined by C_l, C_r, and C.

3) Game Theory

Case 2:

$$TE_{Tt} = \Sigma_{i=1}^{4} TE_{Tt} = TE_{1t} + TE_{2t} + TE_{3t} + TE_{4t}$$

- The buyer (Trader 5) will be the one who defines the rules of this certain market, given he/she needs the energy at certain times and certain amounts during the given day, meaning he sets the certain reward and bonus structures and penalties that affect each trader’s standing. So, the buyer will define:

- → C_l - Penalty for lateness or unreliability
- → C_r - Bonus for reliability (euros/Mwh). With bonus T5 gives rewards to reliable energy sellers
- → C_p - Bonus for productivity and efficiency (euros/Mwh) T5 gives a reward to traders that have a strong footprint with in the Blockchain
- → C - Calculated Price at which T5 buys energy from the other traders.

- A static case study has been take using the 4 time levels of the game evolving and 5 traders (4 sellers and a buyer). The decision controls of the Trader 5 are defined by C_l, C_r, C_p, C.

3) Game Theory:

3 trader game – Seller Strategies:

- The quality properties of each selling trader are:
- → P_{1o} - Production/operational cost of each MWh for trader *o*
- → P_{2o} - The community impact of trader *o* within the operational matrix of Blockchain from zero to one (0 – 1).

3) Game Theory:

5 trader game - Seller Strategies:

- The quality properties of each selling trader are:

- → P_{1o} - Production/operational cost of each MWh for trader *o*
- → P_{2o} - The community impact of trader *o* within the operational matrix of Blockchain from zero to one (0 – 1).
- → P_{3o} - The economic reliability of the trader *o* within the blockchain (0 – 1).
- → P_{4o} – The social impact of the trader within the blockchain of trader *o* (0 – 1).

4) Game Theory: Main Results

Nash Equilibria:

The Nash Equilibriums may possibly be more than one.

There can be several feasible Nash solutions.

Stackelberg Equilibria:

3-player Game:

Under these constraints, the cost for the leading trader (Trader 3) can be minimized by the Stackelberg equilibrium for the following traders (Traders 1 to 2) (Kakogiannis et al., 2014).

5-player Game:

Under these constraints, the cost for the leading trader (Trader 5) can be minimized by the Stackelberg equilibrium for the following traders (Traders 1 to 4) (Kakogiannis et al., 2014).

The Stackelberg Equilibriums may possibly be more than one.

There can be several feasible Stackelberg solutions.

4) Legal Laws and Norms:

Articles from PA agreement	**Analysis:**
Cooperative approaches (Paragraph 6.1)	The formation of carbon “clubs”, including carbon market clubs; NIE aspect of the institutional creation of certain organizations or firms
Transfers of mitigation outcomes (Paragraphs 6.2-6.3)	International transfers of “mitigation outcomes” which can be produced from any type of mechanism, procedure, or protocol
Mechanism to contribute to mitigation and support sustainable development (SD) (Paragraphs 6.4-6.7)	Used to fulfill the NDC (Nationally Determined Contributions) of another party; Trading can be valid from individual to individual or party to party
Framework for the non-market approaches (Paragraphs 6.8-6.9)	Synergies between various ideas in the agreement, i.e. mitigation, adaption, and a technology transfer. This facilitates coordination of non-market approaches.

Source: United Nations (2015)

5) Limitations:

Limitation:	Analysis:
Production Function	Hard to see the input and output of commodities
Forecasted Scenarios	Likelihood that these scenarios will play out is unforeseeable
Trading confidence	What are the traders basing their trades on?
Pricing Signals and Communication	Small market to analyze as of now
Belief Systems	New trading environment will have to be explored more
Labor = L	Individuals in the production of these trades will have to be defined
Scalability and Usability	Systems will have to be created on a mass scale
Regulation	Very little regulation on a regional and national level
Bounded Rationality	Complexity of the decision-making environment it too large in context to a person's mental abilities
Engineering & Technical Problems	System architecture needs to be fully created

Source: Tushar, (2018)

5) Uncertainties:

Uncertainty:	**Analysis:**
Country to Country comparison	Does not always cover the entire diffusion process; will vary and change
Future Commodity prices	Hard to forecast even the price of oil, etc.
Human behaviour, norms and customs	Changing all the time; highly unpredictable
Substantive uncertainty	Lack of all or complete information that would allow for making decisions with certain outcomes
Procedural uncertainty	Limitations on the computational and cognitive capabilities of the actors/traders to pursue their given objectives, given the information they have to access
Strong uncertainty	The absence of unique, additive and fully reliable probability distributions
Weak uncertainty	Related to Savage's standard expected utility (SEU) theory and risk theory
Ambiguity uncertainty	Uncertainty in relation to probability, thus created by missing information that is relevant to the topic and could be known
Fundamental uncertainty	The possibility of creativity and non-predetermined structural change, or the possible events is not predetermined or knowable *ex ante*, for the future is yet to be created
Hypothetical thinking & information extraction	Researchers and individuals make mistakes based on experience and hints, where individuals have no private information

Source: Dequech, (2006) and Esponda, (2014)

5) Discussion

- Institutions function through their influence on the ends that people pursue (Dequech, 2006).

- This essentially gets to the idea of the commons in the fact that the “core” and the “commons” are both the decision makers. This then gets into the idea of cooperation and the idea of repeated interaction. (Hume, 1739) Through repeated interaction trust is built.

- This gets back to the idea of uncertainty which is linked to the cognitive function of institutions. Institutions reduce complexity in reducing procedural uncertainty and fundamental uncertainty. Through a cognitive function institutions create stability to the way people act, which reduces economic volatility (Dequech, 2006).

- Who guards the guardians. This gets to the notion of do guardians really guard themselves. This gets to notions of moral hazard and community enforcement. Potentially full-scale community monitoring in a P2P energy via BCT environment will have to be enacted, but what does this mean for public and private BCTs. This gets back to the notion of ostracism within the group. Essentially what this gets to is the idea of sustaining cooperation within the group.

5) Next Chapter to Add:

- BCT based governance in context to cryptocurrencies and tokenization calls for a revisited understanding about power and control within the dynamics of organizational behaviour. But an adverse notion is that BCT can create excessive inefficiencies as governance decisions can be made without a central authority. So, it will depend in the future on the degree of decentralization of the BCT-based corporate governance forms (Hsieh et al., 2018).

5) Novelty, Conclusion and Implication/Discussion

- This research shows the difficulty in coming to conclusions about strategy choices and payoffs for individual traders even in these relatively simple strategic games.
- As far as the researcher can see no one else has combined P2P energy trading via BCT in analyzing the technology using the methods of NIE.
- There needs to be consistency across market development
- Markets need to show how this is good for the entrepreneur in the market and market conditions
- A national innovation system needs to be set up to then set up the actual BCT system
- Overall, researchers and NIE need to be more aware of behaviour; social norms and customs; governance and legality; and pricing and incentives surrounding these issues.

5) Further Research and Studies: 4 more years

- CS coding and algorithms, i.e. Python
- Game Theory algorithms and applications (Nash and Stackelberg equilibria, Bayesian networks (i.e. Perfect Bayesian equilibriums (PBE)), Markov Chains, and Pareto method in statistical and mathematical analysis
- Monte Carlo statistical simulations
- BCT without a central authority
- Business models in the practical application of a P2P trading platform via BCT.
- Operational Matrix architecture
- High level interviews with key stakeholders