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Research article

Consumer preferences regarding product acquisition, repair, and discharge towards a circular economy: A segment-specific market simulation based on conjoint analysis

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ABSTRACT

Consumer preferences for a circular economy are known to be heterogeneous; however, most existing studies focus exclusively on the product acquisition phase and assume homogeneous utilities. This study aims to understand consumer segments for circular business models in terms of consumer preferences and market shares, and to investigate the commonalities across the three phases of consumer engagement in the circular economy: acquisition, repair, and discharge. We combined choice-based conjoint analysis, ensemble clustering, and market simulation, and applied them to three typical products (refrigerators, laptops, and children's goods) in the Japanese market. The analysis revealed the consistent existence of key consumer segments across the three phases. First, circular-oriented segments (12–33 % of the population, depending on the phase and product category) show a high willingness to adopt circular business models (e.g., 67–100 % within-segment share), making them a promising entry point for target-based marketing. Second, price-sensitive segments (13–30 %) could play a pivotal role in mainstreaming circular business models, highlighting the need for substantial price reductions of circular offers relative to linear offers. Third, balanced decision-makers (19–38 %), who tend to resist traditional circular options (e.g., reuse), are open to new circular business models (e.g., refurbish, subscription, functional upgrading, sharing), indicating the importance of designing attractive product service offers. Finally, linear-insistent segments (24–51 %) almost never choose circular products and repair options (e.g., 0–2 % segment-wise share). This results in a persistently high total market share of linear options, even under ambitious scenarios; e.g., 44–57 % of acquisitions are brand-new, and 51 % of broken products remain unrepaired. Although linear-insistent behaviour in any of these phases may act as a bottleneck, overlapping membership among consumer segments suggests the potential for positive spillover across phases. This study's approach enables more nuanced consumer segmentation, facilitating the identification of diffusion stages, the design of appealing product services, and the development of target-wise marketing strategies towards the circular economy.

1. Introduction

The transition to a circular economy requires behavioural changes by consumers that align with supply-side efforts (Sutherland et al., 2020). According to a systematic review by Camacho-Otero et al. (2018) and a survey of policymakers and businesses by Kirchherr et al. (2018), lack of consumer acceptance, the absence of consumer interest, and inadequate consumer awareness are the most significant barriers to a circular economy. A recent review identified as many as 100 "Rs" beyond reduce, reuse, and recycle, many of which are related to social attitudes, behaviours, and patterns of product use (Zorpas, 2024). This means that regardless of progressive efforts by product suppliers, attracting

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consumers to circular options is a precondition for successful transition to a circular economy. In response to this issue, the European Union's new Circular Economy Action Plan aims to empower consumers to choose circular options that are affordable, durable, repairable, and supported by trustworthy information, while promoting a shift towards circular business models (European Commission, 2020).

Addressing all phases of consumer engagement in the product life cycle is crucial to facilitating the transition to a circular economy (Sandez et al., 2023; Shevchenko et al., 2023). Specifically, a circular economy requires consumer engagement across three key phases in product lifetimes: i) acquiring products and services, ii) repair and maintenance to retain the value of products, and iii) discharge of end-of-use products by choosing a destination (Koide et al., 2023b; Shevchenko et al., 2023; Shi et al., 2022). Although the traditional focus of marketing studies has been on the purchase of brand-new products, the transition to a circular economy calls for an investigation of used product alternatives and after-purchase services (Rejeb et al., 2022). Circular business models seek to use the economic value of products remaining after their main use, which includes both retaining ownership of the product and product-service systems that focus on accessing the product (Linder and Williander, 2017). These three phases must be harmonised for a successful circular business model. For instance, both the demand for refurbished products and the availability of products collected for refurbishment are necessary for the diffusion of refurbishment, whereas consumer heterogeneity in these three phases plays a key role in shaping diffusion patterns (Koide et al., 2023b).

Understanding consumer preferences for circular business models is necessary across these three consumer engagement phases. Due to its ability to quantify consumer preferences, conjoint analysis is a promising tool to support the design of new products, calibrate price sensitivity, and estimate demand, rooted in the long history of marketing and consumer research (Agarwal et al., 2015). In contrast to other survey methods that directly ask about attitudes and intentions, conjoint analysis has the ability to explicitly quantify the trade-off between price and other product service attributes. The application of conjoint analysis in a circular economy has been on the rise but is mostly limited to the acquisition phase of a product. For example, conjoint studies dealing with the electronic goods and toys (Aydin and Mansour, 2023; Eskilsson, 2023; Hunka et al., 2021; Kwarteng et al., 2018; Wallner et al., 2022), sporting goods and jewellery (Chang et al., 2022; Fuchs and Hovemann, 2022), home appliances (Koide et al., 2023a; Lieder et al., 2018) and bicycles and clothing (Cocquyt et al., 2020; Tunn et al., 2021) have identified important product attributes determining consumer preferences for circular business models in the acquisition phase, such as price, year of manufacture, warranty, appearance, and functional degradation. However, empirical studies on the repair and discharge choices remain limited. Consumer surveys focusing on attitudes and intentions towards repair (Bovea et al., 2017; Fachbach et al., 2022; Pérez-Belis et al., 2017; Sandez et al., 2023) have underlined the key barriers to repair, such as cost and convenience. To date, only one conjoint study has been conducted on this topic, focusing on willingness to pay (Güsser-Fachbach et al., 2023). Studies on discharge behaviours for e-waste collection for recycling (Wang et al., 2023; Zhang et al., 2019) have highlighted the importance of cost, convenience, trust, and treatment methods; however, other disposal behaviours such as reselling products for reuse, or hibernation, i.e. temporarily storing the product in the home, have not been considered. Furthermore, all of these studies focused solely on a particular consumer engagement phase, and no comprehensive study has examined the commonalities among these phases.

Consumer preferences for a circular economy are heterogeneous (Cao et al., 2022; Ferraro et al., 2016; Guiot and Roux, 2010; Mugge et al., 2017). A widely accepted approach to understanding this heterogeneity is market segmentation, which refers to dividing the market into subsets that are internally homogeneous but heterogeneous from one another. Specifically, preference-based segmentation identifies market segments based on conjoint analysis results (Djokic et al., 2013). While heterogeneity in consumer preference has been intensively studied in marketing research through individual- and segment-based conjoint methods (Agarwal et al., 2015), the majority of existing studies dealing with a circular economy assume the homogeneity of utilities. Although a limited number of conjoint studies on product acquisition have employed consumer segmentation (Boyer et al., 2021; Chang et al., 2022; Koide et al., 2023a; Wallner et al., 2022), other consumer engagement phases, i.e. repair and discharge, have not been considered. Furthermore, the results of conjoint analysis can be used to estimate the potential market share (Orme, 2020), which can also be specific to each segment. Although several studies have estimated the market share of circular business models (Aydin and Mansour, 2023; Hunka et al., 2021; Koide et al., 2023a; Wang et al., 2023; Zhang et al., 2019), most have focused on the aggregate market share in the product acquisition phase and have failed to consider segment-specific market share across multiple phases of consumer engagement.

As consumer preferences can be specific to particular products, investigating the commonalities among multiple product categories provides more robust insights. In considering the product lifetime, there are three types of consumer durables: 'workhorse' (valued for service utility over a long lifespan), 'up-to-date' (susceptible to being updated for appearance or technology), and 'investment' products[1] (perceived as a special investment) (Cox et al., 2013). In addition, some products are typically used constantly by households, whereas other products are used for a limited time (Koide et al., 2023b). In this study, we investigated three typical consumer durable products with high penetration levels and for which subscription, repair, and sharing services exist in the current market at certain levels, but with different product characteristics: refrigerators (long lifetime 'workhorse' product for constant use), laptops (middle lifetime 'up-to-date' products), and children's goods (short lifetime 'workhorse' product for temporary use) in the Japanese market.

This study aims to understand consumer segments for circular business models in terms of consumer preferences, profiles, and potential market shares and to investigate the commonalities across the three consumer engagement phases: acquisition, repair, and discharge. For this purpose, we use a hierarchical Bayes choice-based conjoint analysis in combination with an ensemble clustering method to identify preference-based consumer segments and estimate the segment-specific market share of circular business models. The remainder of this article describes the methods and results of the conjoint design, estimation of part-worth utilities, segmentation, profiling, and market simulation. The implications of the identified segments for the transition to a circular economy are discussed and, the contributions of this study are summarized.

2. Material and methods

This study uses a series of methods, including conjoint analysis, clustering analysis, segment profiling, and market simulation, to understand preference-based consumer segments. The approach begins with a choice-based conjoint analysis that asks respondents to choose the most preferred alternative among multiple offers involving distinct combinations of product and service attributes. Although choice-based conjoint analysis traditionally entails choices among different brands and product specifications, this study compares different circular business model offerings. The conjoint analysis method was adopted from a previous study focusing on the product acquisition phase, conducted by several of the authors of the present study (Koide et al., 2023a), and was extended to cover all three phases of consumer engagement. The estimated part-worth utilities were used as the basis for the clustering analysis to identify consumer segments, which were then used to profile

[1] 'Investment' product was not included in the target products because these are related to 'special' products such as premium brands or gifted ones.

each segment and simulate the segment-specific market shares of circular business models.

2.1. Conjoint design

Choice-based conjoint analysis involves repeatedly showing conjoint choice tasks with multiple alternatives (e.g., brand-new, reuse in the acquisition phase) to respondents, which vary key product-service attributes (e.g., years since manufacture) across different levels (e.g., latest, three years), and asking them to choose the most preferred option. An example of a conjoint task used in this study is presented in Table 1 (see Table S4 and S7 in Supporting Information (SI) 1 for the other choice phases). The alternatives, attributes, and levels considered in the conjoint tasks across the three phases of consumer engagement are summarised in Table 2. The specifications of attributes and levels were determined based on a survey of available product-service offers in the current market, pre-surveys of important attributes, and interviews with manufacturers.

In the acquisition phase, respondents were asked to choose their most preferred product service offers: i) purchasing a brand-new product, ii) purchasing a used product, iii) purchasing a refurbished product, or iv) using a product under a subscription contract without owning it. Here, product-service offers were based on different levels of attributes, such as price discounts compared to brand-new purchases, years since manufacture, free-repair warranty, and appearance. To reflect reality in the choice tasks, the prices were shown as actual prices with odd pricing (i.e. prices slightly less than round numbers) calculated based on the discount level and base price of a brand-new product.

In the repair phase, the respondents were asked whether they would repair or replace the product, assuming that the product in their main use had malfunctioned. The repair alternative involves different service levels, such as repair cost, completion date, and period and coverage of warranty after repair. For laptops, functional upgrading was offered as an additional option to assess consumer preferences for such offers. It should be noted that repair choice was not included for children's goods due to the focus of the broader project encompassed the present study and limitations in survey length.

In the discharge phase, respondents were asked about different collection routes for discharging products that they no longer use: i) formal collection for disposal/recycling/refurbishing, ii) reselling for the purpose of reuse, iii) sharing the available product with other consumers, iv) informal collection, or v) hibernating the product in their home. It should be noted that alternatives differed slightly across product categories, considering the applicability and real-world practices. Informal collection refers to a collection service provided by a third party outside of the legal (formal) collection route, which was only covered in the case of refrigerators. Sharing with other consumers refers to temporally sharing an available product through a sharing platform, which was only covered in the case of children's goods. The choice tasks offer different service levels, including collection costs or sales, collection dates, information disclosure on the status of the treatment, and

Table 1
Example of conjoint choice tasks (acquisition choice: laptops).

	Brand-new	Refurbished	Reused	Subscription
Price	119,800 JPY	59,800 JPY	71,800 JPY	1780 JPY/mon
Years since manufacture	Latest	Latest	2 years	3 years
Storage capacity	750 GB (large)	250 GB (normal)	250 GB (normal)	750 GB (large)
Battery life	5 hours (long)	5 hours (long)	5 hours (long)	3 hours (short)
Free-repair warranty	3 years	1 week	3 years	Free during contract period

Table 2
Overview of attributes and levels used in the choice tasks.

Attributes	Levels	Ref.	Lap.	Chi.[o]
Acquisition choice (alternatives: *Brand-new, Reuse, Refurbish*[p]*, Subscription*)				
Price	−30 to 80 % discount[a]	✓	✓	✓
Time since manufacture	0–8 years[b]	✓	✓	
Free-repair warranty	Initial-failure-only, 1-, 3-, 5-year[c]	✓	✓	✓
Appearance	As brand-new, with scratches	✓	✓	✓
Capacity	Small (250 GB), large (750 GB)		✓	
Repair choice (alternatives: *Repair, Upgrade*[d]*, Replace*)				
Cost	0-80,000 JPY[e]	✓	✓	
Completion date	Next day, in 1 week	✓	✓	
Warranty after repair	Initial-failure-only, 1-, 3-year[f]	✓	✓	
Coverage	Whole product, only repaired parts[g]	✓	✓	
Upgrading	SSD, battery, exterior, none[h]		✓	
Discharge choice (alternatives: *Formal collection, Resale, Informal collection*[i]*, Share*[j]*, Hibernation*)				
Cost	0-6500 JPY[k]	✓	✓	✓
Sales	0-70,000 (resale) or 0–3000 JPY per month (share) [l]	✓	✓	✓
Collection date	In 3 days to 1 month[m]	✓	✓	✓
Information disclosure	Recycled, refurbished, reused, no information[n]	✓	✓	✓
Data protection	Secure data erasing certificate, no certificate		✓	

Excerpts of attributes and levels that are the focus of this study's analysis. The complete details of all attributes and levels, including those not used for consumer segmentation, are provided in SI 1. Each attribute is only applicable to the corresponding product type. Ref.: Refrigerators. Lap.: Laptops. Chi.: Children's goods.

There were more attributes in the conjoint tasks than in the items listed in Table 2, which is beyond the scope of consumer segmentation in this study. This was because the specific purpose of the broader project that encompassed the present study differed slightly across product categories. Nevertheless, all attributes shown in the conjoint tasks are included in the methodological details in Table S1–S8 and are considered in the model estimation, with the results provided in Table S9–S16 in SI 1.

[a] Price is shown as odd pricing calculated based on the brand-new base price. A negative sign indicates a higher price level compared to a brand-new purchase, which is applicable only to subscription services. For subscription services, prices were shown as monthly fees, which were calculated by dividing the discounted price by the depreciation period (72 months for refrigerators, 48 months for laptops, 6 months for small semi-durable children's goods, and 24 months for large durable children's goods). The brand-new base price was assumed to be 75,000 to 250,000 JPY (refrigerators, depending on the choice of the preferred size range), 80,000 to 160,000 JPY (laptops, depending on choice tasks), 8000 to 100,000 JPY ± 20 % (children's goods, depending on the type of products and choice tasks).

[b] 0-8 years for refrigerators.

[c] 0-4 years for laptops; 5-years was only applicable to refrigerators. For children's goods, warranty was only applicable to large durables.

[d] Upgrade was only applicable to laptops.

[e] 0-80,000 JPY for refrigerators. 0–60,000 JPY for laptops.

[f] Free-repair warranty in the case of the recurrence of failure. 3-year warranty was only applicable to laptops.

[g] Whole product means any failures, even those due to parts other than repaired, are under warranty coverage.

[h] SSD: +500 GB, battery: change with brand-new, surface: choice of colour and materials.

[i] Informal collection was applicable to refrigerator.

[j] Share with other consumers was applicable to children's goods.

[k] 2,500, 6500 JPY for refrigerators. 3000 JPY for laptops. 500 JPY for large durable children's goods.

[l] 0-20,000 JPY for refrigerators. 0–25,000 JPY for laptops. 0–70,000 JPY (resale) or 0–3000 JPY per month (share) for children's goods.

[m] 3 days or 2 weeks for refrigerators. 1 week or 1 month for laptops. 3 days or 1 month for children's goods.

[n] Treatment status can be tracked on the website. Refurbished by the manufacturer is applicable only to refrigerators and laptops. Reused by second-hand shop is only applicable to refrigerators.

[o] Children's goods assume different types of products: buggy, chair, bed, seat, bicycle (large durables), books, clothes, and toys (small semi-durables). The free-repair warranty was only applicable to five types of large durables.

[p] Refurbish was only applicable to refrigerators and laptops. The subscription for refrigerators assumes that the products are brand-new, refurbished, or reused. The subscription for laptops and children's goods assumes reused products.

data protection measures. Complete details of the attributes and levels in the conjoint tasks are given in Tables S1, S3, and S6 in SI 1.

To design conjoint tasks, we adopted an efficient design to enable a relatively complex task structure with a large number of attributes and reduce the respondent burden. The conjoint tasks were generated based on the D-efficient design using Ngene (ChoiceMetrics, 2018), with a prior estimate of the parameters collected from pre-test surveys. In total, 15–24 choice tasks were designed for each combination of the choice phase (acquisition, repair, discharge) and type of product to account for various attributes and levels. To reduce the respondent burden, a blocking design (Hensher et al., 2015) was applied, resulting in four to eight tasks being shown to the respondent for each combination of phase and product type. Before presenting such choice tasks, descriptions of different circular business models and attributes were presented to the respondents. Choice data for the three types of products were collected through an online panel survey of demographically representative samples of N = 911 from 22 June to 31 July, 2022 (refrigerators); N = 1023 from 11 October to 8 November, 2023 (laptops); and N = 1186 from 18 to 22 January, 2024 (children's goods).[2] The survey samples were representative of Japanese households that used a target product for private purposes and were recruited through major online panel companies and drawn from a screening survey considering demographic variables such as age, gender, and region. Only the responses of those who intended to be involved in decision-making regarding the purchase of the corresponding products and passed a quality check based on instrumental manipulation checks (Oppenheimer et al., 2009) were included in the analysis. The implementation of the surveys was reviewed and approved by the Institutional Review Board (IRB) of the National Institute for Environmental Studies of Japan (No.: 2023-003, 2023-003R1) and deemed exempt from review by the IRB of the Graduate School of Engineering, the University of Tokyo (No.: 21–132). Additional details on the conjoint design and recruitment of respondents are included in Section 1.1, SI 1.

2.2. Estimation of part-worth utilities

Hierarchical Bayes conjoint analysis (Lenk et al., 1996) was applied to estimate part-worth utilities considering heterogeneity. Here, the probability that household h chooses alternative j from available choice set G under choice situation s is specified by the multinomial logit model.

$$P_{h,s}(j|G) = \frac{exp(V_{h,s,j})}{\sum_{i \in G} exp(V_{h,s,i})} \tag{1}$$

where the fixed term of utilities $V_{h,s,j}$ is specified as

$$V_{h,s,i} = \sum_{k=1}^{K} \alpha_{h,k} x_{h,s,i,k} \tag{2}$$

Here, the levels of attribute k offered to household h under choice situation s is specified as $x_{h,s,i,k}$ and the weight of their part-worth utilities are specified as $\alpha_{h,k}$. In this study, the utility weights of major attributes assume heterogeneity among households ($\beta_{h,k}$), whereas those of other attributes or interaction terms are assumed to be homogeneous (γ_k).

$$\alpha_{h,k} = \begin{cases} \beta_{h,k} \ (k \in K_1) \\ \gamma_k \ (k \in K_2) \end{cases} \tag{3}$$

Here, $\beta_{h,k}$ are modelled as the mean weight among households (θ_k) and heterogeneity terms ($u_{h,k}$) based on hierarchical models.

$$\beta_{h,k} = \theta_k + u_{h,k} \tag{4}$$

The hierarchical Bayes model was estimated by Stan (Stan Development Team, 2021) using Monte Carlo sampling with 20,000 iterations, a burn-in period of 5000 iterations, and eight chains. The convergence of the estimation was confirmed using r-hat values (<1.10) for all the parameters of interest.

2.3. Consumer segmentation

Preference-based segmentation derives market segments based on consumer preferences rather than socio-demographic variables (Djokic et al., 2013). In this study, consumer segments were identified based on part-worth utilities for circular business models quantified in a conjoint analysis. For this purpose, the estimated weights of the part-worth utilities described in the previous section ($\beta_{h,k}$) were used as inputs to a cluster analysis. However, numerous types of clustering analysis methods are available, and the clustering results largely depend on the choice of algorithm. To address this concern, ensemble clustering analysis, which identifies segmentation based on the agreement among multiple runs of cluster analysis using different algorithms, was employed to minimise the influence of such methodological choices, using the diceR package in R (Chiu and Talhouk, 2018). In this study, clustering using four types of algorithms (k-means, partition around medoids, fuzzy c-means, and hierarchical clustering) was repeated five times for each algorithm with different subsamples. The final clusters were selected based on majority voting to ensure the best agreed-upon segmentation among the multiple algorithms. The number of clusters (k) was tested from two to eight. The final value of k was determined based on the proportion of ambiguous clusters (Şenbabaoğlu et al., 2015) and the interpretability of clustering results. After selecting k, we obtained the membership of each respondent, which was used to calculate the size of each segment by counting the respondents belonging to each cluster.

Although clustering analysis computationally identifies the existence of consumer segments, memberships of each respondent, and size of each segment, these consumer segments typically need to be interpreted and labelled manually. In this study, the clusters were manually labelled according to the characteristics of the part-worth utility weights, such as openness to circular options and sensitivity to price. The mean and quartile ranges of the part-worth utilities of attributes were compared across consumer segments. Furthermore, the identified consumer segments were cross-analysed across the different choice phases (e.g. acquisition vs. discharge), visualized using mosaic plots.

2.4. Profiling of consumer segments

Profiling involves investigating descriptive characteristics of consumers belonging to consumer segments (Djokic et al., 2013). Profiling is an important step, as it enables a more precise understanding of the differences across segments and actual marketing outreach to the identified segments. In this study, socioeconomic characteristics and psychological and behavioural traits measured using marketing scales, previous choices, and product usage status were compared across segments. As marketing scales, Green Consumer Values (Haws et al., 2014), Materialism Measure (Richins, 1987), Domain-Specific Innovativeness (Goldsmith and Hofacker, 1991), Consumer Involvement Profiles (Laurent and Kapferer, 1985), and its importance subscale (Schneider and Rodgers, 1996) were included. The differences in these measures

[2] Sample sizes shown in the manuscript are those used for the analysis in this study after screening and quality check.

among segments were tested using one-way ANOVA for numerical variables, the Kruskal-Wallis test for ordered variables, and the chi-squared test for categorical variables. Following these statistical tests, pairwise multiple comparisons were performed using the Tukey-Kramer test or the Benjamini-Hochberg procedure.

2.5. Market simulation

A conjoint simulation (Orme, 2020) was applied to estimate the potential market share of circular business models based on the estimated part-worth utilities. This type of market share estimation can be conducted for each consumer segment identified in the previous step, allowing for the investigation of segment-specific market shares. In the simulation, the availability of alternatives and their attribute levels, such as price, years of manufacturing, and warranty offers, were set as scenarios, specifying the choice situation. The probability that household h chooses alternative j from the available set G in choice situation s, $P_{h,s}$, is given by Equation (1). This study uses the share of preference as a method to estimate market share. Here, the total or segment-specific market share of alternative j was calculated by summing all the $P_{h,s}$ probabilities of the relevant respondents, as specified in Equation (5):

$$S_{m,s}(j|G) = \sum\nolimits_{h\in m} P_{h,s}(j|G) \Big/ N_m \tag{5}$$

where $S_{m,s}$ and N_m denote market share and number of households in segment m. The estimated market shares were visualised for the total market using bar charts and compared across consumer segments using mosaic plots.

The scenarios used for the market simulation are summarised in Table 3. In this study, the scenarios compare the potential market shares of several scenarios which assume the introduction of new circular business models, improvement of product services, or a combination of these. As a basis of comparison, the *'Business as Usual (BaU)'* scenarios assume the availability of conventional business models, such as purchasing brand-new and reused products, with repair, formal collection, and reselling service offered at moderate service levels. For example, a 30 % discount for a reused product compared with a brand-new purchase without a free-repair warranty, a certain repair fee without a fast completion service, and a certain collection fee without the disclosure of information on the status of the treatment were assumed.

In the diffusion scenarios, i.e. *'reuse diffusion'* (acquisition phase), *'repair diffusion'* (repair phase), *'resale diffusion'*, and *'formal collection diffusion'* scenarios (discharge phase), conventional business models were assumed to have extensive improvement of product service (attribute levels of relevant alternatives). For example, a reused product was offered with a 70 % discount compared to the brand-new price with an extended 3- or 5-year warranty, a repair fee reduced by 50 % with an extended warranty after repair and fast repair service, and free collection and a certain amount of sales with fast collection and information disclosure on the status of treatment were assumed.

In the new circular business model scenarios, i.e. *'new circular business model (CBM) introduction'*, *'new CBM diffusion'* (acquisition phase), *'upgrade diffusion'* (repair phase), and *'sharing diffusion'* scenarios (discharge phase), new circular business models, such as refurbished products, subscription services, functional upgrading, and sharing offers, were assumed to be introduced but co-exist with conventional business models, such as reused products. The scenarios labelled 'diffusion' mean that new CBM introduction is combined with substantial improvements in price and service levels (e.g. 70 % discount and extended warranty).

3. Results

3.1. Preference-based consumer segments and segment profiles

This study followed a series of steps to derive a preference-based consumer segmentation for circular business models. First, a conjoint analysis was employed to estimate the heterogeneous part-worth utilities for circular business models. The results of the distribution of population-level mean part-worth utilities are included in Section 2.1 and Table S9–S16 in SI 1. Subsequently, ensemble cluster analysis identified preference-based consumer segments. The cluster labels and sizes are summarised in Table 4, whereas the segment-specific part-worth utilities of product-service attributes are shown in Figs. 1–3. Here, a general segment refers to the four types of segments identified across the three phases, whereas a specific segment is a more detailed breakdown of general segments that reflects their preferences for specific circular offers. The profiles of these consumer segments, such as socio-demographic variables and marketing scales, are included in Table S17–S24 in SI 1. As a result of these steps, we revealed that circular-oriented, price-sensitive, balanced decision-makers, and linear economy insistent segments persist across the three consumer engagement phases. The characteristics of these identified segments and the cross-analysis of their segment memberships across the three phases are described in the following subsections.

3.1.1. Circular-oriented segments

The existence of a circular-oriented segment was commonly observed; however, the size of the segments and consumer preferences for specific circular offers largely depended on the product and choice phase. The largest share of the *'circular-inclined'* segment (33 % of the population) was identified in the acquisition of children's goods, with a persistent preference for reuse and subscription services (part-worth utility: 1.6 to 2.2) vs. brand-new purchase (Fig. 1). This segment is more likely to be female and live in a non-metropolitan region (Table S19 in SI 1). For refrigerators and laptops, such preferences were more specific to the *'subscription-inclined'* segment, with a smaller population size (14–15 %). This segment indicated a positive utility for subscription service (1.9–4.4) but not for reuse. Individuals in this segment were relatively younger and showed greater concern about mispurchases and lower domain-specific innovativeness for refrigerators or lower interest in consumer involvement for laptops (Table S17 and S18 in SI 1).

In the repair phase, the *'longevity promoter'* segment accounted for 20–32 % of the population and showed a large utility for repairing (6.4–7.7) compared to replacing a malfunctioning product (Fig. 2). For laptops, a *'function lover'* segment (18 %) was also identified. This segment showed relatively large utility for repair (3.5) and additional offers of functional upgrading (2.4). These segments are likely to comprise individuals who purchase the most expensive range of products and are more likely to be male (refrigerators) or younger (laptops) (Table S20 and S21 in SI 1). In the discharge phase, a majority of the children's goods users were classified as either *'reuse facilitator'* (27 %) or *'sharing facilitator'* (26 %) and indicated a positive preference for either reselling (6.4) or sharing used products (6.1) (Fig. 3).

3.1.2. Price-sensitive and balanced decision-makers

Apart from these segments, a *'price-sensitive'* segment was also commonly observed across the three phases of consumer engagement. This segment accounted for 13–20 % in the acquisition phase for laptops and refrigerators, showing the largest utility for price discount (6.5–8.0) and a relatively smaller disutility for circular business models (Fig. 1), with higher share of online shopping and spending less money for purchasing the product (Table S17 and S18 in SI 1). Such a segment also accounts for 24–27 % in the repair phase, again showing the largest sensitivity to repair costs (−1.6 to −2.6) and a modest utility for repair (Fig. 2). Individuals in this segment were more likely to have purchased a lower price range of products (Table S20 and S21 in SI 1). Similarly, a

Table 3
Overview of scenarios assumed in the market simulation.

Scenario	Availability of alternatives					Attribute-level improvement			
Acquisition choice	**New**	**Reu.**	**Ref.**[a]	**Sub.**		**Price discount**[e]	**Warranty extension**[f]	**Functional upgrading**[g]	
BaU	✓	✓							
Reuse Diff.	✓	✓				✓	✓		
New CBM Intro.	✓	✓	✓	✓					
New CBM Diff.	✓	✓	✓	✓		✓	✓	✓	
Repair choice	**Repl.**	**Repa.**	**Upg.**			**Price discount**	**Warranty extension**[j]	**Convenience**[k]	**Functional upgrading**[l]
BaU	✓	✓							
Repair Diff.	✓	✓				✓[h]	✓	✓	
Free Repair	✓	✓				✓✓[i]	✓	✓	
Upgrade Diff.[b]	✓	✓	✓			✓✓[i]	✓	✓	✓
Discharge choice	**Col.**	**Res.**	**Hib.**	**Inf.**[c]	**Sha.**[d]	**Price discount**[m]	**Transparency**[n]	**Convenience**[o]	**Privacy**[p]
BaU	✓	✓	✓	✓					
Resale Diff.	✓	✓	✓	✓		✓	✓	✓	✓
Formal Col. Diff.	✓	✓	✓	✓		✓	✓	✓	✓
Sharing Diff.[d]	✓	✓	✓	✓	✓	✓		✓	

Years since manufacture were assumed to be at a moderate level across scenarios (2 years). Other attribute levels not shown here were assumed to be the averages of the levels shown in the choice tasks. CBM: Circular Business Model. Intro.: Introduction. New: Brand-new. Reu.: Reuse. Ref.: Refurbish. Sub.: Subscription. Diff.: Diffusion. Repl.: Replace. Repa: Repair. Upg.: Upgrade. Formal Col.: Formal collection for recycling/refurbishing. Col.: Collection. Res.: Resale. Hib.: Hibernation. Inf.: Informal collection. Sha.: Share with other consumers.

[a] Refurbish is only applicable to refrigerators and laptops.
[b] Upgrading is only applicable to laptops.
[c] Informal collection is only applicable to refrigerators.
[d] Share with other consumers is only applicable to children's goods.
[e] 70 % discount compared to brand-new purchase instead of 30 % discount (reused or refurbished products); 50 % discount instead of the same price level compared to brand-new purchase (subscription service).
[f] 5-year (refrigerators) or 3-year (laptops and children's goods) free-repair warranty instead of initial failure only.
[g] Battery replaced with new battery and SSD capacity upgraded to 750 GB (laptops).
[h] 20,000 JPY instead of 40,000 JPY of repair cost (50 % discount).
[i] Free repairs instead of 40,000 JPY of repair cost; upgrading offer charges an additional 20,000 JPY fee.
[j] 1-year free-repair warranty of the whole product in the case of the recurrence of failure instead of initial failure of the repaired parts only.
[k] Repair completion by the next day instead of within 1 week.
[l] Functional upgrading of SSD (+500 GB) offered for upgrading alternative.
[m] Free collection instead of a collection fee of 2000 JPY (refrigerators) or 3000 JPY (laptops) for formal collection. Sales of 10,000 JPY (refrigerators), 30,000 JPY (laptops), or 70 % of the brand-new base price (children's goods) instead of no sales for resale.
[n] Treatment status tracking service available instead of no information available. Assumed treatment methods are refurbished by the manufacturer for formal collection and reused by a second-hand shop for resale (refrigerators), or recycled by the manufacturer for formal collection (laptops).
[o] Fast collection (3 days for refrigerators and children's goods; 1 week for laptops) instead of late collection.
[p] Secure data erasing certificate instead of no certificate (laptops).

'price-sensitive' segment was identified for discharging used laptops and refrigerators (29–30 %), with the largest sensitivity to sales of used products (1.7–2.9) (Fig. 3).

The remaining segment, *'balanced decision-maker'*, may need a more careful interpretation. In the acquisition phase, this segment accounted for 25–38 % of the population and showed modest sensitivity to price and disutility for circular business models, especially showing some degree of acceptability for refurbished products (Fig. 1). Such a segment was also observed for repair of refrigerators (28 % of the population), with modest utility for repairs and sensitivity to repair costs (Fig. 2). Similarly, a *'balanced decision-maker'* segment was also prominent in the discharge phase (19–42 % of the population) (Fig. S3 in SI 1), indicating modest (dis)utility for various discharge alternatives with moderate price sensitivity (Fig. 3).

3.1.3. Linear economy insistent segments

The existence of linear economy insistent segments was consistent across the three phases of consumer engagement. In the acquisition phase, the *'brand-new insistent'* segment accounted for as much as 51 % of the population for refrigerators but was also prominent for laptops (36 %) and children's goods (29 %). This segment showed large disutility for all the circular business models (part-worth utility: −4.4 to −6.4 for refurbish, −5.4 to −10.4 for reuse, −6.8 to −12.5 for subscription service) compared to brand-new purchase and showed limited utility for price discount (<1.3) and a larger disutility for years since manufacture (<−0.5) and scratches (<−0.7) (Fig. 1). According to the profiling results, this segment tends to be older and purchases more expensive products at face-to-face stores rather than online (refrigerators and laptops) or is more likely to be male and not living in a metropolitan region (children's goods) (Table S17–19 in SI 1).

Similarly, in the repair phase, 24–26 % of the population was classified as *'repair resistant'*, showing a large disutility (−4.2 to −4.7) for repair compared to replacement (Fig. 2). This segment tends to be older (laptops) or female (refrigerators), and shows less consumer involvement related to interests and importance for refrigerators or hedonic value and symbolic value for laptops (Table S20 and S21 in SI 1). The conjoint analysis of the discharge phase also identified a *'product hoarder'* segment, which accounted for 21–22 % of the population for children's goods and laptops, showing the segment's strong preference for hibernation (5.2–5.8) (Fig. 3). However, this segment was less prominent for refrigerators (6 % of the population), likely because the product is too large for hibernation. The profiling of this segment differs by product category: older people were more likely to hibernate laptops, whereas the opposite was true for refrigerators and children's goods, which was probably due to the higher likelihood of lifestyle changes in the younger population (Table S22–24 in SI 1). Pertinent to either a linear or circular economy, depending on the treatment system, the *'default persistent'* segment accounted for 23 % of the population for laptops and refrigerators. However, this segment was less prominent for children's goods (7 % of the population), probably because of a strong

Table 4
Overview of identified consumer segments and their sizes.

Phase	General Segment	Specific Segment	Characteristics of part-worth utilities	Segment size		
				Ref.	Lap.	Chi.
Acquisition	**Circular-oriented**	*Subscription-inclined*	Positive utility on subscription service	12.2 %	14.8 %	–
		Circular-inclined	Positive utility on reusing and subscription	–	–	33.2 %
	Price-sensitive	*Price-sensitive*	Higher sensitivity to price discount	12.5 %	20.2 %	–
	Balanced decision-maker	*Balanced decision-maker*	Modest disutility from circular business models and modest sensitivity to price discount	24.7 %	29.3 %	38.3 %
	Linear-insistent	*Brand-new insistent*	Large disutility from any circular business models compared to brand-new purchase	50.6 %	35.7 %	28.5 %
Repair	**Circular-oriented**	*Longevity promoter*	Large utility from repair compared to replacement	20.2 %	32.2 %	–
		Function lover	Relatively large utility from repair and additional offers of functional upgrading	–	18.1 %	–
	Price-sensitive	*Price-sensitive*	Higher sensitivity to repair fee	27.4 %	24.2 %	–
	Balanced decision-maker	*Balanced decision-maker*	Modest disutility from repair and modest sensitivity to repair cost	28.3 %	–	–
	Linear-insistent	*Repair resistant*	Large disutility from repair compared to replacement	24.0 %	25.5 %	–
Discharge	**Circular-oriented**	*Reuse facilitator*	Large utility from reselling products	–	–	26.7 %
		Sharing facilitator	Large utility from sharing available products	–	–	25.6 %
	Circular-oriented/Linear-insistent	*Default persistent*	Large disutility from any discharge alternatives other than formal collection	22.6 %	22.8 %	7.0 %
	Price-sensitive	*Price-sensitive*	Higher sensitivity to collection costs and sales	29.2 %	29.5 %	–
	Balanced decision-maker	*Balanced decision-maker*	Modest disutility from various discharge alternatives and modest sensitivity to costs	42.3 %	26.7 %	18.7 %
	Linear-insistent	*Product hoarder*	Large utility from hibernation	5.9 %	21.0 %	21.9 %

Ref.: Refrigerators. Lap.: Laptops. Chi.: Children's goods. A dash (–) under segment size refers to the segments not being identified for the corresponding product. General segment: four types of segments identified across the three phases. Specific segment: breakdown of general segment to reflect preferences for specific circular offers. Default persistent segment in the discharge phase belongs to either circular-oriented or linear-insistent segments, depending on how the formal collection system is organised.

preference for reselling used products in this category. This segment had a large disutility for any of the discharge alternatives (−1.8 to −5.1 for resale, −5.3 for informal collection, −7.0 for share) and a tendency to stick to the default collection option of formal collection (Fig. 3).

3.1.4. Cross-analysis among acquisition, repair, and discharge phases

A cross-analysis of membership in the consumer segments revealed that circular- and linear-oriented segments overlapped across the three phases. Fig. 4 shows the share of the population belonging to a combination of two segments in two different phases. For the discharge and acquisition phases, the chi-squared and multiple comparison tests concluded that the share of most discharge segments showed a statistically significant difference across the acquisition segments[3] ($p < 0.001$; Table S17–19 in SI 1). To illustrate, individuals in the *'brand-new insistent'* segment were more likely to be in the *'product hoarder'* segment (32 %) than any other segments (12–21 %) ($p < 0.05$ for laptops and children's goods). They were also more likely to be in the *'default persistent'* segment in the discharge phase (17–37 %) than any other segment (2–13 %) ($p < 0.05$ for refrigerators and children's goods).

Members of the *'circular-inclined'* segment in the acquisition phase would likely to be open to be a *'sharing facilitator'* in the discharge phase (41 %), and this proportion was significantly higher than other segments (6–27 %) ($p < 0.05$), while members of the *'subscription-inclined'* and *'balanced decision-maker'* segments in the acquisition phase were more likely to be in the *'price-sensitive'* segment in the discharge phase (33–39 %) than the *'brand-new insistent'* segment (21–23 %) ($p < 0.05$ for refrigerators and laptops).

Regarding the repair and acquisition phases, the share of all the acquisition segments showed a statistically significant difference between the repair segments ($p < 0.05$; Table S20 and S21 in SI 1). The most prominent relationship identified here was that members of the *'repair resistant'* segment were more likely to be in the *'brand-new insistent'* segment (66–73 %) than any other segment (24–49 %) ($p < 0.05$). In addition, the members of the *'price-sensitive'* segments in the repair phase were likely to also be *'price-sensitive'* in the acquisition phase (17–25 %), and this proportion was significantly higher than the *'repair resistant'* segment (8–13 %) ($p < 0.05$). Individuals in the *'longevity promoter'* segment were also more likely to be in the *'subscription-inclined'* (16–18 %) and *'balanced decision-makers'* (28–37 %) acquisition segments than the *'repair resistant'* segment (5–15 %) ($p < 0.05$).

Regarding the discharge and repair phases, chi-squared tests indicated that the share of most repair segments differed significantly across the discharge segments ($p < 0.05$; Table S22–23 in SI 1). For example, members of the *'repair resistant'* segment were more likely to belong to the *'product hoarder'* segment than any other segments ($p < 0.05$) for laptops. Users in the *'price-sensitive'* segment in the repair phase were also more likely to be in the *'price-sensitive'* segment in the discharge phase ($p < 0.05$) for refrigerators. Further details of the statistical tests are provided in Table S17–S24 in SI 1.

3.2. Segment-specific market share of circular economy business models

In the present study, the results of conjoint analysis (part-worth utilities) were used to estimate the market share of different circular business models through conjoint simulation. The estimated total market shares are presented in Fig. S1–3 in SI 1. These market shares were estimated for each consumer segment identified in the previous step, with the main results for key scenarios shown in Figs. 5–7 and additional scenarios in Fig. S4–11 in SI 1. As a result, we found distinct market responses across consumer segments, as described for each of the three phases in the following subsections.

3.2.1. Acquisition of circular products

In the acquisition phase, compared to the *BaU* scenario, introducing refurbished products and subscription services will increase the market share of circular business models from 9 % to 21 % (refrigerators) and 21 % to 38 % (laptops) even without assuming an improvement of attribute levels (*'new CBM introduction'* scenario in Fig. S1 in SI 1). Furthermore, if these new circular business models are combined with an improvement of attribute levels, such as price discounts and warranty

[3] Except for the *'product hoarder'* (refrigerators), *'default persistent'* (laptops), and *'reuse facilitator'* segments (children's goods).

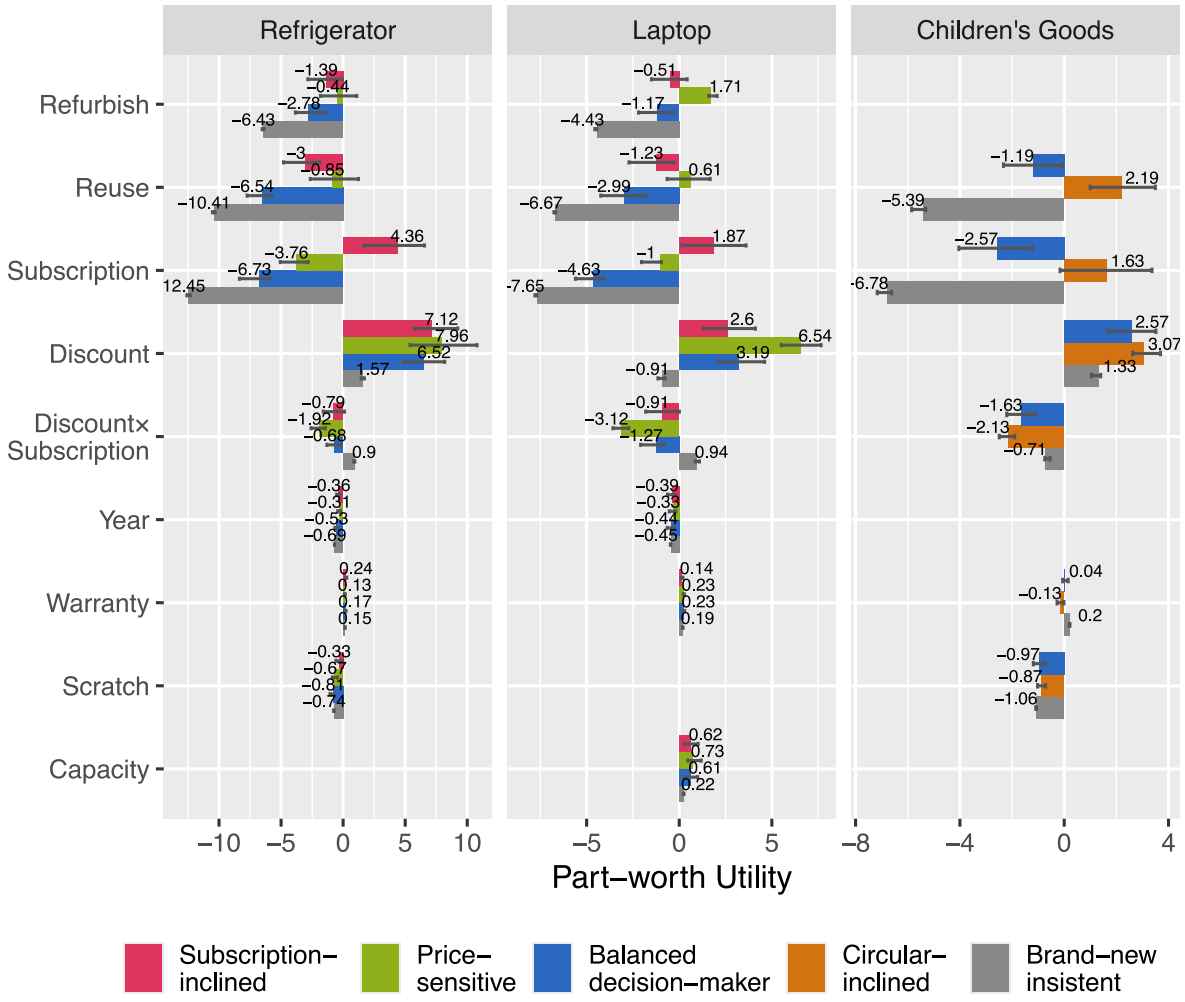

Fig. 1. Estimated average part-worth utilities of acquisition choice by consumer segments. The colours identify the various consumer segments. The horizontal bars and embedded numbers indicate each segment's estimated mean part-worth utility. The error bars indicate the interquartile range of part-worth utility for each consumer segment. Refurbish, Reuse, Subscription: alternative-specific constant (base: brand-new purchase); Discount: relative price discount compared to brand-new (unit: 100 % discount); Discount × subscription: interaction term between discount and subscription; Year: years since manufacture (unit: 1 year); Warranty: free-repair warranty period (unit: 1 year); Scratch: with scratch dummy (base: no scratch); Capacity: 750 GB storage dummy (base: 250 GB storage).

extensions, market share could potentially reach 43 % (refrigerators) or even 53 % (laptops) (*'new CBM diffusion'* scenario). Such market potential is much higher than in the case of solely promoting conventional reuse, where the respective upper bounds for market potential are 23 % (refrigerators) and 37 % (laptops) (*'Reuse diffusion'* scenario). Similarly, introducing a subscription service for children's goods could increase the market share of circular business models to 45–56 % (with or without improvements in attribute levels). However, it should be noted that a significant amount of cannibalisation among the circular business models was predicted with the introduction of new business models. For example, the market share of conventional reuse decreases from 9 % to 6 % (refrigerators), from 21 % to 10 % (laptops), and from 41 % to 37 % (children's goods) in the *'new CBM diffusion'* scenario compared to the *BaU* scenario.

A more detailed investigation of segment-specific market share provides a better understanding of consumer heterogeneity and adoption patterns. Regarding traditional circular business model, i.e. reuse, the expected diffusion of reused products will be mostly limited to the *'price-sensitive'* segment (refrigerators and laptops) and the *'circular-inclined'* segment (children's goods), where the within-segment market share reaches as high as 90–97 % in the *'reuse diffusion'* scenario (Fig. 5). However, the market share of reuse was limited to other segments (up to 14–70 % in the *'reuse diffusion'* scenario).

With the introduction and promotion of new circular business models, such as refurbish and subscription, the story changes dramatically: refurbished products will be extensively diffused across the *'balanced decision-makers'* and *'price-sensitive'* segments, which results in reaching total shares of circular business models of 67–100 % (*'new CBM diffusion'* scenario in Fig. 5). Furthermore, subscription service would be mostly diffused in the *'subscription-inclined'* and *'circular-inclined'* segments, with a segment-specific market share of 39–54 %. Nevertheless, the persistent existence of the *'brand-new insistent'* segment shows that this segment will almost never shift to a circular business model even assuming extensive improvements in attribute levels and the introduction of new business models (share of up to 2 % in the *'new CBM diffusion'* scenario in Fig. 5).

3.2.2. *Repair of malfunctioned products*

Market simulations for the repair phase revealed that the repair choice has the potential to significantly increase its share of choice. Compared to the *BaU* scenario, the choice share of repair could potentially increase from 13 % to 49 % (refrigerators) and from 32 % to 49 % (laptops) assuming that the repair cost is halved and convenience is improved (*'repair diffusion'* scenario in Fig. S2 in SI 1). Furthermore, these choice shares could reach 78 % (refrigerators) and 67 % (laptops) if free repairs are offered (free-repair scenario), and the share could

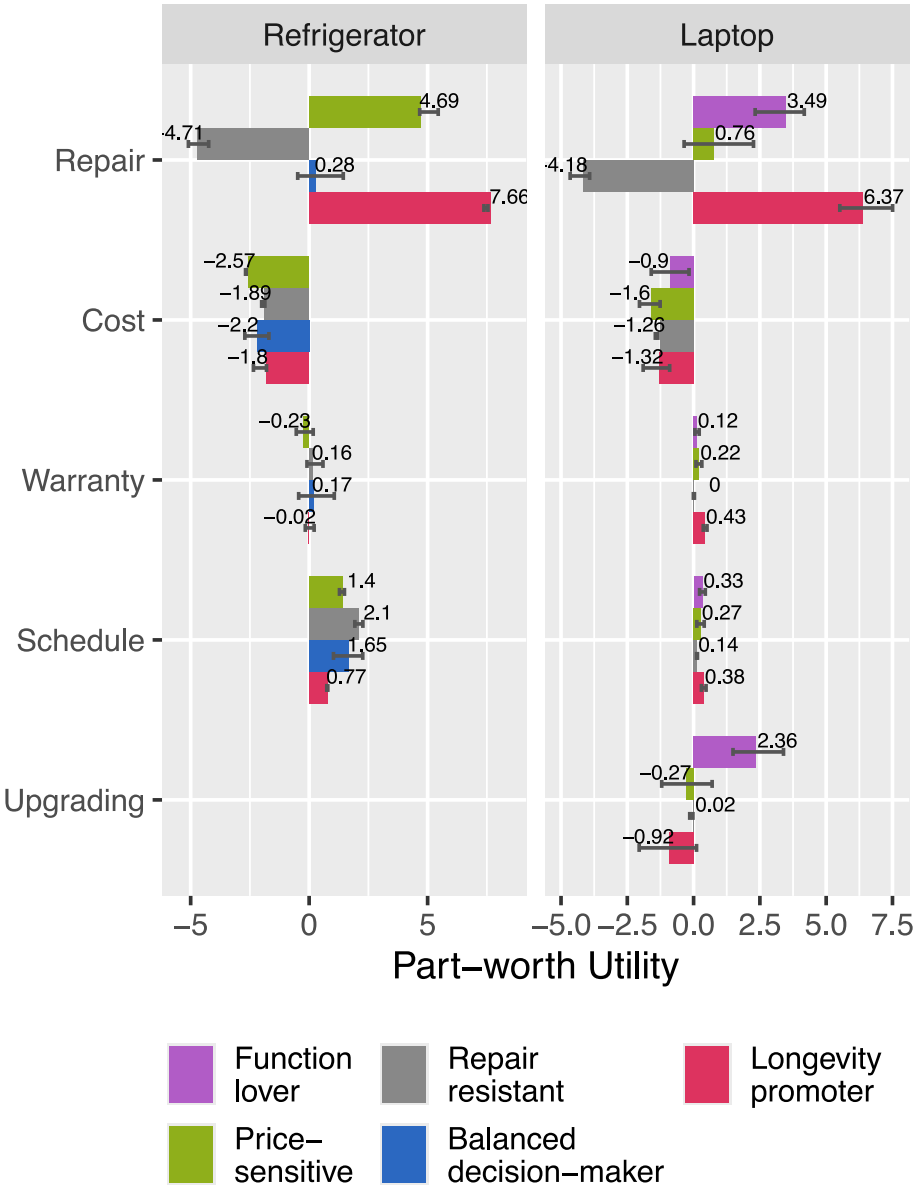

Fig. 2. Estimated average part-worth utilities of repair choice by consumer segments. The colours identify the various consumer segments. The horizontal bars and error bars indicate the estimated mean part-worth utility and its interquartile range, respectively, for each consumer segment. Repair: alternative-specific constant (base: replacement); Cost: repair cost (unit: 10,000 JPY); Warranty: additional free-repair warranty after repair service (unit: 1 year); Schedule: faster repair completion dummy. Upgrade: functional upgrading dummy (base: no upgrading).

reach 72 % (laptops) if functional upgrading is offered in combination with a repair service (*'upgrade diffusion'* scenario).

A segment-specific inspection of market share provides a more nuanced understanding of repair diffusion across different scenarios. In the *BaU* scenario, repair is mostly chosen by the *'longevity promoter'* and *'function lover'* segments (50–66 % choice share in Fig. 6). When repair is promoted along with cost reduction and convenience improvement, the choice share of repair in these segments increases significantly (94–99 % choice share in the *'longevity promoter'* segment) and some portion of the *'price-sensitive'* segment begins to choose repair. If free-repair service is offered along with potential functional upgrading service, most of the consumer segments, including the *'balanced decision-maker'* segment, will shift to repair (76–100 %); however, the *'repair resistant'* segment will still very rarely choose repair (only 17 %).

3.2.3. Discharge of end-of-use products

In the discharge phase, market simulations revealed somewhat contradictory results for different products. The results for two products (refrigerators and laptops) indicate that discharge behaviours largely depend on the attribute levels of the collection services; for example, the estimated share of the reselling route could be as small as 11–12 % (*'formal collection diffusion'* scenario) or as large as 54–63 % (*'resale diffusion'* scenario in Fig. S3 in SI 1). However, for children's goods, there will be persistent discharge behaviour favouring the reselling route (72–73 % in the *BaU* and *'resale diffusion'* scenario), although this behaviour will be partly replaced by sharing if such a new business model is offered (*'sharing diffusion'* scenario). In addition, the persistent share of hibernation was predicted, especially for laptops (26–40 %) and children's goods (14–15 %), whose shares are not likely to change even with extensive improvements in the attribute levels of resale, collection, and sharing services.

A segment-specific inspection of the collection route share revealed linear-insistent behaviours by the *'product hoarder'* segment, whose members persistently choose hibernation across scenarios (a segment-

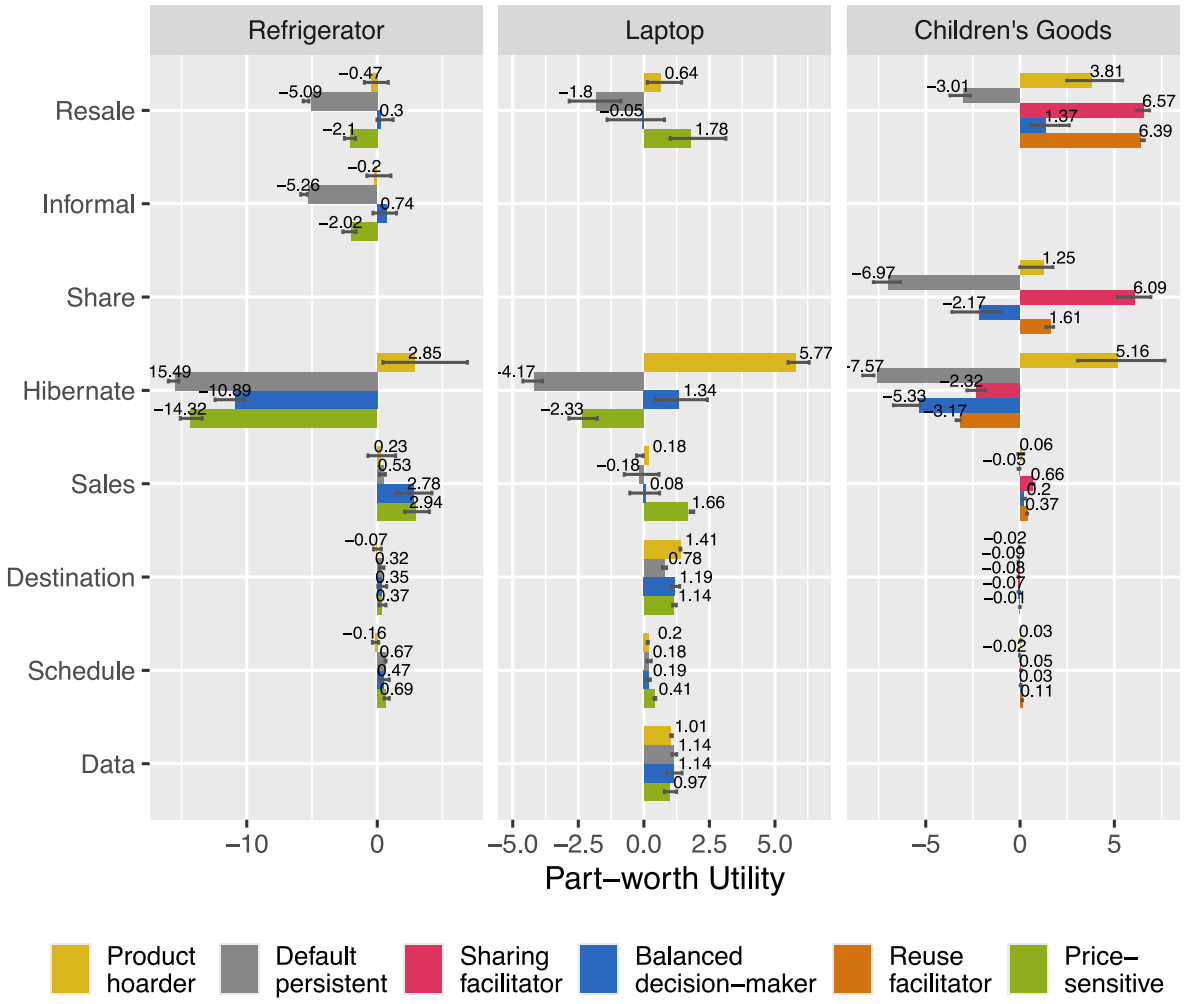

Fig. 3. Estimated average part-worth utilities of discharge choice by consumer segments. The colours identify the various consumer segments. The horizontal bars and error bars indicate the estimated mean part-worth utility and its interquartile range, respectively, for each consumer segment. Resale, informal, share, hibernate: alternative-specific constant (base: formal collection); Sales: sales for reselling discharged products, with cost indicated as negative value (unit: 10,000 JPY); Schedule: faster collection dummy; Destination: disclosure of treatment status dummy (base: no disclosure); Data: secure data erasing certificate dummy (base: no certificate).

specific hibernation share of 79–92 % for laptops, 58–62 % for children's goods, and 54–59 % for refrigerators (Fig. 7), and the *'default persistent'* segment, whose members mostly choose formal collection service (88–100 % for refrigerators, 59–97 % for laptops). In contrast, the individuals in some of the other segments are expected to make more flexible decisions; for example, the choice share of reselling route in the *'price-sensitive'* segment varies between 4 and 83 % (refrigerators) and 29–99 % (laptops), depending on the scenario with different price offers. Furthermore, the persistently high share of reselling routes for children's goods is explained by the unique existence of the *'reuse facilitator'* and *'sharing facilitator'* segments, which show a consistently high choice share for reselling routes (>97 % across scenarios) and sharing routes (52 % in the *'sharing diffusion'* scenario).

4. Discussion

4.1. Circular-oriented segments as entry points for early phase diffusion

The present study identified preference-based consumer segments across three phases of consumer engagement in a circular economy and investigated their market share and commonalities. The most important finding of this study is the persistent presence of certain consumer segments, including circular-oriented, price-sensitive, balanced decision-maker, and linear-insistent segments across all three phases and product categories. Among these, perhaps the most positive finding for supporting the circular transition is the existence of circular-oriented segments, such as the *'subscription-inclined,' 'circular-inclined', 'longevity promoters', and 'sharing facilitators'* segments. Although these segments represent a relatively small portion of the population (12–33 %), they are open to both traditional (e.g., reuse) and emerging circular business models (e.g., refurbishment and subscription). Although the existence of segments open to circular offerings is consistent with previous conjoint studies focused on the acquisition phase (Boyer et al., 2021; Koide et al., 2023a; Wallner et al., 2022), the present study is the first to identify such segments in the other two phases.

Market simulations showed that the within-segment market share of circular products in these segments could be very high, potentially reaching 88–100 % (*'new CBM diffusion'* and *'free repair'* scenarios). These early adopters could potentially shift social norms in other segments. Furthermore, according to our cross-analysis, segment membership overlaps across multiple phases (e.g., circular-oriented consumers in the acquisition phase are more likely to belong to circular-oriented segments in the repair or discharge phases). Given this overlap in segment membership, an important consideration is the possibility of positive spillover effects, which refers to a phenomenon where engaging in one pro-environment behaviour increases the propensity to engage in

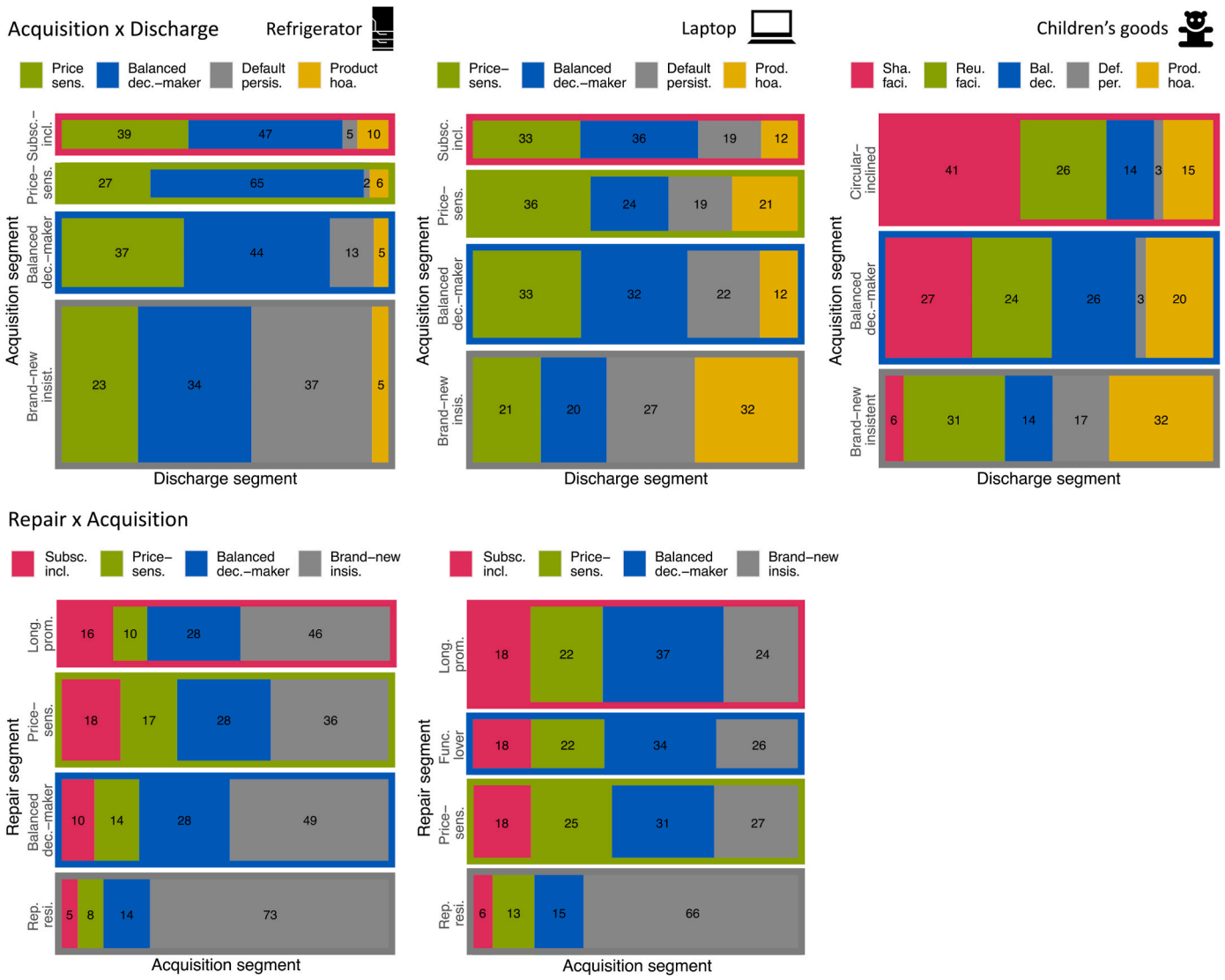

Fig. 4. Cross-analysis of segment size between two choice phases. The fill colour indicates consumer segments regarding discharge (first row) or acquisition (second row). The frame colour indicates consumer segments regarding acquisition (first row) or repair (second row). The embedded numbers indicate the proportion (%) of discharge (first row) or acquisition (second row) segment within acquisition (first row) or repair (second row) segment.

other related actions (Truelove et al., 2014). In the context of circular business models, consumers who initially adopted circular offerings in one phase (e.g., choosing reused products) could potentially begin to shift their choices in another phase (e.g., repairing malfunctioning products). The prominence of these segments could provide a suitable entry point for the diffusion of circular business models, which serve as initial targets of marketing and policy efforts. The profiling of consumer segments could be used to identify and specify these segments for targeted interventions.

4.2. *Approaching price-sensitive segments to mainstream circular business models*

The *'price-sensitive'* segment was commonly observed across all three phases, accounting for up to 30 % of the population. The finding of existence of such segments is consistent with previous conjoint studies of the acquisition phase (Boyer et al., 2021; Koide et al., 2023a; Wallner et al., 2022), whereas such segments were identified for the first time in the other two phases as well in the present study. This segment could substantially impact market share as it is open to traditional circular models depending on price. For example, the segment-specific share of repair reached 70–100 % in the *'repair free'* scenario, compared to within 3–6 % in the *BaU* scenario. Similarly, the segment-wise share of reused products rose to 91–97 % in the *'reuse diffusion'* scenario, whereas it remains as low as 47–72 % in the *BaU* scenario. Here, the pricing of circular alternatives relative to linear options will make a difference, particularly in this segment, and product offerings may require strategic pricing, such as increasing the price of brand-new products while maintaining profits through service-based models and refurbishment offerings. Given the varying degrees of price sensitivity across consumer segments and growing feasibility of segment-based or one-to-one marketing, it may even be appropriate to consider differential pricing across segments.

Based on the findings of market simulations, if a large-scale diffusion of circular alternatives is to be achieved, the prices of circular product offerings, such as refurbished and reused products, will need to be significantly lower than those of brand-new products. According to simulation results, a 30 % discount is not sufficient to ensure that the total market share of circular alternatives approaches that of traditional brand-new products (e.g. only a 37 % share for circular alternatives vs. a 63 % share for brand-new for laptops in the *'new CBM introduction'* scenario). However, a 70 % discount along with additional service-level

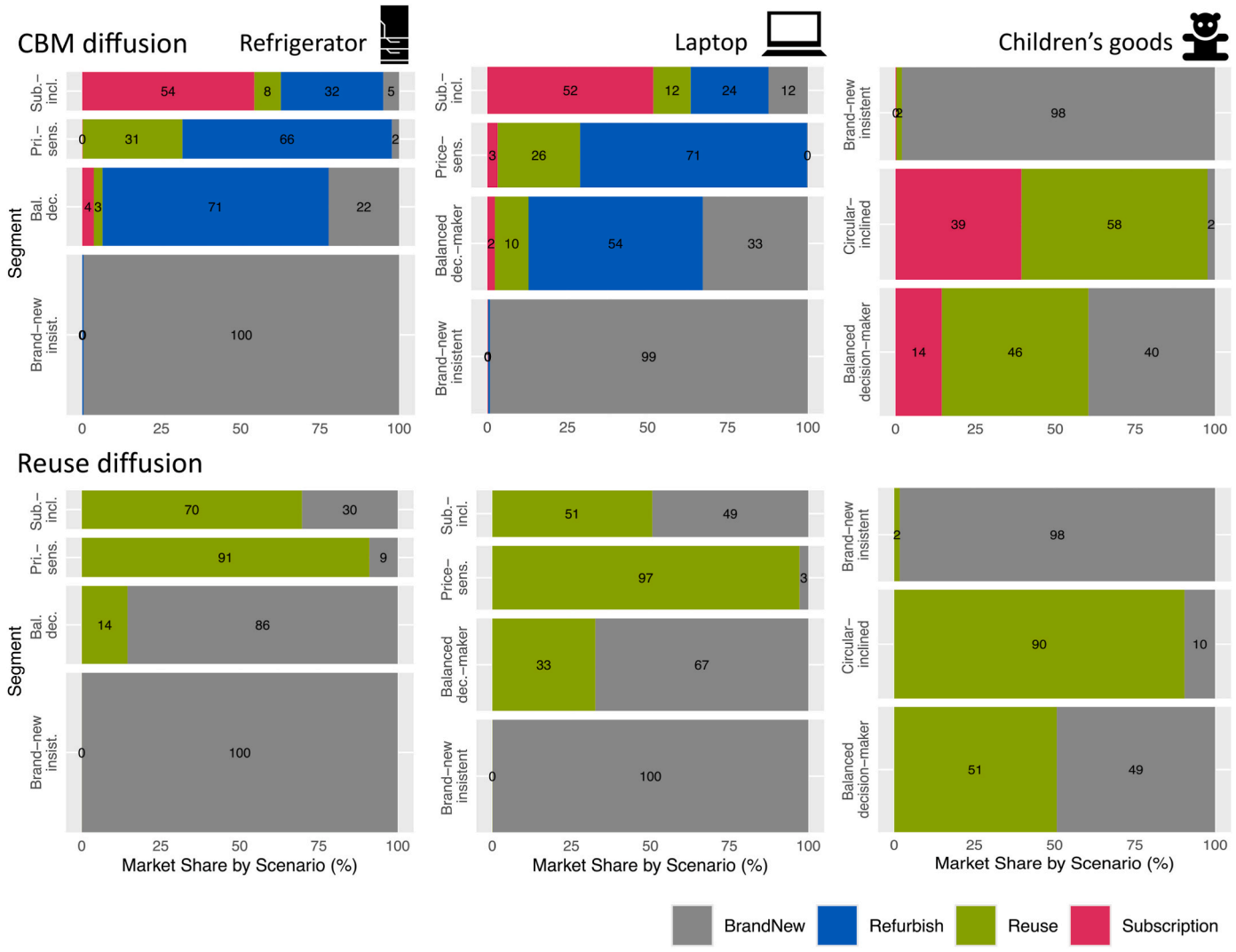

Fig. 5. Estimated segment-specific market share by scenario (acquisition phase). The colours indicate product service alternatives. The height of the graph indicates the size of each consumer segment. The width of the graph and the embedded numbers indicate the proportion of consumers predicted to choose each alternative in each consumer segment. Additional scenarios are included in Fig. S4–6 in SI 1.

improvements, could have a significant positive impact (e.g. a 53 % share of circular alternatives in the *'new CBM diffusion'* scenario).

The price is important in the repair choice; cost was identified as a strong determinant explaining 66–74 % of the utilities, which was higher than that in a previous study on smartphones and washing machines (Güsser-Fachbach et al., 2023). Thus, reducing repair costs, for example, by extending the free-repair warranty period, is likely to be an effective strategy for increasing the likelihood that a consumer will choose to repair a product.

4.3. *Introducing new circular business models to reach balanced decision-maker segments*

The conjoint analysis and market simulations conducted in this study indicate that new business models such as refurbishment, subscription, and functional upgrading offers have clear potential to gain a higher share of available circular options than traditional offerings do. These findings were consistent across all three product categories. The estimated market share under the *'new CBM diffusion'* scenario was 6–20 % higher than under the *'reuse diffusion'* scenario. Such high acceptance levels for new circular business models are supported by previous studies on refurbishment during the acquisition phase (Hunka et al., 2021; Koide et al., 2023a; Kwarteng et al., 2018). The reason new circular business models demonstrate higher market potential may be the existence of the *'balanced decision-maker'* segments. This segment accounted for 25–38 % in the acquisition phase, making it the second largest next to the *'brand-new insistent'* segment. According to market simulations, this segment is particularly open to adopting new circular business models, but not traditional reuse. For example, the within-segment market share of circular options reached 67–78 % (refrigerators and laptops) or 60 % (children's goods) when refurbishment or subscription models were introduced. However, this segment shows only a limited acceptance of traditional reuse, 14–33 % (refrigerators and laptops) and 51 % (children's goods). This suggests that effectively reaching this segment is the key to further mainstreaming circular options, requiring strategies beyond price incentives and traditional reuse models.

The introduction of new circular business models requires attractive product service offerings. The conjoint analysis in the present study identified key characteristics of circular business offerings that influence consumer preferences, including price, years since manufacturing, appearance, free-repair warranty, convenience, and transparency. Our findings are consistent with previous studies on circular product acquisition regarding the relative importance of price (Aydin and Mansour, 2023; Eskilsson, 2023), manufacturing year (Kwarteng et al., 2018), warranty, and appearance (Hunka et al., 2021; Wallner et al.,

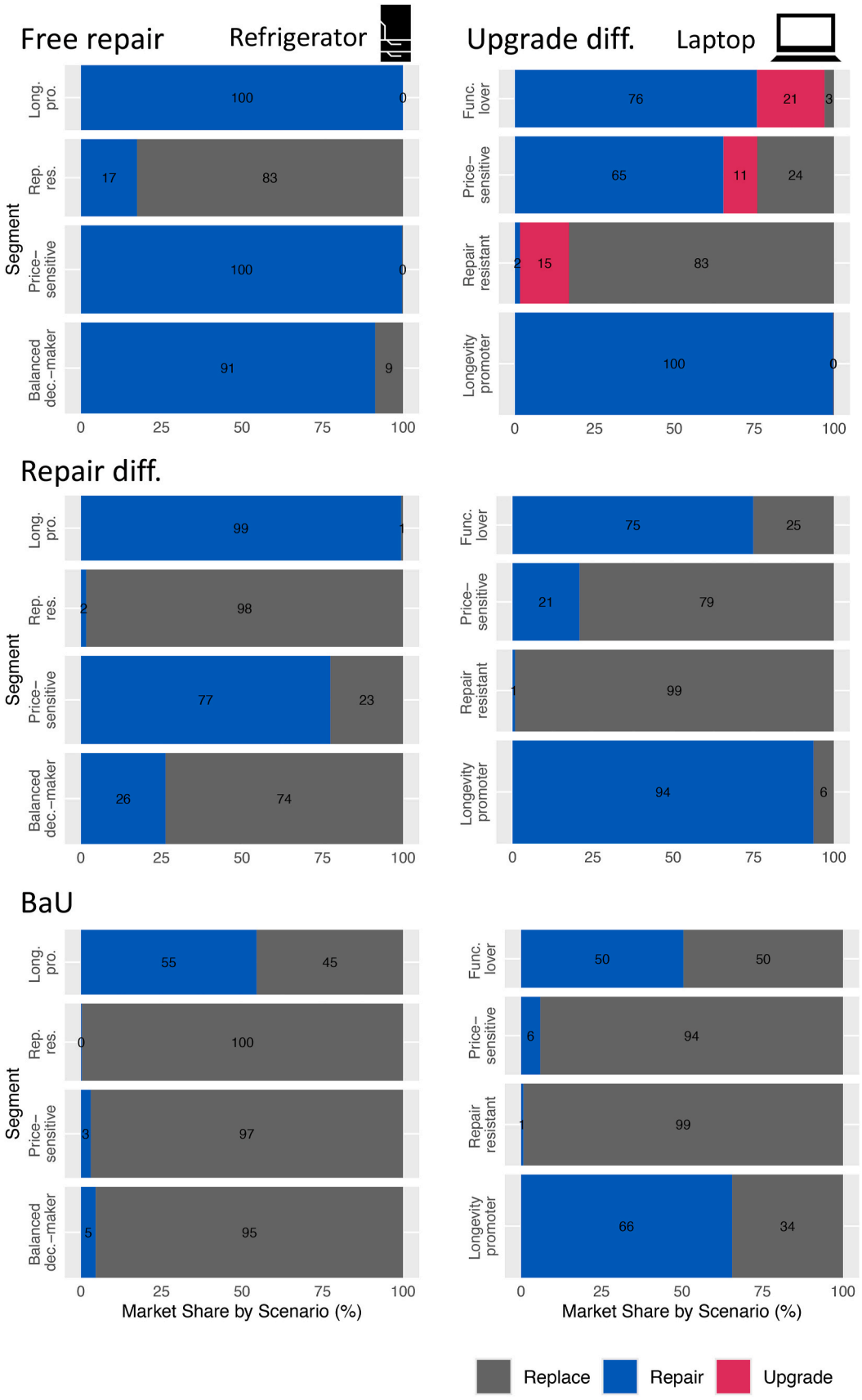

Fig. 6. Estimated segment-specific market share by scenario (repair phase). The colours indicate product service alternatives. The height of the graph indicates the size of each consumer segment. The width of the graph and the embedded numbers indicate the proportion of consumers predicted to choose each alternative in each consumer segment. diff.: diffusion; BaU: Business as Usual. Additional scenarios are included in Fig. S7–8 in SI 1.

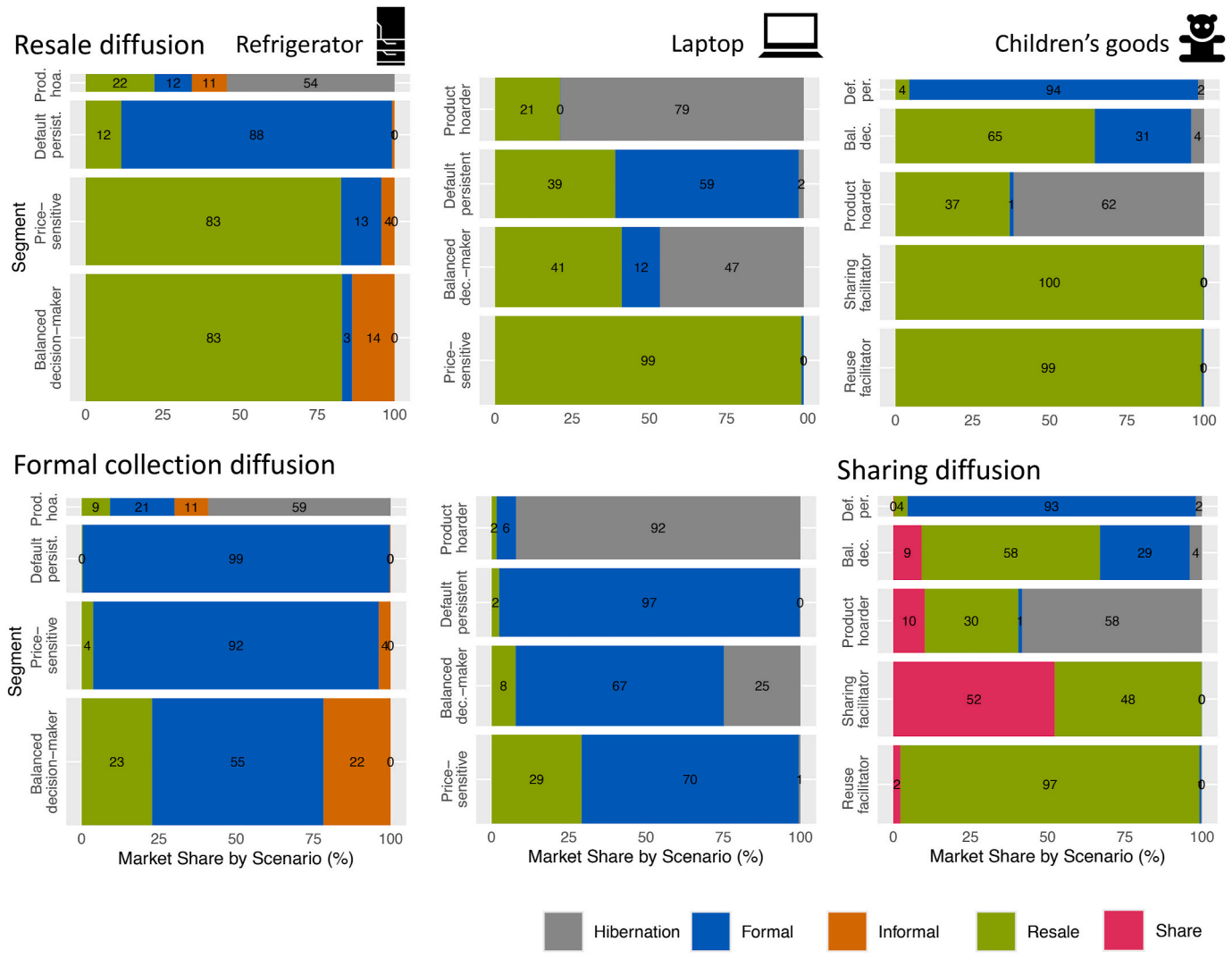

Fig. 7. Estimated segment-specific market share by scenario (discharge phase). The colours indicate product service alternatives. The height of the graph indicates the size of each consumer segment. The width of the graph and the embedded numbers indicate the proportion of consumers predicted to choose each alternative in each consumer segment. Additional scenarios are included in Fig. S9–11 in SI 1.

2022). We extend these findings to the other two phases. In terms of discharge behaviour, transparency and convenience were identified as important attributes, which is consistent with previous studies on e-waste recycling (Wang et al., 2023; Zhang et al., 2019). In terms of repair behaviour, we identified the critical role of cost, which appeared to be more significant than in a previous study (Güsser-Fachbach et al., 2023). This result points to the necessity of designing convenient and transparent collection systems, not only for recycling but also for the resale and sharing of used products, focusing on factors beyond price.

4.4. Long-term transition required for shifting linear economy insistent segments

The most striking finding of this study was the persistent existence of linear economy insistent segments, such as the *'brand-new insistent'*, *'repair resistant'*, and *'product hoarder'* segments. These segments consistently showed high disutility for any circular business models across the three product categories. Moreover, market simulations predict that individuals in these segments will almost never choose circular alternatives even with substantial improvements in a circular business model. Unfortunately, the size of these segments makes them unignorable: the *'brand-new insistent'* segment accounted for as much as 29–51 % of the population, while the *'repair resistant'* segment accounted for 24–26 %, and the *'product hoarder'* segment accounted for up to 22 %. However, the existence of segments lacking openness to circular offerings has only been identified in a few previous conjoint studies in the acquisition phase (Boyer et al., 2021; Koide et al., 2023a). Although the present study found that such segments exist persistently across phases and product categories in the Japanese market, the significance of this cluster may require further scrutiny in other contexts.

The persistent existence of these segments, which show high disutility for circular business models, makes it extremely difficult to move away from linear economy practices. Even with extensive improvements in the attribute levels of circular options, the share of brand-new products remains at 44–57 % (*'new CBM diffusion'* scenario), while 51 % stuck to replacing broken products (*'repair diffusion'* scenario), and 4–26 % of used products are hibernated (*'formal collection/sharing diffusion'* scenarios).

It is important to note that the three phases of consumer engagement are not isolated. Linear-insistent behaviour in any of these three phases can cause bottlenecks in the transition to a circular economy. To illustrate, even if a significant demand exists for refurbished products (e.g. up to 34 % share for refurbished laptops), a relatively high hibernation rate (26–29 %) can cause a lack of high-quality products that might otherwise have been collected for refurbishment. Even if reuse were to be extensively promoted (e.g. up to a 23 % share of reused refrigerators),

the resistance to repair (only 49 % in *'repair promo'* scenario) may place a limitation on product lifetime. Thus, strategies to diffuse circular business models in any one of the three phases may also require effort in the other two, with consideration given to the entire life cycle of products, from manufacturing to after-purchase services. Although a dynamic simulation is beyond the scope of the present study, such a bottle neck was identified in a previous simulation study (Koide et al., 2023b).

The default option has been extensively discussed as a promising approach in the context of the so-called green nudging policy (Sunstein and Reisch, 2018). However, its application to circular business models is yet to become mainstream. In the context of circular business models, circular products can first be suggested to consumers as the default offering, ensuring their entry into the consumer's consideration set (Shocker et al., 1991) while making it still possible for the consumer to opt out of the offer. Such an approach could potentially influence behaviour in the linear-insistent segment. Another consideration is a fundamental shift in culture and social norms. Although quantifying social influence is beyond the scope of this study, a gradual diffusion of circular business models through other segments that are more open to circular offerings could lead to broader societal change. For example, when circular options become mainstream (e.g., a 53 % total market share of new circular business models for laptops in the *'new CBM diffusion'* scenario in the acquisition phase), they may evolve into social norms among consumers, which could, in turn, influence behaviours of the linear-insistent segment. However, such societal transition would require a wide range of supportive policy measures. For example, consumer policies such as regulation and information provision play a critical and positive role in fostering consumer demand for circular business models (Arranz and Arroyabe, 2023).

5. Conclusions

This study is the first to apply preference-based consumer segmentation based on choice-based conjoint analysis to circular business models across the three phases of consumer engagement in a circular economy (acquisition, repair, and discharge). Using three types of typical consumer durables with different characteristics, refrigerators, laptops, and children's goods, we quantified part-worth utilities, identified market segments, and estimated the segment-specific market shares of circular business models. We identified a persistent existence of certain consumer segments, including circular-oriented, price-sensitive, balanced decision-maker, and linear-insistent segments, each showing distinct characteristics in terms of market share and segment profiles. The analyses described in this study can help expand the research on consumer behaviour in the circular economy by enabling a more nuanced segmentation, supporting the understanding of diffusion stages, the design of appealing product-service offerings, and the development of target-specific marketing strategies that take into account the entire product life cycle of circular business models.

In terms of managerial implications, we show that the identified consumer segments common across the acquisition, repair and discharge phases play distinct roles in the transition to a circular economy, ranging from acting as early entry points to being segments that require long-term behavioural shifts. Furthermore, the three phases are not isolated, as any of them could become a bottleneck in the circular transition, and consumer segment memberships tend to overlap across phases. The four types of consumer segments spanning all phases either enable or hinder the diffusion of circular business models. Therefore, tailored strategies are required that reflect the preferences of each segment. Our key recommendation is a combination of approaches, including target-based marketing, introduction of new circular business models, substantial price reductions relative to linear options, shifting circular offerings to default options, and leveraging positive spillovers from one entry phase to another phase. Thus, the present study makes a unique contribution by addressing the entire product life cycle, as these recommendations are relevant not only to the product acquisition phase but also the repair and discharge phases.

As with any academic research, this study is not without limitations. First, the product service attributes considered were restricted to only a few important ones. The cluster analysis focused only on the most important common attributes across product types, largely due to the need to limit the respondent burden. Second, the analyses were limited to three types of products on the Japanese market, which clearly presents limitations in terms of external validity. Expanding the analysis to other countries and products is, therefore, an important topic for future research. Furthermore, owning to the nature of conjoint analysis, perfect rationality was assumed in estimating market share, which could lead to an overestimation of the actual market share. Therefore, the estimated market shares reported in this study should be interpreted as the potential shares, assuming perfect rationality. Consideration of the bounded-rational screening process, such as consideration and awareness sets (Koide et al., 2023a), was beyond the scope of this study. Moreover, because consumer behaviour is known to be dynamic and influenced by social interactions, a more dynamic model of consumer interactions may require the use of comprehensive simulation techniques, such as agent-based simulations (Koide et al., 2023b). Despite these limitations, we believe that this study provides an important foundation for future studies and offers valuable insights to support a continued development of circular business models and strategies.

CRediT authorship contribution statement

Ryu Koide: Writing – original draft, Methodology, Formal analysis, Conceptualization. **Haruhisa Yamamoto:** Writing – review & editing, Validation, Methodology. **Eri Amasawa:** Writing – review & editing, Validation, Methodology. **Keisuke Nansai:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Shinsuke Murakami:** Writing – review & editing, Supervision, Methodology, Conceptualization.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Shinsuke Murakami reports financial support was provided by Panasonic Holdings Corporation. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.

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Data availability

Data will be made available on request.

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