



# A Game-Theoretic Approach to Indian Government Schemes Promoting Circular Economy Systems

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## Abstract

**Purpose:** Despite the widespread adoption of circular economy efforts around the world, game-theoretic literature has not sufficiently addressed the challenges, intergovernmental dynamics, and stakeholder trade-offs inherent in the circular revolution. This paper aims to fill a crucial research gap by applying the Stackelberg game framework to India's unique policy context to provide a novel game-theoretic analysis of Indian government programs promoting circular economy models.

**Method:** Utilizing data from databases such as Scopus, Web of Science, and IEEE, and reports from McKinsey, Statista, and the Government of India, this study constructs a Stackelberg framework identifying the central government as the leader and state governments as followers to outline optimal policy design and implementation strategies on a multi-governance level. The methodology examines socioeconomic and environmental trade-offs of stringent and lenient circular economy mandates to inform balanced policy choices. By modelling the conflict between near-term cost minimization and potential ecological gains, the framework reveals tensions between central and local priorities.

**Results:** The framework revealed a subgame-perfect equilibrium with payoff of 53.32 in the passive-strict profile, and a socially optimum result in the active-strict profile with a cumulative payoff of 53.33, which highlights the difference between individually rational policy choices and a cooperative outcome that would maximize utility.

**Conclusion:** This improvement on the Stackelberg model provides a scalable paradigm for circular economy transitions in intricate regulatory environments by showing how careful coordination can lower enforcement costs and resistance. The study thereby advances literature on circular economy governance and establishes the groundwork for future research on multi-level policy design.

**Keywords:** Circular Economy, Game Theory, Indian Government Schemes, Indian Sustainability Policy, Stackelberg Game

## I. Introduction

In the current paradigm, the circular economy (CE) has received considerable attention in available literature, with proponents claiming the value of the model in addressing waste management and climate change issues. However, the contemporary global economy is governed by the linear model, which is defined as a "system where resources are extracted to make products that eventually end up as waste and are thrown away" (Ellen MacArthur Foundation, 2023). This approach encouraged industrial dominance and GDP growth for early adopters such as the US, UK, and Russia. However, as a take-make-dispose system, the linear economy has significantly exacerbated waste management issues and environmental degradation (Ellen MacArthur Foundation et al., 2014). Municipal solid waste (MSW) alone was found to be 2.1 billion tons in 2023 (Global Waste Management Outlook 2024, UNEP & ISWA) with an estimated total cost of waste control and other hidden costs amounting to USD 640.3 billion. This represents a serious issue in both the economic and environmental realm, prompting the emphasis on alternative solutions in the current literature. CE poses a compelling alternative to the linear economy which liberates growth from resource dependencies (Ellen MacArthur Foundation et al., 2014). For the purposes of this paper, a circular economy is taken to be "a sustainable model of closed loop systems that maximizes resource efficiency by extending product lifespans through reuse, repair, refurbishing, and recycling, effectively keeping resources in constant circulation." (Ellen MacArthur Foundation, (n.d.); Harvard Business Review, 2021). A report on waste management published by UNEP jointly with ISWA estimated that a CE model could reduce waste management costs by approximately 39% as compared to continuing current linear economy practices (Global Waste Management Outlook, 2024).

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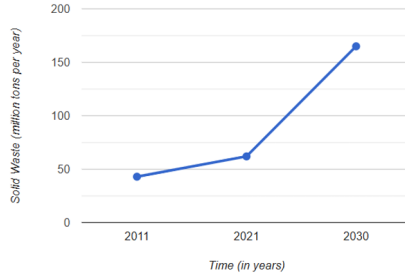


Fig.1: Solid Waste in Indian Cities over years (2011-2030)

Fig.1 reveals the excessive MSW generation in Indian cities over 2011 to 2021 and projected waste per year for 2031 (without the shift to a CE model). The increase in waste generation mirrors the increase in resource depletion and overall consumption following the linear economy model. In FY2023, India processed more than 75 percent of its total waste, but hardly recycled 30 percent of the various types of waste processed (Statista, 2024). This represents a serious gap in effective waste management. Other factors contributing to the transition from a linear economy model to a CE system can be seen in the below infographic.

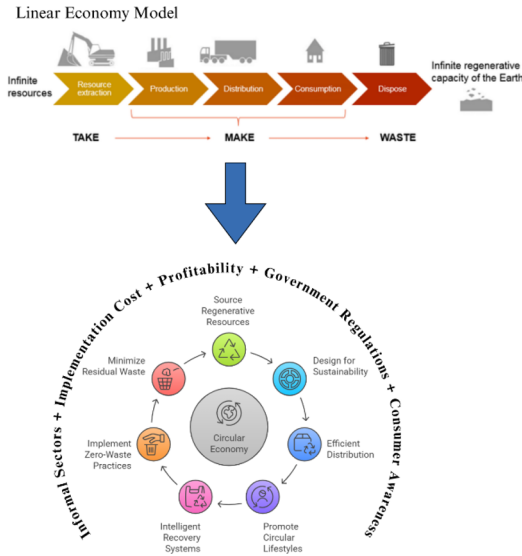


Fig. 2: Transitioning from a linear economy to a circular economy

Beyond the traditional CE model, Fig.2 illustrates the importance of key factors that affect the transition from LE to CE. Many of the given factors pose challenges for India to transition to a circular economy model today. Indian e-waste management, for example, relies majorly on hazardous and unsustainable recycling carried out by the informal sector. The documented rate of sustainably recycled e-waste was estimated to be 5% (Dutta & Goel, 2021), highlighting a major gap in sustainable material recovery, which prevents the establishment of a closed-loop industrial cycle. Similarly, the plastic waste sector exhibits a high collection efficiency of 80.28%, but treatment remains low at 28.4% (Sengupta et al., 2022). These gaps can be attributed to the given causes in Fig. 3.

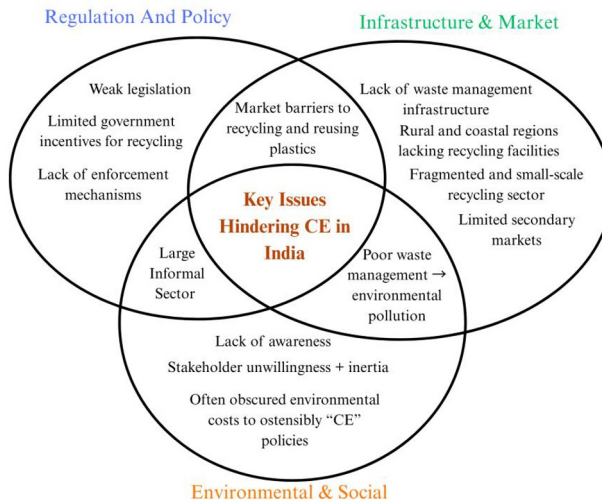


Fig. 3 – Challenges to CE implementation in India

It is important to note that though policy and regulation has been listed as its own category in Fig.3, policy also has the power to affect the environmental and social as well as the infrastructure and market-related problems associated with the CE model implementation. For example, unfair working conditions or environmental pollution due to informal recycling sectors can be addressed through minimum safety standards and formal recognition of the sector by the government (Dutta & Goel, 2021). Government schemes, therefore, can be an effective tool to improve on the stated challenges to CE implementation. Policy interventions can drive circularity when coupled with enforcement and industry collaboration. Thus, analysing the implementation of a circular economy system in India to limit waste management can yield significant insights and practical implications for government policy, prompting the focus for this paper. Sustainability efforts in India are often hindered by conflicting interests between stakeholders (government, industries, consumers) as established through case study analyses. Though CE models offer a viable solution to resource depletion and waste accumulation, their implementation can be obstructed by these strategic conflicts. Game theory (GT), the “science of strategy” studying the theoretical foundation for creating social situations involving rival players with varying payoffs and priorities (Hayes, 2024), provides a framework to analyse these interactions, enabling formulation of policies and incentives encouraging stakeholder cooperation. This paper adopts a game-theoretic lens towards the topic for the reason that while GT has been used globally for environmental management, as evidenced by the current studies into the discipline (Nazari et al., 2020; Moafi et al., 2022; Jiang, 2023), its application to Indian government schemes fostering circular economy systems remains underexplored in the current literature. Different government approaches to incentivizing the shift to a CE model (passive vs. active) can create different payoffs for involved stakeholders. Passive government intervention is defined within the scope of this paper as policies and schemes that do not necessitate direct compliance or behavioural change from stakeholders, i.e. non-binding and reliant on voluntary action, and active government intervention, on the other hand, as policies enforcing compliance or actively intervening in stakeholder behaviour to meet policy objectives.

By understanding stakeholder dynamics through GT, this study can guide policymakers in designing more effective schemes that accelerate India's transition towards a sustainable circular economy. The paper begins with a Literature Review with an overview of GT principles and their relevance to circular economies in Section II, followed by the Research Methodology consisting of an analysis of Indian government schemes and development of a game-theoretic model in Section III, Results & Discussion in Section IV and Conclusion and Policy Recommendations in Section V.

**II. Literature Review**

The growing emphasis on the circular economy has resulted in a rise in reviews in the existing literature on the CE concept, its implementation, and factors affecting the CE transition, as demonstrated by (Arruda et al., 2021; Panchal et al., 2021; De Melo et al., 2022). Case study analyses in recent literature (Shen et al., 2019; Tleuken et al., 2022) demonstrate the importance of government-promulgated policy frameworks in enabling the implementation of CE initiatives, where these frameworks and policies offered crucial support and incentive schemes to direct investment and societal development towards CE outcomes. This has led to a growing body of research on government policies and how they support CE systems, including studies regarding legislative frameworks and policy scenarios, (Liu et al., 2011; Sengupta et al., 2022), further highlighting the critical role that government intervention plays in promoting the uptake and efficacy of circular economic systems.

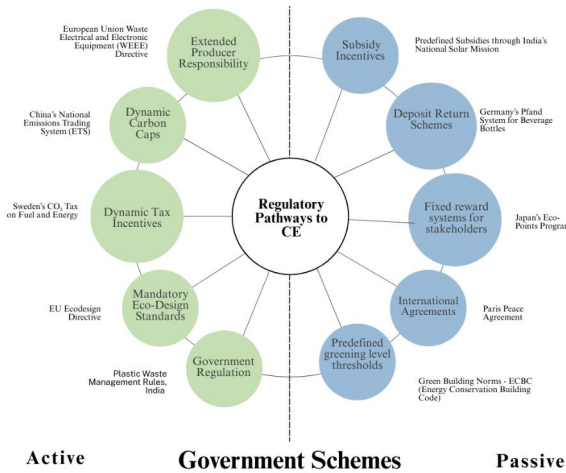


Fig.4 – Government Regulatory Pathways for Circular Economy: Active vs. Passive Approaches

Some of the schemes examined in current literature with reference to active and passive policies are highlighted in Fig. 4. However, there is a notable lack of research on the comparative effectiveness of active and passive government programs in supporting the successful adoption of the circular economy, underscoring the need for more studies in this area that could provide crucial information for well-informed policymaking.

*A. Introduction to Game Theory and Circular Economy*

Understanding how various stakeholders react to policy incentives and regulatory frameworks becomes essential given the crucial role that government interventions play in the adoption of CE. In this regard, GT provides an effective analytical tool for modeling these strategic interactions, looking at how consumers, businesses, and governments react to policy initiatives. GT has been applied to economic system research in a variety of contexts to support closed-loop economies and sustainability. These include, but are not limited to, the design of cooperative frameworks to facilitate resource sharing (Moafi et al., 2022), the resolution of groundwater disputes (Nazari et al., 2020), and negotiation support in energy sector decision-making (Bregar, 2020). These diverse uses establish GT as a useful instrument for policy evaluation in CE systems.

*B. Introducing research gap in GT papers targeting CE Implementation in India*

As one of the world's fastest-growing major economies in 2025, India faces an ongoing challenge in aligning economic growth with circular economy principles. In this sphere, attention can be drawn to (Fiksel et al., 2020; Dutta & Goel, 2021) which highlight some of the key challenges faced by India in efforts to implement a CE model, including informal sectors, lack of WM guidelines, poor government support, and fragmented awareness regarding CE initiatives, despite interest in adopting CE principles. Although existing research has applied a game-theoretic

approach to examining CE implementation by the government (Jiang, 2023; De Giovanni & Ramani, 2023; Wang et al., 2020, p. 29), this system has not been applied to Indian markets to the best of available knowledge, representing a key gap in potential insights regarding policy implications which could be derived from such an approach.

#### *C. Review of Indian Government Schemes fostering Circular Economy*

Indian government initiatives fostering CE systems have been studied extensively by (Priyadarshini & Abhilash, 2020; Mandpe et al., 2022; Mukherjee et al., 2023). Priyadarshini & Abhilash (2020) conducted a meta-analysis of policies such as the Solid Waste Management Rules 2016 and the National Policy on Biofuels 2018, highlighting their alignment with CE principles but also identifying key implementation gaps. Though these policies were held to be relevant to CE principles, their implementation was found to be lacking in aspects of integration with CE standards, with issues such as inadequate processing and disposal facilities, ineffective state level implementation and lack of stakeholder compliance functioning as key barriers. Similar concerns have been raised by (Mandpe et al., 2022) and (Sengupta et al., 2022) with regard to waste management. Ineffective implementation on the part of the government can be linked to multi-stakeholder interactions between policymakers, businesses and consumers (Mao et al., 2020), which present complex interactions with conflicting interests. GT, as established before, can effectively model such interactions to find optimal outcomes, and therefore can illustrate how enforcement levels and penalties impact compliance.

#### *D. Game Theoretic Approaches to Economic Systems and Case Studies*

GT concepts, though initially seen as an isolated system in the 1960s and 1970s, have become an interdisciplinary tool for economists to discern and understand stakeholder strategies with multi-layered perspectives. Existing game theory concepts commonly applied in economic systems include the Nash Equilibrium and Cooperative vs. Non-Cooperative Game Theory. The Nash Equilibrium often forms the basis for GT models and frameworks as a scenario in which no player in a non-cooperative game gains anything by deviating from their initial strategy, assuming all players are rational agents. Approximating the Nash equilibrium of a game can offer insights as to the best response in various scenarios, and this concept has applicability in virtually every branch of game theory as evidenced by the scope of research on this topic (Abedian et al., 2022; Zhou et al., 2022). Cooperative and non-cooperative GT models have expanded researchers' understanding of multi-stakeholder scenarios and outcomes in CE policy implementation. Cooperative game theory (CGT) allows players to form binding agreements and coalitions that result in varying outcomes. In contrast, noncooperative game theory (NCGT) seeks to explain how individuals make decisions based solely on their own logic and without the assistance of other individuals. This GT approach is used in a number of papers; one example is the study by Cobo et al. (2020), which models the strategic interactions between waste managers and regional farmers in a circular integrated waste management system using bilateral optimization and Stackelberg equilibrium. These models demonstrate how well sequential games capture the intergovernmental dynamics and strategic misalignments that define the application of CE policy.

#### *E. Identified Gap and Proposed Research Direction*

These key GT models have widespread applications in current CE studies and can inform policy recommendations in India based on derived outcomes and insights. However, despite the widespread success of GT in advising and implementing CE outcomes, its use remains limited in evaluation of government schemes in India to the same effect. As a key stakeholder in GT interactions and games, the government plays an important role in policy promulgation with interventions affecting multi-stakeholder games at different levels. In India, where a key barrier to CE implementation is poor government regulation, analysis of government schemes utilizing game theory can be effective in optimizing outcomes with clearer regulations that promote CE. The value of such a study can also be seen on the wider stage, since despite the study into GT's varied applications, understanding of decision-making behavior remains limited. Thus, further research integrating game-theoretic models into the evaluation of Indian government schemes is essential to bridge these identified gaps while promoting a deeper understanding of decision makers in an economy. Expanding the application of GT in this domain can enhance policy efficiency, drive stakeholder cooperation, and ultimately accelerate India's transition toward a sustainable circular economy.

### **III. Research Methodology**

#### *A. Research Design*

This study aims to evaluate the comparative effectiveness of active and passive policies in fostering CE systems with the aim of suggesting optimal policy frameworks by employing a non-cooperative game model and answering

the stated research questions as a result. To this purpose, we list examples of Indian passive and active policies fostering CE systems in the past 10 years in Fig.5.

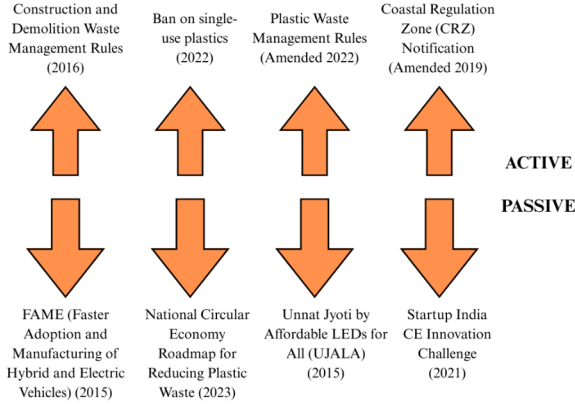


Figure 5: Active and passive policies in India fostering CE systems

This study adopts a theoretical-analytical approach grounded in sequential game theory (SGT) to model and evaluate the impact of government policy types - active and passive intervention - on the adoption of circular economy (CE) practices in India. The methodology integrates qualitative policy analysis utilizing cases for Fig. 5 with formal game-theoretic modeling, supported by empirical case illustrations to validate theoretical predictions. Here, we define passive policies are those that do not require direct compliance or behavioral change from stakeholders — they are typically non-binding and rely on voluntary action. On the other hand, active policies actively influence stakeholder behavior or enforce compliance in order to achieve policy goals. The study's primary goal is to examine the effects of both active and passive government policies on the adoption of circular economy practices' sustainability outcomes and compliance rates. Secondly, by capturing the strategic interactions between various government schemes, it seeks to determine whether sequential game models can accurately forecast long-term adoption rates. Finally, in order to provide insights into the efficacy of policy interventions in fostering sustainable economic growth, the study will evaluate the extent to which active government policies enhance the adoption of circular economy practices compared to scenarios relying on passive policies or minimal intervention.

*B. Conceptual Framework*

This study employs repeated extensive-form (sequential) game models to capture dynamic inter-governmental interactions with regard to CE policy implementation. A non-cooperative game model was chosen because it better reflects the decentralized and frequently contradictory nature of decision-making between the central and state governments in India. The Indian federal structure, especially the inclusion of environmental regulation under the Concurrent List in the Seventh Schedule of the Constitution, allows both the central and state governments to enact laws and take independent action, in contrast to cooperative models that rely on legally binding agreements. The use of a Stackelberg-style non-cooperative framework to model CE policy dynamics is thus justified by the strategic misalignments and autonomous optimization that this constitutional framework causes at every level of government.

While previous studies have effectively utilized dynamic game models to explore optimal policy trajectories within hierarchical stakeholder environments – particularly those including Stackelberg-type leader-follower dynamics (Wei, 2020; Y. Zhu et al., 2022) – they have largely overlooked the specific institutional dynamics between national and subnational levels of governance as endogenous determinants of policy performance. By isolating these two parties, we can further extend the current understanding of policy formulation and implementation by the governance at multiple levels. This study offers granular insights into equilibrium outcomes under varying institutional alignments and regulatory incentives, thereby extending the theoretical frontier of CE policy design within decentralized administrative systems.

The two principal players considered are the Central Government (Leader) and the State Governments (Follower). The Central Government moves first by selecting either a passive or active policy stance, following which the State Governments respond by choosing between strict and lenient regulatory frameworks. For this study, we model a 3-round repeated game to mirror the typical 5-year intergovernmental policy cycles in India (e.g., NITI Aayog frameworks, Swachh Bharat Mission phases), where central guidelines are periodically revised and states respond with varying levels of enforcement. For the purpose of this study, policy payoffs for central and state governments are evaluated according to the given qualitative ordinal utility functions.

$$\text{CG Payoff} = \alpha (\text{Target Achievement Rate}) + \beta (\text{Private Sector Mobilization}) - \delta (\text{Fiscal Outlay})$$

$$\text{SG Payoff} = \mu (\text{Local Activity}) + \xi (\text{Local Sustainability Impact}) - \rho (\text{Administrative Load})$$

In this case, the central government generally aims to minimize the related fiscal and administrative outlay ( $\delta$ ) while maximizing target achievement rate ( $\alpha$ ) with regard to national circular economy goals, and general resource productivity gains through private sector mobilization ( $\beta$ ). The state government's priorities are to attain sufficient waste diversion and local sustainability impact in return for expended effort ( $\xi$ ), promote region-specific economic activity and CE-linked development outcomes ( $\mu$ ) while reducing the administrative, political, and logistical burdens of enforcement and coordination ( $\rho$ ). To empirically ground this payoff structure, the study draws on select case studies of Indian government schemes that reflect varying alignments of central and state-level strategies. These cases illustrate how different combinations of active or passive central policies and strict or lenient state-level enforcement have influenced CE adoption, economic efficiency, and institutional outcomes. By mapping real policy behaviour to the conceptual utility function, we validate the ordinal payoff rankings and demonstrate how strategic interactions unfold in practice. To achieve this objective, we examine policies from Fig. 5 as case studies of active and passive policies by the central government, and their implementation by state governments to assign relative numerical values to payoffs on a scale of 10.

### C. Case Study Analysis

In order to maintain analytical depth and clarity, we choose a small but representative collection of Indian CE policies for each strategy combination, despite the potential for broad applicability with this model. Interpretative robustness is prioritized over empirical saturation in this case-based calibration of utility outcomes. Table 1 describes 8 policies within the last 10 years taken as the sample for payoff calculations.

Table 1: Active and Passive Policies in India from the past 10 years

Policy Name	Type	Description
2022 SUP Ban	Active	Prohibits the manufacture, sale, and use of identified single-use plastic items across India.
PAT Scheme (Phase II onward)	Active	A market-based policy promoting energy efficiency in large industries by trading energy-saving certificates.
E-Waste Management Rules (2022)	Active	Mandates extended producer responsibility and formal recycling of electronic waste.
Construction & Demolition Waste Rules (2016)	Active	Regulates the collection, segregation, and recycling of construction and demolition debris.
Green Credit Programme (2023)	Passive	Incentivizes environmentally sustainable actions through tradable green credits.
2020 EPR Guidelines for Plastics	Passive	Guides plastic producers to manage post-consumer plastic waste through recycling and reuse targets.
UJALA Scheme	Passive	Promotes energy efficiency by distributing LED bulbs, tube lights, and energy-efficient fans at affordable rates.
FAME I – 2015	Passive	Supports electric and hybrid vehicle adoption through subsidies under the National Electric Mobility Mission Plan.

Each policy is evaluated on the basis of the utility functions defined previously, with the average of each player's payoffs for different policies (Active-Strict, Active-Lenient, Passive-Strict, Passive-Lenient) taken to formulate a final payoff for each game outcome. Each policy has been assigned a payoff on the basis of the parameters (ranked from 0 to 5, with two positive and one negative parameter) for CG and SG each, through quantitative and qualitative research and analysis in Table 2.

Table 2: Payoff Matrix for Policy Scenarios Based on Utility Function Analysis

Policy Name	CG Role	SG Role	CG Payoff Parameters			CG Payoff	SG Payoff Parameters			SG Payoff
			Target Achievement Rate	Private Sector Mobilization	Fiscal Outlay		Local Activity	Local Sustainability Impact	Administrative Load	
2022 SUP Ban	Active	Strict	3.25	3	3.25	5.33	1.5	3.5	1.75	5.5
PAT Scheme (Phase II onward)	Active	Strict	3	3.5	1.5	6.67	3.5	3.5	1.5	7
E-Waste Management Rules (2022)	Active	Lenient	3	4	2	6.67	3.5	2.5	2.5	5.67
Construction & Demolition Waste Rules (2016)	Active	Lenient	2	2.5	3.75	3.83	2.5	1.5	3.25	3.83
Green Credit Programme (2023)	Passive	Lenient	2.5	3	3	5	2.5	2	2.5	4.67
2020 EPR Guidelines for Plastics	Passive	Lenient	1	2	1	4.67	1	1	2	3.33
UJALA Scheme	Passive	Strict	4.5	4.5	4	6.67	3.5	4	4	5.67
FAME I - 2015	Passive	Strict	3	4	3	6	3	4	3	6

Key: Central Government = CG | State Government = SG

For a detailed explanation of the sources and data used to justify these payoffs, readers may refer to the Appendix. The summed payoffs for the two sample policies in each profile were averaged to extract a final payoff per player per action profile on a scale of -5 to 10. Utilizing the calculated ordinal payoffs, we construct a sequential game model for Round 1 of the repeated game in Fig. 6.

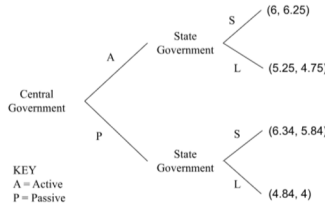


Figure 6: Round 1, sequential game modelling government payoffs for CE policies

#### IV. Discussions and Results

The strategic interactions in the game tree illustrated by Fig. 6 expose two stable Nash Equilibria: (A, L) and (P, S). The Central Government (CG) adopts an active policy in equilibrium (A, L), while the State Government (SG) reacts with lenient implementation of this policy, yielding payoffs of 5.25, 4.75. Conversely, for the (P, S) equilibrium, SG imposes rigorous, strict measures in reaction to CG’s passive policy approach, generating payoffs of (6.34, 5.84). Since the state government’s reactions maximize its payoff after each of CG’s possible actions, the resulting equilibrium path is subgame-perfect. Notably, the passive-strict arrangement generates a higher payoff than the active-lenient choice, suggesting a tendency for CG to opt for passivity in cases when SG is expected to respond by acting strictly. The social optimum, defined as the outcome maximizing the joint utility or welfare of both players, occurs under the active-strict strategy (A, S) and produces a combined payoff of 12.25, the highest among all possible variations. When the Central Government adopts an active policy, the State Government’s tendency to be lenient prevents reaching the socially optimal outcome. This mismatch of incentives could undermine cooperative enforcement. CG may consider employing incentive systems such as cash transfers, institutional support, or increased political legitimacy to encourage SG to take strict measures even if CG is not actively involved as a means to correcting the imbalance. The cost of strict policy execution is weighed in SG’s decision-making process alongside the benefits of local development and environmental results. The reward system implies that SG gains more from rigorous enforcement while CG is passive, which may be explained by more discretion or clearer gains. This discrepancy calls for closer examination of CG’s strategic alternatives under uncertainty, prompting consideration of a mixed strategy approach whereby CG chooses the active policy with probability  $p$  and the passive policy with probability  $(1-p)$  to render SG indifferent between strict and lenient responses. Formally, SG’s predicted benefit from leniency is  $5.25p + 4.84(1 - p)$ , and from strict implementation it is seen to be  $6p + 6.34(1 - p)$ . Equating these and solving for  $p$  yields an impractical value of  $p = 2$ , indicating that there is no mixed strategy equilibrium that balances SG’s preferences across policy responses. The game is likely to converge on (P, S), which is superior to (A, L) in terms of both individual and collective payoffs while also representing a Nash equilibrium. Therefore, CG’s optimal strategy

must be pure. The game is extended over five rounds to account for the time dimension of policy outcomes, and discounting is used to reflect the declining marginal value of future payoffs. Differing discount rates are used for both players based on their different time horizons; CG is taken to be driven by long-term policy goals and national-level planning, while SG tends to prioritize short-term development and political considerations. Discounting future payoffs acknowledges that both actors usually underestimate delayed rewards but to different extents, thereby capturing this imbalance. A higher discount rate for CG (10%) reflects these broader fiscal and political constraints over the long run, whereas a lower rate for SG (5%) accounts for the relatively shorter time horizons at the state level. This approach improves the model's realism by aligning strategic behavior with observed preferences in intergovernmental CE policy dynamics. Table 3 calculates the cumulative discounted payoffs over five periods under these conditions.

Table 3: Cumulative Discounted Payoffs (Five-Period Horizon)

Strategy	Centre Payoff	State Payoff	Total Payoff (Joint Utility)
Active-Strict	24.57	28.28	52.85
Active-Lenient	21.50	21.49	42.99
Passive-Strict	25.96	26.42	52.38
Passive-Lenient	19.82	18.10	37.92

Here, we see that post discounting and payoff cumulation, SG's best response regardless of CG policy design is to opt for strict implementation, while CG then picks its own best choice, passive policy design, which generally minimizes excessive expenditure in many cases by offering a voluntary mechanism to achieve CE outcomes. However, it is the active-strict profile (52.85) which has the highest cumulative payoff, solidifying its position as the configuration that maximizes welfare over the short and long run. This result supports the idea that, in the presence of institutional stability and intertemporal consistency, a shared commitment to proactive and strict policy execution produces better integrated utility outcomes. Additionally, it underscores the strategic leverage CG holds in aligning SG incentives via support mechanisms that are calibrated to internalize the costs and benefits of compliance. The model emphasizes the value of long-term coordination over short-term expediency and offers a strong framework for assessing dynamic intergovernmental relations in the implementation of circular economy policies.

## V. Conclusion and Policy Recommendations

This study addresses key gaps in the application of game-theoretic (GT) modelling to India's circular economy (CE) policy environment by employing a Stackelberg framework to analyse the interplay between active and passive government initiatives. It shows how GT, specifically Stackelberg games, can represent the hierarchical decision-making and stakeholder interactions inherent in Indian CE policy design and implementation, in contrast with previous research that frequently overlooks India's particular CE challenges and the complex intergovernmental policy dynamics in the context of active vs. passive policy approaches as well. The findings show that active government policies with strict enforcement produce the highest long-term circularity outcomes and overall joint utility, while passive policies are more likely to promote stricter state-level implementation due to asymmetrical payoff structures and less political resistance. This dual dynamic proves necessary to overcome high implementation costs and deal with opposition from different actors. The Stackelberg approach draws attention to the trade-offs between stakeholder resistance and ecological success, providing unique policy insights specific to India that are typically missed in generic GT models. Future research gaps that we identify with regards to this study are the investigation of simulations that evaluate this GT framework in practical contexts and an examination of the impact of the aforementioned findings on the UN Sustainable Development Goals. Lastly, examining global scenarios where incentive-alignment tactics and hierarchical policy structures have effectively aided circular economy transitions can also inform future research and policy design. One example of how proactive central policies can overcome coordination challenges and align local implementation incentives is Singapore's top-down enforcement of recycling and resource recovery initiatives under a clearly defined national framework. This dynamic is crucial to the Stackelberg formulation that is being presented here. Theoretical game-theoretic predictions and the practical realities of multi-tiered policy implementation in India's circular economy landscape could be reconciled by Indian policymakers by using lessons learned from such contexts to better calibrate active policy levers and enforcement mechanisms.

**Appendix: Payoff Justification***Key: Central-level metrics*

- 1a – Target Achievement Rate
- 2a – Private Sector Mobilization
- 3a – Fiscal Outlay

*Local-level metrics*

- 1b – Local Activity
- 2b – Local Sustainability Impact
- 2c – Administrative Load

Policy Name	Parameter	Score (0-5)	Justification Summary
UJALA Scheme	1a	4.5	307 bn kWh saved; 36.9 crores bulbs distributed shows broad success.
	2a	4.5	Syska, others joined via PPP model; demand aggregation drove growth.
	3a	4	Zero-subsidy model with ESCO financing minimized central fiscal strain
	1b	3.5	DISCOMs, SDAs involved in rollout; burden partly shifted to states.
	2b	4	~47.88 bn kWh/year saved; 38.78 MT CO <sub>2</sub> avoided—long-term impact proven.
	3b	4	State-level coordination required, creating moderate administrative stress.
EPR Guidelines for Plastics	1a	1	CPCB cited minimal pre-mandate compliance; post-2022 enforcement unclear.
	2a	2	Few brands registered or worked with PROs, limiting circular effort
	3a	1	Near-zero reported cost for CPCB/ULBs; minimal investment in support systems.
	1b	1	Informal sector still processed 50–70%; no new local systems emerged.
	2b	1	EPR did not shift recycling flows or boost outcomes measurably.
	3b	2	Weak monitoring structures, but low engagement also kept workload limited.
Green Credit Program	1a	2.5	Land restoration started for only 14.9% of approved areas despite registration drive.
	2a	3	344 non-PSU entities registered, showing non-state participation.
	3a	3	Central funds decentralized; CPSUs directly fund forest departments, easing central burden.
	1b	2.5	Some private/NGO roles evident, but SFD participation was limited to 60.7%.
	2b	2	Minimal land restored yet; environmental outcome still early-stage.
	3b	2.5	Registration tracking and coordination of CPSUs vs others added workload
FAME I	1a	3	Moderate success; ~76% of revised vehicle targets met by 2024.
	2a	4	OEM growth in 4–5 states; 75 firms joined across 15 regions.
	3a	3	Budget revisions occurred but subsidy-supported growth still constrained rollout.
	1b	3	Charging infra patchy; Gujarat active but others lagged; 24,558 chargers installed
	2b	4	86,252 tons CO <sub>2</sub> cut in Gujarat; modal shift visible in urban centres.
	3b	3	Implementation and grid coordination created moderate burden for DISCOMs/states.
PAT Scheme II	1a	3	Sectoral targets achieved with measurable energy and CO <sub>2</sub> savings in top-emitting industries.
	2a	3.5	542 DCs, energy auditors, and ISO adoptions indicate broad industrial engagement.
	3a	1.5	Market-based model with limited direct central spending except for training and outreach.
	1b	3.5	Appointment of managers, M&V submissions, and SME audit participation shows moderate state-level industry uptake.
	2b	3.5	Significant emissions and energy savings in core sectors, albeit uneven across states.
	3b	1.5	Audit demand spread workload, but oversight mechanisms were lean and standardized.
Construction & Demolition Waste Rules	1a	2	Only 13 of 53 major cities (targeted by 2020) had recycling facilities by 2020
	2a	2.5	A few recyclers like Indo Enviro active, but overall private presence minimal.
	3a	3.75	Central and state funding existed, but underutilization and admin-heavy spending reduced impact.
	1b	2.5	Plant construction limited to few cities; most states lacked segregation and enforcement

	2b	1.5	Diversion negligible, despite infrastructure plans; ecological impact weak.
	3b	3.25	25–30% of budgets spent on staff, monitoring, and enforcement shows high burden.
SUP Ban 2022	1a	3.25	Inspections and seizures occurred, but unresolved violations and partial enforcement lowered overall success.
	2a	3	569 recyclers and penalties collected, but lack of MSME transition support limited private innovation.
	3a	3.25	Enforcement costs were absorbed at state/local level via fines, minimizing central burden.
	1b	1.5	Minimal MSME or state programs recorded; informal sector remained dominant
	2b	3.5	High plastic diversion in some states, but persistent SUP circulation limited long-term gains.
	3b	1.75	Low cost to central/state governance, with simple compliance and environmental fund mechanisms.
E-Waste Management Rules (2022)	1a	3	Steady formal collection growth, but over 60% of e-waste remains informal
	2a	4	Producer registrations surged from 1,151 to 8,744; CAGR >13% in formal e-waste market.
	3a	2	477 crores earned from fees, but only 20% utilized
	1b	3.5	State agencies registered city-level collectors and emerging MSMEs in some areas.
	2b	2.5	Improved formal recovery (~33%), but most material still handled informally.
	3b	2.5	SPCBs overstretched with ~49% post vacancies; CPCB affidavit confirmed capacity strain.

## References

1. What is the linear economy? (2023, February 10). <https://www.ellenmacarthurfoundation.org/what-is-the-linear-economy>
2. Topic: Waste management in India. (2024, February 28). Statista. <https://www.statista.com/topics/5586/waste-management-india/#statisticChapter>
3. Panchal, R., Singh, A., & Diwan, H. (2021). Does circular economy performance lead to sustainable development? – A systematic literature review. *Journal of Environmental Management*, 293, 112811. <https://doi.org/10.1016/j.jenvman.2021.112811>
4. The circular business model. (2021, July 1). Harvard Business Review. <https://hbr.org/2021/07/the-circular-business-model>
5. Circular economy introduction. (n.d.). <https://www.ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview>
6. Global Waste Management Outlook 2024 - Beyond an age of waste: Turning rubbish into a resource. (2024). <https://doi.org/10.59117/20.500.11822/44939>
7. Ellen MacArthur Foundation (EMF). (2013). Towards the circular economy: Economic and business rationale for an accelerated transition. Retrieved August 22, 2016, from <https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Ellen-MacArthur-Foundation-Towards-the-Circular-Economy-vol.1.pdf>
8. Ellen MacArthur Foundation, McKinsey & Company, & World Economic Forum. (2014b). Towards the Circular Economy: Accelerating the scale-up across global supply chains. World Economic Forum. [https://www3.weforum.org/docs/WEF\\_ENV\\_TowardsCircularEconomy\\_Report\\_2014.pdf](https://www3.weforum.org/docs/WEF_ENV_TowardsCircularEconomy_Report_2014.pdf)
9. Hayes, A. (2024, June 27). Game Theory: A Comprehensive guide. Investopedia. <https://www.investopedia.com/terms/g/gametheory.asp>
10. Moafi, M., Ardehshiri, R. R., Mudiyansele, M. W., Marzband, M., Abusorrah, A., Rawa, M., & Guerrero, J. M. (2022). Optimal coalition formation and maximum profit allocation for distributed energy resources in smart grids based on cooperative game theory. *International Journal of Electrical Power & Energy Systems*, 144, 108492. <https://doi.org/10.1016/j.ijepes.2022.108492>
11. India Solid Waste Management. (2023, April 27). International Trade Administration | Trade.gov. <https://www.trade.gov/market-intelligence/india-solid-waste-management>
12. Liu, D., Li, H., Wang, W., & Dong, Y. (2011). Constructivism scenario evolutionary analysis of zero emission regional planning: A case of Qaidam Circular Economy Pilot Area in China. *International Journal of Production Economics*, 140(1), 341–356. <https://doi.org/10.1016/j.ijpe.2011.04.008>
13. Nazari, S., Ahmadi, A., Rad, S. K., & Ebrahimi, B. (2020). Application of non-cooperative dynamic game theory for groundwater conflict resolution. *Journal of Environmental Management*, 270, 110889. <https://doi.org/10.1016/j.jenvman.2020.110889>
14. Dutta, D., & Goel, S. (2021). Understanding the gap between formal and informal e-waste recycling facilities in India. *Waste Management*, 125, 163–171. <https://doi.org/10.1016/j.wasman.2021.02.045>
15. Shen, K., Li, L., & Wang, J. (2019). CIRCULAR ECONOMY MODEL FOR RECYCLING WASTE RESOURCES UNDER GOVERNMENT PARTICIPATION: A CASE STUDY IN INDUSTRIAL WASTE WATER CIRCULATION IN CHINA. *Technological and Economic Development of Economy*, 26(1), 21–47. <https://doi.org/10.3846/tede.2019.11249>
16. Tleuken, A., Tokazhanov, G., Jemal, K. M., Shaimakhanov, R., Sovetbek, M., & Karaca, F. (2022). Legislative, institutional, industrial and governmental involvement in circular Economy in Central Asia: a Systematic review. *Sustainability*, 14(13), 8064. <https://doi.org/10.3390/su14138064>
17. De Melo, T. A., De Oliveira, M. A., De Sousa, S. R., Vieira, R. K., & Amaral, T. S. (2022). Circular Economy Public Policies: A Systematic Literature Review. *Procedia Computer Science*, 204, 652–662. <https://doi.org/10.1016/j.procs.2022.08.079>
18. Zhu, J., Fan, C., Shi, H., & Shi, L. (2018). Efforts for a circular Economy in China: A Comprehensive review of policies. *Journal of Industrial Ecology*, 23(1), 110–118. <https://doi.org/10.1111/jiec.12754>
19. Overview. (n.d.). World Bank. <https://www.worldbank.org/en/country/india/overview>
20. Fiksel, J., Sanjay, P., & Raman, K. (2020). Steps toward a resilient circular economy in India. *Clean Technologies and Environmental Policy*, 23(1), 203–218. <https://doi.org/10.1007/s10098-020-01982-0>
21. Arruda, E. H., Melatto, R. a. P. B., Levy, W., & De Melo Conti, D. (2021). Circular economy: A brief literature review (2015–2020). *Sustainable Operations and Computers*, 2, 79–86. <https://doi.org/10.1016/j.susoc.2021.05.001>
22. Bregar, A. (2020). Implementation of a multi-agent multi-criteria negotiation protocol for self-sustainable smart grids. *Journal of Decision System*, 29(sup1), 87–97. <https://doi.org/10.1080/12460125.2020.1848374>
23. Wang, Z., Huo, J., & Duan, Y. The impact of government incentives and penalties on willingness to recycle plastic waste: An evolutionary game theory perspective. *Front. Environ. Sci. Eng.* 14, 29 (2020). <https://doi.org/10.1007/s11783-019-1208-2>
24. Priyadarshini, P., & Abhilash, P. C. (2020). Circular economy practices within energy and waste management sectors of India: A meta-analysis. *Bioresource Technology*, 304, 123018. <https://doi.org/10.1016/j.biortech.2020.123018>
25. Mandpe, A., Paliya, S., Gedam, V. V., Patel, S., Tyagi, L., & Kumar, S. (2022b). Circular economy approach for sustainable solid waste management: A developing economy perspective. *Waste Management & Research the Journal for a Sustainable Circular Economy*, 41(3), 499–511. <https://doi.org/10.1177/0734242x221126718>
26. Mukherjee, P. K., Das, B., Bhardwaj, P. K., Tampha, S., Singh, H. K., Chanu, L. D., Sharma, N., & Devi, S. I. (2023). Socio-economic sustainability with circular economy — An alternative approach. *The Science of the Total Environment*, 904, 166630. <https://doi.org/10.1016/j.scitotenv.2023.166630>
27. Mao, W., Wang, W., Sun, H. et al. Barriers to implementing the strictest environmental protection institution: a multi-stakeholder perspective from China. *Environ Sci Pollut Res* 27, 39375–39390 (2020). <https://doi.org/10.1007/s11356-020-09983-8>
28. Abedian, M., Amindoust, A., Maddahi, R., & Jouzdani, J. (2022). A Nash equilibrium based decision-making method for performance evaluation: a case study. *Journal of ambient intelligence and humanized computing*, 13(12), 5563–5579.
29. Zhou, J., Lv, Y., Wen, G., Lü, J., & Zheng, D. (2022). Distributed Nash equilibrium seeking in consistency-constrained multiagent games. *IEEE Transactions on Cybernetics*, 53(6), 3675–3687.
30. Cobo, S., Fengqi, Y., Dominguez-Ramos, A., & Irabien, A. (2020). Noncooperative game theory to ensure the marketability of organic fertilizers within a sustainable circular economy. *ACS Sustainable Chemistry & Engineering*, 8(9), 3809–3819.
31. Wei, S. (2020). A sequential game analysis on carbon tax policy choices in open economies: From the perspective of carbon emission responsibilities. *Journal of Cleaner Production*, 283, 124588. <https://doi.org/10.1016/j.jclepro.2020.124588>
32. Lok Sabha Secretariat. (2024). *Annexure to Question AU75: Green Credit Program* [PDF]. [https://sansad.in/getFile/lok SabhaQuestions/annex/183/AU75\\_TQ0IOT.pdf](https://sansad.in/getFile/lok SabhaQuestions/annex/183/AU75_TQ0IOT.pdf)

33. Ministry of Coal, Government of India. (2024, November). Green Credit Program: Guidelines and Implementation [PDF]. <https://coal.gov.in/sites/default/files/2024-11/GreenCreditProgram4.pdf>
34. Lok Sabha Secretariat. (n.d.). Annexure to Question AU420: FAME I progress [PDF]. [https://sansad.in/getFile/loksabhaquestions/annex/184/AU420\\_Dxfltc.pdf](https://sansad.in/getFile/loksabhaquestions/annex/184/AU420_Dxfltc.pdf)
35. International Council on Clean Transportation. (2024, June). Electric-vehicle demand incentives in India: The FAME-II scheme and considerations for a potential next phase [PDF]. <https://theicct.org/publication/electric-vehicle-demand-incentives-in-india-the-fame-ii-scheme-and-considerations-for-a-potential-next-phase-june24/>
36. Bureau of Energy Efficiency. (n.d.). Perform, Achieve, and Trade (PAT) programme overview [Webpage]. <https://beeindia.gov.in/en/programmes/perform-achieve-and-trade-pat>
37. Ministry of Finance, Government of India. (2019). Expenditure Budget 2019–20: PAT support [PDF]. <https://www.indiabudget.gov.in/budget2019-20/doc/eb/sbe76.pdf>
38. [https://www.researchgate.net/publication/314090168\\_Good\\_Practices\\_and\\_Success\\_Stories\\_on\\_Energy\\_Efficiency\\_in\\_India](https://www.researchgate.net/publication/314090168_Good_Practices_and_Success_Stories_on_Energy_Efficiency_in_India)
39. International Energy Agency. (n.d.). Air quality and climate policy integration in India [PDF]. <https://iea.blob.core.windows.net/assets/e4945633-ab7c-45ec-8e3a-aa74dd3de962/AirQualityandClimatePolicyIntegrationinIndia-Frameworkstodeliverco-benefits.pdf>
40. NITI Aayog. (2018). Strategy for promoting construction and demolition waste processing and recycling [PDF]. [https://www.niti.gov.in/sites/default/files/2019-03/CDW\\_Strategy\\_Draft%20Final\\_011118.pdf](https://www.niti.gov.in/sites/default/files/2019-03/CDW_Strategy_Draft%20Final_011118.pdf)
41. Central Pollution Control Board. (2024). Reply in OA No. 1052/2024 under the National Green Tribunal (Kundan Veer Singh Bhullar & Ors. vs. UOI & Ors.) [PDF]. [https://greentribunal.gov.in/sites/default/files/news\\_updates/Reply%20by%20CPCB%20in%20OA%20No.%201052%20of%202024%20%28Kundan%20Veer%20Singh%20Bhullar%20%26%20Ors.%20Vs.%20UOI%20%26%20Ors.%29.pdf](https://greentribunal.gov.in/sites/default/files/news_updates/Reply%20by%20CPCB%20in%20OA%20No.%201052%20of%202024%20%28Kundan%20Veer%20Singh%20Bhullar%20%26%20Ors.%20Vs.%20UOI%20%26%20Ors.%29.pdf)
42. United Nations Environment Programme. (2016). Construction and demolition waste management rules, India [PDF]. <https://icap.unep.org/en/countries/in/national-legislation/construction-and-demolition-waste-management-rules-2016>
43. Lok Sabha Secretariat. (n.d.). Annexure to Question AU2301: SUP enforcement status [PDF]. [https://sansad.in/getFile/annex/267/AU2301\\_JIQng4.pdf](https://sansad.in/getFile/annex/267/AU2301_JIQng4.pdf)
44. MPCB. (2020). Plastic Waste Management Annual Report 2019–20 [PDF]. <https://www.mpcb.gov.in/sites/default/files/plastic-waste/PWMAnnualreportMPCB201920.pdf>
45. NITI Aayog. (2022, July). Plastics alternative study: Supporting circular economy in India [PDF]. [https://www.niti.gov.in/sites/default/files/2022-07/Plastics%20Alternative%20Study\\_Final\\_Report\\_compressed.pdf](https://www.niti.gov.in/sites/default/files/2022-07/Plastics%20Alternative%20Study_Final_Report_compressed.pdf)
46. Department of Environment, Himachal Pradesh. (n.d.). SUP eradication efforts [Webpage]. <https://dest.hp.gov.in/?q=sup-single-use-plastic-eradication>
47. Press Information Bureau. (2022). Press release: SUP Ban Status [Press release]. <https://www.pib.gov.in/PressReleasePage.aspx?PRID=1882855>
48. Central Pollution Control Board. (n.d.). Authorized Producers – e-waste portal [Web portal]. <https://eprewastecpcb.in/#/authorizedProducers>
49. Lok Sabha Secretariat. (n.d.). Annexure to Question AU2384: E-waste Management [PDF]. [https://sansad.in/getFile/annex/266/AU2384\\_9gmDUV.pdf](https://sansad.in/getFile/annex/266/AU2384_9gmDUV.pdf)
50. Council on Energy, Environment and Water. (n.d.). E-waste recycling in India [Webpage]. <https://www.ceew.in/electrical-and-electronic-waste-recycling>
51. Press Information Bureau. (2023). Press release: SPCB vacancies [Press release]. <https://www.pib.gov.in/PressReleasePage.aspx?PRID=1941054>
52. Press Information Bureau. (2024). Press release: Underutilization of CPCB-collected funds [Press release]. <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2040033>

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