

Nudging the Last Mile: Combining Behavioral Insights and Monetary Incentives for Sustainable Delivery Choices

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Abstract

Last mile delivery, the final leg of the supply chain to consumers, significantly impacts the environment. The role of consumers' behavior in this process, has been relatively overlooked and their willingness to find a trade-off between the benefits of home delivery and the impact on the environment has been neglected; behavioral logistics aims to optimize supply chain operations by understanding and influencing human behavior, enhancing efficiency and sustainability. Consumer behavior within the grocery sector is influenced by a myriad of factors and the rise of environmental awareness among consumers provides an opportunity to impact their preferences, steering them towards more sustainable last mile delivery options. The importance of home deliveries in the grocery sector has surged, especially post-pandemic; grocery stores adapt to this trend, focusing on efficient last mile delivery to meet changing consumer demands. By utilizing the experimental economics methodology tailored to the grocery sector, this research systematically examines the impact of financial incentives and nudges on last mile delivery choices. The controlled environment offers valuable insights into consumer responses to various incentive structures, helping to shape strategies that maximize both environmental benefits and economic sustainability. The findings underscore the interplay between environmental sustainability, consumer behavior, financial incentives, and nudges in the last mile delivery of groceries providing valuable insights for businesses, policymakers, and consumers in their collective endeavor to build a more sustainable and efficient last mile delivery system.

Keywords: behavioral logistics, experimental economics, optimization, grocery industry, last-mile delivery, vehicle routing

1. Introduction

In today's increasingly interconnected and e-commerce-driven world, the importance of last mile delivery cannot be overstated. The last mile delivery, representing the final leg of the supply chain, plays a pivotal role in ensuring that products reach consumers' doorsteps promptly and

efficiently; however, this convenience comes at a cost, particularly in terms of its significant environmental impact. The transportation and logistics involved in last mile delivery contribute to emissions, congestion, and resource consumption, all of which have far-reaching consequences for the environment Gündüz et al. (2017). The consumer, as the ultimate recipient of these goods and services, plays a central but often overlooked role in the last mile delivery process. Consumer choices, behaviors, and preferences have a profound impact on how last mile delivery is executed, yet these factors have received relatively limited attention in the broader discussion of supply chain logistics and sustainability. Understanding and influencing consumer behavior in the context of last mile delivery is a critical dimension of behavioral operations studies (Kirchoff et al., 2016). In this research area we aim to contribute by investigating how the supplier can influence the consumers' behavior in the context of last mile delivery, and how it, in turn, can affect the supply chain sustainability. In the grocery sector, the environmental impact of last mile delivery is pronounced due to the perishable nature of food items, often necessitating expedited delivery methods. This urgency can lead to an over-reliance on fossil fuel-powered vehicles and inefficient routing, contributing to elevated carbon emissions and air pollution. The importance of home deliveries in the grocery sector has experienced a remarkable surge, particularly in the aftermath of the COVID-19 pandemic. While the surge in home deliveries in the grocery sector presents numerous opportunities, it also brings forth challenges that must be addressed; they span from logistical complexities (ensuring timely and efficient delivery routes, managing perishable items, and optimizing delivery personnel) to environmental concerns (Cachon and Terwiesch, 2019). The need to balance the convenience of home deliveries with sustainability imperatives arises. Consumer choices and behaviors significantly shape the landscape of last mile grocery operations, as they dictate the frequency and nature of these deliveries. Yet, consumer influence in this context has received limited attention, with environmental concerns often taking a backseat to convenience and immediacy. In this research, we aim to ascertain whether consumers are amenable to striking a balance between the convenience and benefits of home grocery delivery and its environmental impact, and, if so, what incentives or interventions are required to facilitate such behavior. Apart from financial incentives and nudges, social effects and peer influence might play a role in the consumer delivery choice, especially in the grocery sector where consumers usually live in the same area. Social norms and the behavior of others can act as powerful nudges themselves Cialdini (2003). In this vein, our research aims to ascertain if in the grocery delivery others' behavior influences consumers in selecting the delivery option: we can import the motivations of social norms to back our hypothesis that it is further strengthened by the proximity of the other consumers. We investigate if consumers are more likely to choose sustainable last mile delivery options when they observed others (neighbors, in particular) making similar choices in a controlled experimental setting. We conduct an ad hoc designed experiment to answer our research questions and we use the obtained results to optimize the delivery in the grocery sector. More in details, we show the benefit of allowing customers to (i) choose the day on which the delivery is performed (letting the company choosing the most convenient time), or to (ii) choose the time of the delivery (letting the company choosing the most convenient day), while paying a monetary incentive to customers for their flexibility. A larger incentive is paid to customers who provide flexibility of both day and time of delivery. The results of the experiments are used to estimate the percentage of customers providing each type of flexibility.

The second analysis concerns the benefit of consolidating deliveries to customers located in the same area within a "shared cart", to reduce the distance traveled, and consequently the environmental impact of delivery operations. Orders are shipped as soon as a minimum number of requests

from the same area are received. Data on the current number of orders placed are accessible to customers, who can, based on this data, autonomously decide if joining the consolidated delivery system and receive a monetary reward, or to select a standard delivery. The probability that a customer will join the consolidated delivery system, depending on the number of already placed orders, is estimated by the experiments conducted. The paper is structured as follows. In the next section a literature review on the main research topics, i.e., nudge, financial incentives and social norms as drivers in the consumers last mile delivery decisions, and last mile delivery optimization, is addressed. Section 4 presents the hypotheses development and the adopted methodologies. The optimization models used to analyze the benefit of nudging and monetary incentives are described in Section 6, while first results are discussed in Section 5. We draw conclusions in Section 7.

2. Literature Review

Previous research, particularly within the realm of energy consumption and sustainability (Fanghella et al., 2021; Mi et al., 2021), has examined the interplay between nudges, financial incentives, and a broader spectrum of monetary and non-monetary incentives to motivate consumers towards sustainable behavior. Scholars, such as Alcott and Rogers (2014) and Loewenstein et al. (2007), have conducted extensive research on the integration of nudges and financial incentives. They provide valuable insights into the ways in which these two mechanisms can work in tandem to influence consumer behavior towards sustainability. However, it is worth noting that opinions on the extent of their stand-alone (Fiorillo and Sapio, 2019) and mutual influence (Fanghella et al., 2021) may vary among researchers. In summary, this body of literature underscores the importance of considering multiple avenues and approaches in promoting environmentally conscious choices. While scholars may hold differing opinions about the precise interplay of incentives and nudges, there is a shared recognition of their collective potential in advancing sustainability objectives. The integration of experimental economics methodology tailored to the grocery sector has provided a robust platform for investigating the impact of financial incentives and nudges on last mile delivery choices. Experimental studies enable researchers to design controlled environments that simulate real-world decision-making scenarios (Hasson et al., 2010; Löschel et al.) Nudges, a concept popularized by Thaler and Sustein (2008), represent subtle changes in choice architecture that steer individuals towards desired decisions without imposing mandates. Experimental economics studies within the grocery sector have effectively employed nudges to encourage environmentally responsible last mile delivery choices. For instance, experiments have revealed that strategically framing delivery choices can nudge consumers towards selecting greener options (Huitink et al.) While both financial incentives and nudges have been explored independently in the grocery sector, there is a notable gap in the literature regarding their combined impact on last mile delivery choices (Agatz et al., 2021). This research wants to fill this gap exploring if consumers exposed to a nudge emphasizing the environmental impact of delivery choices were more responsive to financial incentives for eco-friendly options.

Also, the optimization of home delivery routes for CO₂ emission reduction involves understanding consumer behavior towards delivery options. The integration of technology, such as online shopping platforms and delivery scheduling systems, plays a crucial role in making delivery services more efficient and environmentally friendly. Literature has addressed the problem of delivery CO₂ emissions optimization from an operational point of view, looking at the dynamic routing, drivers behaviour, and vehicle technology (Arroyo-López et al., 2021) These studies collectively

suggest that technological advancements in vehicle design, driver behavior modification, and optimization of delivery routes and schedules are key areas for CO2 emissions reduction in delivery operations (Mancini and Gansterer, 2021). Choices made by consumers regarding appointment timings can significantly influence the logistical proficiency of businesses offering services (Agatz et al., 2021; Boyer et al., 2009). It emerges that the efficacy of delivery services is deeply intertwined with how customer preferences for delivery time slots are managed. Innovations in dynamic slotting can optimize the range of time slots offered to customers (Lang et al., 2021). As a third contribution, we aim to propose an innovative delivery option, defined as a “shared cart”, which addresses the problem of repeated routes leveraging on customer cooperation attitude coming from pro-social norms behavior.

3. Methodology

Consumers are often inclined to make egoistic choices when selecting products to buy, neglecting the impact of the non-sustainable product on the environment. This phenomenon is described by the concept of social dilemma (Kollock, 1998; Rashidi-Sabet et al., 2022; Van Lange et al., 2013), according to which individuals experience a conflict between self-interest and long-term public interest, such as the health of the environment. In fact, pro-environmental behaviours are less-preferred options for a consumer making purchase choices.

Experiments in controlled environment are recognized as a powerful methodology to test the effect of moral nudges and financial incentives.

We develop a novel task that captures the choice of actual delivery options in grocery buying, represented by a trade-off between private and societal benefits. We implement a two parts experiment, starting with a dictator game and finishing with a novel task series. The dictator game is aimed at capturing the individual propensity to common good, measured by the choice of sustainable delivery options. In fact, dictator games are well suited to reveal the allocator’s true social preference (van Dijk and De Dreu, 2021).

The sample is extracted from a pool of about 700 real consumers of an Italian supermarket’s e-commerce channel *Maxistore Decò Conigliaro*¹. We obtained 40 full responses to date.

3.1. Task design

We design an experiment that simulates the choice of the delivery option of a grocery online purchase through an online Google form. The experiment is divided into two parts.

In the first part, consumers are required to choose delivery option among four options that vary in the customers’ possibility to choose time and date of delivery (1- choose date and time, 2-choose time, 3- choose date, 4- don’t choose time and date). The environmental benefit, in terms of CO2 emissions reduction, increases with the increase of delivery time and date flexibility. The levels of CO2 emissions are 100% for option 1, 30% for options 2 and 3 and 60% for option 4 (see Table 1) (Kemp et al., 2022).

For the sake of realism, we include a set of financial incentives as discounts in the design of the experiment (see Table 2). In real life, choosing a flexible schedule delivery produces an environmental positive externality. However, uncertainty of time and date delivery requires an effort for the consumer to make himself available.

¹connie.it

Delivery option	Environmental impact reduction
1) choose delivery time and date	0%
2) choose delivery time	30%
3) choose delivery date	30%
4) do not choose neither time nor date of delivery	60%

Table 1: CO2 emissions reduction for each delivery option as nudge.

Delivery option	Discount value
1) choose delivery time and date	€ 0
2) choose delivery time	€ 1
3) choose delivery date	€ 1
4) do not choose neither time nor date of delivery	€ 2

Table 2: Discount value for each delivery option as financial incentive.

Additionally, a flexible delivery produces a positive externality to the supermarket operations by enabling cost cuts. We operationalize the positive externality to the environment as a CO2 emissions reduction. In the second part of the experiment, consumers are required to choose delivery options among two choices. One is the regular delivery (choose date and time), and the other is the novel concept of shared cart. The shared cart allows an estimated 60% CO2 reduction, it needs at least 4 orders to be placed with the collective cart to be activated. When the threshold is met, the collective cart will deliver the grocery to the 4 or more consumers at the supermarkets' preferred time and date. For filling the collective cart, cooperation among consumers is required. According to goal-expectation theory (Pruitt and Kimmel, 1977), cooperation emerges when two conditions are met. First, participants should have cooperative beliefs, in that they need to trust interdependent others to make cooperative decisions, that we measure in the first part of the game through the dictator game. Second, participants should have cooperative goals, in this case the filling of the collective cart.

3.2. Treatments

The experiment is implemented with a within-subject design and manipulates the type of incentive implemented (3). The participants are then all provided with the same instructions. In the first part of the game, we design two treatments (T1 and T2). They are called the financial incentive and the green nudge. By separating the application of a financial or green nudge incentive, the experiment aims at clarifying contradictions in the literature about their interplay.

Financial incentive (T1): the financial incentive treatment is structured into two questions for participants. Consumers are first asked to choose the preferred delivery option among the 4 options, while presented with an economic reward for every delivery option, as pictured in Table 3. The economic reward is structured as a discount on future purchases from the same grocery store (Rajapaksa et al., 2019). Next, participants are asked to answer the same question, while presented, additionally to the financial incentive, the CO2 emissions reduction for each delivery option, as described in Table 1.

Green nudge (T2): also the green nudge treatment is structured into two questions for partici-

Treatment	Consumer task	Incentive/nudge
Financial incentive (T1)	Q.1.T1 choose delivery among 4 differently flexible options Q.2.T1 choose delivery among 4 differently flexible options	discounts discounts + CO2 emissions reduction
Green nudge (T2)	Q.1.T2 choose delivery among 4 differently flexible options Q.2.T2 choose delivery among 4 differently flexible options	CO2 emissions reduction CO2 emissions reduction + discounts

Table 3: Description of the treatments T1 and T2.

pants. Similarly to the financial incentive treatment, participants in the green nudge treatment are first asked to choose the preferred delivery option among the 4 options, while being exposed to the green nudge. The green nudge is designed as a moral nudge used in economic games for a public good. It consists of presenting the 4 delivery options associated with their respective CO2 emissions, as described in Table 1. Coherently with the financial incentive treatment, also the consumers in the green nudge treatment are asked again to answer the same question, while presented, additionally to the CO2 emissions reduction for each delivery option, with the discounts associated with every option, as described in Table 2. A synthesis of the two treatments subdivided in the two respective questions is reported in Table 3.

3.3. *Experimental procedure*

All potential participants in the supermarkets' customer list are invited to participate in the experiment and are informed that prizes can be accumulated during the game and will be received by the consumer only after the completion of the experiment. The maximum obtainable prize is €4 in the question with the financial incentive and €2 for the one with the nudge. When entering the experiment, all participants are asked first to fill a survey gathering demographic and their life time-flexibility data. Then, all participants are equally divided into the 2 treatments financial incentive and green nudge. Before that, they are asked a comprehension question, and only those who answered correctly were allowed to start the game. The participants to the financial incentive treatment (T1) will choose delivery option answering to Q1.T1 and Q2.T1 and the participants to the green nudge treatment (T2) will choose delivery option answering to Q1.T2 and Q2.T2 as described in Table 3. Following this first part of the experiment all participants perform the same tasks with equal treatment. They are asked another comprehension question that required a correct answer to continue with the game. In this second part, participants were asked to choose between the shared cart or the "individual delivery" in 4 rounds (Q.3.a, Q.3.b, Q.3.c and Q.3.d). At each of the rounds a different level of cart fulfillment is presented in a random order (levels are 0/4, 1/4, 2/4, and 3/4), to appreciate how the different levels of fulfillment, corresponding to the different number of consumers that behaved cooperatively, influences the customer's decision on the delivery option. The repeated decision making is aimed to explore how history of cooperative peer behavior contributes to the emergence of cooperation (Fehr and Schurtenberger, 2018). At the end of the second part, participants are asked to fill a survey gathering data about their environmental sustainability orientation and their beliefs about others' propensity to cooperate. In fact, in public good provision games, the decision to cooperate depends on beliefs about others' propensity to cooperate or free-ride instead (Fehr and Gächter, 2018).

4. Hypotheses

This paper seeks to investigate first, the interaction between financial incentives and green nudges in influencing consumer behavior towards sustainable grocery purchasing, and second, the role that others' consumer behavior plays in pushing consumer behavior towards more sustainable choices. Initially, we examine the role of financial incentives independently. Experimental evidence within the grocery sector demonstrates that nudges, particularly those that frame delivery choices effectively, can lead consumers to opt for greener options. This evidence suggests that while financial incentives are potent motivators, green nudges might have a profound impact on steering consumers towards green grocery buying. While the standalone effects of these strategies are well-documented, their combined impact is less understood and in other sectors, studies diverge in their findings. This lack of clarity in the incentives interplay forms the basis of our Hypothesis 1, for which in practice, we expect a higher choice of flexible delivery options when the two incentives coexist.

H1: *Green nudges and financial incentives synergically push consumers towards green grocery delivery.*

Further, the research explores the dominance, if any, between green nudges and financial incentives. While the standalone effects of these strategies are well-documented, their compared effectiveness is less understood. This is an important aspect to investigate, since the investment in the two incentives are very different in terms of perdurance: financial incentives require a continuous investment, while the green nudge does not. Hypothesis 1a examines whether the presence of a green nudge could enhance the effectiveness of financial incentives. The rationale is that nudges could prime consumers to value sustainability more, thereby making financial incentives more appealing. In contrast, Hypothesis 1b, being green nudges more effective than financial ones, considers the possibility that financial incentives might not reinforce the power of green nudges. This hypothesis is informed by the limited evidence on the synergistic effects of combining these approaches (Fanghella et al., 2021) and on the possibility, if that is the case, that moral incentives dominate financial ones in the sustainability domain. In practice, we expect a higher choice of flexible delivery options for those individuals that have been offered the financial incentive with the nudge (Q2.T1) than the financial incentive (Q1.T1; H1a), and that the choice of flexible delivery options is higher in Q1.T1 than in Q1.T2 and comparable for Q1.T2 and Q2.T1 (H1b). Consequently, we formulate the sub-hypotheses as follows.

H1a: *the presence of a green nudge reinforces the effectiveness of financial incentives.*

H1b: *the green nudges incentive motivates more than the financial incentives, and the financial incentives do not reinforce the power of green nudges.*

Additionally, this study delves into the social dynamics of consumer behavior, an aspect not extensively covered in existing literature. The sustainable behavior of other consumers, particularly in the context of shared cart delivery options, could have a significant influence on individual consumer decisions. This observation leads to the formulation of Hypothesis 2.

H2: *sustainable behavior of other consumers pushes an individual consumer to behave similarly.*

This hypothesis is further nuanced by examining the impact of initial responses to green nudges. Hypothesis 2a posits that consumers who initially respond positively to a green nudge will not be influenced by the sustainable behavior of other consumers, because they are intrinsically motivated to have a sustainable behaviour. In contrast, Hypothesis 2b suggests that those who do not respond positively to the green nudge initially will be influenced by peer behavior. These hypotheses seek to explore the depth of social influence in environmentally responsible consumer behavior. In practice, we expect a constant number of shared cart choices, while varying the level of cart fulfilment, by the consumers that responded positively to the green nudge. Oppositely, we expect a growing participation to the shared cart as the cart fulfilment level grows, for the consumers who did not respond positively to the green nudge.

H2a: *consumers who initially respond positively to a green nudge will not be influenced by the sustainable behavior of other consumers.*

H2b: *those who do not respond positively to the green nudge initially will be influenced by peer behavior.*

5. Preliminary Results

The experiment presents an intriguing exploration into the effects of financial incentives versus moral persuasion in shaping consumer behavior towards environmentally friendly delivery options. Initially, in Q1.T1, where consumers were under the financial incentive, 31% chose low flexibility (delivery option 1), while 45% and 24% chose medium (delivery option 2 and 3) and high flexibility (delivery option 4), respectively. When the same individuals were later exposed to the combination of both financial and green nudge incentives in Q2.T1, the choice for high flexibility delivery options rose to 59%. This indicates a substantial influence of the combined treatments, suggesting that when financial incentives are consequently coupled with moral nudges, consumers tend to make more environmentally friendly choices. Figure 2 reports consumers' choices for Q1.T1 and Q2.T1. Comparing Q1.T2, where the green nudge was applied, with Q2.T2, where the combined treatment was in effect, we see a similar but slightly less pronounced trend. In Q1.T2, only 10% opted for medium flexibility, while 50% chose high flexibility. With the coupled incentives in Q2.T2, the selection for high flexibility rose to 60%. The increase, though modest, still points towards the effectiveness of the incentives combined but suggests that the green nudge alone already had a significant impact on promoting high flexibility choices.

When comparing the changes between Q1.T1 (financial incentive) and Q2.T1 (combined) to those between Q1.T2 (green nudge) and Q2.T2 (combined), it becomes evident that the financial incentive had a strong initial effect on reducing low flexibility choices. However, the introduction of the green nudge alongside the financial incentive seems to further enhance the consumers' inclination towards environmentally friendly options, albeit at a diminishing rate.

The investigation into the efficacy of the interplay between financial incentives and green nudges on consumer delivery option choices yields notable preliminary results. The experiments' sequential treatment design allows us to parse out the distinct and combined effects of these two types of interventions. Hypothesis H1 proposes that the combination of green nudges and financial

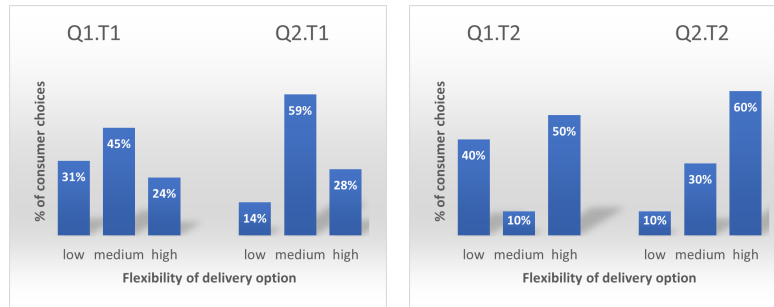


Figure 1: Delivery choice in (a) financial incentive and (b) green nudge treatment.

incentives act synergically in encouraging consumers towards green grocery delivery options. The data confirm this synergy, indeed the results show in both treatments an increase in flexible options shifting from the first to the second question (Figure 2). The combination of moral and financial motivators appears to have a compounded effect, potentially by aligning economic self-interest with pro-social environmental values. Hypothesis H1a proposes that the presence of a green nudge reinforces the effectiveness of financial incentives. The leap in high flexibility choices from 24% in Q1.T1 (financial incentive alone) to 59% in Q2.T1 (combined incentives) supports this hypothesis. Hypothesis H1b considers the possibility that green nudges are more effective than financial ones and that financial incentives do not reinforce the power of green nudges. The evidence partially supports this hypothesis; while green nudges seem motivating more towards a sustainable behavior, data suggests that financial incentives may further bolster the influence of green nudges, as demonstrated by the greater proportion of consumers selecting more environmentally friendly options when both incentives are applied in Q2.T2 respecting Q1.T2. It is worth noting that while persistence over time of the green nudge effect has been demonstrated, it is not the case for the financial reward effect. In fact, the effect of the green nudge in pushing consumers towards greener choices, obtainable for example through an educative campaign, persists also after the application of the educational program. Oppositely, the financial nudge, applicable for example through discounts of green delivery options, cease to push consumers toward greener choices after its immediate application. In conclusion, while both financial incentives and green nudges individually promote more sustainable choices, their combination is particularly potent, leading to a higher selection of flexible delivery options. This suggests a synergistic relationship where financial incentives can augment the impact of green nudges, offering a more nuanced understanding of consumer behavior in the context of environmental sustainability. These findings highlight the potential for integrating economic and moral considerations in strategies aimed at promoting pro-environmental consumer behavior, while the dominance of green nudges and their higher persistence pose the urgency of an economic assessment in a longer perspective. Hypothesis H2 proposes that the sustainable behavior of other consumers encourages an individual consumer to behave similarly. The data from the shared cart option provides strong support for this hypothesis. As the level of cart fulfillment increases, so does the percentage of consumers choosing the shared cart option. This trend is observed across both the green nudge and financial incentive conditions, with the highest levels of shared cart selection correlating with the highest levels of cart fulfillment (3/4 level of fulfillment yielding 90% for the green nudge and 96% for the financial incentive). As represented in Figure 2, reporting the choice of the shared cart for any given level of cart fulfillment, the results suggest a clear pattern of social influence, where consumers are more inclined to choose a sustainable de-

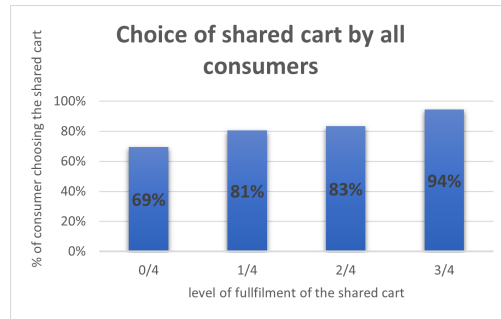


Figure 2: Responses of all consumers to Q.3a, Q.3b, Q.3c, Q.3d

livery option (the shared cart) when they perceive that others are also making similar sustainable choices. This behaviour aligns well with social proof and conformity theories, where individuals tend to follow the actions of the majority, especially in situations where they are unsure of the correct behavior.

Hypothesis H2a suggests that consumers who initially respond positively to a green nudge are slightly influenced by the sustainable behaviour of other consumers because they are already intrinsically motivated towards sustainable behaviour. The data available do not provide a direct measure of intrinsic motivation. However, the high percentage of consumers opting for the shared cart even at lower levels of cart fulfillment (100% at 0/4 level for the green nudge) might suggest that these consumers are indeed less influenced by others' behaviour and more by their own sustainable values. Hypothesis H2b posits that consumers who do not initially respond positively to the green nudge will be influenced by peer behaviour. Figure 2 shows the choices of consumers in both treatments that demonstrated the least sensitivity to both incentives and nudge, thereby choosing the least flexible option ("1) choose delivery time and date") in either Q2.T1 or Q2.T2. This hypothesis seems weakly supported by the data, as there is a very slight increase in the percentage of consumers choosing the shared cart with increasing levels of cart fulfillment. We can argue that there are three categories of customers: one that opt for the sustainable option regardless other behaviour, one that do not select sustainable option maybe for constraints related to their daily routine, and a third one that feels the other behaviour as a nudge to assume a sustainable choice. Although stronger evidence is needed, this preliminary result indicate that even those who showed a mild inclination towards sustainability (belonging to the third category) in the first part of the experiments, are swayed by observing the choices of their peers, for high levels of cart fulfilment, thus demonstrating the impact of social dynamics on consumer behavior.

In summary, the preliminary results indicate that consumer behavior in the context of sustainable choices is influenced by the behavior of their peers, supporting Hypothesis H2. The influence appears to vary with the consumer's initial response to sustainability cues, with those responding positively to green nudges potentially less influenced by peer behavior (supporting H2a), and those not initially inclined towards sustainability being more influenced by peer behavior (weakly supporting H2b). These preliminary results suggest that while both financial incentives and green nudges effectively push consumers towards more environmentally friendly delivery options, their impact varies with the degree of flexibility and the social dynamics involved. In conclusion, these insights underscore the importance of considering social factors when designing interventions to promote sustainable consumer behavior.

6. Benefit of Monetary and Nudges: An Optimization-based Approach

We present two analyses to assess the benefits of monetary and nudge incentives in last-mile-delivery. The first analysis concerns the impact of the customers' flexibility on the time and/or on the day of the delivery on the total cost for the company. We use the output of the previous described behavioral experiments to determine the percentage of customers who 1) are not flexible and desire to choose both the time and the day of delivery 2) are flexible on the day of delivery but not on the time of delivery, 3) are flexible on the time but not on the day, and 4) are flexible on both. Customers choosing option 2) and 3) receive a compensation of € 1, while those selecting option 4, a compensation of € 2. We use this data to generate a sample set of customers distributed on a square area split in 9 districts (3x3 grid). For each customer we assume to know the preferred time and day of delivery and the type of flexibility selected. The correspondent compensation is paid only if the preferred time and/or day is not respected.

Since we would like to consider a large number of customers, we do not explicitly model the routing of the vehicles. Indeed, we consider a fixed cost to serve each district based on the distance from the grocery store. Each customer is assigned to a time-slot and a day. A district must be visited on a specific timeslot and day if at least one customer living in the district has been assigned to that timeslot and day. We assume that a vehicle visits (operates delivery in) at most one district per timeslot. The goal of the problem is to minimize the overall cost given by the sum of delivery costs and compensation paid to customers.

The resulting problem is formulated as an integer programming model. The set of customers is indicated with I , the set of districts with J , the set of days with D and the set of timeslots with T . The preferred time and day for customer i , are defined as τ_i and δ_i , respectively. The cost for serving a zone j is known as c_j . The district in which customer i is located is defined as a_i , while ψ_i^D and ψ_i^T are constant equal to 1 if i is not flexible with respect to the day and the time of delivery, respectively, and 0 otherwise. Finally, the maximum number of available vehicles, corresponding to the maximum of districts that can be simultaneously visited is referred as m . We define 4 types of binary decision variables: y_{idt} indicates whether customer i is assigned to day d and timeslot t . Analogously, x_{jdt} represents whether zone j must be served on day d and in timeslot t , while z_i and w_i indicate whether customer i is served on a day and in a timeslot different from the preferred ones, respectively. The mathematical model can be described as follows

$$\max \sum_{j \in J} \sum_{d \in D} \sum_{t \in T} c_j x_{jdt} + \sum_{i \in I} w_i + \sum_{i \in I} z_i \quad (1)$$

$$\sum_{d \in D} \sum_{t \in T} y_{idt} = 1 \quad \forall i \in I \quad (2)$$

$$z_i = 1 - \sum_{t \in T} y_{i\delta_i t} \quad \forall i \in I \quad (3)$$

$$w_i = 1 - \sum_{t \in T} y_{i\tau_i t} \quad \forall i \in I \quad (4)$$

$$x_{jdt} \geq \frac{1}{N_j} \sum_{i \in I | a_i = j} y_{idt} \quad \forall j \in J \quad (5)$$

$$\sum_{j \in J} x_{jdt} \leq m \quad \forall j \in J \quad (6)$$

$$z_i = 0 \quad \forall i \in I | \psi_i^D = 0 \quad (7)$$

$$w_i = 0 \quad \forall i \in I | \psi_i^T = 0 \quad (8)$$

The objective function, reported in (1) consists minimizes the total costs expressed as the sum of delivery and compensation costs. Each customer must be assigned to a specific day and timeslot, as expressed by Constraints (2). Constraints (3) and (4) allow to detect whether a preferred timeslot or day is violated. Constraints (5) allows to compute whether a district must be visited in a specific timeslot and day or not. Constraints (6) limit the number of vehicles that can be simultaneously used, i.e., the number of districts that can be simultaneously visited. Finally, Constraints (7) and (8) impose that preferred timeslots and days can be violated only for customers who expressed the correspondent flexibility.

Results conducted on an instance with 100 orders, 5 days, and 5 time-slots, showed that considering only flexibility on the day of the delivery (while respecting all the preferred timeslots) allows to reduce costs of 20.3%. If we consider only flexibility on the day of the delivery (while respecting all the preferred days), the gain grows up to 37.5%. If we consider flexibility on both timeslots and days we can achieve a reduction of costs of 42.5%. These results indicate that both type of flexibility types contribute to strongly reduce costs. The monetary compensation incentivizes customers to provide flexibility and the associated costs are widely covered by the significant saving on the delivery costs. This is a win-win situation, since increased customers satisfaction, provides a strong cost reduction for the company and significantly decreases the environmental impact of delivery operations.

The second analysis we conduct concerns the impact of exploiting the shared cart concept. For this, we use data extracted from the behavioral experiments to generate a sample of customers' arrivals and behaviors, and by means of simulation we detect whether customers join the shared cart or go for an individual delivery. The choice of customers is influenced by the choice of previous customers from the same district, since it modifies the filling level of the cart. Once a cart is complete, the order is delivered before the end of the current day. Even if the cart is not complete, the orders are shipped within 2 days. Customers joining the cart are rewarded with a compensation of €2. The results of the simulation are used to construct an instance for the optimization model previously described, in which each shared cart is represented as a single fictitious customer, which delivery day cannot be modified while delivery timeslot is arbitrarily fixed to the last one of the day, in order to accommodate as many customers as possible. The number of available vehicles is set equal to the number of districts in order to become not binding. Customers who choose individual delivery are considered as standard customers with no flexibility.

Results show that the shared cart approach allows to save up to 57.2% of the total costs. This indicates the high potential of this delivery option, both in terms of environmental impact and of costs for the company.

7. Conclusions

This paper presented empirical evidence from experimental economics that sheds light on effective strategies for incentivizing sustainable behavior in consumer choices regarding last-mile grocery delivery. Our study aimed to investigate the interaction between financial incentives and green nudges in influencing consumer choices, with a focus on the relative effectiveness of these strategies. Additionally, we explored the impact of social influence on delivery choices and found that peer behavior plays a significant role. Our key findings indicate that interaction between financial incentives and green nudges play a significant role in influencing consumers' final choices in the last-mile context. When both financial incentives and green nudges are presented together, they have a synergistic effect on encouraging sustainable behavior. Green nudges are at least as effective as financial rewards in driving sustainable choices among consumers. Green nudges, such as eco-friendly messaging, environmental information, and social norms, have a strong impact on consumer decision-making comparable to monetary incentives alone. Furthermore, experiments revealed that consumers are increasingly receptive to green nudges that promote environmentally responsible choices. These nudges not only sway consumer preferences but also contribute to a broader shift in consumer behavior towards more sustainable options in last-mile grocery delivery. On the long-term green nudges are likely to have a lasting effect on consumer behavior compared to financial rewards, which may be perceived as short-term gains. Consumers who are exposed to green nudges are more likely to adopt sustainable practices over an extended period, leading to a positive impact on the environment. Finally, our study revealed the importance of social influence in shaping consumer choices regarding last-mile grocery delivery. Consumers who are aware that others are cooperating for the environment are more inclined to opt for sustainable delivery methods. This finding highlights the potential for societal norms and collective behavior to drive positive changes in sustainability-related decisions. In regards of cost-effectiveness, from a practical standpoint, our findings suggest that businesses and policymakers should consider implementing green nudges as a cost-effective strategy for promoting sustainability in last-mile grocery delivery. While financial incentives can be costly to maintain, green nudges offer a sustainable and affordable means of encouraging eco-friendly choices. In summary, our experimental economics research demonstrates that green nudges are a powerful tool for incentivizing sustainable behavior in consumer choices related to last-mile grocery delivery. The combination of green nudges and financial incentives can produce even more significant results, emphasizing the importance of a multifaceted approach to promoting sustainability. As we move forward in addressing the environmental challenges posed by last-mile delivery, businesses and policymakers should prioritize the implementation of green nudges as an effective and sustainable means of encouraging responsible consumer choices. The impact of the more sustainable choices of customers, boosted by the incentives, on the delivery costs and, consequently, on the environmental impact of delivery operations, is considerable, as showed by the results of our analyses.

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