Investigating the role of social networks in mitigating information asymmetry in economic transactions ⋆

Hantian Zhang[1]

Duke Kunshan University, Kunshan, Jiangsu 215316, China
hz257@duke.edu
LinkedIn

Abstract. This paper addresses the challenges posed by information asymmetry in economic transactions. It explores the potential of social networking as a marketing strategy for businesses, highlighting opportunities for leveraging social media to bridge information gaps. Proposing a novel platform with comprehensive user profiles and a robust information verification system, it integrates social network analysis and information verification to mitigate information asymmetry effectively. Through dynamic updates of trust scores, the platform fosters transparent and trustworthy economic exchanges, facilitating informed decision-making among participants. Moreover, the paper introduces key concepts in game theory such as Nash Equilibrium to enhance understanding of strategic interactions in economic environments.
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Keywords: computational economics · game theory · innovative education · information asymmetry · artificial intelligence

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1 Introduction

The limitations of past frameworks, encapsulated in the inability to address information asymmetry effectively, are illustrated through examples like the second-hand car market, where buyers' lack of information leads to suboptimal outcomes. In many traditional economic models, the adverse selection problem is often illustrated using the example of the used car market, also known as the "lemons problem". In this market, sellers of used cars possess private information about the quality of their vehicles, while buyers have limited ability to ascertain this information. [1] As a result, there is asymmetric information between buyers and sellers, with sellers being better informed about the true quality of their cars.

Recent research underscores the potential of social networking as an integral marketing strategy, particularly for small businesses. As detailed by Vásquez and Escamilla [2] (2014), there exists a significant opportunity to educate small businesses on leveraging social media effectively to bridge information gaps. Considering the role of social networks in mitigating information asymmetry in economic transactions, I propose a platform that leverages the interconnectedness of social networks by employing a sophisticated integration of social network analysis and information verification. Using social network data, it can create comprehensive user profiles that include mutual connections, relationship strength, and historical transaction behaviors. These elements are analyzed to generate dynamic trust scores, which reflect the reliability and credibility of each user based on their network's characteristics and their own transaction history.

In addition to network-based scoring, the platform introduces a robust information verification system that utilizes both crowdsourced feedback and automated cross-verification techniques. Users can rate and verify the information provided by others, which not only enhances the data's reliability but also builds a community-driven validation mechanism. Simultaneously, it employs algorithms to cross-check details of transactions against various external data sources, ensuring the information's accuracy and authenticity. These mechanisms work in tandem to dynamically update trust scores, ensuring they accurately represent the current standing of each user based on the latest available data. This approach allows the platform to effectively mitigate information asymmetry, making economic exchanges more transparent and trustworthy. By integrating social network data into a user-centric platform, it facilitates a more informed and reliable exchange of information between participants.

2 Background

With the rise of AI and complex systems, game environments can become dynamic and adaptive, evolving in real-time based on the actions and interactions of players, both human and artificial. While traditional game theory primarily focuses on rational decision-makers, the integration of AI agents introduces a spectrum of rationality, ranging from purely rational to bounded rationality and even irrational behavior. This diversity in agent behavior requires to develop models that can accommodate and adapt to different levels of rationality, enhancing the realism and applicability of game-theoretic analyses. To better achieve this goal, it is possible to incorporate learning and adaptation mechanisms into game-theoretic models where agents continually update their strategies in response to changing environments and opponent behavior.

In addition, the intersection of AI, GAI, and complex systems with game theory necessitates interdisciplinary approaches that draw from fields such as computer science, cognitive science, psychology, and sociology. By integrating insights and methodologies from diverse disciplines, researchers can develop more comprehensive models of human and artificial decision-making processes within complex socio-technical systems. Meanwhile, though current algorithms have managed to resolve social issues including workers' revenue (Kawaguchi, 2020), the real-world application requires to address the ethical concerns by developing models that account for societal values, equity considerations, and the potential impact of AI-driven decisions on various stakeholders.

By integrating insights from AI, complex systems science, and other relevant disciplines, game theory can continue to evolve as a powerful framework for understanding and analyzing human and artificial behavior in an increasingly interconnected world.

3 An Illustration Example

Google Colab The provided code in google colab conducts a simulation of economic transactions to compare outcomes with and without a proposed platform aimed at mitigating information asymmetry. The code leverages Google Colab and various Python packages such as NumPy, Pandas, NetworkX, and Matplotlib to facilitate data generation, simulation, and visualization.

Initially, synthetic social network data is generated using NetworkX, representing a network of users where nodes denote individuals and edges signify connections between them. Each user is assigned a random trust score, serving as a measure of their credibility within the marketplace.

Two functions are defined to simulate economic transactions: one without the proposed platform and another with it. In both scenarios, transactions occur randomly between buyers and sellers. However, the function simulating transactions with the platform additionally considers whether the seller is verified by the platform, in addition to trust scores.

The simulation runs a fixed number of transactions for each scenario, tracking successful transactions to calculate transaction efficiency. This metric reflects the proportion of successful transactions relative to the total number of transactions simulated.

Finally, the transaction efficiency values for both scenarios are compared and printed. Optionally, the comparison can be visualized using Matplotlib, presenting a bar chart illustrating the transaction efficiency for each scenario.

In summary, the code provides a computational illustration of how the proposed platform affects transaction efficiency, demonstrating its potential to address information asymmetry and improve economic outcomes compared to a baseline scenario without the platform.

A The Pioneers in the History of Game Theory

A.1 Transition from Decision Theory to Game Theory

Pioneered by John von Neumann and Oskar Morgenstern, the journey from decision theory to game theory marked a significant intellectual shift. Their work Theory of Games and Economic Behavior revolutionized the field of economics and more importantly, laid the groundwork for game theory [4].

A.2 Evolution from Pure-Strategy Nash Equilibrium to Mixed-Strategy Nash Equilibrium

John Nash's seminal contributions in the 1950s propelled the evolution of equilibrium concepts within game theory. Initially focusing on pure-strategy Nash equilibrium, Nash's later explorations delved into the realm of mixed strategies (Nash Jr 1950). This transition revolutionized the understanding of equilibrium dynamics, injecting a nuanced understanding of probabilistic decision-making into strategic analyses.

A.3 Differentiation between Non-Cooperative Games and Cooperative Games

The delineation between non-cooperative and cooperative games, pioneered by luminaries such as John Nash, John Harsanyi, Reinhard Selten, and Martin Shubik ushered in a new era of conceptual clarity (Crawford 2016). Their insights demarcated strategic interactions where individual actors pursue their self-interest independently from those scenarios where collaboration and coalition formation become paramount. This conceptual distinction enriched the analytical toolkit of game theorists, accommodating a wider array of strategic scenarios.

A.4 Progression from Static Games to Dynamic Games

The advent of dynamic games championed by John Harsanyi, marked a pivotal juncture in the trajectory of game theory (Vane and Mulhearn 2009). Departing from the static equilibrium paradigms, their work delved into sequential decision-making over time. Their contributions, notably in the realm of repeated games and Bayesian frameworks, propelled the field towards a more nuanced understanding of strategic interactions unfolding dynamically.

A.5 Shift from Games with Perfect Information to Games with Imperfect Information

The Nobel laureates in 2007 Roger Myerson, Eric Maskin, and Leonid Hurwicz have spearheaded the exploration of games tainted by informational asymmetriesMyerson [8]. Their endeavors have shifted the spotlight towards analyzing strategic scenarios where actors possess incomplete knowledge about the game structure or adversaries' strategies. Consequently, game theory has become more applicable to real-world scenarios in economics, political science, and other fields, where information asymmetries are pervasive.

A.6 Elevator talk

The former theoretical approach, typically based on static game theory models, fails to adequately address the adverse selection problem in the used car market for several reasons. Firstly, static game theory assumes complete information among all players, which does not accurately reflect the reality of the situation in the used car market where information is asymmetric. Secondly, traditional equilibrium concepts such as Nash equilibrium do not provide clear guidance on how to mitigate the adverse effects of information asymmetry and promote truthful information disclosure by sellers.

B Review Classic Games, Nash Equilibrium and the Analytical Tools

B.1 Exploring Inspirational Games in Strategic or Normal Form

Volunteer's Dilemma: In the Volunteer's Dilemma, each player faces the decision of whether to volunteer for a task that incurs a personal cost but provides a group benefit if at least one person completes it (Goeree et al. 2017). The strategic form of this game can be illustrated with two players, A and B, with the payoff matrix in Figure1 (payoff matrix in the Volunteer's Dilemma):

	B Volunteers	B Doesn't Volunteer
A Volunteers	(-1, -1)	(-1, 2)
A Doesn't Volunteer	(2, -1)	(-2, -2)

Fig. 1. payoff matrix in the Volunteer's Dilemma

The payoffs reflect the utility each player receives, where volunteering costs a player -1, not volunteering when another player does volunteer yields a benefit of 2, and if neither volunteers, both receive a worst payoff as the public good is not provided. From the shared notebook (link), we can find the equilibria of this game. Two pure strategy equilibria occur when A volunteers while B doesn't volunteer, and A doesn't volunteer while B volunteers. Additionally, the mixed strategy equilibrium occurs when both players volunteer 25% of the time, and don't volunteer 75% of the time.

What fascinates me about the Volunteer's Dilemma is its relevance to real-world collective action problems, from small-scale group projects to large-scale public goods provision. It encapsulates the tension between individual incentives and the common good, which is fundamental to understanding social dilemmas (Murnighan et al. 1993). In my view, the game encapsulates the essence of many modern societal challenges. For instance, the decision to reduce one's carbon footprint by choosing not to drive a car is a form of volunteering where the personal cost covers inconvenience and time, and the societal benefit refers to reduced emissions. However, if everyone relies on others to make such sacrifices, the collective action fails, paralleling the game's scenario where no one volunteers.

The Volunteer's Dilemma provides insightful illumination on strategic interactions by showcasing how individual choices are intricately interconnected and how personal decisions impact collective outcomes. It underscores the tension between self-interest and the common good, emphasizing the need for careful consideration of incentive structures that encourage cooperation over defection. This game deepens the understanding of the complex motivations behind cooperative behavior, the potential for leadership and altruism, and the significant role that social norms and group dynamics play in individual decision-making. In strategic terms, it highlights the subtle but powerful forces at play when individuals collectively face a choice that pits immediate personal costs against broader benefits.

In summary, the Volunteer's Dilemma provides a simple yet powerful model for exploring fundamental issues of cooperation and competition. Its implications for real-world social dynamics and policy design underscore the practical importance of game theory as a tool for analyzing human behavior.

B.2 Delving into Extensive-Form Games

In the Ultimatum Game, two players interact to decide how to divide a sum of money as shown in Figure2 (Game Tree of the Ultimatum Game). Player 1 proposes a division of the sum, and Player 2 can either accept or reject this proposal. If Player 2 accepts, the money is split according to the proposal. If Player 2 rejects, neither player receives anything. This game can be depicted in extensive form, where the decision nodes represent the choices of each player at each step, and the outcomes are the final payoffs. [11]

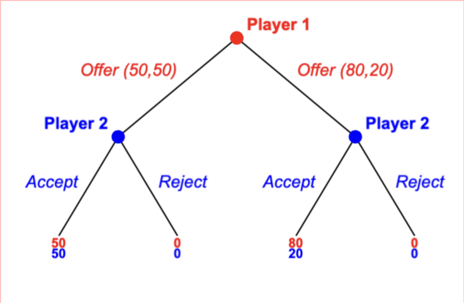

Fig. 2. Game Tree of the Ultimatum Game

Engaging with the Ultimatum Game has shifted my perspective on how fairness and retaliation can play critical roles in decision-making processes, even when such actions contradict the predictions of rational choice theory. Traditional economic models would suggest that Player 2 should accept any non-zero offer since it is better than nothing. However, real-world experiments show that people often reject offers they consider unfair, even at a cost to themselves (Nowak et al. 2000). This behavior has led to new insights into the role of social preferences and the expectation of equitable outcomes in strategic interactions. The Ultimatum Game has fundamentally reshaped my understanding of how fairness and social norms intersect with economic rationality in decision-making processes. Engaging deeply with this game has revealed to me the profound psychological underpinnings that influence human behavior in strategic settings. Take the real life example, in business negotiations, proposals perceived as fair by all parties are more likely to be successful, even if they offer less material benefit. This understanding comes from observing Ultimatum Game outcomes where responders frequently reject low offers, preferring no reward over accepting a deal they see as unjust. It underscores the importance of crafting strategies that are not only economically sound but also perceived as reasonable by all stakeholders involved.

B.3 Critiquing Nash Equilibrium and Envisioning Innovations:

Since the Nash Equilibrium operates under the presumption of full rationality and complete information, it is not always reflective of real-world scenarios. Players are assumed to have unlimited computational abilities and a comprehensive understanding of the entire strategic landscape, an ideal that often diverges from the reality of bounded rationality and imperfect information. In Matching Pennies, each player has a strategy that can be predicted and exploited if played consistently. Therefore, the equilibrium is one where each player randomizes over their strategies to make themselves unpredictable (Goeree et al. 2003). This mixed strategy Nash Equilibrium represents an equilibrium of unpredictability and reveals Nash Equilibrium's assumption that players can randomize perfectly, an idealized mathematical construct that may not hold in reality, where players might struggle with truly randomizing their actions or may not wish to randomize at all due to psychological preferences for certainty.

Contemporary analytical tools like Nashpy and Gambit can adeptly compute Nash Equilibria but struggle with games exhibiting numerous equilibria and more complex strategic interactions due to computational intensity. This complexity often makes the tools less practical for predicting outcomes in dynamic and evolving strategic settings.

To transcend these boundaries, I would like to develop a new tool that advances the analysis of strategic interactions by incorporating adaptive learning models, allowing it to simulate dynamic strategy evolution influenced by past outcomes. It extends beyond traditional Nash Equilibrium by integrating principles from behavioral economics to account for bounded rationality and psychological factors affecting decision-making. In addition, it also features a negotiation module to explore the impact of pre-play communication on strategic outcomes, crucial for understanding cooperative dynamics in games. To handle computational complexity, it employs heuristic algorithms, making it suitable for analyzing large or multi-stage games efficiently (Daskalakis et al. 2009). Based on the ability to integrate empirical data and customize payoff functions, the tool will further enhance flexibility, making it applicable to a wide range of strategic situations, from economic to social contexts. I believe this approach will bridge theoretical models with practical applications, serving both academic and practical needs in strategic decision-making.

B.4 The definitions about Bayesian (Subgame Perfect) Nash Equilibrium

Refer to Textbook: *Shoham, Yoav, and Kevin Leyton-Brown.* 2008. Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations. Cambridge: Cambridge University Press. (Chapter 5, Page 118, Definition 5.1.1)

Definition 1 (Perfect-information Game). *A perfect-information game in extensive form is defined as a tuple $G = (N, A, H, Z, \chi, \rho, \sigma, u)$, where:*

- *N denotes the collection of players involved in the game.*
- *A signifies the universal set of possible actions available in the game.*
- *H is the set comprising all decision points that are not final.*
- *Z encapsulates all terminal points in the game, distinct from H.*
- *χ is the action mapping function that allocates a subset of actions to each decision point.*
- *ρ is the player mapping function that attributes each decision point in H to a specific player in N.*
- *σ is the successor function that assigns a subsequent decision or terminal point following a player's action.*
- *u represents the utility function for each player, mapping terminal points to real-val*

Refer to Textbook: *Shoham, Yoav, and Kevin Leyton-Brown.* 2008. Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations. Cambridge: Cambridge University Press. (Chapter 5, Page 130, Definition 5.2.1)

Definition 2 (Imperfect-information Game). *An imperfect-information game in extensive form can be articulated as a tuple $G = (N, A, H, Z, \chi, \rho, \sigma, u, I)$, expanding upon the perfect-information game structure, where:*

- *$N, A, H, Z, \chi, \rho, \sigma, u$ represent the constructs of a perfect-information extensive-form game.*
- *$I = (I_1, \ldots, I_n)$, with $I_i = (I_{i,1}, \ldots, I_{i,k_i})$, designates the information partitioning for player i, consolidating nodes at which player i cannot distinguish the game's progression due to incomplete information.*

Refer to Textbook: *Shoham, Yoav, and Kevin Leyton-Brown.* 2008. Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations. Cambridge: Cambridge University Press. (Chapter 5, Page 123, Definition 5.1.5)

Definition 3 (Subgame Perfect Nash Equilibrium). *A Subgame Perfect Nash Equilibrium in a game G is comprised of strategy profiles s that sustain Nash Equilibrium across every conceivable subgame G' of G. Here, s', a strategy limited to G', must secure a Nash Equilibrium in G'.*

- *It is understood that the entire game G can be viewed as a subgame of itself, thus endorsing the notion that every SPNE corresponds to a Nash Equilibrium.*

- *The SPNE concept is more rigorous than the standard Nash Equilibrium as it necessitates consistent optimality across all possible continuations of the game.*
- *It is affirmed that any game structured with complete information at every stage possesses at least one Subgame Perfect Nash Equilibrium.*
- *The application of SPNE excludes strategies involving noncredible threats, ensuring each player's strategy is credible and consistent throughout the entirety of the game.*

B.5 The thereom about Bayesian (Subgame Perfect) Nash Equilibrium

Refer to Textbook: Carmona and Fajardo 2009.

Theorem 1. *In any menu game that adheres to a set of foundational assumptions, there is at least one strategy profile that achieves a Subgame Perfect Equilibrium.*

Proof. We initiate by establishing a generalized game structure that includes an internally determined sharing rule, effectively integrating the principals' payoff functions with the agent's optimal choice set. We then apply a second theorem that furnishes a viable solution for the generalized game that also incorporates the aforementioned sharing rule.

Employing a preliminary lemma, the solution from the payoff set is then shown to be a measurable function that resonates with the agent's optimal choice set, which we define as an optimal strategy. This optimal strategy is synthesized with the principals' strategies, also forming part of the subgame perfect equilibrium set.

Finally, we introduce a function h that aggregates the payoffs and is characterized by its measurability and continuity, establishing the prerequisites for a subgame perfect equilibrium. The proof is culminated by demonstrating a correspondence Q that confirms the compactness of the payoff aggregation function, thus satisfying the conditions needed for the existence of a Subgame Perfect Equilibrium.

B.6 The discussion of the definition, theorem and proof

The Ultimatum Game in B.2 belongs to an imperfect-information game as defined. In the Ultimatum Game, the responder does not know the choice (action) made by the proposer when deciding whether to accept or reject the offer. This lack of knowledge about the proposer's action places the responder in an information set where the proposer's choice is not distinguished, which is a characteristic of imperfect-information games. While the Ultimatum Game itself is simple and does not contain proper subgames (since there's no further play after the responder's decision), it is still informative to consider subgame perfection. If the game were extended to allow for repeated interactions or additional stages of play, subgame perfect equilibrium would be relevant to ensure that threats or promises made in the strategy are credible.

According to Carmona and Fajardo, in the Ultimatum Game, the rewards structure tends to make responders more susceptible to "noise" in their decision-making compared to proposers [16]. Consequently, this tendency leads the learning process towards outcomes that align with Nash equilibria but do not meet the criteria for subgame-perfect equilibrium. Hence, it's insufficient for game theorists to exclusively focus on the subgame-perfect equilibrium when forecasting behavior in Ultimatum Game experiments conducted in laboratories.

Moreover, the Ultimatum Game is often used to illustrate issues of fairness, altruism, and the punishment of unfair offers in behavioral economics and evolutionary psychology, as the responder may reject an offer they perceive as unfair even at a cost to themselves. This behavior deviates from the predictions of traditional economic theory based purely on self-interest and utility maximization. Therefore, it inspires how significant it is to investigate the role of social networks in mitigating information asymmetry in economic transactions.

C Game Theory Glossary Tables

Table 1. Game Theory Glossary Tables

Glossary	Definition	Sources
Adverse Selection	A situation where sellers have information that buyers do not have, or vice versa, about some aspect of product quality, causing market inefficiency.	Akerlof [1]
Information asymmetry	An imbalanced condition in which one party in a transaction has more or better information compared to another, causing the transactions to fail.	Akerlof [1]
Pure strategy	A strategy in which a player makes a specific choice or takes a specific action with certainty rather than randomly selecting from among multiple possible actions.	Nash [17]
Mixed Strategy	A strategy in which a player chooses among possible moves according to a probability distribution.	Nash [17]
Extensive Form Game	A representation of games that specifies the order of play, allowable actions, payoffs, and information available at each decision point.	Kuhn [18]
Zero-Sum Game	A situation in which one participant's gain or loss is exactly balanced by the losses or gains of the other participants.	Neumann and Morgenstern [19]
Repeated Game	A standard game that is played several times by the same players, allowing for strategies to be affected by the history of play.	Aumann and Shapley [20]
Mechanism Design	A field of game theory that takes an engineering approach to designing economic mechanisms or incentives, toward desired objectives, in strategic settings.	Hurwicz [21]
Sequential Equilibrium	A refinement of Nash Equilibrium for extensive-form games that captures the idea that strategy should be consistent with the beliefs held about the likely play of the game (including off the equilibrium path).	Kreps and Wilson [22]

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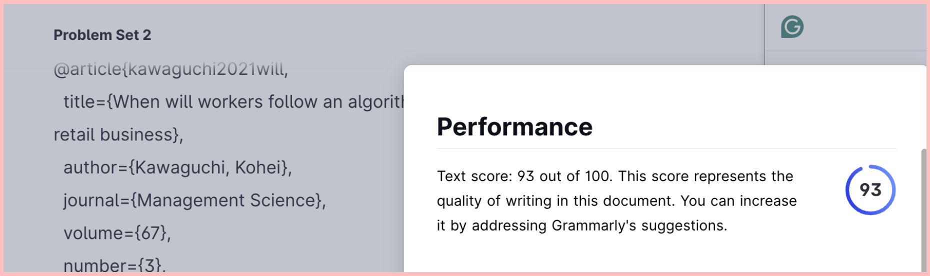

Fig. 3. Screenshot1

Fig. 4. Screenshot2