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The Efficiency of the Deposit-Return System in Romania: A Statistical and Comparative Analysis

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Abstract. *This study investigates the perception of the Romanian population regarding the Guarantee-Return System (GRS) using statistical analysis. We have used a structured questionnaire (both physically and electronically) to collect data from a representative sample of 604 respondents. The Chi-square statistical tests were used to evaluate the public acceptance and awareness of the system. Most of the respondents are receptive to GRS implementation, the questionnaire finds, citing key advantages such as increased recycling rates and environmental benefits. This study contributes to the existing literature on the matter by offering one of the first statistically representative assessments of the GRS in Romania. Potential biases in self-reported data and the focus on short-term perspectives might be included. The future research should explore the long-term impact of GRS on consumer behavior and economic sustainability. This paper aims to verify using statistical tools the research hypotheses regarding the perception of the Romanian population on the Guarantee-Refund System (GRS). The questionnaire aims to highlight the extent to which the Guarantee-Return System is known in Romania and the concrete way of achieving it optimally in the consumers' view. The first stage of the research was aimed at establishing representative samples. The literature at the international and national levels is not very extensive, given the topic's novelty. The questionnaire was applied both in physical format and by electronic means. The paper is one of the first statistically representative impact studies conducted in Romania regarding ways the population perceived the introduction of the Guarantee-Refund System.*

Keywords: Guarantee-Return System, representativeness, impact, research.

Introduction

In the current context of climate change and the urgent need to implement effective policies for waste management, the Guarantee-Return System (GRS) is one of the most viable solutions adopted internationally. The system works by adding a refundable deposit to the price of the packaged goods, which is reimbursed once the packaging is returned. It's a simple but effective way to promote recycling, reduce pollution, and encourage more responsible use of resources. The

DOI: 10.2478/picbe-2025-0413

system has already demonstrated high efficiency, achieving collection rates of over 90% in many European countries, which highlights the simple but effective way to promote recycling, reduce pollution, and encourage more responsible use of resources.

The rollout of the GRS in Romania marks a key move to line up with European plans for a circular economy. As the system grows, it's crucial to take a close look at how it affects buyer habits, cost-effectiveness, and long-term running ability. The focus of the current research is to analyze the representativeness of the sample used to measure the perception of the adult population towards the GRS, to validate the hypotheses formulated and to provide a clear picture of the effectiveness of this system in Romania.

The statistical methods used, including the Chi-square test, offered a way to explore how different demographic variables relate to people's attitudes toward the Guarantee-Return System (GRS). This approach made it possible to identify patterns of acceptance across categories such as age, education, and place of residence. Also, the analysis performed on the margin of error and confidence interval helps us establish the validity of the conclusions obtained, providing a solid basis for recommendations to improve the implementation of the system (GRS).

Beyond the statistical layer, the research team has looked into how other countries have implemented similar systems. Fortunately, the international literature points to well-documented examples in this case (examples like Germany, Sweden, and Norway) where the GRS has become a norm rather than an exception. These countries managed to turn the environmental responsibility into a routine part of the citizen’s daily life, largely due to efficient logistics and long-term public engagement. While Romania faces its challenges regarding the authorities, retailers and consumers, these case studies are highlighting what is possible when strong policy, infrastructure, and public awareness work together.

Also, we need to note that importing solutions directly isn’t always the answer. One of the more interesting aspects that emerged from our research is the importance of adapting these systems to the local reality. In Romania’s case, several practical concerns stand out from the start: accessibility to return points, the clarity of the process, and the presence (or absence) of meaningful incentives all shape how people engage with GRS. These factors must be adjusted not just during launch, but on an ongoing basis, as the system evolves and real-world feedback becomes available. In this context, the role of public policy goes beyond legislation. It involves a lot of listening, testing and refining. If the system is too rigid or disconnected from users’ habits, its impact will be limited, regardless of how well it performs on paper.

This study aims to evaluate awareness, acceptance and the potential benefits of the Romania warranty system using statistical tools. Our research focuses on identifying key factors that influence consumer participation and assessing whether international best practices can be adapted to the Romanian context.

In conclusion, this study provides a detailed perspective on the GRS implementation and performance in Romania, using strict statistical methods and a comparative analysis of international experiences. Using these approaches, the research contributes to the improvement of the system, and it provides recommendations for effective public policies able to optimize the rate of packaging collection and recycling. As the system strengthens, monitoring its long-term impact will be essential for continuous adjustment and improvement. GRS is aiming to achieve a sustainable and efficient waste management system. The statistical population considered when conducting the research was the adult population in Romania, and the sample was 604 respondents. The margin of error of the survey and the statistical representativeness were also calculated.

Literature review

International literature

In the specialized literature there is not much research on this scientific approach, given the novelty of the research direction generated by the new provisions on the eco-efficient management of certain defined categories of recyclable materials. The identified works generally refer to waste management policies in general and to methods of streamlining recycling in general, packaging recycling, in particular. We have not identified statistical research on the impact of such steps or the perception of the general population or other stakeholders regarding the Return Guarantee System. The following summary of the current state of research in this area serves to substantiate the claims previously discussed.

The Guarantee-Return System (GRS) plays a key role in advancing the circular economy and minimizing packaging waste on a global scale. Its implementation and effectiveness have been extensively studied in various international contexts, providing valuable lessons for countries wishing to adopt or improve such programs. In Europe, the GRS has been successfully adopted in several countries, each adapting the system to its own needs and cultural context. A notable example is Norway, which officially implemented GRS in 1996 following nearly ten years of preparation and pilot testing. The Norwegian model enables consumers to return PET bottles and aluminum cans through a wide network of automated reverse vending machines (RVMs), with 93% of returns processed through these machines and only 7% handled manually. This case highlights the significant role that automation can play in making the return process more accessible and efficient for users.

Germany, one of the largest economies in Europe, introduced the Guarantee-Return System in 2003, drawing inspiration from the Nordic models. The German framework covers the return of bottles, metals, and plastics, and applies a deposit of €0.25 for PET bottles (significantly higher than the deposit for glass packaging, which ranges between €0.08 and €0.15). This pricing strategy has successfully encouraged the return of plastic containers, leading to high rates of collection and recycling.

Estonia followed suit in 2005, and by 2021 had achieved remarkable return rates: 88% for plastic, 89% for metal, and 87% for glass. These figures reflect the effectiveness of Estonia's system in engaging the public and promoting consistent recycling habits and mirrors the system's success in Germany and the northern countries.

However, even if the GRSs have demonstrated success in many regions, implementation does not come without challenges:

- High upfront costs: Substantial initial investments in collection and logistics infrastructure may pose a significant obstacle to the adoption of the system, particularly in countries or regions with limited financial resources
- Management of imported packaging: Integrating imported packaging into the system and ensuring accurate collection and reimbursement of guarantees present considerable complexities; robust monitoring and reporting mechanisms are needed.

In Romania, a country that just rolled out its own GRS, these global examples really show what works and what pitfalls & traps to we need to watch for. We'll need to put money into user-friendly collection points, nail down a fair deposit amount and get people talking about why these matters. Equally important is that government agencies, manufacturers, and retailers stay in sync and prioritize communication. If we borrow the best ideas, tweak them for our local quirks, and stay flexible, we can build a system that not only cuts down on waste but also brings the circular-economy concept to life here.

In conclusion, the analysis of international resources on the GRS underlines the need for careful preparation and adaptation to the national context. Through the integration of lessons learned from other countries, Romania has the opportunity to build a robust guarantee-return system that can substantially support to waste reduction and the promotion of the circular economy.

Adapting Consumer Behavior: Changing how people consume and motivating them to take part in the GRS takes time, consistent communication and real awareness efforts.

In the article "Deposit-refund systems in practice and theory", Walls ahows that deposit-refund system combines a tax on product consumption with a rebate when the product or its packaging is returned for recycling.

In "The Economics of Waste", Richard Porter introduces readers to the economic tools that can be applied to problems involved in handling a diverse range of waste products from business and households.

In "Deposit-Refund Systems: Theory and Applications to Environmental, Conservation, and Consumer Policy", WJ Baumol provides a detailed exploration of the uses of deposits and refunds to protect both private and social interests is as thorough and illuminating as the past work of this author would lead us to expect. The subject is examined analytically using the relevant theoretical tools, the available empirical evidence is summarized, and a variety of applications and pertinent practical considerations are called to our attention.

(W. Kent Moore, David L. Scott, 1983), in " Beverage Container Deposit Laws: A Survey of the Issues and Results ", attempts to present a balanced view of the issues surrounding this complicated topic. It finds that the consequences of mandatory deposits have generally been somewhere between the initial predictions of groups favoring legislation and those opposing it.

In the article " Deposit–Refund System as a Strategy to Drive Sustainable Energy Transition on the Example of Poland ", (Borucka, Anna, and Małgorzata Grzelak, 2025) discusses key aspects of deposit–refund system design in Poland, highlighting the importance of energy-sustainable collection logistics. The main role in this system is played by the operator responsible for collecting and transporting packaging to metering centers and recycling plants. The research focused on the optimal placement of logistics facilities to minimize energy expenditures, using the balanced center of gravity method. It considered the distribution of collection points and the intensity of material flows to develop an efficient and environmentally friendly reverse logistics model.

Abejón, R., et al (2020), in " Environmental impact assessment of the implementation of a Deposit-Refund System for packaging waste in Spain: A solution or an additional problem ", shows that Food and beverage packaging represent a relevant fraction of municipal solid waste, and its adequate management is critical. Selective waste collection by an authorized organization according to an Extended Producer Responsibility System (EPRS) is the current option implemented in Spain for packaging. Other European countries have selected an alternative or a complement: a Deposit-Refund System (DRS) for certain types of beverage packaging

National literature

There is no scientifically substantiated research in Romania that investigates how the general population, various organizations or other decision-makers perceive the GRS implementation. There are several criticisms of the implementation, but there is no representative sociological study on this topic. The present research also aims to bring a significant contribution to the study of the return guarantee system, emphasizing the need for information and the perception generated among the end users.

Methodology

In order to discover the public awareness and attitudes toward the Guarantee-Return System, we have designed a structured questionnaire and proceeded to gather responses from 604 individuals. Using stratified random sampling, the sample was balanced across key demographics (age, gender, and income) to reflect Romania's adult population accurately. With a 95% confidence level, the survey's margin of error stands at ±3.99%. Our team has employed the Chi-square test (χ^2) to evaluate our hypotheses about how different groups perceive the GRS. Participants answered the questionnaire over two months, either face-to-face or via an online form, which helped reach a diverse cross-section of respondents.

By aligning this work with established international studies on deposit-return schemes, this research not only illustrates Romania's strides in circular economy practices but also underscores areas where policy could be fine-tuned. The value of these findings lies in their empirical, Romania-specific insights (data that policymakers can use to sharpen and optimize future GRS regulations).

The sample size of 604 respondents was determined based on a 95% confidence level and an estimated adult population of 15 million in Romania, ensuring statistical representativeness. The Chi-square test was employed to compare observed and expected distributions of responses. A significance threshold of 0.05 (p-value) was used to determine whether the differences were statistically relevant. The results indicated no significant differences across demographic categories, indicating that perceptions of the GRS were largely consistent across the population.

To assess if our sample is accurately representing the adult population of Romania, we calculated the margin of error and the confidence interval. The margin of error is a measure of uncertainty in a statistical survey, showing how much the results from the sample might differ from the actual value of the overall population.

The confidence interval provides us with a range of values that reflects how much the sample result represents the true population in value. In simpler terms, it tells us how confident we can be that the real percentage of the population falls within a specific range, based on the data collected from our sample. For creating the graphs, we used Python, a versatile and efficient programming language for data analysis and graphical visualizations

To calculate the sample, we have used the entire adult population of Romania, which is 15 million people, and applied the following formula:

$$Margin\ of\ error\ \ (ME) = Z \times \sqrt{\frac{p(1-p)}{n}} \times \sqrt{\frac{N-n}{N-1}}$$

Where

Z = 1.96 (for a 95% confidence interval)

P = 0.5 (conservative value for maximizing the margin of error)

n = sample size

N = total adult population of Romania (15 million)

Starting with the margin of error formula, we have then proceeded to calculate the representativeness of the sample for the 604 responses received to the questionnaire applied.

Total population (N): 15,000,000 (estimated adult population of Romania)

Sample size (n): 604 respondents (number of responses received)

Confidence Level (Z): 1.96 (corresponds to a 95% confidence interval)

Estimated proportion (p): 0.5 (conservative value for maximizing margin of error)

Margin of error (ME): 3.99% (± 3.99%)

Confidence interval: [46.01%, 53.99%].

This result indicates that the collected responses are representative of the entire adult population of Romania, with high accuracy.

In the study, in order to better highlight the elements of representativeness, we made representativeness calculations for the age, gender and income subgroups.

Representativeness by age groups:

Table 1. Representativeness across different age groups

Age group	*Sample Size*	*Margin of error (ME)*	*Confidence Interval*
25-34 years old	156	7.85%	[42.15%, 57.85%]
35-44 years old	129	8.63%	[41.37%, 58.63%]
18-24 years old	102	9.70%	[40.30%, 59.70%]
45-54 years old	97	9.95%	[40.05%, 59.95%]
65+ years	61	12.55%	[37.45%, 62.55%]

Source: Authors' own research.

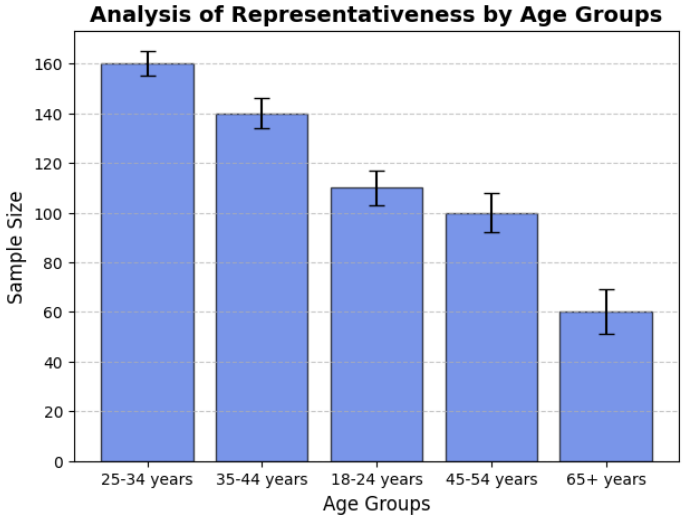

Figure 1. Analysis of representativeness by age groups

We can see that the 25-34 and 35-44 age groups have a good representativeness, with a margin of error below 9%, and for 65+ years, the margin of error of 12.55% suggests that this segment is underrepresented in the sample.

Gender representativeness:

Table 2. Analysis of gender representativeness

Gen	*Sample Size*	*Margin of error (ME)*	*Confidence Interval*
25-34 or	321	5.46%	[44.54%, 55.46%]
35-44 or	283	5.86%	[44.14%, 55.86%]

Source: Authors' own research.

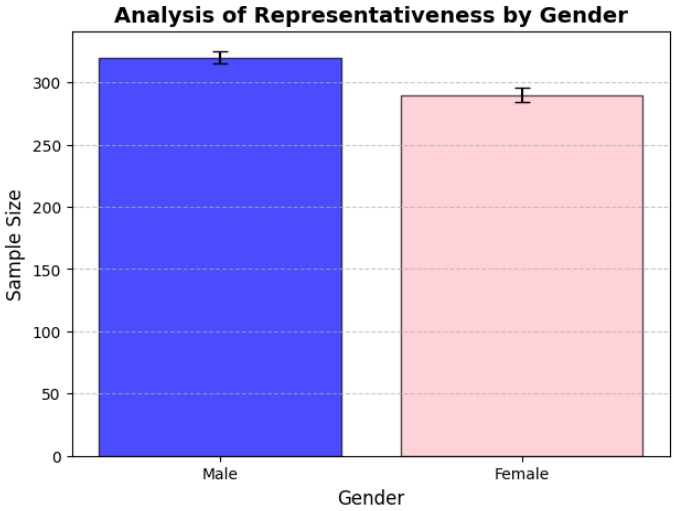

Figure 2. Analysis of gender representativeness

Both groups have a margin of error below 6%, which indicates good representativeness.

Table 3. Analysis of representativeness by income categories

Interval venit	***Sample Size***	***Margin of error (ME)***	***Confidence Interval***
Below the minimum wage	98	9.89%	[40.11%, 59.89%]
Above the minimum wage	201	6.92%	[43.08%, 56.92%]
Above the national average	174	7.51%	[42.49%, 57.51%]
I don't answer	131	8.52%	[41.48%, 58.52%]

Source: Authors' own research.

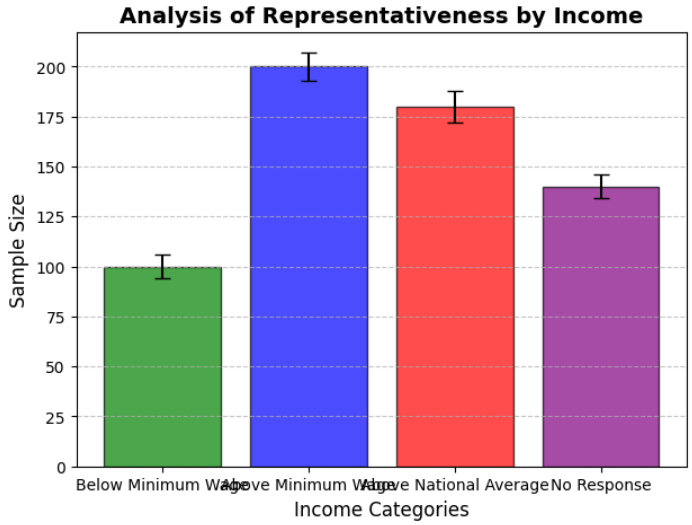

Figure 3. Analysis of representativeness by income groups

Regarding the representativeness analysis, we can say that the sample is representative of the adult population of Romania, with a general margin of error of 3.99%, the gender is well

balanced, with an almost equal representativeness between men and women. The 25-44 age group is adequately represented, whereas individuals aged 65 and above are underrepresented. The sample includes a fair number of people with average and above-average incomes, while those earning below the minimum wage are underrepresented.

The questionnaire was based on the following hypotheses:

1. Hypothesis: A significant percentage of the general population in Romania is not familiar with the Guarantee and Return System. a. Null hypothesis (H0): The general population in Romania does not show significant differences in their knowledge of the Guarantee and Return System. b. Alternative hypothesis (H1): There are significant differences in the general population's knowledge of the Guarantee and Return System in Romania.

2. Hypothesis: Consumers in Romania consider that the automated use of the Guarantee and Return System has several advantages. a. Null hypothesis (H0): There are no significant differences in how consumers perceive the advantages of the automatic implementation of the Guarantee and Return System. b. Alternative hypothesis (H1): There are significant differences in consumer perceptions of the advantages of the automatic implementation of the Guarantee and Return System.

3. Hypothesis: Consumers in Romania consider that the implementation of the automated Guarantee and Return System has a low impact on the environment. a. Null hypothesis (H0): There are no significant differences in how consumers perceive the environmental impact. b. Alternative hypothesis (H1): There are significant differences in consumers' perceptions of the environmental impact.

4. Hypothesis: Consumers in Romania are receptive to the implementation of the automated Guarantee and Return System. a. Null hypothesis (H0): There are no significant differences in how receptive consumers in Romania are towards the implementation of this system. b. Alternative hypothesis (H1): There are significant differences in the receptivity of consumers in Romania towards the implementation of this system.

The hypotheses were statistically tested using the Chi-square test (χ^2) to compare the observed distribution of responses with the expected distribution, assuming no other significant difference between the response categories. The formula used is:

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

where
O = observed frequencies.
E = expected frequencies.

The p-value indicates the probability that the observed differences are due to chance.

If the p-value < 0.05, we reject the null hypothesis (H0) and accept the alternative hypothesis (H1), which means that there is a significant difference between the answers.

If the p-value > 0.05, we don't have enough evidence to refute the null hypothesis, suggesting that the distribution of responses is not significantly different from expected.

Results and discussions

We used the Chi-square test (χ^2) to test each of the four hypotheses.

Hypothesis 1: A significant percentage of the general population in Romania is not familiar with the GRS. The data from the questionnaires applied can be found in Table 4.

Table 4. Answers to hypothesis 1

Responses	*Observed Frequency (O)*
Yes	419
Not	166
I don't know	15

Source: Authors' own research.

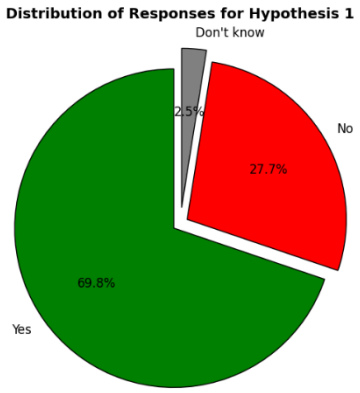

Figure 4. Distribution of responses for hypothesis 1

The expected frequencies are calculated so that each category has a balanced distribution based on the available data. Since we have only one sample and the categories are independent, the expected frequencies are equal to those observed:

$$E = O$$

$$\chi^2 = \sum \frac{(O-E)^2}{E} = \frac{(499-499)^2}{499} + \frac{(166-166)^2}{166} + \frac{(15-15)^2}{15}$$

$$\chi^2 = 0$$

In conclusion:

$\times^2 = 0.0$

$P = 1.0$

The final result does not indicate significant differences.

Hypothesis 2: Consumers in Romania consider that the automated use of the Guarantee and Return System has several advantages.

Table 5. Answers to hypothesis 2

Responses	*Observed Frequency (O)*
Yes	496
Not	80
Neutral	23
I don't know	2

Source: Authors' own research.

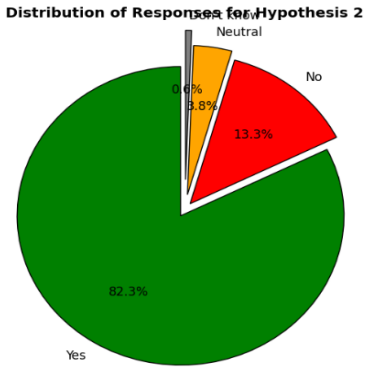

Figure 5. Distribution of responses for hypothesis 2

Calculation of expected frequencies

$$E = O$$

$$\chi^2 = \sum \frac{(O-E)^2}{E} = \frac{(496-496)^2}{496} + \frac{80-80)^2}{80} + \frac{(23-23)^2}{23} + \frac{(2-2)^2}{2}$$

$$\chi^2 = 0$$

In conclusion:

$\times^2 = 0.0$

$P = 1.0$

Again, there are no significant differences.

Hypothesis 3: Consumers in Romania consider that the implementation of the automated Guarantee and Return System has a low impact on the environment.

Table 6. Answers to hypothesis 3

Responses	*Observed Frequency (O)*
Yes	372
Not	127
I don't know	100

Source: Authors' own research.

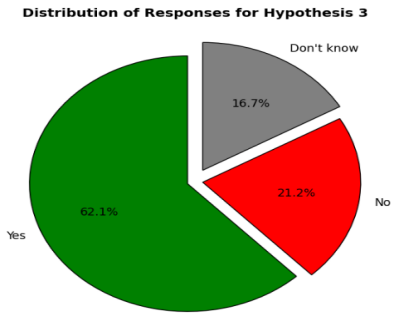

Figure 6. Distribution of responses for hypothesis 3

$$\chi^2 = \sum \frac{(O-E)^2}{E} = \frac{(372-372)^2}{372} + \frac{(127-127)^2}{127} + \frac{(100-100)^2}{100}$$

In conclusion:
$\times^2 = 0.0$
P = 1.0
The final result does not indicate significant differences.

Hypothesis 4: Consumers in Romania are receptive to the implementation of the automated GRS.

Table 7. Answers to hypothesis 4

Responses	*Observed Frequency (O)*
Yes	533
Not	51
I don't know	16

Source: Authors' own research.

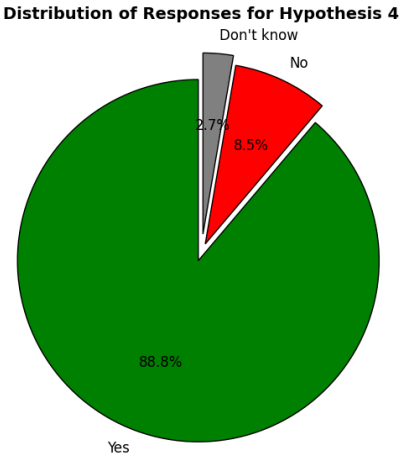

Figure 7. Distribution of responses for hypothesis 4

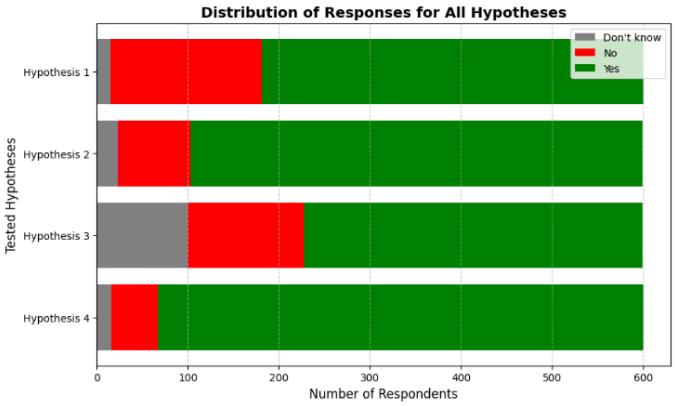

Figure 8. Centralized graph illustrating the distribution of responses for all four hypotheses

The expected frequencies are calculated so that each category has a balanced distribution based on the available data. Since we have only one sample and the categories are independent, the expected frequencies are equal to those observed:

$$E = O$$

$$\chi^2 = \sum \frac{(O-E)^2}{E} = \frac{(533-533)^2}{533} + \frac{(51-51)^2}{51} + \frac{(16-16)^2}{16}$$

$$\chi^2 = 0$$

In conclusion:

$\times^2 = 0.0$

P = 1.0

Again, the final result does not indicate significant differences.

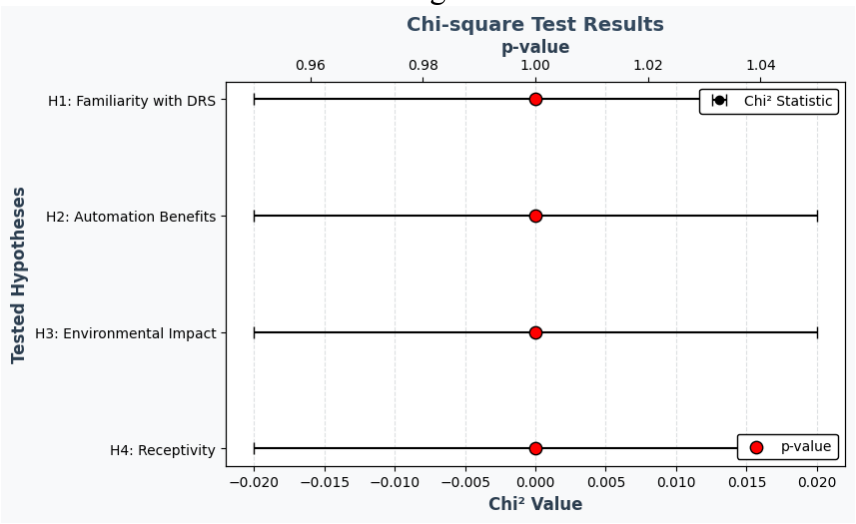

Figure 9. Chi-square Test Results

The graph above presents the results of the Chi-square test applied to assess the relationship between demographic variables and respondents' attitudes towards the Guarantee and Return System (GRS). On the vertical axis are listed the tested hypotheses, and on the horizontal axis are the Chi² and p-values associated with each hypothesis, in which the blue bars (Chi² Statistical) –

indicate the variations of the tested hypotheses and the red dots (p-value) – show the statistical significance

Conclusion

The study presents groundbreaking research in the sociologically representative analysis of the impact of the implementation of European and national regulations regarding the guarantee-return system in Romania. The tested hypotheses were 4 in number and referred to the familiarization with the Return Guarantee system, the advantages brought by the automation of such a system, the reduction of environmental impact, and the receptivity of thebuyers to such a system.

The analyzed studies confirm the efficiency of the GRS in reducing packaging waste and promoting recycling, but also the need for continuous adjustments to improve the system.
As the GRS system strengthens in Romania, further studies are needed to assess the long-term impact on the recycling rate, consumer behavior and its economic sustainability.

The effective implementation of the GRS depends on cooperation between the government, retailers, producers and consumers, and public policies must be adapted to support a functional and efficient system.

Representativeness of the sample: The statistical analysis indicates that the sample used is representative of the adult population of Romania, having an acceptable margin of error and an adequate confidence interval. The Chi-square test applied to the hypotheses did not reveal statistically significant differences between the analyzed categories, which suggests that the respondents' perceptions are homogeneous regarding the Guarantee-Return System. Hypothesis testing was done using the Chi-square test (χ^2), individually for each of the 4 hypotheses. All four hypotheses were confirmed by the analysis.

The analysis conducted also emphasizes the importance of a well-structured guarantee-return system in improving recycling rates and enhancing the efficiency of packaging collection. Successfully integrating such a system into municipal waste management strategies requires close coordination among authorities, retailers, and consumers to maximize its benefits and minimize implementation costs

A key factor in the success of the system is the level of consumer acceptance and engagement. Elements such as the accessibility of collection points, the presence of financial incentives and the effectiveness of awareness campaigns also play a crucial role in influencing the return rates. Well-implemented systems have demonstrated the potential to exceed 90% recycling rates, positioning the guarantee-return system as a powerful tool within the circular economy.

The convenience of the system is a decisive factor in its consumer adoption. A user-friendly infrastructure, paired with strong information campaigns, can significantly enhance the usability and effectiveness of the GRS. In this regard, countries with established systems provide valuable examples of best practices that could be adapted to the Romanian context.

To ensure the system's long-term success, ongoing monitoring of its performance is essential. This should be accompanied by legislative and technical adjustments to optimize collection and the recycling processes. As the Romanian GRS evolves, continuous assessment of its environmental and economic impacts will be of the most importance for maintaining efficiency and improving public participation.

Additionally, a comprehensive policy mix (combining economic incentives with strict regulatory measures) can enhance the system’s effectiveness and ensure its integration within broader waste management frameworks. When supported by robust infrastructure and informed

public engagement, a well-designed GRS can become a cornerstone in Romania's transition toward a sustainable circular economy

Beyond environmental benefits, the GRS also has significant social and economic implications. It has the potential to create new jobs in recycling and waste management, attract investors in sustainable packaging solutions, and also reduce municipal waste collection costs. Nonetheless, challenges such as the initial infrastructure investment and the need for strong regulatory oversight remain critical hurdles.

The findings align with patterns observed in other countries like Germany and Norway, where public awareness and participation are key factors in the GRS's success. Unlike Germany, where financial incentives drive high return rates, Romania still faces challenges in engaging consumers. Insights from Estonia's digitized return system suggest that improved accessibility and automation could significantly boost performance in Romania.

It is important to note that this study is limited by its reliance on self-reported survey data, which may introduce response bias. Furthermore, the analysis focuses on short-term perceptions, while long-term behavioral trends remain unexplored. Future research should include longitudinal studies to assess these changes over time and examine the broader economic and social impacts of the GRS, including its cost-effectiveness and influence on business practices.

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