Market Behavior in a Tradable Credit Scheme for Sustainable Mobility: Insights from a Lab Experiment

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Short summary

Tradable Credit Schemes (TCS) are a promising market-based instrument to manage transport demand and reduce emissions, yet empirical evidence on behavioral responses and market performance remains limited. This study examines individual behavior in a tradable credit market using a lab experiment that captures endogenous price formation and strategic trading within an active central credit market in realistic travel contexts.
The results show that a TCS faces important market challenges, as prices exhibited substantial volatility and concentrated trading intensity, suggesting market power and difficulties in achieving a stable equilibrium, although it can also reduce driving and encourage shifts toward lower-emission alternatives. Market performance is strongly influenced by allocation rules, pricing mechanisms, market size, and participant composition, with heterogeneous characteristics contributing to imbalances in trading behavior and price formation.
Overall, the study highlights both the potential and design challenges of TCSs, emphasizing the importance of robust market design for effective real-world implementation.
Keywords: demand management, emission trading, experimental economics, lab experiment, market design, tradable credit scheme

1 Introduction

Road traffic and congestion are major global challenges with significant environmental, social, and economic impacts (European Commission & Eurostat, 2020). The transport sector is a key source of emissions, accounting for a large share of CO_2 emissions in Denmark, with most coming from road transport (Kany et al., 2022). While supply-side solutions such as automation and electrification are advancing, managing travel demand remains a critical but challenging strategy. Among the approaches considered, Tradable Credit Schemes (TCS) have emerged as a promising market-based instrument, in which a central authority sets a cap on travel-related externalities (e.g., total distance or emissions), distributes a limited number of credits (tokens) to users, and allows them to trade these tokens so that those needing more can purchase them from others, with prices determined by the market.
A small number of field experiments indicate the feasibility and potential of TCS to influence travel behavior, although much of the literature still relies on theoretical and simulation-based approaches, making lab experiments particularly important for gaining insights into participant behavior and decision making. In this context, Aziz et al. (2015) used an online experimental game with a double auction market to analyze daily travel and credit trading across income groups, revealing learning effects, heterogeneous cost sensitivities, and strong responses to carbon costs, particularly for non-work trips among middle and low income users; similarly, Tian et al. (2019) implemented an interactive experiment with human participants and virtual agents, showing rapid market equilibrium convergence, clear loss aversion, and that users were more likely to reduce car use when facing a credit loss than when expecting a gain, while also highlighting improved credit management over time alongside a tendency to overspend early in the allocation period.
In summary, this study contributes to the literature by bridging the gap between abstract lab experiments and context-rich stated preference approaches through the implementation of a tradable credit market in a controlled lab setting that incorporates participants' real commuting behavior. It enables the observation of dynamic trading behavior, endogenous price formation, and market

outcomes, while providing empirical evidence on how allocation rules, pricing mechanisms, market size, and participant composition affect performance. The results reveal substantial variation in outcomes, including price volatility, trading concentration, and partial price stabilization, and highlight the importance of participant heterogeneity in shaping trading dynamics and market efficiency.

2 Methodology

This study analyzes commuter travel and market behavior within a Tradable Credit Scheme (TCS) using a controlled lab experiment based on individualized choice sets derived from a pre-experimental travel diary. Participants were first familiarized with the interface and mechanism, after which the experiment proceeded in three phases introducing scarcity, uncertainty, and changes in token allocation. In each round, participants made both travel decisions (mode and departure time) and market decisions (buying or selling tokens). The experiment was conducted at the Lab for Experimental Economics (LEE) at the University of Copenhagen using `oTree` (Chen et al., 2016). The study received ethical approval, was preregistered, and all materials are documented on the Open Science Framework (Guggenberger et al., 2026), with code available on GitHub.

Participants were adults living in or commuting to Greater Copenhagen, with a focus on car commuters due to their relevance for emissions and token demand, while some non-car users were included for comparison. One week prior to the experiment, participants completed a pre-survey and a one-week travel diary capturing commuting behavior, which was used to construct realistic, individualized choice sets. A post-survey collected information on financial literacy, strategies, and perceptions. Earnings depended on performance and ranged between 200 and 400 DKK, with one participant per session eligible for a payoff up to 700 DKK.

The experiment followed a within-subject design with two test phases and three main phases, each representing a simulated week of five commuting days. Decisions alternated between market and travel choices, with one-minute time limits to ensure synchronized progression. Weekly token and monetary budgets were reset at the start of each simulated week. Travel alternatives included walking, cycling, public transport, driving, and driving-reschedule, characterized by monetary cost, token requirement, environmental rating, and travel time. Costs incorporated value-of-time and operational components, while token requirements were based on estimated CO_2e emissions, with one token corresponding to 1 kg CO_2e. Non-car modes required no tokens, while car-based tokens depend on emissions calculated from distance, vehicle type, and congestion adjustments.

Initial monetary budgets were set at 110% of default commuting costs, while token allocations were based on past emissions using a grandfathering rule with a partial equal allocation. If participants lacked tokens, they could automatically purchase them at the market price plus a fee. Before each travel decision, participants could trade tokens on a centralized market with transaction costs, subject to budget and purchase constraints. Prices adjusted dynamically based on excess demand or supply, with a lower bound to prevent extreme outcomes.

The three main phases varied key conditions. Phase I introduced scarcity through a 20% reduction in token allocation. Phase II added uncertainty to the reduced allocation through temporary cost variations. Phase III maintained uncertainty but replaced the allocation rule with a distance-based allocation, allowing comparison of behavioral responses across allocation mechanisms within the same experimental setting.

3 Results and discussion

Five experimental sessions were conducted with a size ranged from 14 to 20 participants, and session length ranged from 1h43min to 2h10min (Table 1). While participants differed across sessions in age, education, income, and commuting characteristics, the most relevant differences for interpreting the results concern commuting distance, flexibility, vehicle type, and default mode composition. In particular, Session C was characterized by the longest average commuting distances and the highest token requirements, while Session B had the highest share of non-commuting days and intermediate stops. Sessions B and G also included relatively more electric vehicle users, implying lower token requirements for car-based travel.

Initial token allocations differed substantially across individuals under both allocation methods. The allocations differed considerably at the individual level between grandfathering- and distance-based rules. The difference is also visible in the average Gini coefficient, which is 0.63 for grand-

Table 1: Session characteristics

	Session A	Session B	Session C	Session D	Session G
Participants	19	19	14	20	16/15
Date	06.10.2025	07.10.2025	07.10.2025	17.11.2025	18.11.2025
Time	16:00	10:00	15:00	16:00	12:00
Experiment length	1h 43min	2h 7min	1h 50min	2h 10 min	1h 51min

fathering and 0.41 for the distance-based allocation. The monetary budget was distributed more evenly than tokens, as indicated by the moderate Gini coefficients of 0.4. These differences in allocation are important because they shaped the market environment from the start. Participants with high initial token endowments had greater scope to trade and, in some cases, greater influence on prices. This became visible in the market performance.

Market performance

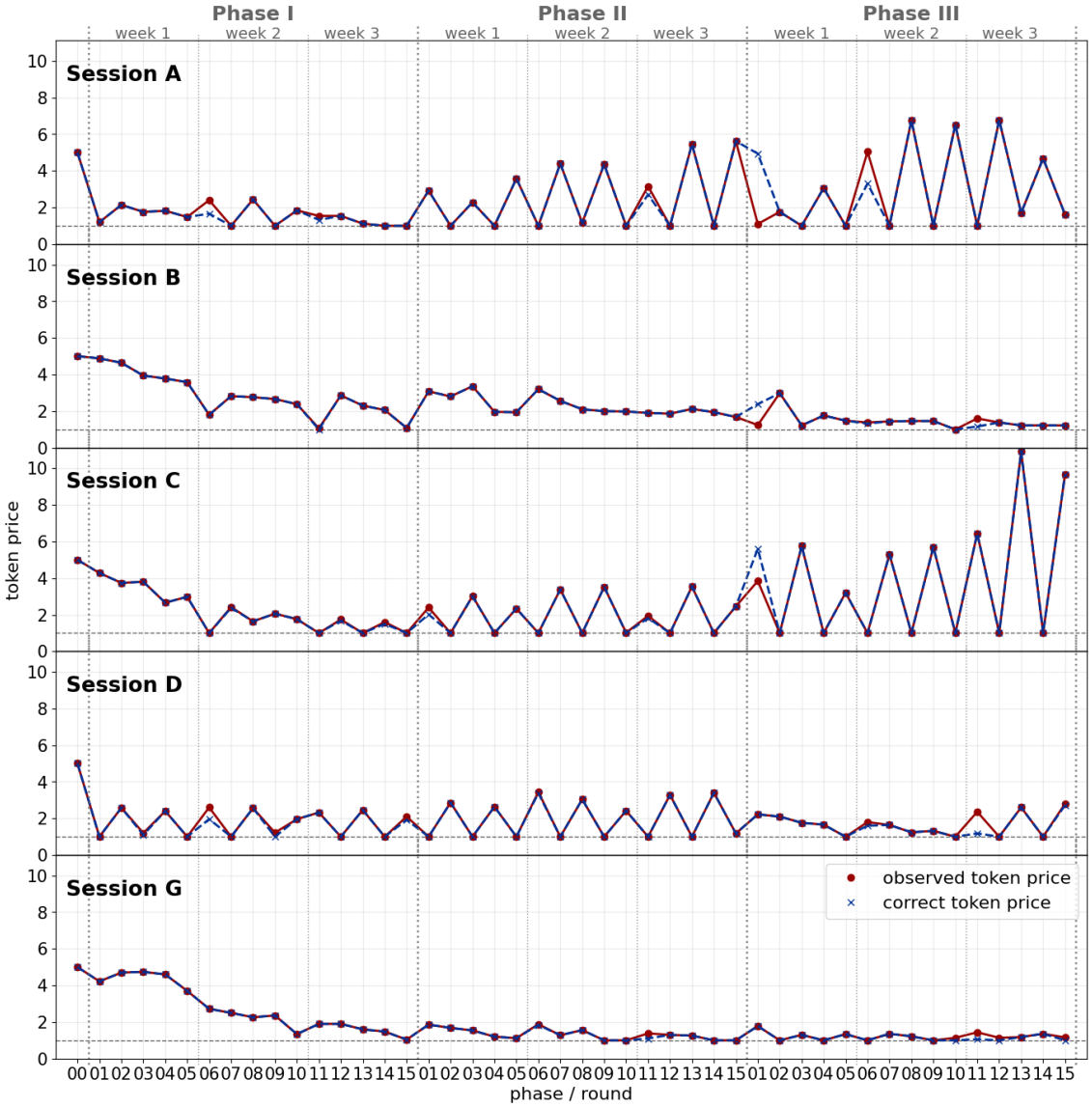
Token prices developed very differently across sessions (Figure 1), with substantial volatility in Sessions A, C, and D, while Sessions B and G remained comparatively stable. Volatility increased in later phases, particularly in Sessions A and C, suggesting that participants adapted their trading strategies over time, whereas persistently high volatility in Session D indicates that instability cannot be explained solely by an implementation issue. A loophole in earlier sessions, which allowed participants to exceed purchase limits, amplified trading intensity, but the comparison across sessions shows that participant composition and commuting characteristics also played an important role. Overall, prices tended to decline, indicating excess token supply, as participants were generally endowed with more tokens than needed. These patterns suggest that price dynamics are shaped by both market design and user heterogeneity, and that fixed price adjustment mechanisms may not be sufficient to ensure stability in small or heterogeneous markets.
Market intensity was concentrated among a small number of participants, with one or two individuals accounting for a large share of trades in several sessions, while others remained relatively inactive. Cluster analysis confirms that most participants were bottom-tier traders, while a small group of top-tier traders used their tokens more intensively. Mid-tier traders, despite relatively large endowments, did not use their tokens as actively. These top-tier traders also appeared to be more financially literate, risk-tolerant, and highly educated, suggesting that individual characteristics and confidence in market environments shape engagement. This concentration indicates that market influence can arise even without large initial inequalities and highlights the role of participation and allocation in shaping market outcomes, particularly in small markets.

Travel behavior

Changes in travel behavior were more stable than market outcomes, with the main shift occurring away from driving toward driving-reschedule and, to a lesser extent, public transport and cycling, while users of already sustainable modes largely maintained their choices, indicating that TCS primarily affects car users and leads to incremental rather than transformative change. Travel choices varied little across phases, though this should be interpreted cautiously due to implementation issues and simplified cost structures, meaning results reflect incentivized stated behavior rather than real-world responses. Participants also did not consistently choose cost-minimizing options, especially for driving, suggesting influences such as preferences, and token-saving strategies, and pointing to bounded rationality and intertemporal decision-making.

Interaction between market and travel decisions

The interaction between market and travel behavior provides additional insight into participant heterogeneity. Bottom-tier traders made a relatively high and stable share of cost-minimizing travel choices, particularly in Phases I and II, indicating more routine behavior with limited strategic adjustment, while mid-tier traders relied more on car-based modes, leaving fewer tokens available for trading. In contrast, top-tier traders showed greater variation and appeared to adapt travel choices strategically over time, using fewer tokens in later rounds and actively preserving them for trading opportunities. A weekly pattern is also visible in Phase II (see Figure 2). This suggests that differences across participants arise not only in trading intensity but also in how travel and



Note: Due to an implementation mistake, prices were updated sequentially rather than based on net trades within a round, interacting with the 1 DKK price floor. This occasionally led to price increases despite net selling. Around 13% of updates were affected, though deviations were small. The blue line shows the token correct price.

Figure 1: Token price development across all sessions. The dashed horizontal line at 1 indicates the lower bound on prices.

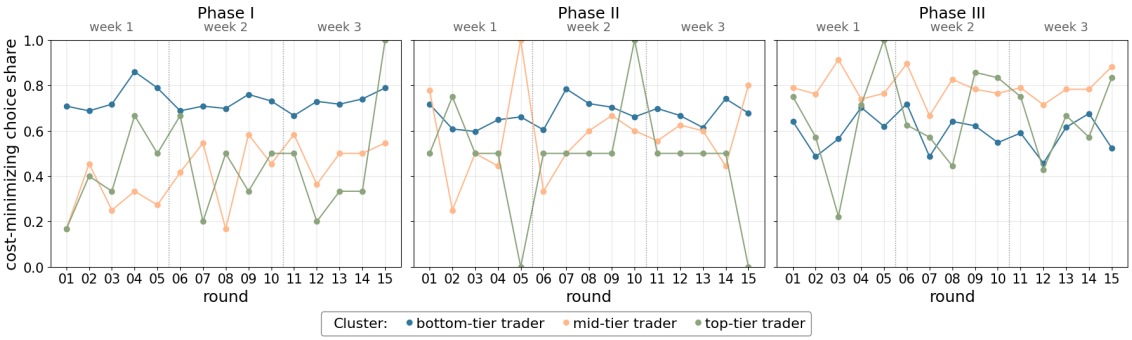


Figure 2: Share of cost-minimizing choices per cluster and phase

market decisions are coordinated, with more active traders optimizing across both dimensions, helping to explain the concentration of market power among a small subset of participants.

4 Conclusion

This study investigates the performance of a tradable credit scheme in a controlled experimental setting with context-aware decision making, focusing on the market outcome. Results show that such schemes can influence individual travel decisions and generate active trading but their effectiveness depends strongly on market design and participant composition.
The market results reveal substantial heterogeneity in price dynamics and trading behavior. In several sessions, prices were volatile and trading volume was concentrated among a small number of participants, raising concerns about market power and efficiency. The findings highlight that allocation rules, pricing mechanisms, and market size jointly shape market performance. In particular, unequal initial endowments and loose market rules can lead to imbalances that undermine stable price formation.
From a policy perspective, the results suggest that tradable mobility credit schemes have potential as a demand management instrument, but require careful design. Key considerations include the choice of allocation mechanism, safeguards against excessive concentration, and pricing rules that balance responsiveness and stability. Moreover, such schemes should be complemented by improvements in alternative transport options to enable stronger behavioral responses. More specifically, the results suggest that adaptive pricing mechanisms, safeguards against excessive accumulation of tokens, and measures to encourage broader participation and user education, as well as protections against strategic exploitation by highly skilled participants, may be necessary to ensure stable and efficient markets. In addition, combining tradable credit schemes with complementary measures, such as improved public transport or infrastructure for active modes, may enhance their effectiveness by expanding the set of feasible behavioral responses.
Overall, this study demonstrates that tradable credit schemes can influence travel behavior and generate active markets, but their success depends critically on careful market design, participant engagement heterogeneity, and integration with broader transport policies. Addressing these challenges is essential for translating the potential of TCS into effective and scalable real-world solutions.

Limitations

The study has several limitations. Small experimental markets likely increased individual influence and price volatility, while the participant sample was not fully representative, limiting generalizability. The simplified, computer-based setting relied on stated rather than observed commuting behavior. The design did not test alternative market structures or include a baseline without token constraints, as this would have made the already lengthy experiment even longer, making it difficult to isolate effects. Early implementation issues may have also influenced outcomes. Despite this, the experiment provides useful insights into trading behavior, travel decisions, and market design in tradable credit schemes.
Future research should use larger-scale, longer-term field studies with observed behavior to better evaluate the feasibility and policy relevance of TCS.

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