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Social evaluation of a Deposit and Refund System pilot project for polyethylene terephthalate packaging

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ABSTRACT

The Deposit and Refund System (DRS) has demonstrated its effectiveness as a powerful economic instrument to help to achieve the European targets for packaging waste recycling, whilst simultaneously ensuring the collection of higher-quality materials for the production of new beverage bottles. In Portugal, a pilot DRS project focusing on polyethylene terephthalate (PET) beverage packaging was implemented by the government to gain insights and experience before the introduction of the mandatory system, which will include other materials. The pilot project involved 23 Reverse Vending Machines (RVM) in supermarkets across mainland Portugal, with a questionnaire assessing behaviour changes in users and non-users. Results from 1,490 responses indicated significant public support for the future DRS and its extension to other packaging materials. Various incentives were applied to the DRS to understand the effects throughout the pilot. The economic incentive proved key to the pilot's success, as it motivated consumers to participate, actively recycling. Consequently, it is expected that the DRS will increase recycling participation rates. Two other factors that contributed to the success of the DRS were the location of the RVM and the effectiveness of communication with the public, impacting their perception of and engagement with the system. The results provided important data for planning the future national strategy, which may also be of interest to other similar realities.

1. Introduction

1.1. Challenges regarding the plastic industry and regulatory framework

After a decrease in 2020 due to the Covid-19 pandemic, European plastics production increased to 57.2 million tonnes in 2021, of which 87.6% were reported as fossil-based plastics, 10.1% as post-consumer recycled plastics and 2.3% as bio-based/bio-attributed plastics. Moreover, 5.3% of the total is polyethylene terephthalate (PET) plastics (Plastics Europe, 2022). In the same year, packaging represented by far the largest end-use market for plastics (Plastics Europe, 2022). One of the main reasons for the increase in this type of packaging in recent decades, according to Leal Filho et al. (2019), is the functional advantages it offers in packaging applications, such as protecting and keeping food safe.

In Europe, by 2020 it was estimated that a total of 3.6 million tonnes of PET bottles were produced, representing an increase of 6% when compared to 2018 (Eunomia, 2022; Geyer et al., 2017; Welle, 2011). Approximately 29.5 million tonnes of post-consumer plastic waste were collected in 2020. Of this, 51% was within unsorted waste. Regarding the treatment options, energy recovery and landfill are predominantly chosen (57% and 38%, respectively), neither of which are the most favourable treatment alternatives when considering waste hierarchy. The rest, 49% was selectively collected waste, where the majority (65%) was sent for recycling. In Portugal, the data for plastics treatment is the following: 32% is recycled, 35% is sent for energy recovery, and 33% is landfilled (Plastics Europe, 2022).

Another challenge is the amount of plastics ending up in the oceans and accumulating in coastal zones, with more than 80% of its annual input of plastic litter coming from land-based sources (Eunomia, 2016; Ocean Conservancy, 2019; Sebille et al., 2016). This poses an environmental challenge due to its origin in fossil fuels, which take years to decompose (PAEC, 2021; Resolve, 2022; Zhou et al., 2020). Plastic pollution in natural ecosystems, including microplastics or nanoplastics, has increased at an unprecedented rate (Kumar et al., 2021). For Portugal, this is problematic since the country has a huge coastline, contiguous with the Atlantic Ocean, of around 2,601 km (INE, 2017).

Considering these challenges, the European Commission published

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"A European Strategy for Plastics in a Circular Economy" (European Commission, 2018), mentioning the need to increase plastics sorting and recycling capacity from 2015 to 2030, and inviting industry groups along the supply chain to make voluntary commitments and accept responsibilities. Another document was Directive (EU) 2018/852 of May 6th, which amended Directive 94/62/EC of December 20th, on packaging and packaging waste, indicating that the European Member States should take the necessary measures to promote high-quality recycling of packaging waste and to meet the quality standards essential for the recycling sectors concerned, establishing a minimum target of 50% for the recycling of plastic packaging by 2025, raising it to 55% by 2030.

Moreover, Directive 2019/904 of June 5th (Directive Single-Use Plastics), aiming to reduce the impact of certain plastic products on the environment, states that European Member States should promote more effective selective waste collection systems, namely through a Deposit and Refund System (DRS), and should ensure selective collection targets of 77% of beverage packaging for recycling by 2025, and 90% by 2029. This Directive also stated that, starting in 2025, beverage bottles made mostly from PET must contain at least 25% recycled plastic and, from 2030 onwards, at least 30%.

Concerning these ambitious targets, an efficient, effective, and convenient recycling system needs to be implemented to increase beverage packaging recycling rates (Oke et al., 2020; Schneider et al., 2021; Zhou et al., 2020). Furthermore, Europe has signed the Plastic Pact to make the lifespan of plastic more circular (Ellen Macarthur Foundation, 2022). Portugal has signed a corresponding Portuguese Plastic Pact regarding the national scale (Smart Waste Portugal, 2022), to improve the nation's compliance with the circular economy principles in plastics management, to be achieved until 2025. The Portuguese strategy includes, by the end of 2020, the definition of a list of problematic or unnecessary single-use plastic items and the establishment of measures for their elimination through redesign, innovation, or alternative delivery models. Other targets involve ensuring that all plastic packaging is reusable, recyclable, or compostable and that new plastic packaging incorporates at least a proportion of recycled plastic.

1.2. Solutions and challenges provided by Deposit and Refund Systems and incentives

Considering the requirements of circular economy principles, DRS has proven to be an effective method to collect one-way beverage packaging, to encourage high levels of recycling and obtain better quality material, such as bottle-to-bottle alternatives (Calabrese et al., 2021; Laubinger et al., 2022; Malindzakova et al., 2022; Schneider et al., 2021). In addition, it allows better control of plastic waste flows (Abbott and Sumaila, 2019).

According to Zhou et al. (2020), more than 40 countries in the world have implemented a DRS for end-of-use beverage packaging. Reloop (2022) confirmed that, as of 2022, DRS exists in 13 European countries and could return high levels of PET collection.

As a strategy, DRS essentially fuses two instrumental approaches: a tax (deposit) on products linked to their disposal cost, but also a subsidy (refund) as a reward for engaging in recycling, minimising the need to transport waste materials to another destination (Ino, 2011; Linderhof et al., 2019). In this context, it is important to align the value of the deposit with the disposal cost, serving as an upfront fee to cover the expenses associated with product disposal. In contrast, the refund aims to stimulate recycling by subsidising packaging waste collection and is recommended to fluctuate, typically being lower than the cost of disposal. In general, the purpose is to achieve an effective balance within the recycling incentive system (Ino, 2011).

The effective transition to a Circular Economy depends on the entire value chain, from consumers to companies and policymakers. Consumers are crucial, as their choices determine whether products end up in landfills or are returned to the production chain (Forlin and Scholz, 2020). Some conceptual models elucidate the intricate dynamics that shape an individual's recycling choices, encompassing three key factors: economic considerations influencing the net costs of recycling, personal moral sentiments, and also social pressures. Together, these factors contribute to reshape the decisions that citizens make regarding their recycling behaviour (Czajkowski et al., 2017).

Other studies also showed three main factors that can have a crucial effect on participation in recycling programs: inconvenience, financial incentives, and the information provided about the waste collection system. Firstly, the characteristics of the waste collection mechanism determine the degree of inconvenience perceived by consumers when they need to modify their habits. This is related, for instance, to the need to store and handle waste, the proximity and number of recycling bins, and the time and effort devoted to recycling (Roca et al., 2022; Roca i Puigvert et al., 2020). On the other hand, financial incentives, such as cash and prizes, can help to promote recycling behaviour. However, the effects of these instruments does not persist indefinitely and notably disappear when the financial incentives are removed (Roca et al., 2022; Roca i Puigvert et al., 2020).

Moreover, according to Li et al. (2021) consumers with a lower level of environmental awareness are more receptive to nonfinancial incentives than to financial incentives, although, in the long term, these measures weaken the pro-environmental attitudes that motivate recycling (Roca et al., 2022). Furthermore, the information that is available to consumers affects their attitudes towards recycling (Oke and Kruijsen, 2016; Roca et al., 2022). While knowledge and concern for the environment, as well as social norms, increase recycling behaviour, a lack of awareness regarding waste impacts explains individual mismanagement. So, public education and recognition are essential elements for the success of any waste management program (Kirakozian, 2016; Roca i Puigvert et al., 2020; Thøgersen, 2003). However, an awareness about environmental issues is not sufficient to guarantee the behaviour change expected (Kirakozian, 2016). As Kirakozian (2016) mentioned, many studies assess the effectiveness of isolated policies, but these instruments need to coexist and their synergies must be taken into account.

The available literature provides evidence that incentives affect recycling behaviour and attract greater participation in recycling programs, with monetary incentives being the most effective incentive (Lu and Wang, 2022). On the other hand, incentives like gamification can be valuable to increase adoption in users with otherwise low levels of behavioural intention (Vorobeva et al., 2023).

Assessing specific cases, DRS encourages positive behaviour change (Oke et al., 2020). The system itself and the incentives need to be thoughtfully designed to effectively incentivise whilst preventing adverse changes in social norms. As Gneezy et al. (2011) report, concerning incentives in changing lifestyle behaviours, "large enough incentives clearly work in the short run and even in the middle run, but in the longer run the desired change in habits can again disappear." When assessing community resident waste participation, Sun and Asari (2023) mentioned that recycling behaviour tends to grow in the early stages, but gradually shows saturation without growth in the middle and late stages. In greater detail, Arriagada et al. (2022) and Thøgersen (2003) affirm the same conclusions in behavioural trends from economic incentives, showing that the magnitude of the incentive is relevant: a large incentive could provide a sufficient extrinsic justification for behaviour, but a small incentive could provide an insufficient justification.

1.3. Scope and main objective

In 2020, the recycling rate of plastic packaging waste in Portugal was 33.9% (Eurostat, 2023). In this context, Portugal needs to increase the quantity of packaging waste being sent for recycling. Moreover, the country needs to ensure that the waste collected is of a sufficient quality to be incorporated into the production of new beverage bottles, promoting the maximum circularity of these materials. Considering the requirement to comply with circular economy principles, it is necessary to motivate producers to adopt clean production methods, but also to

encourage consumers to provide relevant waste products for recycling (European Commission, 2020).

With the DRS pilot project for PET bottles, using Reverse Vending Machines (RVM), the Portuguese Government intended, initially, to develop knowledge and experience for the design and implementation of the future beverage packaging deposit system to be extended to other packaging materials throughout the national territory. Moreover, it was intended to promote the adoption of sustainable behaviours, facilitating the recycling of the material collected and its incorporation into the production of new beverage packaging.

The focus was on PET bottles because it is one of the most frequently used plastics in food-packaging plastic (e.g., beverage bottles such as water and soft drinks) and also the most effectively recycled due to its properties and low absorption levels of post-consumer contaminants compared to other plastics (Leal Filho et al., 2019; Malindzakova et al., 2022). Also, the PET bottles collected become a resource with value, given their shape, design and capacity to be collected for recycling in high volumes (Ellen Macarthur Foundation, 2016; Kawai et al., 2022) and used in bottle-to-bottle recycling (Welle, 2011; Zhou et al., 2020).

In this context, the purposes of monitoring this pilot, carried out by the authors, was to determine, though a social approach, the factors that affect the efficiency of the waste collection system, citizens' behaviour, and the contribution of financial incentives. The main results are fundamental to Portuguese policymakers, who can adjust waste collection systems and communication campaigns to engage the population in the future recycling system. This may also be useful for other countries that intend to implement DRS since the types of information collected are scarce in the literature.

2. Methods

2.1. Case study

In Portugal, following the requirements established by the Single-Use Plastics Directive, the Government published Law n.° 69/2018 of December 26th, establishing a mandatory deposit system that had to be implemented, by January 2022, for non-reusable beverage packaging made of plastic, glass, ferrous metals and aluminium. The deadline was subsequently extended. The same Law created a consumer incentive system, in the form of a pilot project, for the return of non-reusable PET plastic beverage packaging, by using RVM, located in supermarkets geographically distributed from the North to the South of the mainland territory. Specifically, 23 Municipal Solid Waste Management Systems exist and each of these systems has adequate infrastructure to ensure an appropriate destination for the urban waste generated and collected. To ensure national representativeness, one RVM was installed in each of the 23 established municipal systems.

The choice of plastic packaging for this pilot project, particularly PET, was based on several favourable considerations, namely it being a material on which many European policies focus; it is clean and widely used by the beverage industry; it is the plastics material with the highest market value; and the most used and demanded by the food industry for incorporation into new food grade packaging. In addition, it can be compacted in the RVM, which reduces storage and transport costs.

The pilot project includes non-reusable PET packaging for beverages, such as water, juices, soft drinks, and alcoholic beverages (except dairy drinks), sold on the national market and destined for the final consumer, with a volumetry between 0.1 l and 2 l. The requirements for the acceptance of packages in the RVM have been established: they must not contain liquids, or be deformed, and they must have an intact cap and label, including a legible barcode.

To encourage the disposal of used PET packaging in RVM, the Portuguese Government created an economic incentive, expected to encourage reuse and recycling: for each package collected by the RVM, the user was rewarded with 0.02 € for packages with a volumetry between 0.1 l and 0.5 l, and 0.05 € for packages with a volumetry superior to 0.5 l and up to 2 l.

The pilot project has experienced four different stages throughout its duration. In the first stage, which occurred between March 2020 and February 2021, the RVM offered the user the choice between two options: a discount ticket or a donation to a Private Social Solidarity Institution. In the second stage, which occurred between February and May of 2021, the deposit of packaging was higher than initially expected. Because there was a limit on the amount made available by the Environmental Fund allocated to this project by the Portuguese Government, it was necessary to change the type of reward available for each bottle delivered. In this situation, it was decided to keep only the donation option, at least at that phase. In the third stage, which started in May of 2021, no reward exists. However, the appeal to continue using the RVM was reinforced, given the environmental benefit resulting from the recycling of collected packages. Later, a fourth stage was planned, starting in January 2022, after the monitoring work carried out by the authors, where each item of packaging received a point, and it was possible to exchange these points for prizes.

This pilot project was implemented by the consortium formed by the Portuguese Association of Natural and Spring Water Industries (APIAM), Portuguese Association of Non-Alcoholic Refreshing Drinks (PROBEB), and the Portuguese Association of Distribution Companies (APED), having been financed by the Environmental Fund of the Ministry of the Environment and Climate Action (MAAC). The consortium implemented the pilot project, which began in March 2020 and ended in December 2022, in which NOVA School of Science and Technology, NOVA University Lisbon was responsible for monitoring the social component, and also the operational component, the results of which are disseminated separately.

2.2. Questionnaire

To study the monitoring of the social component of the pilot project, two questionnaires were implemented: the first conducted six months after the start of the pilot project, namely in September 2020, and another in May 2021, at the beginning of the third stage (Fig. 1).

A structured survey by questionnaire was applied in person to a sample of customers in the selected supermarkets, where the RVM were located, to understand and evaluate the differences in the profile of users and non-users of the RVM, concerning the following variables: characterisation of the respondents, purchasing behaviour and destination of used packaging, system knowledge of the respondents, system evaluation and behavioural intention, and packaging return behaviour.

The social component was based, in general, on the responses given in the questionnaire, in the second campaign, although enhanced with information from the first campaign, which was used to evaluate the progress of the studied variables during the project.

Two groups were created depending on the response they gave to the question "Have you ever used these automatic packaging collection machines before?": a group of users of RVM (G1), and a group of non-users of RVM (G2). This approach was taken based on the conviction that a better understanding of what distinguishes these two groups will offer more informed support for political decisions on the optimal DRS operational conditions and the most suitable public communication strategies to encourage behaviour change and improve the use of the DRS.

2.3. Data processing

To understand the behaviour, knowledge, and perceptions of the consumers regarding the DRS pilot on the Portuguese mainland, a questionnaire was structured and presented to a sample of residents. In this case, 1,490 questionnaires were validated by the end of the campaign.

The data was processed using IBM SPSS statistics software. To assess whether the differences between the two aforementioned groups were

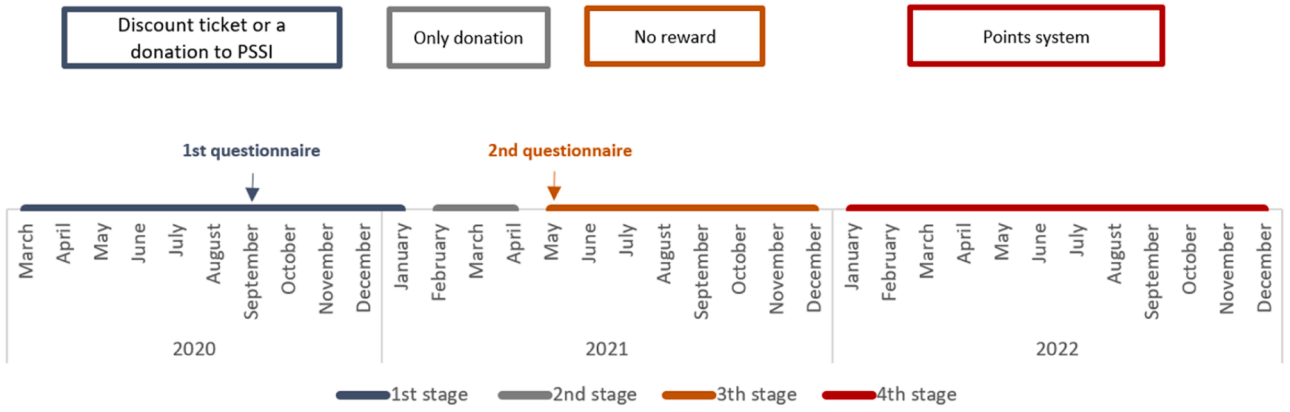

Fig. 1. Project timeline, with identification of the stages and application of the questionnaires.
PSSI - Private Social Solidarity Institution.

statistically significant, the ANOVA test was used for sample means, and the Chi-square test for sample frequencies. A value of $p \leq 0.05$ was considered the minimum acceptable level of significance for all statistical tests. Concerning the type of questions, the variables concerning the system evaluation and behavioural intention were measured using a Likert-type scale.

3. Results and discussion

3.1. Characterisation of the respondents

In the second questionnaire applied in the project (without incentives), around 43.8% corresponded to the group of RVM users (G1), and 56.2% to the group of non-users (G2). Most respondents were female (64.8%), the predominant age range was 35 to 44 years, and 38.3% had an academic degree. The differences between the groups were observable when considering their level of education, with the group of users having more individuals having studied up to middle and high school (G1 = 49.3% vs. G2 = 43.1%) and fewer having accessed higher education (G1 = 38.9% vs. G2 = 44.6%). Concerning this variable, the differences in the respondents' characterisation between the two groups are not statistically significant ($p > 0.05$).

The only exception was the analysis regarding professional activity, where the differences are statistically significant between the two groups (χ^2 (9) = 15.031; $p = 0.082$). The group of users, compared to the group of non-users, includes a large number of full-time employees (G1 = 59.9% vs. G2 = 51.2%), and a smaller number of retired people (G1 = 15.6% vs. G2 = 20.8%) and students (G1 = 6.2% vs. G2 = 7.6%).

3.2. Purchasing behaviour and destination of used packaging

The implementation of the packaging return system changed the behaviour of consumers, both in terms of the disposal of packaging in the waste bin and the municipal selective collection systems. From the group of users (G1), 71.0% referred to putting packaging in the RVM, as shown in Table 1. Therefore, it is expected that the extension of this system to other types of packaging (e.g., metal and glass) can change disposal behaviour for used packaging, which may increase participation rates and, consequently, the recycling rate and the quality of recycled materials.

Table 1
Disposal of beverage packaging after use.

Response categories	Respondents (%)			Statistical test
	G1 (users)	G2 (non-users)	Total	
Municipal recycling bin	25.3	**84.3**	**58.5**	χ^2 (4) = 863.431; $p < 0.001$
RVM	**71.0**	0.0	**31.0**	
Waste bin	3.2	14.4	9.5	
Others	0.2	1.1	0.7	
Don't know	0.3	0.2	0.3	

It is important to notice that the majority of non-users (G2) make use of municipal selective collection (84.3%). However, a higher percentage of non-users deposit recyclable materials in the waste bin (G1 = 3.2% vs. G2 = 14.4%). Concerning the answer "Don't know", it is interesting to verify low percentages in both groups, showing that people can have an awareness of their attitudes.

3.3. System knowledge of the respondents

The two groups differ significantly in their responses regarding their level of knowledge about the DRS for PET bottles, with particular emphasis in the case of users' group of RVM on communication in the establishment itself (G1 = 76.5% vs. G2 = 43.3%; χ^2 (9) = 337.537; $p < 0.001$). For the group of non-users of RVM, 38.1% first received information about the operation of the system from the interviewers undertaking the questionnaires. This is an important issue regarding the dissemination of knowledge about the new system. The findings of Oke and Kruijsen (2016), Roca et al. (2022), Roca i Puigvert et al. (2020) and Thøgersen (2003) outline how the information available to consumers affects their attitudes toward recycling. This result shows an opportunity for improving future packaging DRS to be implemented in Portugal, or other similar realities, namely that they should be accompanied by communication campaigns using other channels.

3.4. System evaluation and behavioural intention

The respondents' evaluations of the pilot project are an informative tool that can help to anticipate the acceptance of such a system, when generalised in the near future to more locations and for other packaging materials, in line with the Portuguese mandatory legal framework. Generally, respondents from both groups rated the studied RVM systems quite positively, with an average score value of 8.1, measured on a 10-point Likert-type scale, with being 1 the worst evaluation and 10 being the best evaluation. The differences between groups were statistically significant (G1 = 8.3 vs. G2 = 7.9; F (1,1465) = 70.062; $p < 0.001$). In particular, the group of non-users had a slightly lower evaluation, but this group has referred to a need to try the machine at least once to reach a more informed evaluation.

Comparing the scores attributed to the system within the second questionnaire to the responses in the first questionnaire, the value attributed generally decreased in both groups (G1 = 9.1 vs. G2 = 8.5 and 8.8 for the total of the sample) (F (1,1485) = 150.315; $p < 0.001$).

Responses concerning the change in the incentive, from the initial option of either discount vouchers on purchases or the possibility to donate, to the donation only option, which existed at the time of the second questionnaire, reveal the importance of the prize, or incentive, not only for encouraging participation but also for the evaluation of the system, as seen in other studies (Arriagada et al., 2022; Gneezy et al., 2011; Sun and Asari, 2023).

Regarding the advantages of the system, relative to the municipal systems of selective collection, the group of users more frequently cited the benefits of an economic incentive/refund (G1 = 39.9% vs. G2 = 34.1%; χ^2 (1) = 5.288; p = 0.021), followed by the guarantee of better quality recycling (G1 = 25.9% vs. G2 = 20.3%; χ^2 (1) = 6.583; p = 0,010). Users' group expressed less believe in the scheme's ability to increase participation in packaging separation (G1 = 24.4% vs. G2 = 28.1%; χ^2 (1) = 2.572; p = 0.109), but assigned greater value to its practicality than the group of non-users of RVM (G1 = 9.8% vs. G2 = 5.5%; χ^2 (1) = 9.645; p = 0.002). Roca et al., (2022) also mentioned the degree of inconvenience perceived by consumers as an important characteristic for a successful waste collection mechanism.

Most respondents from both groups did not identify any disadvantages (G1 = 60.5% vs. G2 = 51.8%; χ^2 (1) = 11.107; p = 0.001). However, of those that did, the factor most often mentioned was that this system is less practical than current methods (G1 = 32.3% vs. G2 = 39.1%; χ^2 (1) = 7.085; p = 0.008), the reference to this factor increased significantly in the second campaign, a trend that might be justified by the fact that there was no longer an economic incentive (values of the first campaign: G1 = 10.4% vs. G2 = 27.5%; χ^2 (2) = 73.866; $p < 0.001$).

The comments of the respondents revealed that in the future, transporting glass packages may represent a difficulty due to their greater weight, compared to plastics. It was also mentioned that the packaging labels of bottles are easily lost or degraded, whilst being essential for the system to recognise and accept the packaging. This reveals an opportunity for ecodesign, like more resistant labels on disposable packaging. Storing the packages, without crumpling them, was again identified as a difficulty for RVM, especially for those who live in apartments with a lack of space, when compared to other recycling destinations where undamaged packaging is not mandatory, such as recycling bins. The degree of inconvenience perceived by consumers when they need to modify their habits is important in facilitating the acceptance of a system (Roca et al., 2022; Roca i Puigvert et al., 2020).

In the study made by Roca et al., (2022), the importance given to financial incentives, such as cash for recyclables and prizes, could help to promote recycling behaviour and is the key to the success of DRS. Determining the optimal level of incentive is crucial, considering that the tax cannot be too high or low, and should provide sufficient extrinsic justification for behaviour change, as mentioned by Thøgersen (2003). Therefore, the respondent's perception of the reward was assessed. Concerning the value to be added to the packaging, most of the respondents considered that the refund value should be relatively low, up to 0.05 €. However, the group of non-users stated higher values, as shown in Table 2.

After depositing the packages in the machines, both groups show a preference for the discount ticket on purchases, as shown in Table 3. It is perceived that financial incentives, such as cash and prizes, can help promote recycling behaviour. It was the most referenced answer, but in the long term, these incentives could weaken the pro-environmental attitudes that motivate recycling (supported by Roca et al. 2022).

Table 2
Respondent's assessment of the ideal refund value for the future RVM packaging return system.

Response categories	Respondents (%)			Statistical test
	G1 (users)	G2 (non-users)	Total	
Up to 0.05 €	**49.9**	**39.9**	**44.2**	
Up to 0.10 €	**22.4**	**26.2**	**24.6**	
Up to 0.15 €	5.9	5.5	5.7	$\chi^2(5) = 17.413$; $p < 0.004$
Up to 0.20 €	4.7	6.2	5.6	
More than 0.20 €	7.3	8.1	7.7	
Other	9.8	14.1	12.2	

Table 3
Respondent's assessment of the ideal way to receive the refund value for the future packaging return system in the RVM.

Response categories	Respondents (%)			Statistical test
	G1 (users)	G2 (non-users)	Total	
A discount voucher for purchases	**55.1**	**41.8**	**47.7**	
Accumulate points on a loyalty card	**11.0**	**17.7**	**14.8**	
Cash	**9.3**	**18.0**	**14.3**	
To be able to donate this value to an institution (social)	**6.7**	**4.8**	**5.6**	
To be able to donate this money to a charity (animal)	3.0	2.2	2.5	$\chi^2(7) = 48.336$; $p < 0.001$
To be able to donate this money to an institution (environmental)	1.1	2.2	1.7	
To be able to donate this money to a charity (cultural)	0.0	0.1	0.1	
Another way	13.8	13.2	13.3	

Respondents commented on the possibility of the voucher issued for an in-store discount having the opportunity of being sent to the smartphone. This way, unnecessary paper consumption is reduced and there is no risk of the user losing it. The use of a smartphone can also promote the possibility of a gamification option. In addition, it would be an advantage to be able to use the discount voucher in other national commercial establishments, since the RVM accepts packages of national origins beyond those purchased at the establishment where the machine is installed. Only accepting national packages was mentioned as an issue because in the Portuguese case, there is an extensive land border with Spain of 1,319 km (INE, 2017). Recycling Spanish packaging could be problematic in terms of its acceptance in Portuguese RVM.

A voucher is an incentive to return the beverage packaging waste, thus contributing to a social cause, particularly with the option of reverting the value of the prize to a donation to a Private Social Solidarity Institution. However, there is the risk that recycling behaviour may become a reward-dependent activity for some, which cannot be guaranteed for all recyclable waste and therefore cannot be expected to become an accepted social norm.

In the study made by Roca et al. (2022) an important characteristic in evaluating a DRS was that the information that is made available to consumers significantly affects attitudes towards recycling, and consumers need information to comprehend the repercussions of their actions (Kirakozian, 2016). This was confirmed in the present study, being determined as the most important factor for the operation of the system mentioned by both groups (G1 = 43.2% vs. G2 = 43.9%). Other factors mentioned by the respondents were the location of RVM (G1 = 22.2% vs. G2 = 21.7%) and the deposit value (G1 = 20.8% vs. G2 = 19.5%; χ^2 (8) = 16.591; p = 0.035).

Overall, the respondents agree with the implementation of a DRS in Portugal for most beverage packaging: when considered a 5-point Likert-type scale, measured between 1 "strongly disagree" and 5 "strongly agree", the mean value was 4.07, with no statistically significant differences between the two groups ($F(1.1471) = 0.190$; $p = 0.663$).

Regarding the location of the machines, both groups show preferences for large shopping malls (G1 = 82.4% vs. G2 = 75.8%), particularly those who were already using the RVM (G1) (χ^2 (1) = 9.476; p = 0.002), and supermarkets closer to home (G1 = 47.2% vs. G2 = 39.4%), also seeming to be more convenient for present users (χ^2 (1) = 9.252; p = 0.002). However, non-users of RVM mentioned other alternatives such as "at the municipal market", "at the train station", and "at the gas

station", making the differences statistically significant between groups (χ^2 (1) = 9.648; p = 0.002).

3.5. Packaging return behaviour

Other questions were only directed to G1 (users of RVM), to study additional information regarding their packaging return behaviour. The implementation of the packaging return system changed the behaviour of this group: before the introduction of these machines, 85.6% already separated and placed recyclable bottles in selective collection (recycling bin or door-to-door system) and 12.5% placed them in the general waste. There has effectively been a transfer of habits (from the bin to the RVM) and there is a subgroup of the sample that has been motivated to use the new DRS. This change could relate to the economic incentive applied at the beginning of the project. However, these habits may not continue to be effective over time, as mentioned by Gneezy et al., (2011) and Sun and Asari (2023).

The main reasons given by respondents for joining this system were the concern for the environment/recycling (42.9%) and the economic incentive (34.7%), these being the most referred to categories in both campaigns. "Solidarity" was also mentioned, and the percentage increased from 3.8% in the first campaign to 14.5% in the second, possibly due to the change of stages of the project.

3.6. Analysis of the consumers' participation

To create a better understanding of the project's evolution and its social impact, the quantity of packaging collected per RVM each day was compiled monthly. The data demonstrates that the implementation of the economic instrument was successful in changing the behaviour (Fig. 2), even taking into account the slow growth in participation due to the initial dissemination of the project and the Covid-19 pandemic situation. Supporting the findings of other studies (Arriagada et al., 2022; Gneezy et al., 2011; Sun and Asari, 2023) it is possible to observe the decreased evolution in the long term. As mentioned by Lu and Wang (2022) the monetary incentive is the most effective incentive affecting people's recycling behaviour and attracting more participants to recycling programs. However, participation in packaging delivery decreases with the change of incentive: the lowest levels of packaging delivery were observed when there was no incentive, only returning to slightly higher levels with the reintroduction of the incentive, in this case accumulating points to exchange for prizes.

4. Conclusion

The DRS is an innovative approach in Portugal, aiming to increase the quantity and quality of packaging waste collected for recycling. In this context, the potential expansion to other packaging materials, besides PET packaging, will improve the likelihood of meeting the recycling targets, but will also promote circularity by incorporating recycled materials into new packaging.

The implementation of a DRS system in Portugal entails costs associated with system expansion. This is particularly relevant for the investment in RVM infrastructure and maintenance, as well as collection operations to ensure efficient logistics to prevent delays in bag collection from commercial establishments by management entities. However, the results obtained from the social component of the project returned positive results, indicating strong public support for the future extension of the DRS to various packaging materials (i.e., plastic, glass, ferrous metals, and aluminium), and across the entire national territory. The pilot project served as an opportunity to promote packaging recycling behaviour and establish habits that would persist even when the system transitions into a deposit and refund scheme.

Moreover, the economic instrument employed was effective in changing behaviour, especially when combined with strategies like environmental education, targeted towards individuals who exhibit less positive attitudes towards recycling. The economic incentive proved to be sufficient, while effective communication and strategic placement of the machines were identified as the main important factors. The refund aspect can encourage consumer participation and boost recycling rates. However, uncertainties arise when the future system operates as a real DRS without offering additional rewards. This was observed during some of the project's stages, where a number of users abandoned packaging (without citing acceptance condition issues) before returning it to the RVM. This happened mainly due to machine downtime/maintenance or even because of the high turnout at the only RVM on the site, raising questions regarding the added benefits of the system. The dependency on vouchers as an incentive to return beverage packaging waste may result in recycling behaviour that is dependent on rewards.

Implementing this system may lead to a transfer of behaviour from traditional collection methods to the RVM, rather than increased participation rates for selective deposition. In general, negative

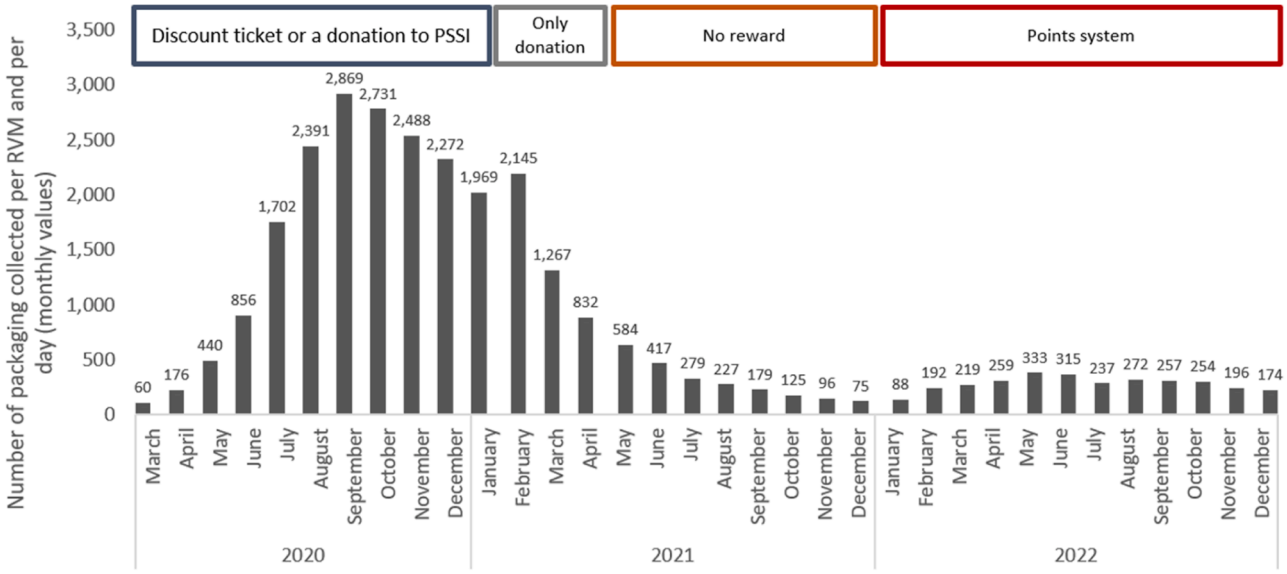

Fig. 2. Evolution of the number of packaging collected per RVM and per day (monthly values)
PSSI - Private Social Solidarity Institution.

experiences with urban waste collection services may also influence public perception of the DRS. The location of RVM poses risks, limiting accessibility for certain populations, such as those residing in rural areas. In addition, frequent or prolonged maintenance periods could negatively impact system usage and adherence.

Future developments should consider technological advancements in the machines to improve user behaviour, especially regarding accommodating bottles with larger capacities and handling higher volumes of packages within shorter time frames. Specific communication campaigns targeting relevant channels for RVM usage should be prioritised for effective implementation.

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CRediT authorship contribution statement

Graça Martinho: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Ana Alves:** Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Project administration. **Pedro Santos:** Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Project administration. **Mário Ramos:** Validation, Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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