Research article

Modelling the influence of social learning on responsible consumption through directed graphs

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Abstract: This study examines the impact of social learning on consumption and production decisions in a societal context. Individuals learn the actual value of nature through information and subsequent network communication, which is illustrated using the Directed Graph theory and DeGroot social learning process. In this context, individuals with greater access to private information are called "neighbours." Results suggest that in a perfectly rational scenario, individuals have high confidence in their abilities and base their decisions on a combination of personal experience, perception, and intellect; thus, society is expected to converge towards making responsible consumption choices R_c^*. However, when individuals are bounded or irrational, they exhibit persuasion bias or stubbornness, and diversity, independence, and decentralization are lacking. It leads to a situation where the consumption network lacks wisdom and may never result in responsible consumption choices. Thus finite, uniformly conspicuous neighbours will swiftly converge towards the opinion of the group. When a large proportion of individuals consume excessively (extravagance) or below the optimal level (misery), the consumption network is dominated by unwise decision-makers, leading to a society that prevents promoting sustainability. In conclusion, this study emphasizes the need for a more rational and informed decision-making process in promoting a sustainable future.

Keywords: responsible consumption choice; Directed Graph theory; DeGroot social learning; matrix analysis; rationality; wise society; intellect, eigenvalue plot; social network; society

1. Introduction

Social learning refers to the process by which one modifies their views after considering the acts of others. People who see the choices of others are more likely to adopt such behaviours themselves, which is a crucial conclusion of social learning. Studies show that individuals rely on the opinions and advice of their peers in almost every area of their life, often more than they rely on their own direct experience or intuitive intuitions [1]. First, people tend to converge on the same activity, which frequently deviates them away from responsible consumption. However, results are often fragile because they are very susceptible to informational shocks and hence highly reliant on the circumstances under which they emerge (i.e., path-dependent). The notions of "information cascades" and "informational herding" were introduced in the works of [2–5]. In these models, people sequentially make judgments after seeing the acts of those who came before them, resulting in a cascade1 of knowledge. It is not often the case that everyone in the network of observers can see and know the decisions made by everyone else in the network before them. Therefore, insufficient information is collected, leading to faulty decisions. Individual consumption networks are often far more complicated as; a person may not be privy to other people's experiences (Bounded rational). Given the complexity of inference difficulties in consumption networks, we have accommodated bounded, perfect, and imperfect rationality situations in our work. So, consumption choices are assessed based on these criteria of rationality2 conditioned on information availability and extent of influence on decisions.

Our study focuses on the mechanisms through which information and its externalities may cause or prevent behavioural convergence and divergence in the context of responsible consumption. The DeGroot, a non-Bayesian Rule of thumb model and frequently realistic, has been widely explored in numerous studies concerning interactions via social networks. It accurately depicts that when an individual gains information from others, this impacts their choice mechanism. Individuals' social networks primarily facilitate the spread of values, attitudes, and choices. They spread information about goods, services, and societal initiatives; encourage or discourage people from pursuing higher consumption. It may be difficult for individuals, even with complete information about the network, to update their views accurately because of the complexity of that social network. We also illustrate consumption networks, where individual choices converge to the rational limit, with more considerable confidence in their choices.

The directed graph theory and DeGroot model offer a robust mathematical framework for exploring the role of social learning in shaping responsible consumption choices. These mathematical tools provide a rigorous and systematic way to analyse and understand the complex dynamics of social networks, including the flow of information, influence, and opinion formation. The directed graph theory visually represents the relationships between individuals in a social network and the flow of influence and information. It captures the interactions between individuals and highlights key influencers and opinion leaders. On the other hand, the DeGroot model is a mathematical framework that quantifies the extent to which those of others influence each individual's beliefs and behaviours.

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[1] a circumstance where an agent or group of agents operate without regard to signals from their private information. When social observational knowledge outweighs the signals from the present agents, this occurs. To put it another way, social learning is temporarily halted when an agent acts in a cascade because their actions are not informative to subsequent agents. *A negative information externality is thus imposed on subsequent agents by cascades.*

[2] The ears and eyes represent the senses through which man learns and acquires information. While the brain processes sensory data, makes inferences and plans of action, and then decides whether to carry them out. However, with the advancement in techniques, availability of data and technology, individuals can act rationally because of the access to abundant and low-cost information.

It provides a quantitative measure of the influence of different individuals in the network and the strength of the relationships between them. By combining the directed graph theory and the DeGroot model, researchers can gain new insights into the dynamics of social networks and the role of social learning in shaping responsible consumption choices. For example, the analysis may reveal key critical influencers in promoting environment friendly preferences or highlight the most effective strategies for disseminating information about sustainable products.

The study of consumer behaviour and the formulation of a definition of responsible consumption necessitates the consideration of cultural factors, such as religion, in addition to quantitative frameworks. Insightful explanations about human character and behaviour may be found in religious texts. Religious texts refer to how hassled[3] and frugal[4] people are in general. Religious scriptures often mention the concepts of thrift, waiting for better times, saving money, and wanting more material possessions. Consumerism externalities, the need for and the desire for positional goods, and the practise of conspicuous consumption[5] are all discussed. Religious scriptures also recognise the human tendency to satisfy physiological and aesthetic wants[6] while urging moderation and compassion. Responsible consumption is emphasized, as is the value of knowledge gained through rational decision-making. All religious texts, however, advise their adherents to restrain these instincts and instil empathy in their conduct and behaviour. Humans are endowed with wisdom, which can only be attained by using reason to make life decisions. Therefore, a society might be led away from wisdom if its members mindlessly follow the views of others[7]. The significance of social learning in influencing responsible consumption may be better understood if researchers consider a more comprehensive range of cultural views.

The availability of information has made it feasible for contemporary human society to make informed decisions about efficient resource utilisation. In economics, the focus is on the actions of a "rational consumer" who seeks to maximise utility while considering the cost of information and market pricing. However, this oversimplified picture does not capture irresponsible consumption choices. It holds when a person maximises utility by squandering resources and negating the negative externality of their choices on society and the environment. Individual actions that are wasteful cannot be considered reasonable and logical. Regardless of religion or belief, parents raise their children in every society. Similarly, most people care for their parents and feel some obligation to their neighbours, co-workers, friends, and family members[8]. So, the interconnection of individuals with other economic actors sometimes makes our choices either bounded rational or derive us towards absolute rationality [6].

The role of social learning in consumption networks has been widely studied in network science literature. Research in this field has shown that individuals' consumption choices are influenced by the behaviours and opinions of their social network members. The diffusion of innovations, such as new products or sustainable practices, often occurs through weak ties or individuals that are not close friends but have a more distant relationship [7]. Moreover, the structure of social networks can also significantly impact the spread of information and influence among network members. For instance, highly centralised networks with strong ties between a few key individuals can facilitate the spread of information and promote coordinated action. On the other hand, decentralised networks with weak ties

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[3] (Proverbs, 21:5, Al-Quran, 17:11),

[4] (Proverbs, 28:22–24, Al-Quran,17:100),

[5] (Luke, 12:15, Timothy, 6:9–10, Quran, 102:1–2)

[6] (John, 2:16, Quran, 3:14).

[7] (Matthew 15:14).

[8] Moreover, the wife and kids have an influential role in influencing the consumption choices of the family. Individuals feel content with their lives because of the beautiful emotions they experience when they spend money on their kids and family.

can increase the diversity of information and promote the spread of new ideas. Understanding the dynamics of social networks can provide valuable insights into how to promote responsible consumption through social learning and influence [8,9].

Some individual choices are based on the greater weight of their neighbour's opinion and information. It means that the gap between our most radical and moderate ideas gradually shrinks over time in a society where large social movements compete for control over our choices on consumption and production. This question calls for evaluating group relations and how these structures foster inclusivity in information exchange, at least in part. We will be analysing the consumption choices of individuals based on the work of [10,11]. Regarding consumption choices, we have explored whether community members eventually adopt a common viewpoint or retain divergent views based on Perron-Frobenius Theorem [12]. A society with the most significant influence on its members' beliefs is demonstrated through centrality and asymptotic behaviour[9]. Moreover, the time required to achieve consensus describes our conditions based on the extent of connectedness among members of society. When community or group members exhibit wasteful spending habits, the group moves away from developing the collective wisdom necessary to avoid making careless decisions that may have lasting adverse effects on its members' well-being.

The increasing awareness of the far-reaching environmental and social implications of consumer behaviour has led to a spike in interest in the role of social learning in encouraging responsible consumption decisions [13–15]. For example, sharing details about others' energy-saving practices led to a significant uptick in people taking up such practices themselves. Academic studies in this field have examined how social learning affects people's purchasing habits and how it might motivate people to make more environmentally friendly decisions. It exemplifies how people might learn to make more sustainable buying decisions by watching and emulating others. For instance, [16] has underlined the significance of social views in sustainable consumption by analyzing the Green-Feminine stereotype and its influence on environmentally conscious actions. [17] used the extended theory of planned behaviour to forecast home food waste reduction, highlighting the importance of social learning in determining waste management practices.

Different psychological processes behind social learning, including result expectancies and behavioural intentions, have a moderating role in encouraging environmentally friendly purchasing decisions. Social learning may motivate responsible consumption decisions, recognized in intervention design literature [18]. The importance of social learning processes is also explored in the context of the psychological aspects of intervention design for encouraging sustainable consumption. Social learning interventions are needed to close the "attitude-behavioural intention" gap in responsible food consumption [19].

Responsible consumption is encouraged through community-based efforts that facilitate shared knowledge and coordinated action. The Transition Town movement began in Totnes, England, and now advocates for more environmentally responsible and secure communities worldwide. Social learning and behavioural change opportunities may be found in community initiatives like gardens and renewable energy cooperatives [20]. Businesses that engage in CSR efforts through social learning may influence customers' actions. Patagonia[10] is well known as a pioneer in the sustainable outdoor gear industry [21]. Patagonia's strategy has shown the efficacy of social learning by impacting both customers and other businesses. Consumers benefit from having access to information about energy

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[9] A mathematical notion known as asymptotic behaviour shows how a function acts when the input (or independent variable) gets closer to infinity. There is a built-in method for limiting behaviour in every Markov chain.

[10] They advocate for responsible consumption and waste reduction via programmes like the Common Threads Partnership.

efficiency ratings on appliances because of obligatory labelling initiatives such as the EU Energy Label and the Energy Star programme [22]. The proliferation of online platforms and social media has significantly aided the dissemination of information and the shaping of consumer behaviour[11].

The research significance of this work lies in its contribution to understanding how individuals form their preferences and make decisions in a world where information is limited and uncertain. *The practical problem addressed in this article is the influence of social learning on responsible consumption choices in society. We aim to investigate how individuals' decisions are shaped by social interactions and the implications this has for promoting sustainability.* The novelty of our work lies in its exploration of the relationship between rationality, bounded rationality, and imperfect rationality and the role of social learning in shaping responsible consumption choices. By using DeGroot and Bayesian methodologies, the study provides a more nuanced and sophisticated understanding of how individuals use information from others to form their preferences and make decisions. By considering the role of social learning, this research expands the current understanding of responsible consumption choices beyond individual-level factors. It provides insights into how collective wisdom and behaviour can shape individual decision-making. Additionally, the focus on the role of digital technology in facilitating social learning is novel, as previous research has largely overlooked the impact of digital technology on responsible consumption behaviour.

This work aims to study responsible consumption choices, and Section 1 explains our work's introduction with a literature review in Section 2. The methodology explained in Section 3 includes theorizing a consumption social network and using directed graphs, eigenvalue plots, and the Perron-Frobenius Theorem. In Section 4, responsible consumption choices are defined in the context of the crowd's wisdom and two propositions are presented based on the consensus phenomenon in social networks. Furthermore, we have explained three scenarios representing rational, bounded rational and irrational choices of individuals in Section 5. The goal is to bridge the gap between empirical and theoretical studies on social learning by incorporating recent technological advancements and social media. We need more specific information to tease out the processes of memory storage, information aggregation, and information transmission in the consumption networks of individuals. The proliferation of social media sites in recent years has made it feasible to keep track of in-depth records of communication inside actual social groups. In turn, theorists may calibrate and expand their models by learning from empirical investigations of the natural conversational structure, communication frequency, and information degradation along transmission pathways.

2. Literature review

In recent years, much discussion has been on how social learning might encourage more sustainable lifestyle choices. Understanding how people learn and adopt sustainable purchasing patterns has become critical in light of the rising concern for responsible behaviour. This study seeks to comb through the available research on modelling the effect of social learning on responsible consumption by using directed graphs as a framework for analysis. The term "social learning" describes how people pick up new skills, values, and habits by witnessing and mimicking those of their peers in a group setting [23]. An important factor in moulding one's behaviour and choice-making is

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[11] For example, the #MeatlessMonday movement promotes cutting down on meat consumption on Mondays for environmental and health benefits. People committed to healthy eating may find and support one another via online social networks where they can exchange recipes, anecdotes, and inspirations.

social learning which entails learning from the experiences, actions, and consequences of others [24]. When people see their friends and coworkers engaged in eco-friendly behaviours like recycling and buying secondhand goods, they pick up those habits themselves. Individuals may be encouraged to engage in more responsible consumption habits after seeing the beneficial effects of these actions modelled for them [25]. The term "responsible consumption" describes buying and using products that consider the potential adverse effects on the environment, society, and ethics. It entails minimizing waste, conserving resources, and advocating for fair trade to help the environment and ensure a sustainable future[12].

Researchers have dived into the theoretical underpinnings of social learning theory and its relevance to sustainable behaviour to understand the connection between social learning and responsible consumption [28–30]. Each part demonstrates how cultural norms, peer pressure, and informal learning all play a role in molding people's consuming habits. The connecting factor between social learning and responsible consumption is how social interactions and observations influence people. A person's social networks, which might include friends, family, coworkers, and media influences, are essential sources of information on engaging in responsible consumption. Individuals' perspectives and decisions on responsible consumption are influenced by the social norms, beliefs, and behaviours they witness inside these networks. In order to simulate the effect of social learning on responsible consumption, it is essential to grasp these elements. People who believe their social circle supports and displays environmentally conscious actions are more inclined to follow suit. Individuals are more likely to make environmentally conscious purchases after seeing members of their social network make similar ones, such as when they see individuals using reusable bags, reducing their energy use, or participating in community recycling initiatives [31].

Social networks and the spread of information are only two examples of complex systems that benefit significantly from directed graphs employed as a modelling tool. Interpersonal connections, societal conventions, trust, cultural values, and the spread of knowledge all affect people's tendency toward responsible consumption. These models are helpful because they represent interdependencies between people and make it easier to investigate information dissemination patterns [32]. Considering aspects like network topology, connection strength, and individual adoption thresholds, these models allow researchers to delve further into the mechanics of social learning and its impact on responsible consumption [29]. The impact of social learning on responsible consumption across several domains, including energy saving, waste reduction, and sustainable buying, has been the subject of several empirical studies that have employed social learning models. These case studies illustrate how social learning mechanisms might influence consumers' efforts to reduce environmental impact [30,33].

Social ties in the form of interpersonal interactions have been found to increase the likelihood that an individual would adopt sustainable habits [34,35]. Responsible consumption is influenced by *social norms*, both descriptive (perceptions of what others do) and injunctive (perceptions of what others approve or disapprove of). Social norms' impact on individual choices can be modelled using directed graphs. For examples, see [15,36–38]. When people trust the information, they get and those in their social networks, they are more likely to adopt behaviors from their surroundings [39]. However, graph models can capture the cultural factors influencing people's perspectives and actions regarding sustainability [19,40]. Social learning and responsible consumption rely on the free flow of information,

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[12] Buying locally produced and organic foods is an example of responsible consumerism because of the positive effects on the local economy and the environment. Another strategy to lessen waste is to choose items with minimum packaging [19,26,27].

and determining the effects of information sharing across social networks is possible through directed graph models.

The dynamics of social learning are complex and diverse regarding responsible consumption. Important mechanisms in the spread of responsible consumption include *feedback loops, contagion effects, and information cascades*. By mapping these patterns, researchers can gain insights into intervention techniques to encourage sustainable behaviour. When people model responsible consumption, it encourages others to do the same and creates a positive feedback cycle. This procedure strengthens the habit and helps it spread further [15]. The term *"contagion effect"* describes the propagation of a pattern of behaviour in which people consume more of a particular product or service. There is a cascade effect wherein consuming patterns spread across the network as people see and mimic the actions of their social connections. People experience information cascades when they begin to adopt consuming routines based on the actions and decisions of others rather than their own. The same holds for the spread of responsible consumption within a network: if some people are persuaded to adopt these practices, even if their preferences run counter to them, the trend spreads [3].

Researchers have also created agent-based models, network diffusion models, and Bayesian networks to simulate and forecast the spread of responsible consumption behaviour inside social networks. Social learning affects consumer responsibility, and the evolution of group outcomes may be studied using these models. The dynamics of social learning and responsible consumption have been illuminated using computational models such as agent-based and network diffusion models [29,41], Bayesian networks [42] and directed graph representations [43]. These models aid in improving the area by allowing researchers to simulate, forecast, and comprehend the propagation of consumption preferences inside social networks [44,45]. These case studies give empirical data and practical insights to better understand the dynamics of social learning and the variables that either encourage or discourage the adoption of responsible consumption behaviors.

Empirical data and novel insights have resulted from studies using directed graph models on responsible consumption. Using directed network models, some researchers have examined how social learning affects responsible consumption in the real world [46]. Effective intervention tactics to encourage responsible consumption may be better understood with the help of directed graph models. Interventions may exploit social learning processes for long-term behaviour change by focusing on essential people or critical network positions. In addition, pinpointing key hubs in the system helps boost the propagation of eco-friendly habits among consumers [47]. Researchers can better develop treatments that take advantage of social learning processes and influential people to promote sustainable habits if they have a firm grasp on the network structure and dynamics at play [48–51].

3. The theorization of consumption social network

In this work, we recognise that individuals are influenced by various factors, including their social network, cultural norms, personal values, and economic conditions. For example, peer pressure and social norms may encourage individuals to purchase products that are not environmentally friendly. At the same time, personal values and environmental concerns may lead to responsible consumption patterns. We aim to understand these complex relationships and how they shape individual consumption behaviours and decisions. One example of this can be seen in the phenomenon of "social comparison", where individuals compare their possessions and lifestyles to those of others in their social network and strive to maintain or improve their relative social standing. For example, a study

by [52] found that young women in the UK were influenced by the values of their peers, which led them to engage in materialistic consumption patterns. Moreover, people tend to conform to the consumption patterns of their reference groups (family and friends) based on the perceived level of similarity between the individual and the reference group [53]. Moreover, the physical environment, such as urban design, significantly impacts consumption patterns, as it determines what products and services are available and accessible to consumers [54].

3.1. Individuals and interaction

The main goal of the theory is to see whether it may shed light on the dynamics of groups when planning consumption decisions via the lens of social connections, which includes interactions between individuals. The current hypothesis reduces the complexity of influencing large groups of N individuals to a direct interpersonal impact by (a) connections among group members, (b) patterns of interaction within the group, and (c) linkages among group members' viewpoints.

There must be a clear and consistent set of definitions and postulates to apply the rules of logic and give a mathematical model its deductive power and internal coherence. A theory's plausibility is questioned when it is shown to be too simplistic compared to the complexity of actual human social behaviour for mathematical ease. In game theory, "the rational economic man" is described, but economic conduct frequently deviates significantly from this ideal. The proposed theory partly addresses this problem by using the theory of directed graphs[13], a branch of mathematics that may be used without the need to make exact quantitative assumptions about empirical data.

The workhorse model in our work is the DeGroot; given continuous information with probability, p_h, individuals forecast the future condition of the world each time as follows. Even before they get a chance to consult with anybody else, their finest source of data is what they have discovered on their own. They take an average of their most recent estimate and the guesses of their neighbours to whom they have listened in the next interval. According to the rules of a social network, connections between people/nodes are made through describing finite set $N = \{1, 2, \ldots, n\}$. We term that network in which consumption choices are formulated deduced from the opinion of respective group members. Consumption interactions among individuals are captured through an $n \times n$ stochastic[14] matrix C. Then $C_{hi} > 0$ demonstrates that individual h *for making his/her choices allocate some* weightage to the opinion of i to make some consumption choices. The actual state of the world $\theta \in R$ is that *we have responsible consumption choices*. Each individual has some initial Choice with a probability $p_h(0)$; we assume $\theta = 1/n \sum_{h=1}^{n} p_h(0)$ and with time[15] (k) individual updates his choices as $p_h(k)$.

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[13] Harary and Robert Norman have investigated the directed graph theory, an extension of graph theory, with an eye toward its application in the social sciences. These mathematicians helped the author in establishing the theorems of this theory and match the findings of studies on the power of social networks [55].

[14] In a stochastic matrix, values across each rows are normalized sum to one.

[15] In time $k \in \{0, 1, 2, \ldots\}$ and $p_h^{(k)} \in \mathbb{R}$ and $p_h^{(k)}$ to lie in $[0, 1]$. A probability of 0 means that an event is certain not to occur, while a probability of 1 means that an event is certain to occur. In the context of a social network, probability can be used to model the spread of information or influence between individuals. For example, the probability of an individual adopting a new idea or behavior can be estimated based on their network connections and the influence of others in their network. Overall, the use of probabilities in social network analysis provides a way to quantify and model the uncertainty and complexity of social relationships and interactions. By ensuring that probabilities always lie within the interval [0, 1], we can ensure that the models and predictions we make are based on valid and meaningful assumptions.

$$p_h(k+1) = \sum_{i=1}^{n} C_{hi}\, p_i(k)$$

Each individual is adjusting their opinions based on the average of others around them. An example of this can be herding behaviour which refers to the phenomenon where individuals in a network tend to follow the opinions and decisions of others rather than forming their own independent opinions. It can result in individuals converging on a common opinion, even if it is not the most accurate or best supported by the available evidence[16]. Although individuals cannot modify their behaviour, they may share information with their neighbours to revise their opinions. There are chances that an Individual gets a noisy signal $p_h^{(0)} = \mu + e_h$,[17] when time $k = 0$.

Various mechanisms can drive herding behaviour, including social influence, network structure, and individual behaviour. Understanding these structures helps understand social network dynamics [56]. In the context of the empirical illustration of the crowd's wisdom, the doubly stochastic[18] matrix can represent individuals' influence in a network on each other's beliefs.

3.2. Directed graph

A digraph (directed graph) is a type of graph in mathematics and computer science that consists of vertices or nodes connected by directed edges, which have a direction and lead from one vertex to another. In a directed graph, the vertices (also known as nodes) can represent individuals or entities, and the directed edges can represent the interactions or relationships between them. The direction of the edge represents the direction of the interaction or relationship, and the edge's weight can represent the interaction's strength or importance [57].

By representing individuals and their interactions through directed edges, a directed graph can provide insights into the structure of consumption and relationships of a system or network Any change with a probability higher than zero is considered viable. It may be said that the consumption matrix C is connected if a way exists from each node to any other node. The matrix is said to be connected if and only if $C_{hi} > 0$. Additionally, there are also self-loops with non-zero probabilities, C_{hh} of cycling back to the initial state h. Every possible combination of nodes h and i in the entire graph of a finite-state process has an edge between them and a transition probability. Each node represents one of many possible outcomes in this representation of the Markov chain [58,59].

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[16] One example of herding behaviour in a consumption social network is the adoption of a new product. If an individual observes that many of their friends and acquaintances have purchased a new product, they may be more likely to purchase it themselves, even if they had not initially considered doing so. This is because they perceive that the product is popular and therefore a good choice.

[17] where $e_h \in \mathbb{R}$ is an unforseen noise term, and μ is a specific natural condition n. In a social network, an individual can receive a noisy signal when they receive information that is inaccurate, misleading, or otherwise distorted. This can occur when the information is transmitted through the network, and it becomes distorted as it passes from person to person. For example, if a piece of information is initially accurate but is later changed as it is passed along, the final information received by an individual may be different from the original. Noisy signals can also arise due to intentional or unintentional misinformation, where individuals in the network may deliberately or inadvertently spread false information. Additionally, social networks can also be subject to biases, where certain individuals or groups receive more attention or are more likely to be heard than others, leading to the spread of biased information.

[18] It is a square matrix whose elements are non-negative and the sum of elements in each row and each column is equal to 1.

3.3. Representing consensus

We have discussed the conditions under which a consumption network's participants' preferences stabilise within finite boundaries rather than continuing to oscillate indefinitely. *As a result, wisdom cannot be realised in such convergence* [11]. *A consumption matrix C can be regarded as* convergent *if* $(\lim_{k \to \infty} C^k p = (\lim_{k \to \infty} C^k (Cp))$, This implies that, $r^* = r^* C$ and $p \in [0,1]^n$. In economics, the consumption matrix can converge if the limit of C as time goes to infinity exists and is finite. In practice, the convergence of the consumption matrix can be influenced by various factors such as income, preferences, and market conditions. For example, consider a matrix that represents a household's monthly consumption of food items. If the household consistently spends the same amount each month on each food item, then the matrix's limit would represent the household's steady-state monthly consumption. Another example is a matrix representing the population of different species in an ecosystem. Suppose the populations of the species reach a balance and no longer change. Convergence, in this sense, means that all starting consumer opinions will eventually converge to the same point. Moreover, when there is no convergence, individuals are either stubborn or utterly reliant on the opinion of others. For convergence, aperiodicity is the requirement.

Periodicity is evident in the below matrix as,

$$C = \begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

If $p_1(0) \neq p_2(0)$, If this is the case, the belief vector will always be in flux as people constantly revise their opinions. However, convergence does not require that an individual h always put some weight on his own opinions to formulate a consumption choice that is $C_{hh} > 0$ for any h. However, convergence does not mean that the crowd is wise, and blindly following the opinions of others does not lead us towards responsible choices in our lives. There is also a left eigenvector r of C with the sum of rows equal to 1 [60].

$$(\lim_{k \to \infty} C^k p)_h = rp$$

The limiting choices mean that individual weightage to the initial opinions of others. Moreover, Individual h influence in their respective group, corporation or government is represented by r_h whereas, $r (r1, \dots , rn) \in [0,1]^n$. It would measure how much each influences the consumption choices of others.

$$(\lim_{k \to \infty} C^k p)_h = \sum_h r_h p_h(0)$$

Noting that $(\lim_{k \to \infty} C^k p = (\lim_{k \to \infty} C^k (Cp))$, This implies that.

$$r = rC$$

It is sufficient to know that $r_h = \sum_{i \in N} C_{ih} r_i$. Every h has an influence equal to the weighted sum

of the influences of all the individuals i who pay attention to h, where each individual's influence (denoted by r_i) is multiplied by their confidence (denoted by C_{ih}), in h. A Consumption matrix C is reaching a consensus if $p_1(\infty) = \cdots = p_n(\infty) = rp(0)$. Therefore, suppose the initial vectors of

opinions are, $p(0) = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}$ Then updating gives us, $p(1) = C.p(0)$, $p(2) = C.p(1) = C^2.p(0)$,

$r(Cp(0)) = rp(0), \forall p(0)$

$$C^k \to C^\infty = \begin{pmatrix} r \\ \vdots \\ r \end{pmatrix}$$

Our research has focused on how long-term consensus on consumption patterns may be maintained. We use the Perron-Frobenius theorem from probability theory [61]. Each person who is not a part of one of these closely linked groupings will eventually come to accept the restricting views held by the absorbing group as the norm and then C^k Reach its limit if one exists. These findings point in the same direction, showing that less cohesive societies converge more slowly than more cohesive ones. Therefore, whether the network demonstrates wisdom may be completely independent of the convergence rate.

The vector r quantifies each individual's societal impact: The views of more powerful individuals have more weight in the eventual unified decision. It is straightforward to demonstrate that an individual's sway in a network is precisely proportional to his or her degree, $r_h = 1 + d_h$, in symmetric networks. For a network to be considered negligible, there must be a maximum degree, $dmax$, which holds regardless of the actual size of the network. The "wisdom of crowds" effect is captured by this argument [62]. According to the formalisations of [11,62], the only structural aspect of a symmetric network that affects the distribution of social influence is the degree distribution, not the average social distance impacting the pace of convergence [63].

### 3.4. The Perron-Frobenius theorem

The second-largest eigenvalue modulus $|\sigma_{SLEM}|$ controls the pace of convergence to r^*. The rate may be written as $1 - |\sigma_{SLEM}|$ [19] [21]. As the distance becomes more prominent, the rate of convergence increases. Departure from equilibrium, measured in terms of the total variation distance, has a temporal characteristic that may be measured in terms of the mixing time. As a result of the exponential nature of convergence, the mixing time for the exponential decay is e^1

$$C_{mix} = -\frac{1}{log|\sigma_{SLEM}|}$$

3.4.1. Eigenvalue plot

The spectral gap is the space between the radii whose lengths equal the magnitudes of the second and first most significant eigenvalues (SLEM and LREM, respectively). It is a representation of eigenvalues on the complex plane. If the modulus of two eigenvalues is 1, then the chain has two periods.

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[19] where $|\sigma_{SLEM}|$ is the spectral gap
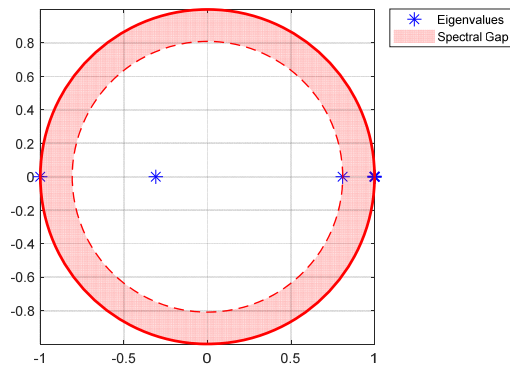
Figure 1. Two eigenvalues have a modulus of 1, indicating period 2.

One of the most important ramifications of using C in econometric model construction is how the chain behaves as it approaches infinity. Identifying and isolating the states whose return-time probability approaches zero asymptotically from the recurring states (those whose return-time probabilities go to one) is necessary. Therefore, based on Perron Frobenius theorem and eigenvalue plot, we are representing consumption social networks as,

Table 1. Consumption social network 1.

$$
\begin{bmatrix}
0.1198 & 0 & 0 & 0.0903 & 0.2058 & 0.2740 & 0.0828 & 0 & 0.2274 & 0 \\
0.1092 & 0 & 0 & 0.1782 & 0.0039 & 0.1152 & 0.1477 & 0.1541 & 0.1717 & 0.1201 \\
0.2843 & 0.3200 & 0 & 0 & 0 & 0.0438 & 0.1796 & 0 & 0.0503 & 0.1220 \\
0.1004 & 0.0485 & 0.2595 & 0.1515 & 0.2251 & 0 & 0 & 0.0549 & 0.0052 & 0.1549 \\
0.2753 & 0.0415 & 0 & 0.1675 & 0.0706 & 0.0182 & 0.0038 & 0.1761 & 0.0212 & 0.2258 \\
0.1212 & 0.1813 & 0.1383 & 0.1637 & 0.1569 & 0 & 0.0140 & 0 & 0.0945 & 0.1301 \\
0 & 0.1635 & 0.0292 & 0.0291 & 0.0910 & 0.0285 & 0.2269 & 0.2275 & 0.1422 & 0.0621 \\
0.0064 & 0.0267 & 0.0080 & 0.1128 & 0 & 0.0180 & 0.2295 & 0.3421 & 0.2298 & 0.0268 \\
0.3040 & 0.2471 & 0.0086 & 0.1916 & 0 & 0 & 0.0665 & 0.0784 & 0.1038 & 0 \\
0.1252 & 0.1366 & 0.0051 & 0.1757 & 0.1565 & 0.0195 & 0.0457 & 0.0895 & 0.1791 & 0.0671
\end{bmatrix}
$$

Table 2. Consumption social network 2.

$$
\begin{bmatrix}
0 & 0.3076 & 0.3968 & 0 & 0 & 0 & 0 & 0.0317 & 0 & 0 \\
0 & 0.1765 & 0.3477 & 0.4788 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1.0000 & 0 & 0 \\
0.4724 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.5276 \\
0 & 0 & 1.0000 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0.8879 & 0 & 0 & 0 & 0 & 0 & 0.1221 & 0 \\
0.7817 & 0.2183 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1.0000 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0.6923 & 0.3077 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.7408 & 0 & 0 & 0 & 0 & 0 & 0.2592
\end{bmatrix}
$$

The spectral gap is shown as a pink disc in the graphs. The time the Individual takes to mix and adopt group opinions depends on the spectral gap. More rapid mixing occurs with wider gaps, whereas

slower mixing occurs with narrower ones. It is because the Figure 2 spectral gap is broader than that of Figure 3, allowing for a quicker mixing rate, and people converge quickly to the opinion of others. When a person talks to his friend about a product through any communication mechanism, other individuals acquire that information after one period. After two periods, this information further spreads based on the observation that the first period is known, e.g., information regarding product consumption, and this cycle continues over time. It attempts to demonstrate that social networks influence convergence rates over time. Therefore, we develop a model incorporating preferences and determining how they are designed and the role of social and market influence. It can be applied to various kinds of consumers like one having self-reliance and not communicating with others regarding his decision to consume a product, saving, and investment patterns. Contrary to that, others can be those individuals who pay much attention to information received from others and make their decisions based on it.
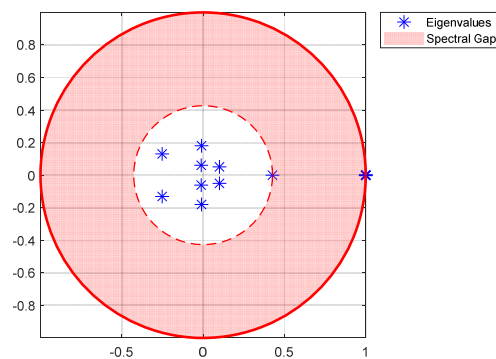
Figure 2. Eigenvalue plot for consumption social network 1.
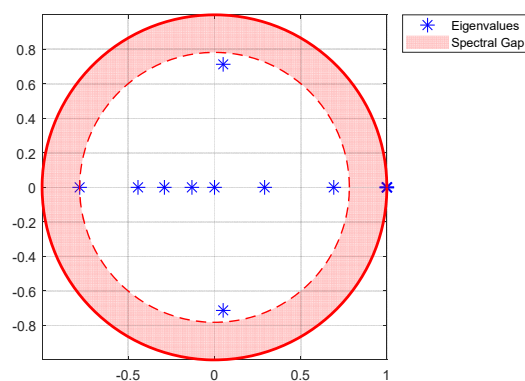
Figure 3. Eigenvalue plot for consumption social network 2.

4.   The wisdom of crowds in the context of consumption networks

It refers to the idea that the collective decision or judgment of a large group of people can often be more accurate and reliable than the judgment of a single expert. This concept can be applied in the

context of consumption networks to understand how large groups of people can influence buying behaviour. We start by finding the long-term choice convergence for three kinds of consumption networks, i.e., *rational, bounded, and imperfect rationality scenarios*. Moreover, a community needs a large population size to have enough variety of thought to flush out individual mistakes and uncover the truth. We can say that crowd is "wise" if the influence of the most powerful in the group vanishes [11,64]. Nearly as ancient as democracies themselves is the belief that "wisdom of the crowd" (collective wisdom) can be used to solve societal issues. According to Aristotle, who is often credited with coining the phrase "the wisdom of the crowd," human emotions impact all of us to some degree and cause us to make wrong judgments. Human desires cancel each other out, leading to intelligent decisions if we can find the mean of all options. [43] contends that using the collective information of the public to make predictions is superior to relying on a small team of specialists. He believes that diversity[20], autonomy[21], and decentralisation[22] are necessary for tapping into the collective intelligence of a crowd and that modern computing technology has made it possible to help "decision makers" to generate accurate forecasts about several aspects of life. An example of the crowd's wisdom in promoting responsible consumption and production is using *crowdsourcing* platforms to gather input from a large group of people on environmental issues. For example, a company could use a crowdsourcing platform to solicit customers' ideas on making its production processes more sustainable. It is tempting to rely on the "wise crowd" to help understand public opinion on policy matters because of the potential for reducing individual bias[23].

4.1. Defining wisdom and responsible consumption choices

Wisdom in the context of responsible consumption choices can be defined as the ability to make informed decisions based on a deep understanding of the interconnectedness of social, economic, and environmental systems. It requires weighing the long-term impacts of one's actions and considering the consequences for future generations. This convergence towards a common understanding can help to promote wisdom in decision-making, as individuals can pool their collective knowledge and make informed decisions based on a shared understanding of the situation. In the literature, [65–67] examine the impacts of unsustainable consumption and production patterns and provide insights that a collective effort can help us shift towards more responsible choices during our lifetime.

In our work, a set of $n \times n$ interaction matrices represent the order of networks. We define a society as the sequence, $(C(n))_{n=1}^{\infty}$. To avoid confusion, we shall refer to the (h,i) entry of the interaction matrix n as, $C_{hi}(n)$. *Slow convergence may be considered a priori required for a "wise"*

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[20] Having a diverse group of individuals with different backgrounds and perspectives leads to a broader range of ideas and solutions being considered when making decisions. For example, a diverse group of people working on developing sustainable products will have a greater chance of coming up with innovative and impactful solutions.

[21] Autonomy allows individuals to act freely and express their opinions, which can help to avoid groupthink and promote creative thinking. For instance, an autonomous group of consumers can freely choose to purchase products that are environmentally friendly and socially responsible, rather than products that are cheap and easily accessible.

[22] Decentralization of decision-making powers and responsibilities helps to prevent a sin-gle person or group from dominating the decision-making process. This can help to ensure that responsible consumption and production choices are made at the local level, where the needs and circumstances of the community can be best understood.

[23] Most notably, Jarod Lanier believes that "the beauty of the internet lies in its ability to bring people together and that the value of these interactions comes from the individuals involved. When we treat the internet as if it has an opinion, we run the risk of becoming irrational and losing sight of the actual value of these interactions.

individual, state, corporation, or group. However, a highly linked network and rapid convergence speed are not necessities for acquiring wisdom [64,68]. There is an actual state of nature $\theta \in [0,1]$. If the information that people receive has restricted support, this may be readily generalised to enable the actual state, which is the Responsible state denoted as R_c^*. At time $k = 0$, an agent h in a network n observes a piece of information, $p_h^{(0)}(n)$ that is contained inside a discrete interval $[0,1]$ normalized without sacrificing realism. In the scenario, variance is $\sigma^2 > 0$, and the mean is θ. Information $p_h^{(0)}(n),..., p_n^{(0)}(n)$ are entirely unrelated to one another for all values of n. Many highly informed community members, as determined by the variance lower bounds rules, increase the likelihood of convergence to the truth. In this era of digitisation, access to information is not a problem. Therefore, individuals can make rational choices that help society *achieve responsible consumption mechanisms.*

Consider the consumption network $C(n)$, and label its associated influence vector as $r(n)$. Attitudes of individual h in the network at time k are represented as, $p_h^{(k)}(n)$. It can be shown that for each n and implementation of, $p_h^{(0)}(n)$. For each size n of the networks, there exists an upper bound, $p_h^{(\infty)}(n)$, beyond which the beliefs of any given set of nodes h converge. Each final option is a stochastic variable that changes based on the input information. By definition, a *wise consumption network* sequence is one in which all possible limiting choices converge concurrently in probability to the actual state θ and only wise individual, group, or State can achieve R_c^*.

However, widespread consensus is not always desirable. There is an agreement (of sorts) in the herding case, but it might implode. We would like consensus to be at $p^* = \frac{1}{n}\sum_{h=1}^{n} p_h(0) = \theta = R_c^*$. Influential people (such as media, local and religious leaders, and their close associates) have a disproportionate impact on the behaviour and beliefs of others. The idea is that if we consider the network of individuals who influence one another through their interactions and the flow of information and ideas, the presence of a few influential actors can disrupt the stability and diversity of the network. A "doubly stochastic" network refers to a system where the flow of information and influence is spread evenly and randomly across all participants, creating a balanced and diverse network. The absence of double stochasticity and the presence of influential actors can lead to a network dominated by a few voices and perspectives, reducing the wisdom of society as a whole. For understanding wise societies, the law of large numbers[24] can be helpful in our model. We have

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[24] In probability and statistics, the "law of large numbers" asserts that the "mean" of a larger sample will approach the "average" of the whole population. This is because a bigger sample will be more statistically reliable as a representation of the whole population. This principle can be applied to the context of responsible consumption and production by considering the collective behavior of individuals and organizations in making choices about what to consume and produce. For example, if a large number of individuals choose to purchase products that are environmentally friendly and socially responsible, it is likely that the average level of sustainability in the population will increase. This shift towards more responsible consumption choices will in turn encourage producers to adopt more sustainable production methods, as they respond to changes in consumer demand. As the number of individuals making responsible consumption and production choices continues to grow, the average level of sustainability in the population will converge towards a more responsible and sustainable average. In this way, the law of large numbers can be used to help promote responsible consumption and production, by encouraging the collective action of individuals and organizations towards a common goal.

averages of a random variable that are non-identical. It will be used to define wisdom in terms of power rankings. Label the individuals for all values of h and n, $r_i(n) \geq r_{i+1}(n) \geq 0$. Thus, the people are listed from most influential to least.

4.1.1.   Proposition I

Consumption network $(C(n))_{n=1}^{\infty}$ is wise if, $\plim\limits_{n \to \infty} \max\limits_{i \leq n} |p_h^{\infty}(n) - \theta| = 0$ and individuals make rational choices based on utilising sight, hearing, and intellect converging towards a responsible state R_c^*. *For wisdom to be achieved, the information must be i) independent, ii) uncorrelated, iii) have a mean θ, and have variances > 0. If $(r(n))_{n=1}^{\infty}$ is any sequence of influence vectors, then,* $\plim\limits_{n \to \infty} r(n)p^0(n) = \theta$, *When $n \to \infty$* Individuals with the most influence tend to zero $r_1(n) \to 0$, resulting in a wise society. Furthermore, wisdom is a precondition to attain R_c^*.
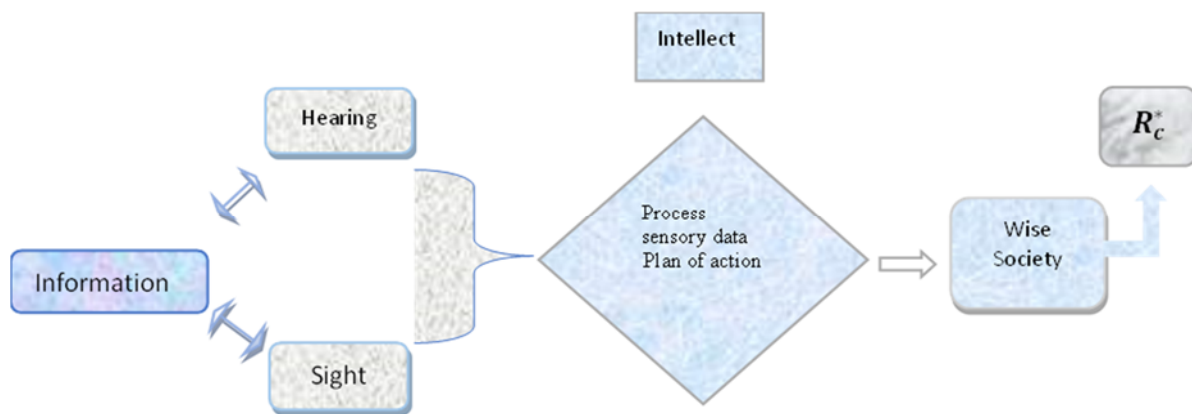
Figure 4. Responsible consumption in the context of rationality.

A waste of tax money would be defined as inefficient spending on public resources or management failing to assess the resources' true potential. Living above one's means, debt, poverty, and hunger may result from persistent overspending on an individual level. Societal extravagance may result from conventions, religious responsibilities, imitation, or the need for praise. It has been argued that actions harmful to humans, animals, and plants are also examples of extravagance. Responsible consumption based on intellect[25], hearing[26], and sight[27] refers to the idea that individuals should make informed and deliberate choices about what they consume and how they consume it, considering their intellect, the information they hear, and what they see.

[25] Intellect refers to an individual's ability to critically evaluate information, weigh the pros and cons of different choices, and make informed decisions. When making decisions about what to consume, individuals should use their intellect to carefully consider the social, economic, and environmental impacts of their choices.

[26] Hearing refers to the information that individuals receive through various sources, such as media, advertising, or word of mouth. When making decisions about what to consume, individuals should seek out diverse sources of information and critically evaluate the reliability and accuracy of the information they receive.

[27] Sight refers to the visual representations of products, their packaging, and the production processes used to create them. When making decisions about what to consume, indi-viduals should use their sense of sight to evaluate the appearance and quality of prod-ucts, and to consider the environmental impact of their production processes.

This interpretation, however, does not contribute to an objective definition of the notion. A person's spending habits on food, clothes, and health care, or at any one moment, cannot be used to indicate their frugality or wastefulness. Even sacred texts advise appreciating one's blessings and avoiding the waste that might result from limited or irrational decision-making. Currently, a universally accepted standard for determining moderate and excessive consumption levels is lacking. Consumption levels are considered moderate when they (a) fall within the range considered acceptable by the target social group and (b) fulfil the intended purpose for which they were purchased (c) spending stays within the allotted budget. Standard responsible individual conduct regarding expenditures on necessities such as food, clothes, housing, transportation, healthcare, and education, as judged by members of the appropriate social strata. Each main kind of spending would have moderation defined by how the typical person in that socioeconomic class sees the category.

According to the probability limit condition, as the number of individuals making responsible choices increases, the influence of any single individual will diminish, allowing the collective wisdom of the group to emerge and individual choices to converge to the actual state of nature. In this way, the wise society can be seen as a self-correcting system, where the collective behaviour of individuals drives the convergence towards a responsible state. In such a system, individuals will make choices that prioritise the long-term health of the environment, the well-being of future generations, and the sustainability of social and economic systems.

4.1.2. Proposition II

The consumption network or group is not wise and will never lead to responsible consumption decisions if there is a finite, uniformly conspicuous neighbour regarding $(C(n))$, then, $\text{plim}_{n \to \infty} r(n)p^0(n) \neq \theta$. So individual choices will never converge to the actual state of nature R_c^* as n $\to \infty$. Individuals with the most influence never approach zero $r_1(n) \neq 0$.

In a society where individuals blindly follow the choices and actions of others, the overall decisions made by the group will not lead to wise and responsible consumption. It is because individuals are not using their judgement and abilities of hearing, sight, and intellect to gather information but instead relying on the influence of others. Then for individuals in a society, the cost is either no convergence or a faster convergence resulting in deviation away from wisdom. Therefore, information becomes (i) dependent, (ii) correlated, (iii) has a mean greater than θ, and has variances = 0. An example of this can be seen in the fashion industry, where people blindly follow the latest trends and wear clothes not because they like them but because they believe others will approve of them. As a result, they may make extravagant purchases, even if they cannot afford them, and waste resources on things they do not need. In literature, this concept is portrayed by [69], where the characters are consumed by the desire to fit in with the wealthy and make extravagant purchases to keep up with their neighbours.

Harmony is the key to achieving responsible choices in an individual's life. Aristotle was on to something when, 2300 years ago, he began the study of happiness. Aristotle's "Golden Mean" states that "virtue" is found midway between the extremes of excess and deficiency. We know deep down that being happy is the whole goal of living[28]. Scientists have connected dopamine to the euphoria

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[28] The man was created to serve his fellow man, but he turns into his adversary when he *puts no value on anything outside his own practical needs* [32].

most people feel while shopping: when someone goes out to buy something new, the brain expects a reward from that sparkling item, so it fires dopamine in the brain's reward centre. Most individuals cannot afford to purchase anything they want to consume indefinitely, whether it is food or drink. *Self-control* comes into play for the ordinary person in this situation, as it may help explain why so many individuals have trouble saying no to a sweet treat. Everyone experiences the urge to give in to their baser animal instincts. However, the *logic-based portion of their brains where self-control resides* does its best to rein them in.

4.1.3. Assumptions

There are two states in the economy; state 1 is the Responsible level of consumption (R_c) and state 2 = is a Higher or lower level of consumption (L_c). Two risks for moving as Individual move from R_c with risk probability α to L_r and Individuals with risk probability φ to remain in L_c. These probabilities are considered transitioning from one state to another.

$$U_{R_c} = (1 - \alpha)U\left(c_{R_c} + B^i\right) + \alpha U(c_{L_c} - \emptyset) \tag{a}$$

Individuals in R_c Have responsible consumption choices while there are social and environmental benefits B^i. However, there are higher external social and environmental costs if the individual move to a higher consumption state Lc.

$$U_{L_c} = (1 - \varphi)U\left(c_{R_c}\right) + \varphi U(c_{L_c} - \emptyset) \tag{b}$$

If an individual moves from L_c to R_c, then consumption will be (c_{R_c}) as costs or damages are greater than benefits. Individuals remaining in a state L_c Have to bear monetary, social, and environmental costs, which will be transmitted to the whole society if they are in the majority. In a consumer-oriented society, people tend to conform to the behaviours and preferences of the majority. When the proportion of individuals who engage in extravagant consumption (p > 1/2) is large, there is an excess of consumption relative to the optimal level, leading to economic inefficiencies and an unsustainable balance in the long run. On the other hand, when a large proportion of individuals are below the optimal level of consumption (misery), there can be a lack of demand for goods and services, leading to economic stagnation. In their paper, [70] argue that herding behaviour arises when investors lack information and rely on the actions of others to make investment decisions. Moreover, it can be in a consumer-oriented society; the wealthy elite engages in excessive consumption to demonstrate status [71]. This behaviour leads to a trickle-down effect, where the lower classes strive to imitate the wealthy. As a result, the economy's equilibrium is determined by the consumption patterns of the wealthiest individuals.

$$R_c < L_c, \text{where p} > ½$$

Ergodic state $L_c = L_c^*$

Consequently, the preferences of society are shaped by those in L_c^*. There are many costs associated with higher/irresponsible consumption levels, including increased pollution, non-renewable resources, potential global warming, volatile weather, and potential loss of environmental habitat. We

are overusing natural resources by more than seventy per cent. Moreover, this behaviour negatively affects individuals and societies by contributing to financial instability, social unrest, obesity rates, and health and mental problems. These are some of the costs that we have mentioned by remaining in L_c State. These costs are labelled as x_h and degree or level of consumption as $ꭙ_h$

$$ꭙ_h + x_h = 1$$

The cost associated with consumption that is either extravagant (higher) or miser (lower) are minimised at a steady state when, x_i Converge to a lower value. Now utility function of individual h is shown as,

$$U(c_h B^h x_h) = ln(c_h + B^h) + \Phi x_h$$
$$B^h = 1 + ꭙ_h, \qquad x_h = (1 - ꭙ_h)$$
$$U = \ln[(c_h) + (1 + ꭙ_h)] + \alpha \ln\left(\frac{1 - \varphi}{\alpha + ꭙ_h}\right) + \Phi(1 - ꭙ_h)$$

Φ is the weight associated with the costs of other activities; if a responsible consumption Φ converges to a smaller nominal value, the least costs are imposed on the environment. Applying F.O.C concerning $ꭙ_h$

$$ꭙ_h = \frac{1}{\Phi} + 2(\frac{(1-\varphi)}{\varphi - \Phi - 1})$$

Weight is inversely related to the degree of consumption level $ꭙ_h$, as Φ it is smaller for responsible consumption, but when Φ is high results in higher costs imposed on society and the environment. There is a systemic challenge to wisdom in random consumption networks: the dominance of a few influential individuals that disrupt the effective coordination between, State, group, corporations and individuals and sway them from attaining the actual state of nature, i.e., R_c^*. Both observational learning and the iterative updating approach presented here run the risk of collective mistakes if too much weight is placed on the opinions of a small minority of members of the population [72]. As a result, each action's optimistic individual will accurately calculate its pay out, and ultimately, society will learn which acts are ideal. For this result, connectivity is the sole attribute of the network required. In our context, we have explained three scenarios, one where individuals would have perfect knowledge of the state of nature and ignore the opinions of others. While the other two are the rational and bounded rational situations.

5. Scenarios illustrating individual choices

5.1. Rationality

It is worth noting that groups with many individuals having little information may provide accurate outcomes if each person chooses their own [43]. When individuals are free to do what they like, they frequently copy one another [73]. There seems to be a troubling uniformity in a society where everyone has complete freedom to behave as they like. In religious terms, God gave us the hearing,

eyesight, and intellect to make informed or rational choices in life.[29] Those who do not utilise their senses effectively put harm to themselves and others in the form of creating negative externalities for society and the environment. Religious texts emphasise the importance of rationality in an intersubjective environment. Humans are part of a broader world, and our thoughts operate inside a greater framework of comprehensibility. Several passages in the religious scriptures explain a "tribe, country, or community who thinks." In contrast, criticise those "who do not apply their reason".[30]

The five senses, sight, sound, smell, taste, and touch, are how humans gain insight and understanding, as theorised by philosophers. Only two of man's five senses have been described thus far: sight and hearing. It is because the information a person may get from smelling, tasting, and touching is restricted. Man obtains most of his knowledge via his senses of hearing and sight. Things we hear are stored in our memories. According to statistical analyses, hearing is highlighted ahead of sight because humans learn most of their daily experiences via auditory means. Humans were not created to mindlessly absorb any heretic or aberration prevalent in the world without questioning its legitimacy. Hearing is not to ignore the one who attempts to tell us right from wrong and instead hold on to the misconceptions. Given its importance to human cognition, the visual system is often the subject of study in psychology. Philosophers give it much thought since it is essential for making sense of the world's mysteries. We may learn from and profit from enlightening glances. Moreover, the sense of sight is not blindly following the crowd and ignoring the reason. We have intellect, hearing, and sight to know the truth, but those who are not efficiently using these will lead to suboptimal choices in life, harming themselves and the environment.

Rationalism is a philosophical viewpoint that emphasises reason above emotions. Therefore, reason is the only way to find and verify ultimate truths (information) [74]. The finest illustration of this is the body of knowledge known as mathematics, as it only uses the reason that we can explore the depths of numerical relations, build proofs, and deduce ever more complicated socioeconomic prevailing among societies. Spinoza's Ethics uses a methodology that is, once again, deductive and is based on Euclid's Elements of Geometry [75]. Therefore, rationality occurs in a communicative and intersubjective setting because of existing and thinking.

The ontological roots of reason have shifted dramatically at a time when we quantify rationality in terms of measurable qualities and computerised judgments, leading to the identification of highly idealised, inevitable irrational forms of rationality as the origin of human intelligence. The reason, the trait that sets us apart from the rest of creation and advantages us above others, acts mainly and basically in a qualitative and axiological environment. One may classify human wants and requirements into the things we cannot live without and the luxuries and improvements that make life more congenial. There will be a direct impact of the information acquisition cost in time the attainment of responsible consumption choices. Therefore, if information received by an individual is unbounded and costless, then asymptotic learning can achieve, which leads to a wise society. That is why we need to use our intellect to make good decisions.

According to [64], individuals are prone to a cognitive bias known as persuasion bias, which causes them to incorrectly attribute a lack of independence to the knowledge they have gleaned from a common source. Information aggregation effectiveness is influenced by the structure of available social networks and the information itself. When there is a great deal of variation in the quality of the information being aggregated, it is easier for people to separate irrelevant or irrelevant-to-the-present-

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[29] (Proverbs,18:13, 4:7–8; Acts, 17:17, James 1:19, Quran, 17:36; 2:269)

[30] (Proverbs, 18:15, Quran: 2:164)

state bits of information from the whole. Empirically consumption matrix should be doubly stochastic for a wise society. We have defined some boundaries for this purpose $0.50 < p_{hh} < 0.85$ *while* $p_{hi} = (1 - p_{hh})$. It means that an individual in a rational society places more weight on their own opinion but also considers the opinions of others to some extent. The fact that the weight placed on others' opinions is less than 0.50 implies that the individual values their own opinion more than the opinions of others.

A rational consumer[31] always purchases at the best price based on their needs. Such a consumer is expected to put the purchased products to good use and not waste them. However, what constitutes appropriate use and fair benefit is subjective and can vary from person to person. Education and moral mandates are necessary to ensure that individuals make responsible and wise purchasing decisions. These can help promote social control and ensure that consumers make choices that align with a shared understanding of what is considered appropriate and beneficial [76]. There is an open-ended question: how often have we considered the social and environmental aspects of our purchase decision? Before buying a shirt, shoes, smartphone, computer, or any other product, did we think about the social and environmental performance of the brands or companies or the human rights conditions behind the production of those products? The answer will be a big "No". This phenomenon is known as the *"intention behaviour gap[32]"* [77] because we have all the best intentions. However, when it comes to decision-making, people neglect their intentions and follow herd behaviour. There are specific questions about why that gap exists and who drives it, as we often fail to do what we intend to do regarding sustainability. This intention behaviour gap can be minimised when people have confidence in their choices, utilise information from other sources effectively and finally decide based on *reasoning* considering positive and negative externalities. Information access is not a problem in this digital age. However, we as a consumer are good at rationalising our own unsustainable decisions by blaming corporations and framing unsustainable as a production problem. This is just part of the tale; today's issues directly result from our culture's insatiable pursuit of greater convenience at a lower cost and faster speeds. Therefore, changing consumption norms is just as important as bettering production circumstances.

The likelihood of consumers choosing healthier products can be enhanced by reducing costs. In the digital age, more consumers are now concerned with the way of production of goods and services and their environmental costs and benefits. It means digitisation has improved our ability to become rational and responsible consumers. There is a *Potential Effect of Pro-environmental Self-identity on Responsible Consumption Behavior.* Different kinds of Behaviors, including consumption, are explained through identity. It can coordinate through attitudes, values, and behaviours [78]. Consumers

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[31] A rational consumer should not emulate others [Matthew 15:14] and should formulate choices through available information.

[32] If a consumer decides to buy a new T-shirt and narrows his choices to two equally cool T-shirts. Consumer understands one of the shirts comes from a company known for very decent working conditions in production, i.e., no child labor, fair wages, no toxic chemicals for colouring and made with organic cotton. At the same time, the other shirt comes from a brand quite notorious for so-called "sweat shop" working conditions. If that question is raised in public, most of us will answer that we are going to buy a more responsible shirt. However, our choices are faced by several factors, including peer pressure and income constraints. This phenomenon might be linked with available information we have about certain things as a consumer. There are certain examples from past where labors must face desperate working conditions including (April, garment factory collapsed in Dhaka Bangladesh. some famous world renown cloth brands were producing there. However, after that as well people still buy clothes from such brands neglecting costs they are imposing on labor and environment and social class. Then there is famous story of Foxconn a company producing smartphones, computer at Linghua China. According to guardian, workers due to unfavorable working conditions commit suicide. If these companies provide workers favorable conditions and pay can contribute to reducing poverty. Since we all have a heard stories about, child and slave labor in chocolate, sugar, gold, or coal factories.

express their self-identity through consumption choices, which extends to pro-environmental identity. Consumers with pro-environmental identities demonstrate responsible consumption behaviour. Market dynamics and consumer choices can play a significant role in promoting sustainable practices. By buying organic, sustainable, and fair-trade products, consumers can drive demand for these items and incentivize companies to adopt more environmentally-friendly practices. This approach does not require a complete overhaul of consumption patterns but rather a shift in consumer attitudes and purchasing habits [79].
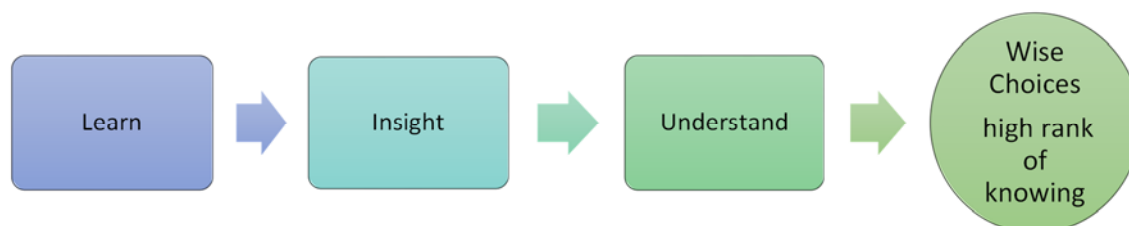
Figure 5. Learning towards wise choices.

Learning towards wise choices refers to acquiring knowledge, insight, and understanding to make informed and responsible decisions. This concept is rooted in the idea that by gaining a deeper understanding of a subject, we can make more informed choices that align with our values and contribute to our well-being and that of others. For instance, a person may learn about the environmental impact of single-use plastics, reduce them, and switch to more sustainable alternatives. Another example is someone who learns about the unethical labour practices in the fashion industry and purchases clothing from brands that prioritise fair labour practices and environmentally sustainable production processes. In literature, this concept has been explored in [80], which examines the role of personal choices in promoting a just and sustainable world. While [81] explores the idea that our current economic and social systems are driven by ignorance and argues for a shift towards a more holistic, interconnected, and responsible way of life. In conclusion, learning towards wise choices is a crucial aspect of responsible consumption and a way to promote a more sustainable and just world. By gaining knowledge, insight, and understanding, we can make informed decisions that align with our values and contribute to a better future for all.

Boycotts are situations where individuals stop buying commodities from a particular manufacturer to express disapproval. When a product does not align with religious teachings, religious leaders advise their members not to use specific products, due to which companies witnessed a tremendous drop in sales. Thus, from the example, it is evident that religious sentiments can broadly impact people's consumption choices. If that is so, they can also spread responsible consumption patterns and teach the adherents about the consequences of climate change. Therefore, places of worship and clerics have an influential role in disseminating information regarding the consequences of environmental degradation and promoting the teaching of efficient utilisation of resources. In other words, our behaviours are driven by ideas, beliefs, and ideologies that we may not fully comprehend. Bringing anything to the light of Reason is an excellent way to get partial freedom and independence.

5.1.1. An example of the rational consumer using the Bayesian rule

Let us suppose a responsible individual forms all choices (consumption, education, marriage, investment, production) by utilising information efficiently through reasoning. That Responsible individual further gives a signal to accept, represented by G, While B represents information that indicates that a particular choice is not suitable for the individual and society. When the majority choice is to accept, there are more chances that individuals will choose G to formulate their choices. This work is in the form of conditional probability for G as $P[G|E]$. When the correct action chosen is based on information B, then $P[B|F]$. e.g., Individual 1 buys a car x; however, after a few days of discovering that it has a terrible fuel average. So, he gives information about car x to his friend (individual 2) and then individually chooses to reject that car and exclude it from his preferences list. This kind of likelihood is depicted by r, then r > 0.5,

Table 3. Rationality of individuals, based on information.

Individual information	True Probability state	
	Reject	Accept
B	r	1-r
G	1-r	r

Further, we assume that all individuals act rationally. Based on the reasoning through utilising all information, the first individual decides whether to make a choice based on his information or whether there is a need for information to extract from other sources and uses his sight, hearing, and intellect to collect the best possible options available. If the Bayesian rule is employed, then,

$$P(E|G) = \frac{P(E)P(G|E)}{P(G)}$$

$$= \frac{P(E)P(G|E)}{P(E)P(G|E) + P(F)P(G|F)}$$

$$= \frac{sr}{sr + (1-s)(1-r)}$$

$$> s$$

The probability of accepting information G is found by summing the product $P[G|E]$. The first person, if making a choice based on his thinking, will always raise his estimate s with a G, according to the equation, since $r > 0.5$. It means the other person will agree if he thinks s is more than 0.5 but disagree otherwise. Observing a G will lead the agent to conclude that accepting is the logical decision, even if he initially assumed that accepting and rejecting are equally feasible possibilities ($p = 0.5$). Moreover, it also depends on the level of trust and interaction of individual two on 1. Conveying accurate information to individuals helps other people to make their choices more sustainable. With digitisation, it is easy to access information through online rating scales based on reviews of valuable

customers for different kinds of products and services.

The second person decides after carefully weighing the first person's conclusion and data. For the most part, in making his own decision, the nth agent takes into account not just the actions of the previous $n-1$ individuals but also the information at his disposal. Using Bayesian reasoning, he selects the optimum course of action. $q = r$

$$P(E|Previous|Personal\ Information) = \frac{sr^a(1-r)^b}{sr^a(1-r)^b + (1-s)(1-r)^a q^b}$$

Any direct or indirect influence in a respective group with any communication can be measured through matrix multiplication. It can also be represented as a column representing the influence exerted by members while a row represents the power applied to respective members [82]. Zero corresponds to several locations. The respective entity has no power to influence others. Similarly, one represents strong power to influence others in decision-making. It is appropriate to classify an economy where consumption is an important constituent. Consequently, deficiency of synchronisation and reduced reliance on the choices of others are indicated by zeros in random locations. The transition matrix exemplified in the form of the heat map as,
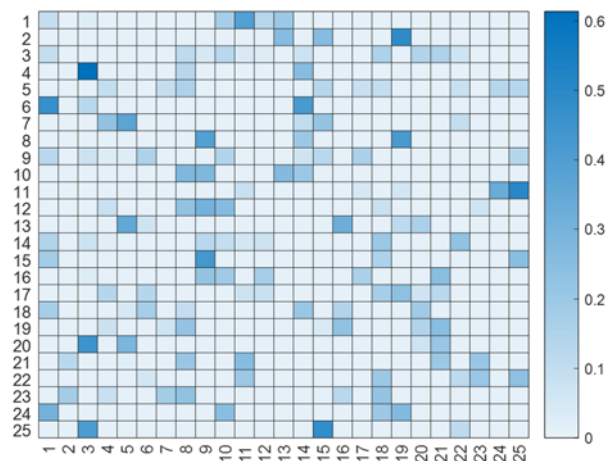
Figure 6. Consumption matrix of rational consumer.

The heat map is likely to visualize the transition probabilities between different states. The diagonal line represents the weight or influence of an individual's opinion on their choices. In the context of responsible consumption choices, the Perron-Frobenius theorem is used to demonstrate the stability and predictability of the system over time. Darker regions on the heat map indicate a higher probability of staying in a particular state. In comparison, lighter regions indicate a higher likelihood of transition to another state. The dark regions on the map likely indicate high probabilities of remaining in the same state, which is consistent with the concept of ergodicity.
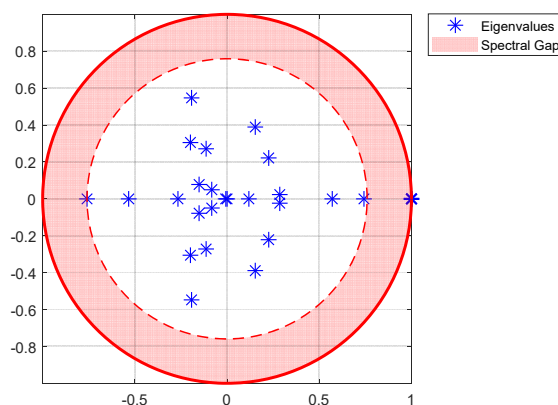
Figure 7. The current economic spectral gap is thin, indicating a considerable time interval for mixing /convergence towards equilibrium, i.e., (tmix ~3.6326).

In the context of responsible consumption choices, heterogeneous preferences mean that individuals have different values, beliefs, and priorities when purchasing goods and services. This diversity can help reduce inefficient herding because individuals are less likely to follow the actions of others blindly, and instead make choices based on their own needs and wants. When individuals know past behaviour or prevailing trends, they can counterbalance or reverse those observations to make more informed decisions [83]. It can lead to more responsible consumption choices that better align with individual values and goals. The figure below shows a graph plot function. There will always be a slow convergence rate in the case of complete learning. Change may happen as individuals learn and make decisions based on their needs and values rather than blindly following others. An example of this phenomenon can be seen in the research of [84] asserting that as consumers become more aware of environmental and social issues, they are more likely to choose sustainable consumption options, such as sharing goods and services rather than buying and owning them. This shift in behaviour can be seen as a form of counterbalancing past consumption patterns and a move towards responsible consumption choices based on individual values and beliefs.

Sweden has a stellar reputation for its dedication to environmental protection and conscientious purchasing practices. Tax breaks for maintenance services, increased recycling, and funding for renewable energy projects are just a few of this nation's green measures. Waste production and greenhouse gas emissions have been drastically cut in Sweden due to the country's strategy. [85] Patagonia, an outdoor apparel and equipment manufacturer, is often considered a model of conscientious purchasing and an environmentally sound enterprise. Transparency in the supply chain is a priority for the firm, and it emphasizes making high-quality goods that are made to endure. Patagonia gives back to environmental organisations and grassroots activists by donating a part of company profits. From Patagonia's "Corporate Responsibility" [86].

Bhutan is frequently held up as an example of a nation that puts people and the environment ahead of economic progress. Conservation of natural resources is essential to the country's pursuit of Gross National Happiness (GNH). Bhutan has enacted rules that give preference to renewable energy sources, conserve the country's abundant biodiversity, and encourage organic farming. The significance of community health and cultural preservation has also been highlighted. Bhutan wants to be a "zero-waste" organic country [87]. The Interface is a worldwide flooring producer dedicated to

environmental protection and ethical business practices. The corporation has lofty environmental objectives, such as having zero carbon footprint and eliminating landfill garbage. Interface prioritises eco-friendly manufacturing processes like upcycling and biomimicry in addition to cutting-edge product design [88]. Sustainable tourism and environmental protection are two of Costa Rica's best-known exports. The nation has substantially invested in renewable energy sources, including hydroelectric and geothermal electricity, to achieve its carbon neutrality objective by 2021. Protecting large swaths of forest home to great species variety, Costa Rica has also actively promoted eco-tourism [89]. These examples highlight how countries and companies can make conscious efforts towards responsible consumption and sustainable practices. Individuals, businesses, and policymakers must promote more informed and sustainable decision-making to mitigate these losses.
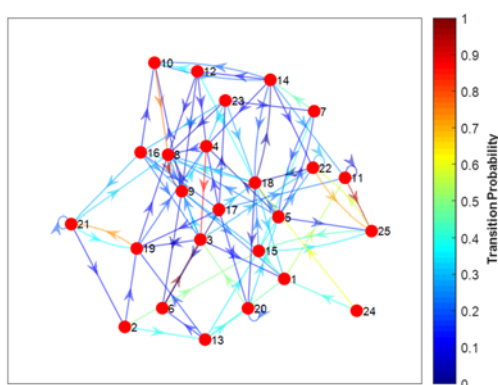
Figure 8. Structure showing interactions of individuals among each other.

Overall, the advancement in techniques, availability of data, and technology can help individuals to act more rationally by providing them with the information and resources they need to make informed decisions. By employing these techniques, complex patterns of individuals' decision-making regarding consumption, investment, or saving can be evaluated based on sustainability. Studies have shown that social influences can significantly shape consumer behaviour and attitudes towards responsible consumption, including choices related to sustainable products and environmentally friendly practices [90]. Companies and organisations have used social learning strategies to encourage responsible consumption behaviours. For example, product labelling and certification programs, such as Energy Star or USDA Organic, provide consumers with information on the environmental impact of products and promote responsible consumption choices [91]. Social media and other digital platforms have also been utilised to promote responsible consumption by providing consumers with information and peer-to-peer communication. Online platforms, such as forums and review sites, can provide consumers with information on products and services and offer a space for discussion and sharing experiences [92]. For example, research has shown that individuals are more likely to adopt new products if they observe others using them successfully.

Regarding production choices, social learning can play a role in the diffusion of new technologies and innovations. It can lead to increased efficiency and productivity in the long run. For example, farmers observing their neighbours using new technologies are likelier to adopt them. However, it is essential to note that social learning can also lead to suboptimal outcomes if individuals are influenced

by wrong information or misinformation. In conclusion, social learning plays a significant role in individual consumption and production choices, but it is essential to consider both the positive and negative effects of this process. Understanding how individuals use social information to make decisions can help policymakers design interventions to promote more efficient outcomes.

5.2. Bounded rationality

Individuals are limited in their ability to see and understand their environment. Thus, a threshold exists beyond which social forces (culture, religion, values, norms) may sway an individual away from their right choices. The second is that individuals in a particular sequence have only partial knowledge of the individuals who came before them, which is the foundation of the original information cascade model. Humans are assumed to be boundedly rational in the original independent cascade model, meaning they will not always make rational judgments based on the information they can see if that knowledge is incomplete or incorrect. In contrast to other definitions, in which individuals have access to *"secret information"* kept by their predecessors.

Individuals or heuristics with bounded rationality make decisions that are not guided by Bayes' Law or any anticipated utility-maximising decision procedure. In DeGroot's (1974) ground-breaking concept, for instance, agents constantly adjust their preferences until they match those of their peers in the social network. Maximizing predicted benefits in each period is the goal of biased individuals, but they ignore the repercussions of their actions on others by entirely discounting future value. A person in such a situation may be unable to mature enough to make appropriate decisions. Furthermore, asymptotic learning never happens when individuals may watch all predecessors and have limited knowledge [93].

Additionally, they demonstrate that herding happens for any limited information structure. Therefore, when knowledge is limited, individuals give their opinions a weight of less than ½. In such a scenario, individuals have bound away from rationality and reasoning by always relying on others' decisions. There is still a negative information externality since each act in her self-interest without considering the impact of his/her choice on others.

5.2.1.   Context

A false information cascade may last indefinitely if each person only sees a small fraction of the whole history of events. In other words, asymptotic learning is not a given, and societies might end up veering away from their efforts to promote responsible consumption choices. In bounded rationality, information aggregation is often self-limiting since more illuminating acts typically induce cascading onto most actions in the individual's observation sample. Getting information from others should be done to improve but not to get influenced. A meat eater's choice of restaurant means something different to a vegetarian. It is easy to deduce a decision-makers penchants from her behaviour if previous decision-makers' preferences are well known. The opposite is true if individuals keep their preference secret; in this case, observers must decipher prior private information from actual preferences. Asymptotic learning is shown to not occur in a social learning model [94,95] if agents have a finite number of preference categories and information is bounded—several possible manifestations of this mistake, including the ones mentioned above.

5.2.2. Low trust in private information

When Individuals have a lower level of trust in their information, they rely on others for decision-making. Individuals, when they allocate less weight to themselves than neighbours, can be represented by $\beta < 0.50$—representing a lower self-confidence level to propel us into a natural state. A group's consensus on a consumption issue, denoted by the letter C, may be represented as a matrix with columns labelled "e", "f", "g" and "h", respectively, representing the weight given to the initial positions taken by individuals E, F, G, and H. The rows show the weight given to these views by the other views in the group. The coefficients on the right-hand side of the general differential equations show the percentage by which one opinion changed due to a change in another during the same unit. Thus, the values placed into the cells should reflect that.

$$e_n = 0.24e_{n-1} + 0.50f_{n-1} + 0.26g_{n-1}$$

$$f_n = 0.50e_{n-1} + 0.33f_{n-1} + 0.17h_{n-1}$$

$$g_n = 0.10e_{n-1} + 0.69f_{n-1} + 0.21g_{n-1}$$

$$h_n = 0.65f_{n-1} + 0.24g_{n-1} + 0.11h_{n-1}$$

There are no directed pathways from F, G, or H to E. The value 1 in cell a indicates that in any given unit, E's opinion is entirely controlled by his prior opinion, while the value 0 in the other cells in a row an indicate that views F, G, and H do not affect E. Since, f_n, is a middle ground between the prior positions of E and F. Each row in C (and in C^2 and C^3), represents a group's consensus by adding up to 1, with the fractions along the row representing the individual member's contributions to the group's overall viewpoint. C's sum of a column shows how one member's viewpoint in the first period affected the rest of the group (including the impact of his initial opinion on his second opinion). The consumption matrix for the bounded rational group is represented below,

**Table 4.** Consumption matrix for bounded rational individuals.

	e	f	g	h
e	0.24	0.50	0.26	0
f	0.50	0.33	0	0.17
g	0.10	0.69	0.21	0
h	0	0.65	0.24	0.11
	0.85	1.88	0.7	0.28

In the context of bounded rationality, individuals tend to rely more heavily on the opinions of others, especially those in influential positions, when making decisions. It can result in a convergence of opinions towards the group's consensus, with a large spectral gap meaning that this convergence occurs faster. This phenomenon of opinion convergence can be seen in many areas, including consumer behaviour, financial markets, and political opinions. However, it is essential to note that this convergence may not always lead to optimal outcomes, as the opinions and behaviour of the influential group may not always align with individual needs and values. The influence distribution through time may be inferred from the sums of the columns representing the increasing powers of C. We can see that in Group G, F is the lone member of the structure, and he is steadily expanding his power at the

cost of the other members. However, he has the least say since he is affected by everyone else's opinions in the group. The group's hierarchy may be represented as a matrix, with rows representing the authority exercised over a member and columns representing the authority exercised by that person. Matrix multiplication may be used to determine the precise distribution of direct and indirect leadership in any organisation, regardless of its power structure or communication network.
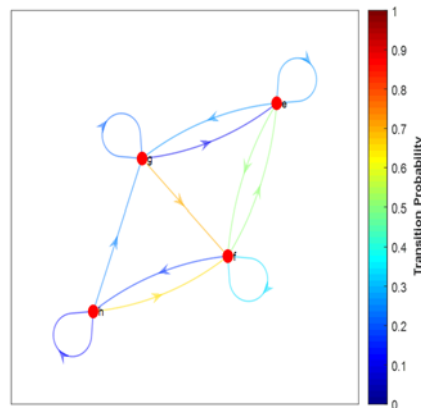
Figure 9. Graph plot representing the extent of connectivity interactions among group members.
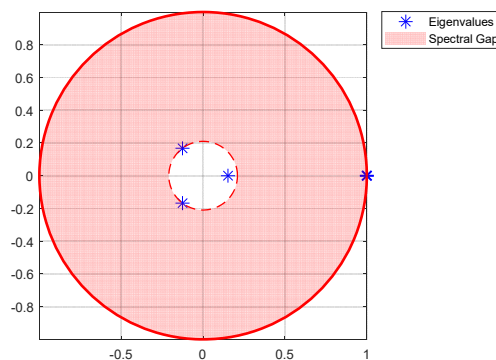

Figure 10. Eigenvalue plot for the bounded rational group.

The royal family is a vital example of a tightly linked network where individuals may not converge on the best course of action because all agents directly view a relatively limited number of people who cannot observe all group members. If the royal family in a network receives lousy information, it might have a cascading effect on the rest of the population. When this occurs, individuals in the population still rely on their private information during the introductory phase, but their actions do not spread across the network. This finding is strongly related to information cascades in single-action models, where people may cease paying attention to their internal information after exposure to new information from the outside world. Most often, people buying some commodities rely on the opinion of others, e.g., for buying a car, individuals rely on the opinion of friends or persons in their social circle. In today's digital age, however, consumers can access rating scales for goods, companies, and institutions, allowing them to make more educated purchases. The family plays a vital

role in shaping consumer habits in many civilisations. Ads for children and women are more likely to persuade consumers, especially mothers, to buy their products. While in Asian societies, mainly in India and Pakistan Culture of dowry is prevalent[33]. With the increased use of social media platforms, there is a subsequent increase in influenced consumption decisions directed by friends, family members and society, e.g., extravagancy seen in weddings which is a waste of resources and the ultimate burden on the environment[34]. People think that if they do not follow others, it will devastate their social status. Therefore, such choices lead to conspicuous consumption that causes towards squandering of resources.

There are cases when advertisers specifically target children by showcasing products on sites to influence parental purchasing decisions. Economically, it stimulates consumer spending and economic growth but negatively affects social values and the environment. The recent 420-million-rupee fraud perpetrated by a lady in the guise of a "committee" has shocked the people of Pakistan. First, a small group of individuals must have faith in the network before word can spread, and then numerous constrained options may emerge, resulting in a false information cascade. If people in today's market often consult with their peers before making critical choices, we may expect to see widespread conformity. Therefore, people give some thought to what they think. They are also willing to give other people's ideas greater weight, as seen by a transition matrix with fewer zeros in certain spots, representing a higher concentration of connectedness.
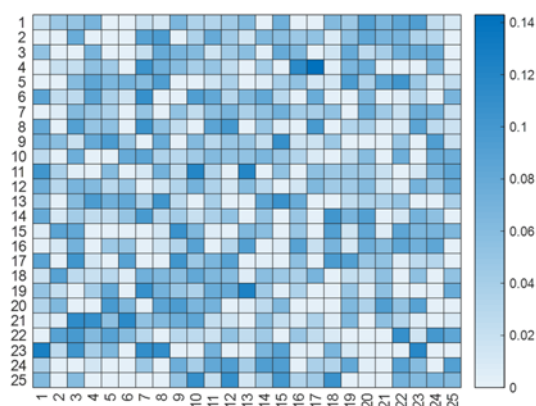

Figure 11. Consumption Matrix for Bounded rational economy.

In the above consumption matrix, the economic decision is determined through the extent of dependence on each other in formulating socioeconomic decisions. It is based on a theorem formulated by [96]: Such consumption network quickly converges toward stability, affirming ergodicity, and visually it is confirmed through an eigenvalues plot.

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[33] Dowry is a re-enactment of ancient Hindu society, in which daughters have not been given a portion of the family property but instead were compensated with money, some of which could be in the form of items (like dowry). Dowry is a sum of money, assets, or property given to the bride by her family at the time of her wedding in way to lure a suitable husband for her. When man marries her then dowry and woman both become the husband's or his family's property. This is total unethical and women should not be traded like a commodity. Due to cultural values and norms, status symbol parents are forced to adopt that dowry for their daughters resulting in delay in marriages in Asian societies.

[34] Most notably, at weddings, people emulate celebrities and social media act as a source of spread of information.
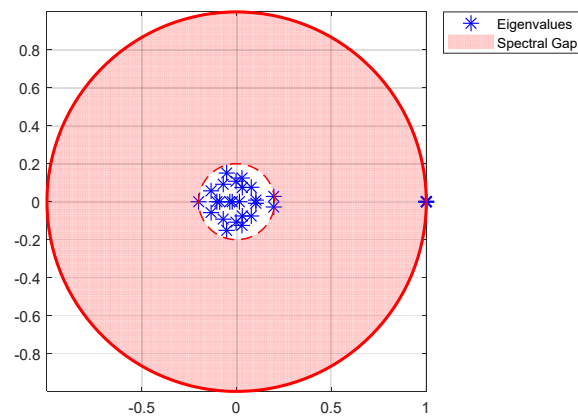
Figure 12. Individual converges towards equilibrium in a shorter time (~0.6567).

Optimizing individuals will follow others rather than using their information leading to inefficient equilibrium [2]. There are several examples of influenced decision-making. Daily, we must decide which store/restaurant to go to or buy groceries and which universities join based on popularity (beauty contest example of Keynes, the behaviour of investors in asset market). Researchers choose a hot topic in fertility choices, voting, and academic writing. Similarly, the first few decision-makers formulate the direction of the crowd.
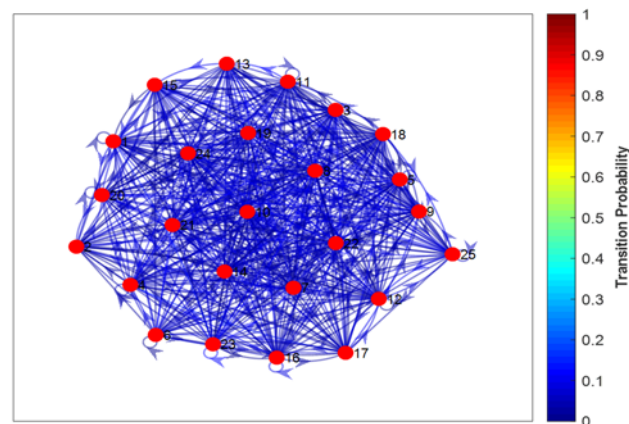
Figure 13: This graph shows the strongly connected structure of the Bounded rational consumption network.

According to [97,98], advertisements targeting children and items arranged on shelves of marts exemplify how efficiently marketers take advantage of consumers' limited information capacity. Perception from knowledge is that people are more indulgent in making choices when they have experience and ease of doing so. Therefore, trust in companies, their products, institutions, and other individuals is also a key determinant in shaping people's attitudes regarding economic decision makings. Quicker decision-making without effectively utilising sight, hearing, and intellect results in sacrificing the environment (Deviation from responsible consumption is characterized by faster

convergence and connected network). For example, when purchasing a car, a consumer may not have enough information about all available options to make the optimal choice. Instead, they may rely on simplified heuristics, such as the reputation of a particular brand, to make their decision. Similarly, a corporation may not have enough resources to gather all relevant information and analyze it thoroughly before making an investment decision. As a result, they may rely on rules of thumb or experience to make their choice. This limited rationality can prevent individuals, groups, and corporations from making wise and responsible consumption choices. For instance, a person may buy a product without considering its environmental impact, or a corporation may prioritize short-term profits over long-term sustainability.

Consumption decisions with the least access to information led to social, economic, and ecological problems in India. For example, burning agricultural wastes, industrial pollutants, and vehicle pollution contribute significantly to the country's air pollution problems. Alternative farming methods and transportation choices have been resisted due to people's limited ability to make well-informed decisions [99]. Indonesia's deforestation and forest degradation are caused by irrational consumer preferences for agricultural goods, timber products, and palm oil. This results in environmental costs, such as the destruction of habitat and the release of more greenhouse gases. Loss of ecosystem services and money from sustainable forest management and ecotourism are two examples of economic losses [100]. Some have criticised ExxonMobil, a large oil and gas business, for being "irrational" since it continues to put its focus on fossil fuel production and investment despite the pressing need to switch to cleaner energy sources [101]. Climate-related environmental damages, such as increasing carbon emissions, have resulted. Potentially stranded assets and the need to adjust to a low-carbon future are two economic costs [Nestlé, a multinational food and beverage corporation, has come under fire for its allegedly irrational water use habits. The company's water extraction methods have been criticised, especially in arid regions. It has resulted in water depletion and ecological damage, among other environmental costs. Reputational harm and probable regulatory measures are two economic consequences [102].

5.3. Complete irrationality

One takeaway from studies of human fallibility and social learning is the importance of avoiding cognitive biases that encourage individuals to rely too heavily on their information. Overconfidence or the belief that others have relied too heavily on the experiences of their forefathers when making decisions. Persuasion bias, however, has the reverse impact, leading people to give too much weight to precedent (bounded rational case). The cascades model includes overconfident people, which leads to a similar result [103]. The group cannot gather information effectively when people follow the crowd rather than think for themselves. When people behave in ways that are obviously out of line with the norm, they reveal personal information about themselves. Factors such as group size, the prevalence of overconfidence, and the accuracy of their information affect the socially optimum number of persons in a group. It balances the high attribution rates of people against the positive information externality. Overconfident or antisocial agents rely heavily on their knowledge to inform others, leading to more informed decisions in the future. When stubborn individuals make irrational choices, it will ultimately result in incorrect preferences by everyone who follows them. It can be regarded as a case of bounded rationality when an individual puts some weight on his own opinion to formulate a choice that is less than the weight assigned to choose probabilities of other members of respective members. In other

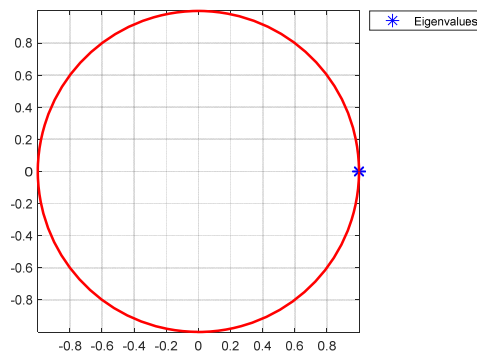cases, when an individual is stubborn, he puts all weight on his own opinion.

Overconfidence and the tendency to be easily persuaded are two examples of psychological bias that may affect social learning in consumption networks. One case of imperfect rationality is that the patterns of interaction are recorded by an $n \times n$ consumption interaction matrix C, where $I_{hi} = C_{hi}$ for $h, i = 1, 2, \ldots, n$. In this case C_{hi} act as Kronecker delta. $C_{hi} \begin{cases} 0 & for \ h \neq i \\ 1 & for \ h = i \end{cases}$

$$C_{hi} = \begin{bmatrix} 1 & 0 & \ldots & 0 \\ 0 & 1 & \ldots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \ldots & 1 \end{bmatrix}$$

By increasing the power of C_{hi} to C_{hi}^2

$$\begin{bmatrix} a_{11} & a_{12} & \ldots & a_{1n} \\ a_{21} & a_{22} & \ldots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \ldots & a_{nn} \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} & \ldots & a_{1n} \\ a_{21} & a_{22} & \ldots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \ldots & a_{nn} \end{bmatrix} = \begin{bmatrix} 1 & 0 & \ldots & 0 \\ 0 & 1 & \ldots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \ldots & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$


Figure 14. Stubborn agents putting all weight on their own opinion.

It is an extreme case of irrationality when an individual puts all weight on his own opinions neglecting helpful information available, and does not use reasoning. While in the second matrix, zero in the diagonal is another extreme case where the individual has no self-confidence and always relies entirely on information from others to decide.

Many individuals engage in conspicuous consumption to set themselves apart from their peers, get acceptance from others, satisfy their curiosity and need for novelty, and satisfy their egos [104,105]. Tolerating such imitation in the name of the value it provides to the customer is crucial to the capitalist economic system. Only the desire to "keep up with the Joneses" may justify purchasing certain

products with no practical use. Still, this investment provides nothing in the way of tangible benefits for the consumer. It might have unfavourable results in certain circumstances. It is common knowledge that wasteful spending places an unnecessary strain on finite resources that might be put to more productive use elsewhere today. Alternatively, manufacturing things less essential to society would be irrational.

$$\begin{bmatrix} 0 & 0.50 & 0.50 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0.25 & 0 & 0.75 \\ 0 & 0.55 & 0.45 & 1 \end{bmatrix}$$
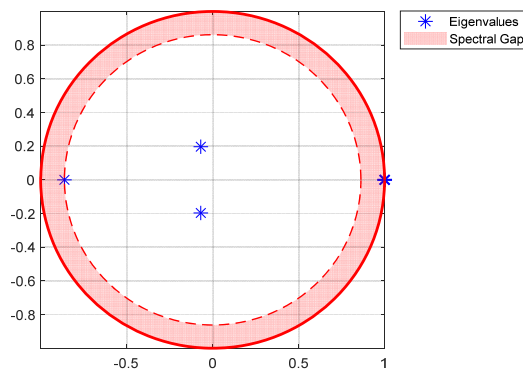

Figure 15: Individuals putting no weight on their opinion. Consensus is not possible in such a consumption network. Delayed convergence (long-term).

Table 5. Consumption matrix for irrational scenario.

$$\begin{bmatrix} 0 & 0 & 1/2 & 1/4 & 1/4 & 0 & 0 \\ 0 & 0 & 1/3 & 0 & 2/3 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1/3 & 2/3 \\ 0 & 0 & 0 & 0 & 0 & 1/2 & 1/2 \\ 0 & 0 & 0 & 0 & 0 & 3/4 & 1/4 \\ 1/2 & 1/2 & 0 & 0 & 0 & 0 & 0 \\ 1/4 & 3/4 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

In the context of bounded rationality, having a zero in the diagonal of the decision-making matrix can represent a situation where the individual has no self-confidence and relies entirely on information from others to make decisions. It means the individual lacks the ability or resources to gather and process information independently and instead relies solely on external sources for information and guidance. Such reliance on external sources of information can lead to suboptimal decisions, as the information provided may not always be accurate, relevant, or aligned with the individual's best interests. Additionally, this lack of self-confidence can limit individuals' decision-making ability and negatively affect their personal, professional, and financial well-being. Examples of this in the context of responsible consumption and production include A consumer who only purchases products based on recommendations from friends or advertisements rather than considering the environmental impact and

ethical implications of the products they buy. A company relies solely on the opinions of focus groups or market research rather than incorporating sustainability and ethical practices into its business model.
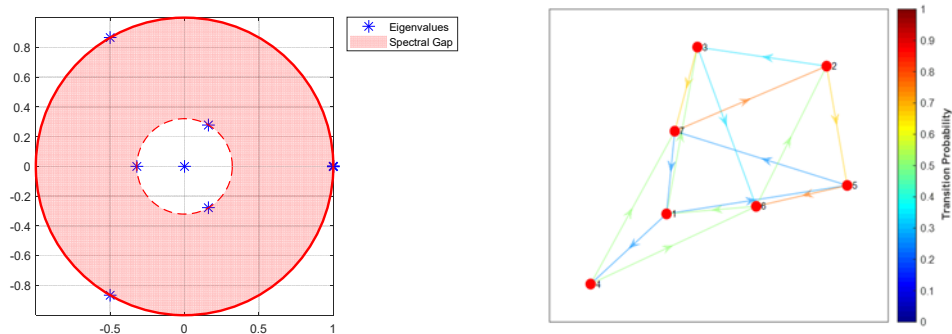
Figure 16. eigenvalue and graph plot for bounded rationality.

In contrast, the irrational situations detailed in the above text draw attention to deviations from pure rationality. Overconfidence and persuasion bias, for instance, might cause people to put too much stock in their judgement or to follow the herd without question blindly. Because of this, people may make poor choices based on inaccurate preferences. At the opposite end of the irrationality spectrum, people may entirely dismiss their views and depend only on the opinions of others, or they may place all weight on their own beliefs while ignoring beneficial information that is readily accessible. Bounded rationality, on the other hand, allows for rational decision-making even when people's cognitive abilities are limited. It acknowledges that people may not have complete information or the mental capacity to understand all available information. However, they strive to make good decisions using the tools and knowledge. Although bounded rationality prioritises making judgments that maximise utility given restrictions, it does so via heuristics, simplifications, and dependence on external information sources.

Conspicuous consumption is one real-world example of complete irrationality. It is the practice of buying and flaunting high-priced items for no other reason than to show off one's social standing and financial success. Conspicuous consumption is a social practice wherein individuals want to distinguish themselves from their peers and be seen by the larger community. This thinking often results in frivolous purchases that provide no real value. The person may put off rational concerns like cost-effectiveness or environmental impact in favour of things like social approval and the appearance of affluence. One example of completely illogical consuming behaviour is the purchase of pricey designer apparel to display the brand logo and indicate social status, despite the availability of more inexpensive and practical alternatives.

Greenhouse gas emissions, air pollution, and climate change are all made worse by certain nations' excessive use of fossil fuels. Irrational clinging to polluting energy sources despite their obvious environmental costs may have far-reaching ecological repercussions. Planned obsolescence designs things to wear out quickly to force users to buy replacements more often. The exploitation of scarce resources, the rise in waste during manufacturing, and the increasing use of energy all contribute to the deterioration of the natural environment due to this activity. Significant economic losses and ecological devastation may befall nations if they emphasise economic development and consumption without

addressing the long-term environmental repercussions. These scenarios show how completely illogical spending decisions, motivated by status signalling or short-term economic advantages, may have severe consequences for people's wallets and the environment.

The United States has been criticized for its high levels of consumerism and excessive consumption patterns. The culture of overconsumption has led to environmental degradation, resource depletion, and waste generation. According to a report by the World watch +Institute, the U.S. accounts for a disproportionate amount of global resource consumption and waste production, causing significant economic and environmental losses [106]. This "throwaway fashion" culture contributes to textile waste, pollution, and exploitative labour practices. The inefficiency of this model becomes evident in the environmental and social costs associated with the industry [107]. China has experienced significant environmental and economic losses due to its reliance on coal for energy production. The country's rapid industrialization and urbanization have led to severe air pollution and greenhouse gas emissions. The irrational choice to prioritize economic growth at the expense of environmental sustainability has resulted in increased healthcare costs [108].

Many electronic device manufacturers have been accused of employing planned obsolescence strategies, designing products with deliberately limited lifespans. Apple, for instance, has faced criticism for its iPhone battery degradation issue, which some argue was intended to push users to upgrade to newer models. This practice contributes to electronic waste, resource depletion, and unnecessary consumer spending [109]. Deforestation in the Amazon rainforest causes severe environmental damage in countries like Brazil. Loss of biodiversity, contributing to greenhouse gas emissions, and climate change are both consequences of deforestation for agriculture and logging. That means less money for sustainable forest management and ecotourism, both essential economic drivers. Air and water pollution caused by China's fast development have adversely affected the environment and human health. Controlling pollution, paying for healthcare, and losing productivity all cost money, which eats away at GDP growth.

Fish populations and marine ecosystems have been depleted due to overfishing and harmful fishing techniques like bottom trawling. This results in economic losses in the fishing sector, which has a direct detrimental effect on the lives of fishing communities. It causes damage to marine habitats and has adverse effects on the environment. Economies and ecosystems in countries that rely heavily on fossil fuels like oil and coal suffer from inefficiency and waste. These include exposure to unpredictable energy markets, exhaustion of limited resources, and health problems caused by air pollution. Irrational spending habits might put people in a difficult financial position. Spending too much money on frivolous stuff because someone feels pressured by her peers or thinks it will improve her social standing is a sure way to get into debt and ruin her financial future. Maintaining one's financial security requires making reasonable and well-informed decisions that align with one's requirements and ideals. Wasteful spending seldom considers alternatives that might have less adverse environmental effects. Waste, pollution, and depletion of natural resources are exacerbated by consumer culture's penchant for cheap, throwaway goods and rapid trends. Individuals may help create a healthy world by decreasing their environmental impact via "conscious consumerism," which includes purchasing long-lasting and eco-friendly goods. Consumption and the pressure to "keep up with the Joneses" have been linked to bad psychological outcomes. Anxiety, tension, and discontent may result from a relentless pursuit of financial items or from basing one's self-worth on outward indicators of success. Adopting a more conscientious and values-based approach to shopping might help us feel happier and more accomplished.

Making irrational purchases might mean supporting businesses or sectors with dubious moral standards. For instance, buying from businesses that exploit their people or cause environmental damage may go against one's morals and contribute to societal inequities. We may better align our activities with our beliefs and effect good social change if we are well-informed and mindful of the ethical implications of our consumer decisions. Individuals may aid in long-term sustainability by adopting sustainable consumption habits. Choosing items made responsibly, ecologically friendly, and constructed to last will help cut down on waste, save resources, and inspire other producers to do the same. A more sustainable future is possible with the support of reasonable consumption habits. When making purchases, it is essential to remember what we need, the bigger picture, and how our purchases will affect our beliefs and long-term objectives. By doing so, people may improve not just their own lives but also that of others and the world.

These examples highlight how irrational consumption choices, whether by individuals or at a larger scale by countries and industries, can result in both environmental and economic losses. Individuals, communities, and nations can mitigate these negative impacts by making more rational and sustainable consumption choices and working towards a more environmentally and economically sustainable future. The study's limitations are that it relies solely on theoretical models based on deductive assumption and lacks empirical data to demonstrate and validate its results. It limits the generalizability of the findings. We will incorporate empirical data in future work to support and strengthen the results for the broader research community and practitioners. By incorporating empirical data, the study will have the potential to provide more insightful and practical recommendations for the understanding of opinion dynamics in social networks.

6. Conclusions

Knowing how information cascades might affect us is crucial in today's highly interconnected digital environment. Businesses and individuals benefit from using the traits of social conformity as leverage, which may have disastrous social and environmental consequences. Theorists have known for a long time that specific relational patterns are crucial; therefore, we examined these patterns in great depth using digraph theory. This work analyses consumption and production decisions in a social learning environment, where individuals learn the actual value of nature through information and subsequent network communication using the DeGroot Social learning process. The study of choices in the context of rationality, bounded rationality, and imperfect rationality is one of the central assertions of this study. We refer to people perceived by others as knowing more detailed private information as neighbours.

A society where individuals have high confidence in their ability to reason and make decisions based on a combination of their senses, personal experiences, and intellect can be considered a "wise" society. Such individuals are more likely to make informed and responsible consumption choices as they can critically evaluate information and weigh the potential consequences of their actions. When individuals trust their ability to reason, they are less susceptible to manipulation and false information, which can lead to more responsible and ethical consumption practices R_c^*. This scenario, where individuals make decisions based on a combination of factors and not solely on what they are told, is an example of a perfectly rational scenario where wise choices are made.

In contrast, bounded rational and irrational choices lack diversity, independence, and decentralization due to persuasion bias and stubbornness, resulting in irresponsible attitudes towards

consumption and production. When community or group members exhibit wasteful spending habits, the group moves away from developing the collective wisdom necessary to avoid making careless decisions that may have lasting adverse effects on its members' well-being. Efficiency in learning is undermined by influential individuals or organisations who get a disproportionate share of society's attention, and their peculiar mistakes mislead everyone. It may sound like a depressing conclusion, but it reflects the presence of a powerful minority inside a significant majority. This initial balancing condition emphasises the need to ensure that no one person, group or corporation has more significant influence than it does in the more extensive system. First, it is counterproductive to social learning to focus too much on select opinion makers unless their information much outweighs that of the general population.

Social learning refers to the process by which individuals, groups, and organizations learn from the experiences and behaviours of others, both within and outside of their networks. At the individual level, social learning can occur through exposure to information and opinions shared by friends, family, and other trusted sources and media and advertising campaigns promoting sustainable practices. For example, people might learn about the benefits of reducing their carbon footprint by seeing their friends share information about reducing energy consumption or buying electric vehicles. At the group level, social learning can occur through collective learning and problem-solving activities, such as community meetings and workshops. For example, a group of residents in a neighbourhood might come together to learn about and implement practices for reducing waste and conserving resources, such as starting a community composting program.

Corporations and organizations can also promote responsible consumption and production choices through their behaviours, practices, and the information and resources they provide consumers. For example, a company might implement sustainable manufacturing processes, offer environmentally friendly products, or engage in public education and awareness campaigns related to sustainability. Corporate social responsibility (CSR) practices and communication can positively impact consumers' attitudes and behaviours related to sustainability [110]. Social learning and peer influence are essential in shaping environmentally responsible behaviours, such as recycling and reducing energy consumption [111].

A double stochastic transition can represent the social learning mechanism of individuals as they become more rational in their consumption and production choices. In the digital age, individuals can access information and communicate with others more efficiently, allowing them to make informed decisions based on the crowd's collective wisdom. It results in a transition from irrational to rational behaviour as individuals learn from one another. For example, consider the responsible consumption and production of clothing. Initially, individuals may not be aware of the environmental impact of fast fashion and may make irresponsible purchasing decisions. However, as more information becomes available and shared through social media and other digital channels, individuals become more aware of the environmental impact of their clothing choices. They then start making more responsible purchasing decisions by choosing brands with a lower environmental impact or using second-hand clothing. Similarly, companies that once prioritized short-term profits over sustainable practices in clothing production may change their behaviour as consumers become more informed and demand environmentally responsible products. These companies may use sustainable materials and production processes to meet consumer demand and maintain their market share. Overall, the digital age has allowed individuals to access information, communicate with one another, and make informed decisions that lead to more rational behaviour in their consumption and production choices.

Boundedly rational social learning may have more potential than was previously thought if they listen to a diverse collection of people and avoid emphasising any one set of people. When people decide on weights, how should those weights be distributed to prevent any group from amassing undue power? Social learning may be streamlined if most people ignore obstinate or closed-off communities. These are all avenues that might be explored in the future. Our work on convergence rates sheds light on the connection between group dynamics and the emergence of consensus. The idea that insular cultures would converge slowly, whereas cohesive ones might converge rapidly, seems consistent. The theory has broad strategic applications where social networks are a factor. The presence of a social network is an obvious need. For a comparable function, thinking about companies that offer equivalent goods in direct competition is relevant. In this case, one company may gain from the marketing efforts of another. Adding people with different backgrounds and perspectives would make the network more dynamic. *More knowledgeable people may interrupt a cascade if they join the process late.* If an individual in an observational learning scenario is persistent enough, their neighbours will learn the value of the superior action by frequently seeing the payoffs of the inferior activity. Because of this, they act, which informs their neighbours, and so on.

Many religious texts emphasize the importance of being mindful of one's environmental impact and promoting sustainability. By applying these teachings daily, individuals can learn about the benefits of responsible consumption and production and become more conscious of their choices. For example, in Hinduism, the principle of "ahimsa", or non-violence, applies not only to human beings but also to all living creatures and the environment. This principle encourages individuals to be mindful of their consumption patterns and environmental impact, leading to more responsible choices. In Islam, "khalifa", or stewardship, is central to environmental responsibility. Muslims are encouraged to take care of the earth and its resources, ensuring their preservation for future generations. It can be achieved through reducing waste, conserving energy, and practising sustainable agriculture. In Christianity and Judaism, the Bible mentions the importance of being good stewards of the earth and its resources. Christians are encouraged to be mindful of their consumption patterns and work towards protecting the environment. Overall, by following the teachings of their respective religions and incorporating them into their daily lives, individuals can engage in social learning and make informed, responsible choices regarding consumption and production.

Responsible choices involve spending less time and energy on material items and services to spend more time with the people who matter most. The primary tenet is to value experiences above stuff. Ethical, environmental, and consumption-related societal concerns drive people to simplify their lives voluntarily. Current consumption habits are not compatible with long-term sustainability. Using energy-efficient appliances, refilling, reusing, sharing household equipment, cycling, car-sharing, community laundry, kitchen gardening, and downsizing to smaller homes are all behaviours that proponents of responsible consumption promote. A *responsible individual* would not choose hardship but provide enough for their necessities. Such a buyer will engage in social resource sharing. Capitalism's problem is not just that it makes too much; it also makes the wrong things, like fast fashion and planned obsolescence, instead of public transportation, affordable housing, and healthcare for all. It is inefficient since it does not cover the basics while wasting money. In this regard, the system is very inefficient. It is unreasonable to prioritise corporate profits and elite accumulation above human well-being and environmental sustainability in production organisations. The solution to this craziness is economic democracy. Under democratic circumstances, people concentrate production more on social and ecological concerns. Today, choices regarding what to create and how to utilise resources

are primarily decided by 1%. Therefore, manufacturing should be made accessible to more people. Responsible consumption and production decisions need strong collaboration and mutual trust among people, communities, businesses, and governments.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

The authors declare no conflict of interest.

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