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Peer-to-peer network : Kantian cooperation discourages free riding

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Abstract

The problem of how to achieve cooperation among rational peers to discourage free riding is one that has received a lot of attention in peer-to-peer based web-communities and is still an important one. The field of game theory is applied to the task of finding solutions that will encourage cooperation while discouraging free-riding. The cooperative conduct of peers is typically portrayed as a traditional version of the game known as the "Prisoners' Dilemma." It is common knowledge that if two peers engage in a situation known as the Prisoners' Dilemma more than once, collaboration can be achieved through the use of punishment. Nevertheless, this is not the case when there is only one interaction between peers. This article demonstrates that Kantian peers prefer to cooperate and attain social

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welfare even when they interact only once. The experimental results indicate that when Nashers engage in several interactions, their average payoff is negative. In contrast, when individuals adhering to the Kantian principles engage in repeated interactions, their payoffs exhibit both stability and social optimality. This, dissuade peers from freeriding.

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1. Introduction

Participants in a P2P economy platform encounter decisions that resemble those of the Prisoner's Dilemma. They are faced with the choice of either cooperating through adherence to platform regulations, honest engagement, and trust maintenance, or deviating by exploiting vulnerabilities, violating agreements, or acting exclusively for their benefit. The dilemma emerges when individual motivations (the pursuit of maximum personal advantages) collide with the interest of the collective. A platform that is less effective overall, a deterioration of trust, and decreased participation may result when individual interests are prioritized over the greater good.

Peer-to-peer web communities (P2P) allow users to communicate and exchange resources (e.g., e.g. files, music and information sharing) directly with one another without the use of central servers or middlemen. These groups use peer-to-peer (P2P) technology to build user-driven, decentralized ecosystems. P2P web communities obviate the necessity of a centralized authority or server by dispersing data and functionality among the network of engaged users. The process of decentralization serves to mitigate the potential risks associated with censorship, server failures, and the presence of single points of failure.

These communities are scalable since a new node (peer or individual) joins a P2P network, the load on the system increases, and simultaneously, the system's resources enrich to accommodate the increased load. Because each node is merely a relatively insignificant portion of the whole, the network has a lower risk of being breached or failing altogether. If a network is centralized and an attack is launched against one of the servers, then the entire network's performance can be dramatically hindered.

Peer-to-peer (P2P) file-sharing platforms allow computer users (at the Internet edge) to share files. With these strategies, users don't have to know or meet the users with whom they exchange files. This has been a hot topic among individuals who share music files and, more recently, those who share movies due to the dramatic increase in available network bandwidth in recent years. P2P applications include Napster, a file-sharing service, and BitTorrent (which employs a central server known as a tracker to coordinate the peers' actions and seeds that, at any given time, have a complete copy of the item to upload). A centralized server coordinates the activities of the peers and seeds in both of these services.

In peer-to-peer computing, each node can contribute resources, such as files, processing power, storage, or bandwidth, to the network. Nonetheless, there is frequently the possibility that some nodes may not contribute their fair share, while others may contribute more than their fair share. For instance, [1] indicates that nearly 85 per cent of Gnutella users did not share any files with any other users. Napster similarly suffers from lower contribution with $40-60\%$ of peers only sharing $5-20\%$ of the shared files [2]. This creates a situation where some nodes benefit from the contributions of others without contributing themselves, leading to free riding.

1.1 *Issue in P2P*

Cooperation and free riding are terms used in peer-to-peer (P2P) computing to describe the resource-sharing behaviour of individuals in a network. Cooperation occurs when nodes contribute their resources to the network, allowing other network members to exchange resources. Free riding, on the other hand, refers to the behaviour of nodes who consume network resources without contributing any of their own resources in return. Cooperation is generally regarded as advantageous for P2P networks because it helps ensure that there are sufficient resources available for everyone to use. However, free riding can reduce the overall amount of resources available and discourage others from contributing their own resources, undermining the effectiveness of a P2P network. One of the challenges in P2P computing is finding ways to encourage cooperation and discourage free riding.

One strategy to handle this issue is through incentives and penalties. For example, nodes that contribute more resources to the network could receive higher priority for accessing resources or receiving rewards, while nodes that contribute less could be penalized by having their access to resources limited or receiving fewer rewards. Using reputation systems, in which nodes are ranked based on their contributions to the network over time, is another way. This facilitates cooperation and discourages free riding, as nodes with a better reputation may receive preferential treatment in the network.

1.2 *Research Gap*

Cooperative and free-riding behaviour in peer-to-peer computing has been studied and formally analysed using game theory [3, 4, 5, 6, 7, 8]. Several pertinent research have been conducted that employ game theory to evaluate P2P systems. These studies include free-riding [5, 6], predicting nodes behaviour, and framework for incentives. Game theory has been used in the literature as a technique to construct incentives for collaborating (sharing and contributing) in P2P networks. Some examples of these types of incentives include inherent altruism, monetary schemes, reciprocity-based schemes, direct reciprocity, and indirect reciprocity [9]. Analysis of interactions between peers has typically been done by considering a Cooperate/Free-ride Social Dilemma, analogous to the well-known Prisoner's Dilemma (PD) game [10, 11, 12, 13, 14]. The prisonerâ€™s dilemma is an age-old example of a social dilemma of an interactional cooperative and conflict issue in which (often) two participants have to decide whether to cooperate or defect (non-cooperate) at the same time.

It is well known that if two players in a PD scenario do not interact with each other more than once, then defection (non-cooperation) is the only optimal action for both players. Yet, if they interact multiple times, cooperation yields gains that outweigh defection's gains in the near run. With finitely repeated interactions, a vicious cycle keeps repeating until the first round. At this point, the game returns to a single interaction (single-shot) PD, and the only rational action for both players is to defect [15]. In reality, unless the game is played repeatedly for an arbitrary amount of time, repeated encounters might not be able to address the cooperation problem [16]. According to [17], in the PD scenario, participants cooperate less when they choose a mixed strategy (i.e. random selection between cooperation and defect) than when they stick to one of the strategies (either cooperation or defect) exclusively. These observations (presented in a game theory context) are pertinent to the discussion on peers' cooperative conduct in peer-to-peer computing since the resource-sharing conundrum in peer-to-peer is depicted as the Prisoner's Dilemma.

However, it is improbable that two peers engage in frequent interactions within a peer-to-peer network such as BitTorrent, iMesh, and Vuze. The central issue here is how to achieve cooperation between rational peers in a one-time interaction that is also socially beneficial in peer-to-peer computing.

1.3 *Our Contribution*

In this short paper, we apply the *Kantian equilibrium* theory proposed in [18] to analyze the cooperation issue in Peer-to-Peer computing. It has been shown that cooperation has been proven to originate even from a single interaction. In a P2P system, the likelihood of anonymous peers engaging in frequent interactions is lower, whereas the likelihood of them interacting once is significantly higher. Consequently, researching cooperative behaviour through the lens of Nash's equilibrium solution concept is of lesser significance, and we should instead focus on achieving cooperation through single-shot interactions. We believe that the Kantian equilibrium, a novel framework for the analysis of cooperation, will provide a solution to the problem. In this paper, we reproduce the file-sharing game proposed in [19] analogues to PD and investigate cooperation in two scenarios: 1) when peers are Nash optimisers (Nasher) and 2) when peers are Kantian optimisers (Kantians). (We borrow these terms from [20, 21]). We demonstrate that Kantians cooperate and promote societal well-being more than the Nashers. Our experimental findings demonstrate that in situations involving several interactions, the average payoff of peers in Nash equilibrium is negative. In contrast, in situations where Kantian peers engage in repeated interactions, their payoffs exhibit both stability and social optimality. This demonstrates that Kantian peers discourage free riding.

Nonetheless, our study is merely an early attempt to apply Kantian equilibrium as a solution notion in a peer-to-peer file-sharing situation. The purpose of this work is to examine and analyse the subject of peers' cooperative conduct in file sharing via the lens of Kantian equilibrium. This type of analysis is missing from the peer-to-peer computing literature. It is noted that the adaptation of Kantian Equilibrium as a solution concept in P2P file sharing is beyond the scope of this study.

2. Background

The notion of game theory looks into conflict situations [22, 23, 24]. Peer interaction and decision-making are facilitated by this tool. It establishes a common language for formulating, structuring, analysing, and ultimately comprehending various strategic scenarios. A game, in the sense of game theory, identifies peers' identities and preferences, as well as the actions (strategies) they can take and the results of those actions.

2.1 *Game and Mixed Strategies*

A game in a normal form has a finite set of peers $\mathrm{P} = \{1, 2, \cdots, i, j, \cdots, n\}$. A finite set, $\mathbf{A}_i = \{\mathfrak{a}_1, \mathfrak{a}_2, \cdots, \mathfrak{a}_n\}$ of actions (or strategies) is available to each peer $i \in \mathrm{P}$. For the given n peers, $\mathcal{A} = \mathbf{A}_1 \times \mathbf{A}_2 \times \cdots \times \mathbf{A}_n$ represents the complete actions space. An n-tuple *action profile*, $\mathfrak{a} = (\mathfrak{a}_1, \cdots, \mathfrak{a}_i, \mathfrak{a}_j, \cdots, \mathfrak{a}_n)$ is an element of $\mathcal{A}$ that represents the choice of action of each peer $i \in \mathrm{P}$. There exists a payoff function $\mu_i : \mathcal{A} \to \mathbb{R}$ for each peer $i \in \mathrm{P}$. We refer to this game as $\mathfrak{g}$.

A pure strategy is a non-probabilistic strategy in which a player chooses a specific action without randomness. A mixed strategy, on the other hand, is a probabilistic strategy in which a player randomly chooses among different pure strategies with certain probabilities. Formally, a mixed strategy σ_i of peer $i \in \mathrm{P}$ is a probability distribution over $\mathbf{A}_i$, such that

$$\phi_i = \{\sigma_i : \mathbf{A}_i \to [0,1] : \sum_{\mathfrak{a}_i \in \mathbf{A}_i} \sigma(\mathfrak{a}_i) = 1\}.$$

The utilization of a bimatrix is a logical technique to depict a game that is played in conventional form with two peers. A two-peer normal form game as described below. Assuming, a number of peers is equal to 2, that is, $n = 2$, P_r and P_c. Further, if $\mathbf{A}_r = \{\mathfrak{a}_{r_i} \mid 1 \le i \le 2\}$, and $\mathbf{A}_c = \{\mathfrak{a}_{c_j} \mid 1 \le j \le 2\}$ are the action sets available for peers P_r and P_c, respectively. Then a bi-matrix representation of the game under consideration is depicted in Table 1.

Table 1

A bi-matrix for n = 2

	P_c Strategies	
P_r Strategies	$\mu_r(\mathfrak{a}_{r_1}, \mathfrak{a}_{c_1}), \mu_c(\mathfrak{a}_{r_1}, \mathfrak{a}_{c_1})$	$\mu_r(\mathfrak{a}_{r_1}, \mathfrak{a}_{c_2}), \mu_c(\mathfrak{a}_{r_1}, \mathfrak{a}_{c_2})$
	$\mu_r(\mathfrak{a}_{r_2}, \mathfrak{a}_{c_1}), \mu_c(\mathfrak{a}_{r_2}, \mathfrak{a}_{c_1})$	$\mu_r(\mathfrak{a}_{r_2}, \mathfrak{a}_{c_2}), \mu_c(\mathfrak{a}_{r_2}, \mathfrak{a}_{c_2})$

Let peer, P_r's actions correspond to the rows, and peer P_c's actions correspond to the columns. The notations $(\alpha, 1-\alpha)$ and $(\delta, 1-\delta)$ represent P_r and P_c's mixed strategies in the above mentioned game. If P_r and P_c adopt a mixed strategy approach, then their expected payoff is

$$\mu_{P_r}((\alpha, 1-\alpha), (\delta, 1-\delta)) = \alpha\delta\mathfrak{a}_{r_1} + \alpha(1-\delta)\mathfrak{a}_{r_1} + (1-\alpha)\delta\mathfrak{a}_{r_2} + (1-\alpha)(1-\delta)\mathfrak{a}_{r_2},$$

$$\mu_{P_c}((\alpha, 1-\alpha), (\delta, 1-\delta)) = \alpha\delta\mathfrak{a}_{c_1} + \alpha(1-\delta)\mathfrak{a}_{c_1} + (1-\alpha)\delta\mathfrak{a}_{c_2} + (1-\alpha)(1-\delta)\mathfrak{a}_{c_2}.$$

We will now define a few key terms.

Definition 1: Let us have a two-peer one-shot strategic game $\mathfrak{g}$ in which each peer can cooperate or not cooperate with her opponent. In $\mathfrak{g}$, they will each receive $\mathcal{R}$ if they both prefer to cooperate. If one chooses to cooperate and the other does not, the cooperator will receive $\mathcal{S}$ and the non-cooperator will receive $\mathcal{T}$. If either peer decides not to cooperate with the other, each will receive $\mathcal{P}$. We say, a two-peer game $\mathfrak{g}$ is **Prisoner's Dilemma**, if for each peer $i \in [2]$, such that $\mathcal{T}_i > \mathcal{R}_i > \mathcal{P}_i > \mathcal{S}_i$.

Definition 2: A game $\mathfrak{g}$ is said to be monotone rising if, for every peer *i*, μ_i is a monotone growing in the actions adopted by all of the other peers *j* who are lower than *i*.

Definition 3: If action profile $\mathfrak{a}$ yields at least the same benefit for every agent as another action profile $\mathfrak{a}'$, and if there exists at least one peer who distinctly favours $\mathfrak{a}$ over $\mathfrak{a}'$, in this case, it seems reasonable to say that $\mathfrak{a}$ is better than $\mathfrak{a}'$, then we say that $\mathfrak{a}$ Pareto-dominates $\mathfrak{a}'$. Action profile $\mathfrak{a}*$ achieves Pareto-optimality when no other action profile outperforms it in terms of Pareto dominance.

Definition 4: Let $\mathfrak{a}$ is an action profile. A social welfare of $\mathfrak{a}$: SW $(\mathfrak{a}) = \sum_{i=1}^{n} \mu_i(\mathfrak{a})$. Then $\mathfrak{a}$ is a social optimum (efficient) if SW $(\mathfrak{a})$ is maximal.

2.2 *Nash Vs Kantian Equilibrium*

The articles [25, 21] present Kantian equilibrium as a solution concept for symmetric games. Economists have been using this solution concept as an alternative to the concept of Nash equilibrium. Kantian equilibrium is driven by Kant's 'Categorical Imperative,' which suggests an individual should take those actions the individual wants everyone to take (or wish to see universalized). Roemer intends to implement the Categorical Imperative (CI) in an optimization model as a new theory of social cooperation that will lead to situations that are good for everyone. Kantian equilibrium is based on the premise that in a cooperative situation, everyone asks, "What would be best for me if everyone did it?" When everyone responds in the same manner, everyone acts accordingly. There are variations of this concept applicable to situations in which only some react in the same way. One way to think about the Kantian equilibrium concept is as either a descriptive or a prescriptive one. This means it can either describe how peers behave or how they ought to behave. Alternately, it might be both descriptive and prescriptive at the same time. The main point of Roemer's argument is that Kantian optimization "solves" what seems to be the two biggest problems (the tragedy of the commons and the free-rider) with Nash optimization from the point of view of human welfare.

Given the structure of rational choice and our preferences, there are two possible optimization strategies: Nash and Kantian are possible [26]. Here, the Nash optimizer may ask, "Given my opponent's chosen action, what is the optimal action for me?" Whereas, the Kantian optimizer may ask, "What action do I want both of us to play?"

In this study, we focus on simple Kantian equilibrium [27] rather than multiplicative Kantian equilibrium [25].

Definition 5: Nash and Kantian equilibrium are formally stated as follows. An action profile $\mathfrak{a}^* = (\mathfrak{a}_1^*, \ldots, \mathfrak{a}_i^*, \ldots, \mathfrak{a}_n^*)$ is a **Nash equilibrium** of the game if, for every peer i, $\mu_i(\mathbf{a}^*) \geq \mu_i(\mathfrak{a}_{i'}, \mathfrak{a}_{-i}^*)$, for all $\mathfrak{a}_{i'} \in \mathbf{A}_i$.

Nash equilibrium is the state in which each individual chooses an action that maximizes his or her utility while holding the actions of others fixed. To put it simply, a Nash Equilibrium occurs when no peer can unilaterally change its action to improve its own payoff, given the actions chosen by the other peers.

Definition 6: Let $\mathfrak{a}^* = (\mathfrak{a}_1^*, \ldots, \mathfrak{a}_i^*, \ldots, \mathfrak{a}_n^*)$ and $\mathfrak{a}' = (\mathfrak{a}_{1'}, \ldots, \mathfrak{a}_{i'}, \ldots, \mathfrak{a}_{n'})$, and $\mathfrak{a}^*, \mathfrak{a}' \in \mathcal{A}$. An action profile $\mathbf{a}^* = (\mathfrak{a}_1^*, \ldots, \mathfrak{a}_i^*, \ldots, \mathfrak{a}_n^*)$ is a **simple Kantian equilibrium** of the game if, for every peer $i, \mu_i(\mathfrak{a}^*) \geq \mu_i(\mathfrak{a}')$, for all $\mathfrak{a}^*, \mathfrak{a}' \in \mathcal{A}$.

Stated otherwise, an action profile $\mathfrak{a}^*$ is considered a basic Kantian equilibrium if selecting $\mathfrak{a}^*$ is more advantageous for each player compared to selecting any other strategy $\mathfrak{a}'$. Kantian equilibrium is the state in which everyone adopts the same action to maximize their utility. That is to say, $\mathfrak{a}^*$ is an example of a simple Kantian equilibrium if the action that every peer chooses is better for them than the action that every peer chooses any other action. According to Roemer, the Kantian optimization protocol is a behavioural model of cooperation. A Kantian optimizer does not speculate on how others will react to its potential deviations. In fact, the Kantian follows a behavioural norm based on Kantian ethics [28].

3. File Sharing Game (FSG)

In Peer-to-peer (P2P) computing systems, such as BitTorrent, the sharing of files and resources is defined by a decentralized approach, where participating peers share among themselves. A peer can be either a lecheer or a seeder. Seeders are peers who have the entire file or files and are actively sharing them with other peers. Leechers are peers who are currently downloading the file(s) and may also contribute by uploading fragments of their downloaded content to other peers. This means that a lecher has the option to either share or not share the files, or portions of the files, with others to download them. However, a peer may or may not engage in both downloading and uploading files simultaneously. Further, peers are more likely to share files because the more they send, the faster their download speeds become.

We formalize peer-to-peer file (resource) sharing (trading) by modelling them after two peers' (P_r and P_c) game called File Sharing Game (FSG). Within the FSG, peers can benefit β by obtaining (or downloading) a required file hosted on the nodes of other peers, which yields positive utility. Peers are also required to upload the file for other peers to be able to download it; however, doing so results in a bandwidth usage cost of u^{ς} and d^{ς}, respectively, and this results in negative utility.

Furthermore, the act of assigning disk space (s^{ς}) to share files incurs an extra cost on individuals. It is important to mention that peers may be subject to costs (n^{ς}) because of their system or network usage (or cost of maintaining the overlay [29] or payment per-MB connection [10]). Thus, component $\beta \in (0,1)$ provides benefits whereas factors u^{ς}, d^{ς}, s^{ς}, $n^{\varsigma} \in (0,1)$ result in costs. Whereas, $\beta > u^{\varsigma} > d^{\varsigma} \geq s^{\varsigma} \geq n^{\varsigma}$.

In this article, we evaluate the above-mentioned simple file-sharing scenarios and recreate the File Sharing Game discussed in [19] and adapt it to be equivalent to the two-player Prisoner's Dilemma (PD). Peers in FSG have the option of either sharing (trading) files (resources) with one another or not sharing (trading) files (resources). We have taken into account different aspects that determine the payoff of peers, however for analysis purposes, we simplified the payoff matrix to depict FSG as a Prisoner's Dilemma.

If both peers share files, then it will be possible for each peer to download the necessary file and obtain β; nevertheless, both peers will still be required to upload and download the files, and it costs u^{ς}, and d^{ς}. Additionally, each peer incurs costs for managing the storage space, s^{c}, and network expenses n^{c}. This ends up giving both of the peers an $\beta-(u^{\varsigma} + d^{\varsigma} + s^{\varsigma} + n^{\varsigma})$ score. In this case, we assume that the advantage that a peer receives from downloading the desired file is equivalent to the cost that peer incurs from making the file available for download. We assume they get no value because the benefit equals the cost, and therefore, $\beta - (u^{\varsigma} + d^{\varsigma} + s^{\varsigma} + n^{\varsigma}) = 0$.

Let P_r share a file with P_c, but P_c won't do that. In this scenario, P_r uploads a file to share it with P_c. P_r incurs costs for uploading files, maintaining storage, and network expenses. However, in this scenario, P_r's download capacity is not fully utilized, and most crucially, P_r cannot benefit from acquiring the file from P_c because P_c is not sharing the content with P_r. Therefore, the payoff of P_r is $-(\beta + u^{\varsigma} + d^{\varsigma} + s^{\varsigma} + n^{\varsigma})$. We assigned this value of negative ς. On the other hand, P_c is not posting any files but can get the required file; as a result, P_c derives some positive utility from the situation. While the P_c advantageous β from the file download benefit β and savings storage maintenance costs and upload bandwidth, it incurs a minor expense just for download bandwidth and network connectivity. As a result, P_c's payoff is $(\beta + u^{\varsigma} + s^{\varsigma}) - (d^{\varsigma} + n^{\varsigma})$, which we simplify by setting it to 1.

If both peers refuse to cooperate and share the files. Then they can save on upload and download costs as well as storage maintenance costs, but they will not be able to obtain the desired files. It is vital to note that peers are connected to the network and so bear network costs, even though they do not share data. Thus, the payout for both peers in this scenario is $(d^{\varsigma} + u^{\varsigma} + s^{\varsigma}) - (\beta + n^{\varsigma})$, and we set this to $-\ell$.

The payoff matrix for file (resource) sharing (trading) in peer-to-peer networks is derived and displayed in Table 2, given below. The FSG game becomes the prisoner's dilemma game, with $1 > 0 > -\ell > -\varsigma$.

Example 1: Let $\beta = 0.9$, $d^{\varsigma} = 0.3$, $u^{\varsigma} = 0.25$, $s^{\varsigma} = 0.25$, and $n^{\varsigma} = 0.10$. If both peers choose to share a file under this configuration, they will each receive zero payoff. Conversely, if one peer shares and the others do not, the sharing peer will receive -1.80 and the non-sharing peer will receive 1. Both peers will incur a -0.2 penalty if they choose not to share the files. So, the FSG game becomes the prisonerâ€™s dilemma game, with $1 > 0 > -0.2 > -1.8$, whereas, $(\frac{1-1.8}{2} < 0)$.

Table 2

File Sharing Game Payoff Matrix

		P_c Strategies	
		Share File	Don't Share file
P_r Strategies	Share file	0, 0	$-\varsigma, 1$
	Don't Share File	$1, -\varsigma$	$-\ell, -\ell$

Let P_r to decide between two options, "Share File" and "Don't Share File'', with probabilities α and $1-\alpha$. In a similar vein, P_c will either "Share File" with probability δ or "Don't Share File" with probability $1-\delta$. Assumed mixed strategies are $(\alpha, 1-\alpha)$ for P_r and $(\delta, 1-\delta)$ for P_c.

Focusing on P_r, the best response to a given P_c's strategy δ takes the form

$$\mu_{P_r}(\delta) = \arg\max_{\alpha\in[0,1]}(\alpha[(1-\delta)(-\varsigma)] + (1-\alpha)[\delta + (1-\delta)(-\ell)]).$$

Similarly, P_c's best response to a given P_r's strategy α takes the form

$$\mu_{P_c}(\alpha) = \arg\max_{\delta\in[0,1]}(\delta[(1-\alpha)(-\varsigma)] + (1-\delta)[\alpha + (1-\alpha)(-\ell)]).$$

4. Discussion

It is interesting to examine how the strategic situation described above plays out when a pair of Nash peers and a pair of Kantian peers engage in file (resource) sharing. In this section, we discuss the cooperative behaviour of peers who are either Nashian or Kantian in their theoretical orientation.

4.1 *Theoretical Analysis*

4.1.1 Nashers

As stated previously, a Nasher is the one who adheres to the Nash equilibrium protocol and asks, "What is the optimum action (strategy) for me to take, given the actions my opponent has chosen?".

Remark 1:

- The FS game has a unique pure dominant strategy Nash equilibrium, that is, *Don't Share File, Don't Share File*.
- The Nash equilibrium of FS game is always (0, 0): both prefer to Don't Share File for sure. This outcome of the game is inefficient.

The FS game involves two peers who are each given the choice to cooperate or defect, without knowing what the other peer will choose. here, each peer's dominant action is to defect, regardless of the other peer's action, leading to a dominant strategy equilibrium where both peers prefer not to share a file. In this game, the Nash Equilibrium occurs when both peers Don't Share Files, as neither peer can improve their payoff by unilaterally changing their action. The action profile (Don't Share File, Don't Share File) is a dominant strategy equilibrium and more robust than a Nash equilibrium. Both peers' actions "Don't Share File" is a strict Nash equilibrium, because if one peer switches from "Don't Share File" to "Share File" while the other stays with "Don't Share File," that peer gets a payoff of $-\varsigma$. In this case, the payoff for both peers is $-l$.

No matter what the other peer does, there is no reason for a peer to change its strategy from "Don't Share File" to something else, since "Don't Share File" is the dominant strategy for both peers. Because of this, the Nash equilibrium is always at (0,0).

4.1.2 Kantians

A Kantian peer is the one who follows Kantian equilibrium protocol and asks, *"What action do I want all of us (including me and my opponents) to choose?''*.

In the FS game, the payoff function of P_r is

$$\mu_1(\alpha,\delta) = -\alpha(1-\delta)\varsigma + (1-\alpha)\delta - \ell(1-\alpha)(1-\delta),$$

and due to symmetry, the payoff function of P_c is

$$\mu_2(\alpha,\delta) = \alpha(1-\delta) - \varsigma(1-\alpha)\delta - \ell(1-\alpha)(1-\delta).$$

Here, $\alpha\delta$ indicates the likelihood that P_r (P_c) chooses Share File. The FS game is symmetric, and as a result, the utility function of the P_c is also $\mu(\alpha,\delta)$. We analyze the efficiency with the mixed strategy in terms of expected utility.

The FS game is strictly monotone increasing since:

$$\frac{d\mu(\alpha,\delta)}{d\delta} = (1-\alpha)(\ell+1) + \alpha\varsigma > 0. \tag{1}$$

With Eq.(1), we reproduce the following results stated in [25].

Proposition 1:

- A simple Kantian equilibrium exists if a game has a common diagonal.
- If a game is monotone increasing, then a simple Kantian equilibrium is also Pareto efficient.

Let us first compute peer P_r's expected payoff $\mu_{P_r}((\alpha,\ 1-\alpha),(\alpha,\ 1-\alpha))$ from employing action vector $((\alpha,\ 1-\alpha),(\alpha,\ 1-\alpha))$ in Table 2. This gives us:

$$\mu_{P_r}((\alpha,1-\alpha),(\alpha,1-\alpha)) = \mu_{P_c}((\alpha,1-\alpha),(\alpha,1-\alpha)) = \varsigma\alpha^2 - \ell\alpha^2 - \alpha^2 + \alpha + 2\ell\alpha - \varsigma\alpha - \ell \quad (2)$$

We obtain the following results from Eq. (2).

Proposition 2:

1. The simple Kantian Equilibrium of the FSG game is Pareto efficient.
2. If $1+\ell \geq \varsigma \geq 1$, the simple Kantain Equilibrium of the FSG game is $(\alpha^*,\alpha^*) = (1,1)$.
3. If $1+\ell > \varsigma$, the simple Kantain Equilibrium of the FSG game is $\alpha^* = 1$.
4. If $\varsigma < 1$, the simple Kantain equilibrium of the FSG game is $\alpha^* = \frac{2\ell+1-\varsigma}{2(\ell+1-\varsigma)}$ and $0 < \alpha^* < 1$.

Proof:

- The first part is derived from the observation stated in Proposition 1.
- If and only if $\varsigma \leq 1+\beta$ is true, the payoff function $\mu(\alpha,\alpha)$ of the FS game is concave. It is not difficult to see that the first-order condition $\frac{d}{d\alpha}(\mu(\alpha,\alpha)) = 0$ constitutes the simple Kantian equilibrium. If $1 \leq \varsigma$ then the solution is a corner one, at $\alpha^* = 1.$ This supports part 2.
- The payoff function $\frac{d}{d\alpha}(\mu(\alpha,\alpha)),$ on the other hand, is convex when $\ell + 1 < \varsigma.$ In this case, the simple Kantian equilibrium comes into existence when either $\alpha = 0$ or $\alpha = 1.$ But, the payoff value of the peers is higher at $\alpha = 1.$ This gives 3.
- It is not difficult to notice that instance 4 provides evidence that the solution is interior if ς is less than 1.

4.2 *Cooperation and Free-riding*

As a measurement of cooperation and free riding, we make use of Pareto efficiency, as well as the price of anarchy (PoA) and the price of stability (PoS). In the literature, the PoA and PoS metrics are applied to establish how effective a particular equilibrium outcome is. These measurements assist in determining the degree to which the equilibrium action profile and the socially efficient action profile differ from one another. PoA is the ratio of the worst-case equilibrium action profile to the optimal solution (best-case scenario, here, it is Pareto efficiency). In contrast, POS is the ratio between the best-case equilibrium action profile and the optimal solution quality.

Formally,

- $\text{PoA} = \frac{\text{payoffs in worst equilibrium outcome}}{\text{payoffs in socially optimum outcome}}$ and,
- $\text{PoS} = \frac{\text{payoffs in best equilibrium outcome}}{\text{payoffs in socially optimum outcome}}$.

Note that, any stable condition (Nash or Kantian equilibrium) obtained by peers is socially beneficial if PoA is one or near to one.

For further discussion, the payoff values in Table are expanded upon by adding positive integer ε (without loss of generality) so that the denominator never becomes 0. It is important to highlight that neither Nash nor Kantian equilibrium will be affected by this value addition. Then, we have the following observations.

Remark 2:

1. If Nashers interact in file sharing, then PoA = PoS = $\frac{\varepsilon}{\ell} > 1$.
2. If Kantians interact in file sharing, then PoA = PoS = $\frac{\varepsilon}{\varepsilon} = 1$.

It is evident from the discussion up to this point that Nashers while interacting in resource sharing, concluded to not share files. Notwithstanding one peer's preference for file sharing (resources), free-riding maximizes the return for the other peer. When P_r and P_c prefer not to share resources (files), they both stop making use of shared resources.

In this case, the best response a peer may give is "Don't share file", because it's irrelevant to what the other peer does. Keep in mind that if the peers are willing to cooperate and share resources, everyone is better off. Peers incur when they upload files so that others can download them, but they benefit by downloading files provided by others. Because none of their peers can effectively employ these resources, this predicament is worse for society than leaving the resources unutilized. Point 1 indicates that when Nashers interact the price of anarchy is greater than one. Point 1 shows that the price of anarchy when Nashers interact is more than one. Peers do not create an equilibrium action profile that is Pareto efficient.

Share File is the Pareto-efficient action profile in this case. PoA > 1 shows that the peers' action profile is detrimental to society and is caused by a lack of cooperation, which also encourages free-riding. On the other hand, when Kantian peers engage in file sharing, they create the Pareto-efficient action profile Share File, Share File. PoA and PoS therefore equal one, as suggested by Point 2. Both Kantian peers disapprove of free riding since they prefer to cooperate while sharing files.

4.3 *Experimental Analysis*

The analysis of cooperative behaviour among peers in peer-to-peer (P2P) resource or file sharing is conducted within a game theoretic framework, as previously mentioned. Researchers have utilised the Prisoner's Dilemma (PD) game scenario for this purpose. The File Sharing Game (FSG) has a resemblance to the Prisoner's Dilemma (PD) game. This study used a simulation of FSG to obtain a deeper understanding of cooperative conduct among peers. The NetLogo [30] is utilised in conjunction with the PD Two Person Iterated (PDTPI) [31] setup for this purpose. While the PDTPI setting provides users with the option to select from a variety of strategies, we will focus on the following strategies:

1. **Act-Randomly** - randomly cooperate or defect
2. **Cooperate** - cooperate always
3. **Defect** - defect always
4. **Tit-for-Tat** - If your opponent cooperates this round, you will cooperate the following round. If your opponent defects this round, you must defect the following round. Begin by cooperating.

4.3.1 Payoffs

For this study, we take the payoff matrix from Table 3 and turn it (without loss of generality) into the above payoff matrix.

Table 3

FSG Payoff Matrix for Simulation

		P_c Strategies	
		Share File	Don't Share file
P_r Strategies	Share file	0, 0	–3, 1
	Don't Share File	1, –3	–2, –2

4.3.2 Setups

The investigation of peers' cooperative behaviour is conducted across six distinct contexts, as depicted in Table 4. For instance, in Setting 1, P_r (Peer-1) exhibits random behaviour by choosing to either share or not share files, whereas P_c (Peer-2) employs the tit-for-tat strategy.

It is important to observe that, except for Setting 7, all other configurations involve peers who adopt a Nash strategy. However, in Setting 7, peers engage in FSG and adhere to a Kantian approach. In the given context, P_r engages in cooperative behaviour with P_c by engaging in the act of file sharing. Given that P_r engages in cooperation, it follows that P_c reciprocates this behaviour, employing a tit-for-tat strategy.

Table 4

File Sharing Game Settings

Setting	Configuration	Average Payoff
Setting-1	P_r Strategy: Act-randomly	P_r: -0.986
	P_c Strategy: Tit-for-Tat	P_c: -1.014
Setting-2	P_r Strategy: Defect	P_r: -0.399
	P_c Strategy: Act-randomly	P_c: -2.514
Setting-3	P_r Strategy: Act-randomly	P_r: -1.060
	P_c Strategy: Act-randomly	P_c: -0.970
Setting-4	P_r Strategy: Defect	P_r: -1.964
	P_c Strategy: Tit-for-Tat	P_c: -1.993
Setting-5	P_r Strategy: Defect	P_r: -1.986
	P_c Strategy: Defect	P_c: -1.986
Setting-6	P_r Strategy: Defect	P_r: 0.993
	P_c Strategy: Cooperate	P_c: -2.979
Setting-7	P_r Strategy: Cooperate	P_r: 0
	P_c Strategy: Tit-for-Tat	P_c: 0

4.4 *Findings*

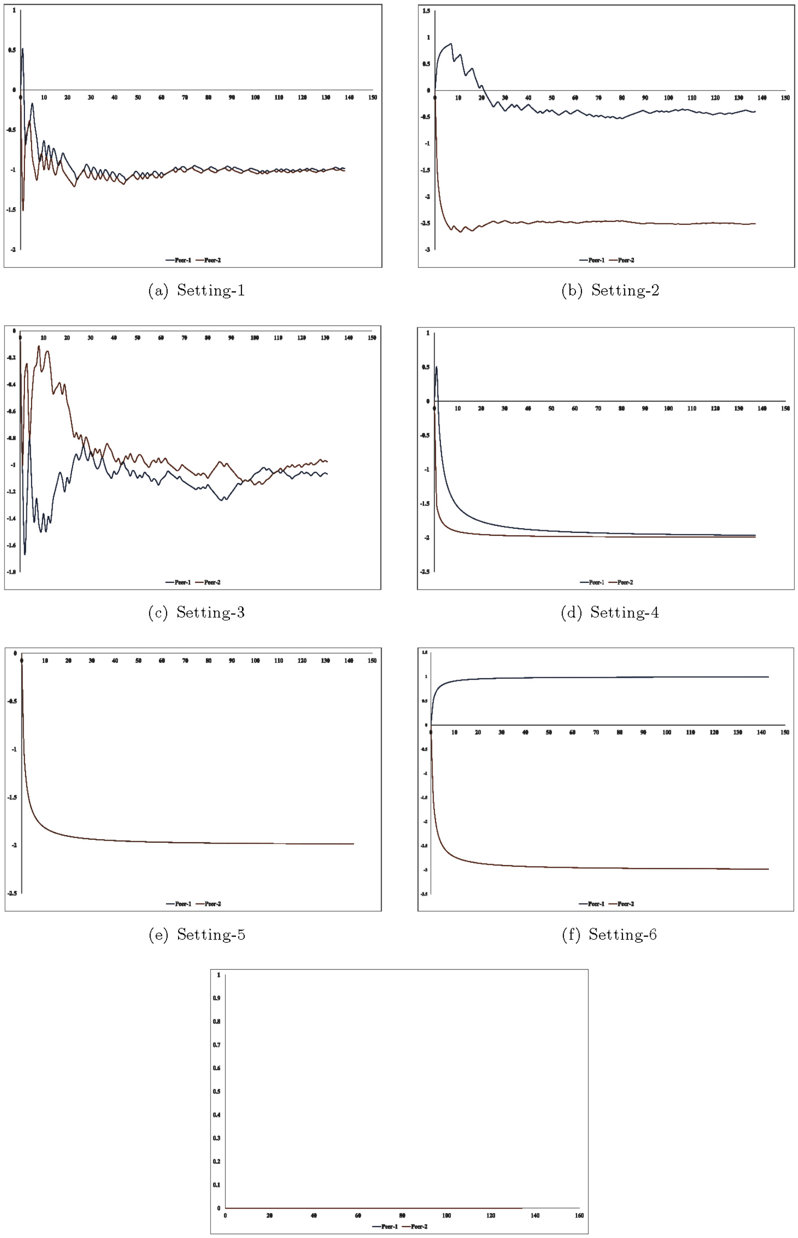
Figure 1 depicts the relationship between the number of iterations in the game and the payoffs obtained by each peer at each iteration. The x-axis indicates the number of iterations, while the y-axis represents the payoffs.

According to the findings shown in Table 4 and Figure 1(a) to 1(e), it can be observed that peers in Settings 1 to 5 consistently experience negative average payoffs. Both peers receive the lowest average payoffs when they both choose not to exchange files. As seen in Figure 1(e), the peers in question experience negative payoffs starting with the initial iteration. In the third iteration of the experimental setup, participants were given the option to either share or not share a file. The selection of these tactics by peers was done randomly. In the present context, throughout the initial rounds, namely the first nine rounds, peers experience favourable payoffs. However, after the tenth round, peers encounter unfavourable payoffs.

At one side, the sixth setting illustrates in Figure 1(f) the advantageous outcome for P_r through defection, whereas P_c does not experience any benefits from cooperation. In this scenario, P_r is engaging in the practice of free riding, whereby they are not reciprocating the sharing of files with another peer. The findings presented in Figure 1(f), it can be observed that P_r exhibits a favourable outcome through the act of defection, commonly referred to as free riding. It is important to acknowledge that under Settings 2, 4, and 5, despite P_r's decision to defect and not exchange files, P_c also tends to defect or occasionally cooperate. Consequently, the reward of P_r experiences fluctuations.

On the other side, in Setting 7, every peer assumes the role of a Kantian moral agent. In this context, each peer engages in the act of sharing files and anticipates reciprocation of this conduct from other peers. In essence, each peer anticipates cooperation from their counterparts. As seen in Figure 1(g), it is evident that participants in each successive round engage in cooperative behaviour, resulting in advantageous rewards. This demonstrates their adherence to Kantian principles, as outlined in the specified section. This discovery is also attributed to Proposition 2.

In the context of setting 7, it is observed that peers engage in cooperative behaviour and engage in the sharing of files among themselves. As a result, they achieve a condition of social efficiency, which is also an equilibrium state. Hence, in this particular scenario, both PoA and PoS are equal to one. Additionally, this observation indicates that both individuals within the peer group exhibit a preference for abstaining from engaging in free-riding behaviour.



(a) Setting-1

(b) Setting-2

(c) Setting-3

(d) Setting-4

(e) Setting-5

(f) Setting-6

(g) Setting-7

Figure 1

Payoffs of Peers in Different FSG Settings

We want to clarify that the simulation compares well-known strategies, our aim was not necessarily to introduce entirely novel strategy, but rather to provide a thorough examination and evaluation of these recognised strategies in our setting. The purpose of this simulation was to evaluate the robustness and effectiveness of the Kantian Equilibrium as a solution concept for FSG (as a prisoner's dilemma game). Unlike traditional solution concepts such as Nash equilibrium, which focuses solely on individual rationality and self-interest, Kantian Equilibrium adds a moral aspect by including factors of cooperation and reciprocity. We acknowledge that this simulation does not incorporate this particular feature of Kantian equilibrium. However, this is evidenced by the simulation, where both peers have a negative benefit when playing Nash equilibrium, whereas both achieve a zero benefit when playing Kantian Equilibrium.

5. Business Implications

In this work, we make an effort to apply the principles of Kantian equilibrium to the study of cooperative conduct among peers. Although we have only touched on one application of Kantian equilibrium here, this relatively novel concept has important implications for the growth and development of enterprises based on online web communities.

The notion of Kantian equilibrium, derived from the realms of philosophy and ethics, pertains to a condition wherein individuals adhere to principles that they would be inclined to witness being universally embraced, irrespective of their self-interests. The application of this notion to web communities can provide significant commercial ramifications, particularly in the cultivation of a more ethical, principled, and positive online milieu. The examination of Kantian equilibrium has the potential to have an influence on digital communities from a commercial standpoint.

5.1 *Formation of Ethical Community and Standards*

To achieve a state of Kantian equilibrium, corporations should adopt and uphold community norms of conduct that are reflective of the universal values of fairness, respect, and collaboration. This has the potential to improve the quality of life in online communities by fostering an environment where people feel secure and valued. The concept of Kantian equilibrium promotes the idea of enabling individuals to assume responsibility for upholding the ethical norms within a community. Businesses can engage the community in dialogues about regulations, protocols, and principles, enabling users to collaboratively influence the establishment of communal standards.

5.2 *Building Trust and Transparent Framework*

Managing online communities with a focus on Kantian principles can increase trust and credibility among members. When users are encouraged and rewarded for doing the right thing, they are more likely to stick around and make useful contributions. Further, businesses may be given a framework for developing transparency and openness in their relationships with people by making use of Kantian ideals. This framework can be beneficial. It is possible that cultivating a sense of fairness and inclusivity within the community can be accomplished via the use of communication that is both effective and transparent regarding policies, changes, and decision-making procedures.

5.3 *Long-Term Value Creation*

The Kantian equilibrium framework prioritises the pursuit of acts that contribute to the overall welfare of the community in the long run, as opposed to focusing solely on immediate benefits. Organisations that emphasize the long-term expansion and favourable advancement of their online communities are more inclined to generate enduring value for both users and the entity.

5.4 *Externalities and Collaborations*

The Kantian equilibrium framework promotes the notion that firms should take into account the wider societal consequences of their choices. This encompasses the mitigation of negative externalities, such as the dissemination of false information, the perpetration of cyberbullying, and the prevalence of harmful conduct within online communities, consequently fostering a more favourable digital environment. The concept of Kantian equilibrium has the potential to serve as a source of inspiration for fostering collaborative endeavours within online communities. Organisations can motivate individuals to engage in collaborative initiatives and endeavours that align with commonly held moral principles and have a positive impact on society as a whole.

6. Conclusion

In this brief research work, we investigate the resource-sharing patterns of rational peers in the setting of peer-to-peer computing. To accomplish so, we make use of Kantian equilibrium, which offers a different theoretical foundation for the cooperative actions of rational peers. Let us be clear: our goal is not to show that Kantian equilibrium is superior to Nash equilibrium or that Nash equilibrium is irrelevant in P2P systems. The notion of Nash equilibrium has been around for a long time and has been the subject of a significant amount of research; as a result, its benefits and drawbacks are completely understood. On the other hand, Kantian equilibrium is an innovative approach to predicting the outcome of a strategic situation. Here, we draw a relationship between the resource-sharing behaviour of self-interested peers and Kantian equilibrium and examine how this behaviour is best understood in light of Nash equilibrium. We demonstrate that when peers follow Kantian protocol, both peers are in a better position, and free riding is discouraged. The opposite is true when two Nashers interact. In this instance, they choose not to share files, making free riding unavoidable.

6.1 *Kantain Equilibrium: Adaptibility in P2P*

Unlike Nash equilibrium, which is considered to be more widely used and adaptable in real-world situations, Kantian equilibrium offers a useful viewpoint that integrates moral and ethical considerations [32] into decision-making processes [33].

To achieve Kantian equilibrium, moral considerations are incorporated into the decision-making process. In this scenario, it is presumed that participants will behave following universal moral laws or principles, such as the categorical imperative, even if doing so requires them to give up short-term rewards. However, a closer alignment between Roemer's Kantian optimization and Kantian ethical theory can be achieved by assuming some appropriate things about the meaning of maxims [26].

The Kantian equilibrium emphasizes collective rationality [27], which is when participants consider trust in the moral repercussions of their acts and work toward outcomes that are morally defensible for all of the members of the group. So, in practical applications, Kantian equilibrium is utilized less frequently [34] since it necessitates the existence of an agreement on moral principles and presupposes that persons always behave in line with these principles, which may not always be reliable in situations that occur in the real world [20]. Kantian equilibrium may be less flexible than other alternatives since it is based on established moral standards that may not always be appropriate or that may not be agreed upon by all players [27].

Kantian equilibrium probably fails to take into account strategic considerations and practical restrictions [35, 26], both of which have an impact on decision-making in situations that correspond to the real world. On the other hand, it does address these ethical issues by placing a greater emphasis on moral values. When everyone adhered to Kant's categorical imperative, it was pretty evident that the world would be placed in a more favourable position or a better place to live. However, we make the admission that, regrettably, this does not provide any insights into how such behaviour could realistically be done in the real world, which is filled with a tremendous number of egoists.

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