MASTER

Consumer adoption and economic performance of circular business models
the case of washing machines

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Award date:
2018

Eindhoven, July 2018

Consumer Adoption and Economic Performance of Circular Business Models:
The Case of Washing Machines

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BSc Industrial Engineering
Bilkent University, 2016

Student identity number 1037686

in partial fulfillment of the requirements for the degree of

Master of Science
in Operations Management and Logistics

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TU/e School of Industrial Engineering
Series Master Theses Operations Management and Logistics

Subject headings: circular economy, consumer behavior, discrete choice experiment, market segmentation, leasing, servicizing

Consumer Adoption and Economic Performance of Circular Business Models: The Case of Washing Machines

Abstract

This thesis aims to generate insights into consumer behavior and economic performance of circular business models by taking the specific case of washing machines and focusing on repeated leasing. We run a survey on Amazon MTurk to assess the preferences of consumers among the alternatives of purchasing a new machine, and leasing a new or used machine. The results reveal that the market is segmented and that consumers have distinct preferences stemming from the psychological antecedents such as disgust, pride of ownership, and convenience of leasing. An important finding is the unpopularity of leasing. At low leasing fees, the segment that prefers purchasing comprises more than 50% of the market. Using data from a European white goods manufacturer, we show the influence of segmentation and low demands for leasing on the economic performance. The leasing only model never appears to be a more profitable strategy than the sales only model, while a hybrid strategy has potential when the manufacturer charges high leasing fees. We also approach the problem from the consumer's vantage point by calculating the total cost of ownership, and illustrate the challenge in making the leasing offer appealing to both the manufacturer and the consumer. Finally, through sensitivity analyses on various cost elements as well as the market segmentation, we investigate the ways in which this challenge can be overcome. Our findings demonstrate the impact of financing the leasing offer, and the importance of product design.

Keywords:
circular economy, consumer behavior, discrete choice experiment, market segmentation, leasing, servicizing, consumer products.

Summary

The circular economy is advertised as a promising way to solve the worldwide problems due to the exponential population growth and the depletion of natural resources. The concept is receiving increasing attention from governments: the European Commission (EC) and China have passed legislations to promote circular economy principles, by increasing reuse and recycling. Several companies have also been attempting to adopt circular business models, some examples include Interface Inc. in the U.S. for modular carpets that are leased to consumers, and Bundles and Homie offering leasing options for washing machines and dryers in the Netherlands.

For circular economy to be an effective solution, consumer acceptance is essential, but not always certain. Research shows that consumers might show unwillingness to engage in leasing/servicizing (Planing, 2015; Liu, Li, Zuo, Zhang, & Wang, 2009; White, Stoughton, & Feng, 1999), due to various reasons. For example, they may feel disgusted towards a product that has been used before by someone else (Abbey, Blackburn, & Guide, 2015), or may prefer purchasing because they take high pride in ownership (Beggan, 1992). On the other hand, it is possible for consumers to see leasing as a more affordable and convenient way of accessing the use of a product (Moeller & Wittkowski, 2010; Berry & Maricle, 1973). This is because the consumer avoids the upfront retail price and the maintenance and repair costs when the product is leased. Despite its importance, little is known about consumer behavior towards circular business models (van Weelden, Mugge, & Bakker, 2016; Planing, 2015). Besides an understanding of consumer behavior, companies that would like to transition circular models also lack practical analyses that can assess profitability (van Loon, Delagarde, & Van Wassenhove, 2017; Matschewsky, Kambanou, & Sakao, 2017).

The purpose of this thesis is to help satisfy these needs by investigating the consumer perception of circular business models, and its impact on the economic performance. We take the case of washing machines, and focus on repeated leasing with refurbishment in between. We analyze a simple setting where a machine is either sold or leased for two periods with fixed duration. Without adding any unnecessary complexity, this setting allows us to observe the main trade-offs present in consumer decision-making and profitability calculations. Through a survey run on Amazon MTurk, we determine the consumer demand for leasing and purchasing alternatives, and assess the potential drivers of consumer behavior such as feelings of disgust, pride of ownership, and perceived convenience of leasing. Then we integrate the results into an analytical model to examine the economic performance of three strategies as sales only, lease only, and hybrid.

First, to determine the leasing fees to offer for a new machine (first period) and a used machine (second period), we took the manufacturer's point of view, and analytically compared the net present values (NPV) from selling a washing machine to leasing it for two periods. We used cost estimates from a European white goods manufacturer, and adapted the model presented

in van Loon et al. (2017) to our setting. We identified seven pairs of leasing fees to ask in the survey, each representing a ratio of NPV of profits from leasing to selling. For instance, at the lowest leasing fees of P_{L1}=\$13.00/month for a new machine and P_{L2}=\$6.50/month for a used machine, the manufacturer makes 1/4 of the NPV of profits per machine of selling it for \$800. We calculated the discount for a used washing machine as 50% by the depreciation rate, which was fixed in all seven pairs of leasing fees.

We ran a survey on Amazon MTurk, and accepted responses from 852 participants after an attention check procedure on the response time and pattern. We used discrete choice experiment (DCE) type questions, which resemble a realistic choice making situation, and asked the respondents to state their choices among the alternatives of (i) Purchasing a new washing machine at the retail price of \$800, (ii) Leasing a new washing machine at P_{L1}/month, (iii) Leasing a used washing machine at P_{L2}/month, (iv) None of the above. Each respondent answered seven DCE-type questions presented from the lowest leasing prices to the highest, while the retail price of the machine was kept fixed at \$800. To assess the potential psychological antecedents of the choice, the participants also rated 12 statements on their individual values. For example, a statement about the disgust factor read: "I would never use laundromats or a shared washing machine, I think they are dirty." A rating of 0 meant that the respondent did not agree with the statement at all, while a rating of 10 meant that s/he totally agreed.

After collecting and cleaning the survey data, we conducted a confirmatory factor analysis (CFA) to ensure that the statements used in the survey were statistically grouped together under the same factor. Using the ratings of the statements proven to be in the same latent factor, we calculated average disgust, pride of ownership, and convenience of leasing scores for each respondent. On the resulting dataset, we ran various discrete choice models: Multinomial Logit (MNL), Nested Logit (NL), Mixed Logit (MIXL), and Latent Class Multinomial Logit (LC-MNL). LC-MNL fits the data and estimates the demand reasonably well, with about 1% absolute error for the demand of each alternative. This model showed that consumers display significant heterogeneity in their preferences due to their individual valuations of the assessed psychological factors, as well as demographics such as age and income. We found that the market is grouped into three segments with distinct preferences: the first segment comprises of 35.6% of the population, and is most likely to lease a used washing machine among the given alternatives. This segment includes price-sensitive consumers with low incomes, who do not necessarily feel disgusted towards used products. The second segment makes up 12.7% of the population and prefers leasing new washing machines. They find leasing convenient, but experience feelings of disgust towards used washing machines. This segment has the highest income among all segments. The third segment comprises 51.6% of the population, and includes the consumers who prefer purchasing the product, because they take high pride in ownership. These findings are not favorable for a manufacturer seeking to develop circular business models for two reasons. First, because of the unpopularity of leasing alternatives (especially for new products) and second, because of the discrepancy between the demand for leasing new and used products. As we demonstrate in the total profits calculation, the fact that leasing is unpopular may cause the firm to lose consumers if a lease only strategy is adopted. Our calculations further establish that the difference between the demand for leasing new and used products may be detrimental to the profitability of a lease only or hybrid strategy, due to the supply-demand interdependency in a repeated leasing system. Although we do not solve for the exact profits, a best/worst case analysis affords us to determine upper and lower bounds, and to show that it is crucial for the manufacturer to handle the situation well in case of an overage/underage in the supply.

To better understand the unpopularity of the leasing alternatives, we approached the issue from the consumer's vantage point, and calculated the total cost of ownership (TCO) for selling and leasing alternatives. Since it is challenging to predict how consumers evaluate alternatives and estimate their costs, we made calculations for two "extreme" types of consumers: at one extreme stands the "primitive" consumer who neglects the time value of money and maintenance/repair costs in the purchasing alternative, and at the other extreme, the "omniscient" consumer who perfectly estimates the maintenance/repair costs and makes calculations considering the time value of money. The TCO calculations for both consumer types revealed that in most cases, leasing new machines appears more expensive than purchasing new or leasing used machines. This helps explain the low demand for leasing new machines. Our findings also illustrate the difficulty in designing a leasing contract that makes the business model attractive to both the consumer and the manufacturer. To ameliorate the leasing offer, a manufacturer can take several actions, such as improving the financing scheme and the product design. Through sensitivity analyses, we show the effects of these actions on the total expected profits of the manufacturer (when the leasing prices are kept fixed), and the leasing prices (when the manufacturer decides to change the leasing prices). Our findings suggest that improving the financing scheme is crucial: by decreasing the discount rate and the lease administration costs, a firm can significantly increase total profits. By designing a more durable product and decreasing the refurbishment and maintenance/repair costs, the offer can also be enhanced, but improving the product durability appears less effective than improving the financing scheme. We also compare the expected total profits from sales only, lease only, and hybrid strategies and conclude that the hybrid strategy has potential to be the most profitable strategy under various cost levels, while the lease only strategy can only be more profitable than a hybrid strategy if the market is almost exclusively comprised of consumers who favor leasing over purchasing. However, we acknowledge the necessity for further analysis to calculate the exact levels of profits under each strategy.

We believe that this thesis is valuable for taking an initial step to establish the importance of consumer behavior in circular business models. Neglecting the consumer part of the equation may seriously impact the economic performance and hence the effectiveness of circular business models. The study has also produced considerable insights for a firm in the transition process. Although we examined the case only for washing machines, our study design presents a practical path for assessing the consumer demand and economic performance of circular business models for any kind of consumer products.

Acknowledgements

This thesis is the end of my time as a master's student at Eindhoven University of Technology, and an intern at INSEAD Business School, both of which I greatly enjoyed. I would like to take the opportunity here to thank the people who have made this thesis possible.

I consider myself lucky to have had Jan Fransoo as my mentor during my masters, who has done well beyond his requirements as a mentor. Thank you for teaching me a lot, and also for supporting me through the highs and lows of this part of my academic career. Although this thesis marks the end of my masters, I sincerely hope that it is only the beginning of our research collaboration.

I am more than grateful to Luk Van Wassenhove, for giving me this great opportunity to conduct my thesis as an intern at INSEAD, and for always making the time to invest in this project. Thank you for the academic freedom and careful guidance you have given me. I am looking forward to learning more from you during my Ph.D.

I am deeply indebted to Joseph Blackburn, whose valuable suggestions and constructive feedback have considerably improved this thesis. I thank Klaus Wertenbroch for his ideas on the marketing part of this project, and Harwin de Vries for his helpful comments on the modelling decisions.

I would like to thank Tarkan Tan, my second advisor in the Excellence Program, for his feedback on my mini research projects, as well as his help in my choice to pursue a Ph.D. degree. I thank Shaunak Dabagdhao for his willingness to complete the assessment committee.

Last but not least, thanks a million to my friends, who make Fontainebleau, Eindhoven, and Ankara, "home". And to my family, whose unconditional love and support I feel no matter where in the world I am.

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Chapter 1

Introduction and Motivation

"People don't want to buy a quarter-inch drill, they want a quarter-inch hole."
Theodore Levitt, Harvard Business School (Christensen, 2016)

The world is facing problems due to the exponential population growth and escalating demand for natural resources. It was estimated that by 2050, global population will reach approximately 9 billion (Godfray et al., 2010), and require three times the resources currently in use (Planing, 2015). Despite the efforts to encourage recycling, it has been argued that 60% of the materials are simply lost in the material flow, i.e., not recycled or reused (Ellen MacArthur Foundation, 2013). In the recent years, these discussions paved the way for questioning the feasibility of the linear "take-make-waste" system, and gave rise to the idea of a more circular economy, an alternative *"in which we keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life."* (Waste and Resources Action Programme, 2018)

To ensure that the maximum value is extracted and recovered from products, in a circular economy, the functionality of a product is sold rather than the product itself. In other words, the company retains the ownership of the products while consumers pay per use of the product. The quote above by Theodore Levitt nicely summarizes the idea behind circular business models such as leasing and servicizing. It is advertised as a promising approach to slow down resource loops since it brings in economic incentives both for manufacturers and consumers (Bocken, de Pauw, Bakker, & van der Grinten, 2016). This is because, in a circular system, manufacturers are encouraged to design and produce more durable, repairable and reusable products, whereas consumers are encouraged to use less and pay less (Bocken et al., 2016).[1]

These ideas have gained recognition throughout the world: the European Commission (EC) and China have passed legislation to adopt circular economy principles: designing out waste, keeping products and materials in use, and regenerating natural systems(Ellen MacArthur Foundation, 2013).China focuses on promoting by municipalities and firms (van Loon et al., 2017; Mathews & Tan, 2011), whereas the EC aimed at increasing reuse and recycling (European Commission, 2017). Additionally, non-governmental organisations such as the Ellen MacArthur Foundation and the Waste and Resources Action Programme have helped promote the circular economy. In consequence, it gets increasing attention also from the industry, with several companies attempting to transition to circular business models. Examples include Interface Inc. for modular carpets in the U.S. and Electrolux for pay-per-use washing machines[2]. More

[1] We acknowledge that these claims require further serious academic research.
[2] Electrolux has stopped this experiment.

recently, Bundles (2017) and Homie (2017) started offering high-end washing machines in the Netherlands via pay-per-use or pay-per-month subscriptions.

The above examples include both leasing and servicizing business models. For clarity, we explain the difference here. First, in a leasing model, consumers are charged per the duration they use the product (e.g., leasing a washing machine for a month), whereas in a servicizing model consumers pay-per-use (e.g., paying per the number of wash-cycles). Second, on the contrary to servicizing, leasing requires a product to be dedicated to each consumer, i.e., “pooling” consumers is not possible (Agrawal & Bellos, 2016). Note that by the second aspect, leasing is also different from a sharing scheme (such as bike or car-sharing). In this thesis, we analyze the case of repeated leasing with refurbishment in between, hereafter referred to as leasing.

The circular economy is also a popular topic of discussion in academia, with researchers studying several aspects, as explained in further detail in Section 2. However, most of the studies in the Operations Management (OM) literature take theoretical approaches modelling the strategic behavior of different parties such as the manufacturer, the consumer and the competitors. In order to make the trade-offs explicit, these papers make simplifying assumptions on the reality, and generally neglect the market demand. Thus, the studies that analyze the feasibility and potential performance for a circular business model from an operational perspective are scarce in the literature. Moreover, companies that would like to transition to circular models lack practical analyses that can assess profitability (van Loon et al., 2017; Matschewsky et al., 2017).

A successful transition to a circular economy requires engagement beyond the efforts of a company. For the circular economy to be an effective solution, it is of utmost importance that it is accepted by consumers, and hence that academy and practice understand consumer behavior towards a circular economy. It is possible for some consumers to shun leasing models due to various reasons. Consumers may attach a high value to the ownership of products (Beggan, 1992), and show an unwillingness to engage in leasing/servicizing (Planing, 2015). For instance, a survey about public awareness of circular economy in Tianjin, China showed that 72% of respondents would not rent a camera, or toy for children; while only 5.5% of the respondents would prefer leasing over buying. It was concluded that consumers choose to buy if they can afford it (Liu et al., 2009). This behavior is also observed in the Electrolux case. The company adopted “Functional Sales” for their professional appliances, in which customers did not purchase the goods but paid a monthly fee for the function provided (White et al., 1999). Some customers thought that leasing implied insufficient means to purchase the product (White et al., 1999). It is also possible that consumers avoid leasing because they feel disgusted towards products previously used by others (Abbey, Meloy, Guide, & Atalay, 2015). Such negative perceptions of leasing may create serious barriers to the adoption of circular business models, as seen in the examples of failed trials above.

On the other hand, some consumers may hold positive perceptions towards leasing/servicizing. Leasing is promoted to be greener, hence environmentally conscious consumers may prefer leasing over buying. Further, some consumers may find leasing preferable for the convenience it provides: since the company bears the costs and takes the responsibility for maintenances and repairs, it takes the “burdens of ownership” off the consumer’s shoulders (Berry & Maricle, 1973; Moeller & Wittkowski, 2010). However, from the literature, it is unclear to what extent these positive (and negative) perceptions would be influential on consumer behavior. Even though many companies seek to transition to circular systems, consumer support is not always certain, which may hinder the success of a circular economy. Despite its significance, little is known about consumer behavior towards circular business models, and experimental research is needed to gain understanding (Planing, 2015; van Weelden et al., 2016). Such understanding is also lacking in practice: the customer value of circular business models is unclear (van Loon et al., 2017; Matschewsky et al., 2017).

This thesis aims to help satisfy the lack of practical analyses to assess consumer perception and economic performance of circular business models. Our objective is two-fold. Firstly, we seek to gain empirical insights into the nature of consumer behavior towards leasing. Secondly, we use these empirical findings in an analytical model to investigate the economic performance of the lease offer. We analyze the case for white goods, in particular, washing machines and we use the cost and revenue estimates of a European manufacturer. Besides analytical modelling, we make use of an experimental study to gather data through Amazon Mechanical Turk, and discrete choice models to determine the demand for circular business models and the significant factors underlying consumer adoption. To the best of our knowledge, this study is among the first to empirically analyze consumer perception of circular business models, and use empirical data to analytically evaluate profitability.

We believe that this thesis is of high practical relevance, not only for taking an initial step to introduce the consumer demand into the picture but also for its insightful findings to advise a firm in the transition process to circular business models. In terms of consumer adoption, we find substantial heterogeneity in the market: a high percentage of consumers prefer purchasing to leasing, and there is a significant difference between the demand for leasing new and used machines. We conclude that pride of ownership, feelings of disgust towards used products, and the perceived convenience of leasing are important drivers behind the consumer behavior. Our total profit calculations demonstrate the consequences of this segmentation by comparing the three strategies of (i) sales only, (ii) lease only, (iii) hybrid strategy. Firstly, we find that offering leasing only is not a good strategy, because it means losing a large group of consumers who prefer to purchase. On the other hand, adopting a hybrid strategy to offer both leasing and purchasing options appear to have a potential to be more profitable than a sales only strategy. Secondly, we show that the discrepancy between the demand for leasing new and used products can be very harmful to the total profits due to the supply-demand interdependency in a repeated leasing system. Thus, a manufacturer should try to bridge the gap between the demand for the consecutive leases of a product, and/or manage the system so that the overage and underage costs are minimized. We run sensitivity analyses on various cost elements and caution practitioners about the importance of financing schemes, as well as the durability of the product design in a leasing system.

The remainder of this manuscript is organized as follows. We briefly discuss the relevant literature in Section 2. In Section 3 we introduce the methodology, explain the analytical model, data collection and analysis processes for assessing the consumer demand; and then use the demand to identify the best strategy in terms of economic performance. In Section 4, we approach the issue from the consumer's point of view by calculating the total cost of ownership, and discuss the potential of the leasing offer under various circumstances. We conclude this thesis in Section 5 with managerial insights and limitations.

Chapter 2

Literature Review

In addition to the works cited in Chapter 1, this study draws on two main bodies of literature: (i) leasing/servicizing models, and (ii) consumer behavior and market segmentation. In this section, we review the existing literature in these areas, summarize the learnings and identify the contributions of our work.

2.1 Leasing/Servicizing Business Models

Most of the research on leasing/servicizing in operations management (OM) literature has focused on a Business-to-Business (B2B) context[3] , especially for industries such as aerospace, machine tools, and other capital equipment (Baines et al., 2009). The strategic consequences of servicizing versus selling models have been investigated in economics literature as well[4]. Though insightful, these works are not directly applicable to Business-to-Consumer (B2C) settings: the customer in a B2B model is a business making more rational and predictable choices than an individual consumer, thus consumer behavior and marketing is less of an issue in B2B.

With the increasing attention that circular economy is receiving, leasing/servicizing has recently started to be subject in the OM literature also for consumer products. Several researchers analyzed the environmental and economic performance of leasing/servicizing by taking game theoretical approaches and showed that, contrary to the commonly-held belief, leasing/servicizing is not always greener (Agrawal, Ferguson, Toktay, & Thomas, 2012; Agrawal & Bellos, 2016). Furthermore, it is misleading to assume that leasing always improves product durability: when the market is segmented, the firm might be targeting different segments with different leasing models. In this case, leasing does not always increase product durability and hence does not necessarily improve environmental performance (Orsdemir et al, 2017). These papers are important for their counter-intuitive findings. However, their theoretical approaches require simplifying assumptions on the reality, such as on the consumer demand.

The transition process to circular models has been qualitatively examined in several papers in the context of shifting the focus from products to product-service-systems (PSS). These papers mostly highlighted the challenges that the change management brings from an organizational vantage point (White et al., 1999; Oliva & Kallenberg, 2003; Rothenberg, 2007; Matschewsky et al., 2017). Nevertheless, when a firm decides to offer leasing/servicizing to individual consumers more issues on top of the organizational challenges rise relating to consumer behavior and

[3]Also termed as “installed base management” and “Product-Service-Systems (PSS)”. See Baines et al., 2009 for an overview.

[4]See Waldman, 2003 for an overview.

market conditions, and the additional financial costs. To our knowledge, van Loon et al. (2017) is the first (and only) paper that considers leasing for a consumer product from an operational perspective and presents a simple model to help practitioners in the transition process. By analyzing the case of baby strollers, they showed that it is challenging to determine such leasing fees that make the leasing offer both profitable for the firm and attractive for the consumer. This is due to the second-hand market available, where used strollers can be sold at high resale prices. In addition, they commented that the firm is exposed to higher risks resulting from the supply-demand interdependency and potential delinquent consumers (Bardhi & Eckhardt, 2012; Catulli et al., 2013; van Loon et al., 2017). New financing schemes and appropriate legislation for protection against such risks are necessary for the circular business models to advance (van Loon et al., 2017). While we use the analytical model in van Loon et al. (2017) as a starting point, our work introduces the consumer demand into the picture and empirically assesses the attractiveness of the leasing offer to consumers at different leasing fees. We then move on to calculating the total profits for the firm and investigating the total value of offering leasing. Thus, our work takes a step forward and contributes to the OM literature in guiding the transition process to circular business models.

2.2 Consumer Behavior and Market Segmentation

This study is also based on the vast bodies of marketing and OM literature on consumer behavior[5]. In the OM literature, the recent papers discussing the consumer behavior and market segmentation for remanufactured products are specifically related to our study. Remanufactured products are similar in nature to the repeated leasing in our setting, in the sense that in both models the consumer is offered a previously used product. These papers are noteworthy for identifying distinct segments of consumers in the market, in contrast with the common assumption of homogeneity in the Closed-Loop Supply Chains (CLSC) literature (Majumder & Groenevelt, 2001; Ferrer & Swaminathan, 2006). Guide and Li (2010)'s seminal work found a group of "newness-conscious" consumers that would never prefer remanufactured products, while another "functionality-oriented" and price-sensitive group regards remanufactured products as perfect substitutes for new products. Therefore, cannibalization concerns for remanufacturing firms can be overcome by smart pricing strategies that target different segments in the market (Atasu, Sarvary, & Van Wassenhove, 2008). In a similar vein to Guide and Li (2010), an experimental study by Abbey, Blackburn and Guide (2015) identified two distinct consumer segments: one group was roughly indifferent between new and remanufactured products and made their decisions based on price, while the other group preferred the new product and showed insensitivity to price discounts. Further, they investigated the drivers of such behavior and found that consumers associate a higher risk of functionality and cosmetic defects with remanufactured products, and the consumers displayed significant variability in their preferred discount factors and their valuations of brand equity (Abbey, Kleber, Souza, & Voigt, 2017). Disgust was identified to be another factor that has a detrimental effect on consumer adoption of remanufactured products (Abbey, Meloy, et al., 2015). Moreover, informing consumers about the professional remanufacturing process did not help silence the hygiene concerns, the negative perceptions persisted even when the consumers were educated (Abbey, Meloy, et al., 2015) [6]. Hence, disgust is identified as a potentially influencing factor on the consumer behavior towards leasing.

[5] See Bendoly, 2010 for an overview.

[6] Catulli et al., 2013 notes that consumer trust neither previous users nor the leasing company, this may also help explain the ineffectiveness of educating consumers.

Disgust, as a psychological concept, is explained by the law of contagion which states that when a source (person/object) touches a recipient, it transfers its "essence" to the recipient, making it contaminated. The essence remains with the recipient even after the contact, i.e., "once in contact, always in contact" (Rozin & Nemeroff, 1990; Argo, Dahl, & Morales, 2006; Morales & Fitzsimons, 2007). Contamination beliefs may be unconscious: in a study by Rozin, Millman, and Nemeroff (1986), some participants were unaware of their disgust feelings, and some resisted to verbalize them as they thought it sounded "foolish". Moreover, the essence transferred to the recipient does not need to be visible for disgust to occur (Argo et al., 2006), but visualization increases the effect (Rozin, 1986). The finding of Argo et al. (2006) implies that consumers may still hold the same negative perceptions toward a used product, with or without visible cosmetic defects, which helps explain why educating respondents did not change their mind in the study by Abbey, Meloy, et al. (2015). An important point here is the changes in disgust sensitivity with culture and individual differences. Cultural differences appear to be of great influence for disgust sensitivity (Rozin, Haidt, & McCauley, 1993). As for the individual differences, studies have argued that: women are more sensitive to disgust than men (Haidt, McCauley, & Rozin, 1994); disgust sensitivity decreases as people age in adulthood (Quigley, Sherman, & Sherman, 1997); and disgust sensitivity is inversely related to socioeconomic status (Doctoroff & McCauley, 1996).

In the marketing literature, Argo et al. (2006) examined how the consumer reactions changed when a product was touched by others. They concluded that even though consumers would like to touch products when shopping, products previously touched by others are less favorable, with disgust as the underlying mechanism (Argo et al., 2006). Morales and Fitzsimmons (2007) analyzed how consumers responded to "product contagion", i.e. when a disgust-inducing product (e.g. mayonnaise or feminine napkins) touches another product. In their setting, the contamination belief was irrational since both the target and source products were sterilized and packaged. Nonetheless, disgust was found to be effective on consumer behavior even under such conditions. Similar to the observations of Rozin et al. (1986), Morales and Fitzsimmons (2007) also noted that disgust occurred even when the participants were cognitively busy, thus, it is an automatic and unconscious reaction. Marketing research on consumer behavior in access-based consumption (which includes leasing and sharing systems) has concluded that the consumers were concerned about hygiene in such systems: users of ZipCar (i.e. a car-sharing service in the U.S.) expressed fear of contamination (Bardhi & Eckhardt, 2012) as well as the participants of professionally refurbished baby prams in a small-scale pilot study (Catulli et al., 2013).

Leasing is inherently different from purchasing remanufactured products in the sense that the consumer does not have the ownership of the product in leasing, but only access to the use of it. Therefore, if consumers highly value the ownership of products, they may show unwillingness to adopt circular business models. This phenomenon is known as the "pride of ownership" or "the mere ownership effect" in the psychology literature (Beggan, 1992). It was shown that people regard their possessions as an extension of their "self", and thus like to own objects (Belk, 1988). Findings from a study by Beggan (1992) supported this idea: due to self-enhancing bias, it was observed that the participants evaluated their belongings more favorably than the objects they did not own. The effect was amplified if the participants strongly needed self-enhancement (Beggan, 1992).

Consumers may also shun leasing systems because of the social stigma around leasing. The case of Electrolux, as mentioned in the introduction, shows that consumers may believe that leasing implies insufficient means to own (White et al., 1999), while accumulating material goods projects an image of status (O'Shaughnessy & O'Shaughnessy, 2002; Thompson & Troester, 2002). Historically, leasing was regarded as an inferior consumption mode, while ownership provided a sense of personal independence and security (Ronald, 2008). In an attempt to explain how the person-object relationship is changed when an object is rented rather than owned, Durgee and O'Connor (1995) provided another vantage point to the pride of ownership and defined two types of materialism, i.e., terminal materialism and instrumental materialism. In terminal materialism, possession is key: owning the object brings satisfaction on its own, whereas in instrumental materialism, consumption is key: the satisfaction is provided by using the product. Therefore, pride of ownership is linked to terminal materialism, and consumers do not experience perceived ownership for a leased/accessed product (Bardhi & Eckhardt, 2012). Similarly, through a survey on the users of a German peer-to-peer sharing network, ownership of products was found to be still highly valued by consumers despite the increasing demand for rentals (Moeller & Wittkowski, 2010). Bardhi and Eckhardt (2012) also noted that ownership continues to be the "ideal normative mode of consumption" also in the contemporary American society.

On the other hand, some consumers might be inclined to lease consumer products for the convenience it provides. Convenience is manifested as a consumer's desire to conserve energy in shopping and consuming (Seiders, Voss, Godfrey, & Grewal, 2007), and leasing is regarded to be naturally more convenient than ownership, as it lifts the "burdens of ownership" from the consumer (Berry & Maricle, 1973). These burdens are the risks regarding the product obsolescence and the responsibility for maintenance and repairs. The convenience factor was acknowledged by one of the respondents in the study by Durgee and O'Connor (1995), who expressed that she rented her washer and dryer "to save wear and tear on her own". Moreover, the convenience of rentals was also shown to be a significant factor in increasing the demand for peer-to-peer rentals (Moeller & Wittkowski, 2010).

Consumers may also find leasing more affordable and prefer it over purchasing since they pay monthly fees rather than an upfront retail price. Lower income groups who would have to save money if they would like to purchase the product may choose to lease instead, for the "instant gratification" that leasing provides (Durgee & O'Connor, 1995). This situation is exemplified in the case of Zipcar, where users can access the cars they cannot afford to own (Bardhi & Eckhardt, 2012), and the pilot study with baby prams, where the participants stated that they liked to use prams from high-end brands without having to pay the high selling price (Catulli et al., 2013).

Therefore, we determine the potential antecedents behind the consumer demand for leasing new or used washing machines as feelings of disgust toward a used product, pride of ownership, perceived convenience and affordability of leasing. Section 3.2 explains the survey design to assess these factors. We acknowledge that there are other factors that affect consumer perception of circular business models, as also noted in the psychology literature. However, it is practically not possible to identify and evaluate all potential drivers in one academic study, let alone under the limitations of a master thesis. Our contribution to the literature in terms of consumer behavior lies in empirically considering the consumer part of the equation in circular business models and assessing the effects of affordability, pride of ownership, disgust, and the convenience of leasing simultaneously in the same context. It became evident from the literature review that though there is research on consumer behavior for similar models, consumer perception of circular business models has not been adequately researched.

Chapter 3

The Study

In this chapter, we present the simplifying assumptions we made, describe the methodology and comment on how this methodology achieves our research goals.

This study has two main research goals. First, we aim to gain an understanding of the consumer perception towards circular business models. Second, we seek to investigate the impact of consumer behavior on the economic performance of a manufacturer and evaluate the overall profitability of circular models.

With these goals in mind, we take a holistic approach to our study design (Mitroff, Betz, Pondy, & Sagasti, 1974). We start with the realistic problem of the lack of analyses of consumer behavior and profitability in circular business models, and we arrive at a conceptual model through some simplifying assumptions. Put differently, these assumptions help us to develop an "auxiliary model" that is intuitively plausible and solvable by simple arithmetic to generate insights (Geoffrion, 1976). The assumptions are:

- The focus of this thesis is limited to washing machines. Though clearly a small part of the consumer market, it is simple enough to demonstrate the main trade-offs and lay groundwork that can be used for other types of consumer goods.
- We analyze the specific case of a monopolist manufacturer who offers leasing or purchasing of a premium washing machine. Therefore, in our setting, we aim to determine the demand for three options to access the use of the same premium washing machine: purchasing the machine, leasing the new machine, leasing the used machine.
- We assume a leasing offer with a fixed duration, such that the consumer cannot cancel leasing before the end of the determined leasing duration. This results in a setting where the machine is either leased for two periods or sold at the beginning, i.e., the machine can be leased at most twice.
- For the economic performance analyses, we assume ample manufacturing and refurbishment capacity, such that the supply of machines is only constrained for leasing used machines by the number of machines collected after the first lease.
- As for the antecedents of consumer behavior, we address the potential effects of disgust, affordability, convenience, and pride of ownership. Understanding consumer behavior is a formidable task and there may well be many other factors that affect the consumer acceptance of circular business models, e.g., the effects of culture, generation, or gender. Though interesting, the effects of these factors are out of the conceptual model of this

research. Aside from the time and feasibility concerns, we concentrate on only four of the potential antecedents to make the trade-offs in the consumer decision-making more explicit.

Even though this thesis analyzes a simplified version of reality, we believe that it encompasses various ways of conducting OM research. Our study takes a normative approach and has both empirical and axiomatic parts (Bertrand & Fransoo, 2002): By means of a consumer survey, we seek to get an understanding of the consumer behavior towards leasing and to use that knowledge in an analytical model to compare the economic performances of selling and leasing. Through this process, we aim to find the best strategy for the manufacturer under the given setting, which may not necessarily be the overall optimal strategy. Note that we only comment on the comparison of the economic performances of leasing, selling, and hybrid strategies, and we do not optimize the profits of leasing. We decide on the leasing fees to offer through an analytical model rather than an optimization model. Hence, this model cannot make conclusions about the profitability of the leasing option. In other words, if the model finds that offering leasing is less profitable than not, it should not mean that it is never profitable. It should rather be interpreted as a warning sign for a manufacturer to improve the offer (or do not offer leasing at all). This easily tractable model suffices to achieve our research goals, as we do not set out to optimize pricing in this thesis, instead, we seek to provide a quick and easy profitability analysis and explicitly show the effects of consumer behavior on the economic performance of leasing.

Through these considerations, we arrive at a clear methodology that is comprised of three main steps to pursue our research goals:

1. Analytically determining the leasing fees to offer, through a comparison of the profits per machine made in the leasing and selling cases.
2. Design of a consumer survey, data collection, and analyses to assess consumer behavior and demand for leasing.
3. Incorporating the estimated consumer demand, identification of the best strategy among the alternatives of (i) sales only, (ii) lease only, (iii) hybrid.

Section 3.1. describes the analytical model, Section 3.2. states our hypotheses. Sections 3.3-3.6 explain the data collection and analyses, and Section 3.7 presents the calculation of the total profits and the determination of the best strategy for the manufacturer.

3.1 Analytical Model

For the analytical model, we take van Loon et al. (2017) as an example. Their model calculates and compares the net present values of selling and leasing products with a fixed lease duration. They assume that the products can be leased until the physical end-of-life is reached, after n leases. We modify it to include two leasing periods per machine, i.e., $n = 2$, with each leasing period lasting t months. Assuming two leasing periods provides the simplest way of achieving our research goals: it affords us to compare the profits from a new versus a used machine without adding any unnecessary complexity. It is straightforward to adapt the model to include more leasing periods, or to use it for different types of products. Moreover, this analytical model is relevant and realistic, considering the actual decision that a manufacturer must take before offering leasing: how to determine the leasing fees to offer? Figure 3.1 visualizes the costs, revenues of the manufacturer per machine and their occurrences in sales and lease systems.

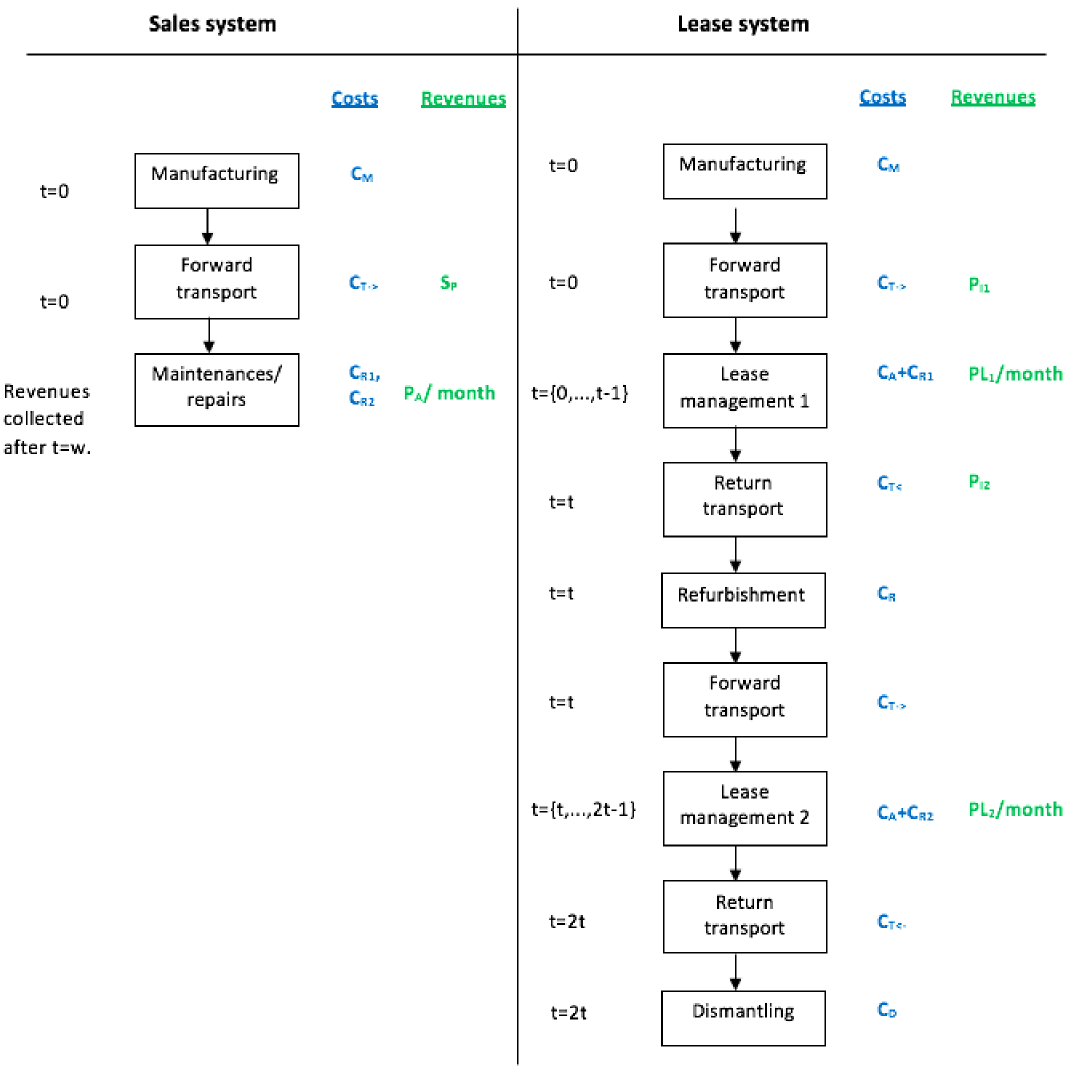


Figure 3.1: Costs, revenues and their occurrences in the sales and lease system (adapted from Figure 2 in van Loon et al., 2017)

In the sales system, the machine is manufactured and transported to the customer's house when it is sold at the sales price S_P. The manufacturer bears the costs of manufacturing C_M and forward transportation $C_{T\rightarrow}$. The machine has a limited warranty period, w, during which the repairs and maintenances are handled and paid by the manufacturer, costing C_{R1} and C_{R2} on the average when the machine is new and used, respectively. C_{R1} and C_{R2} are calculated as the monthly failure rate, multiplied by the average cost of repairs. After the warranty period, the costs of maintenances and repairs are paid by the customer and hence are a source of revenue for the manufacturer, amounting to P_A per month on the average. P_A is calculated as the monthly failure rate multiplied by the average revenue from repairs.

In the lease system, the machine is leased twice and each leasing duration lasts t months, hence the lifespan of the machine is $2t$ months. Similar to the sales system, the machine is manufactured and transported by the company. At the start of the leasing period, the customer needs to pay a deposit P_{I1} and P_{I2} in the first and second leasing periods, respectively. The deposit is returned when the machine is back at the company at the end of the leasing period. During the lease periods, the manufacturer receives the monthly leasing fees (P_{L1}, P_{L2}) and pays the lease management costs (C_A) and maintenance and repair costs (C_{R1}, C_{R2}). We assume different maintenance and repair costs per month (C_{R1}, C_{R2}) for the two periods due to depreciation. However, the monthly cost of lease administration, C_A , which also includes the credit checks and financial costs, is the same in both periods. This is another difference from van Loon et al. (2017): they differentiate between the costs, while we include them together under the same cost structure for simplicity. At the end of both leasing periods, the machine is returned and the costs of return transportation ($C_{T\leftarrow}$) are covered by the manufacturer. After the first lease, the machine needs to be refurbished by the company at the cost of C_R. After the second lease, the machine reaches the end of its lifetime and needs to be dismantled at the cost of C_D. The notation is given below in Table 3.1.

In Sections 3.1.1 and 3.1.2, we calculate the total discounted costs, revenues and profits in each system, by discounting with a monthly discount factor, α, based on the monthly discount rate DR:

$$\alpha = \frac{1}{1 + DR}$$

Table 3.1: Notation of costs and revenues in sales and lease systems, per machine.

Notation	**Explanation**
t	Leasing duration (in months)
w	Warranty period (in months)
Costs	
C_M	Manufacturing cost
C_R	Refurbishment cost
$C_{T\rightarrow}$	Forward transportation cost
$C_{T\leftarrow}$	Return transportation cost
C_{R1}	Monthly average costs of maintenances and repairs during $t = (0, t]$
C_{R2}	Monthly average costs of maintenances and repairs during $t = (t, 2t]$
C_A	Monthly lease administration costs
C_D	Dismantling cost
Revenues	
S_P	Sales price
P_{I1}	Deposit for the first leasing period
P_{I2}	Deposit for the second leasing period
P_{L1}	Monthly leasing fee for the first leasing period
P_{L2}	Monthly leasing fee for the second leasing period
P_A	Monthly average revenues from maintenances and repairs

3.1.1 Lease System

For the lease system, the model accounts for imperfect collection and refurbishment rates, with c as the collection rate and r as the refurbishment success rate. We assume the refurbishment success rate and cost to be constant, i.e., independent of the age of the product.The discounted cost of leasing a new machine in the first period is:

$$TC_{Lease1} = C_M + C_{T\rightarrow} + \frac{1-\alpha^t}{1-\alpha}(C_A + C_{R1}) + c.\alpha^t.C_{T\leftarrow}$$

The manufacturing and forward transportation occur at the start of the period ($t = 0$), hence are not discounted. The lease management costs are attributed to the start of each month, and the calculation during $t = \{0, ..., t-1\}$ follows from setting $S = \sum_{i=0}^{t-1} \alpha^i$ and observing that:

$$S - \alpha S = \sum_{i=0}^{t-1} \alpha^i - \sum_{i=1}^{t} \alpha^i$$
$$S(1-\alpha) = 1 - \alpha^t$$
$$S = \frac{1-\alpha^t}{1-\alpha}$$

The return transportation costs occur at $t = t$ for the machines that were returned (c). The discounted cost in the second period is the same as in the first period, except that it occurs for the machines that were collected and refurbished ($r.c$), and at the end of the two periods ($t = 2t$), the machines that were collected are dismantled. Hence, the total discounted cost of leasing one washing machine in two periods to two customers is:

$$\begin{aligned} TC_{Lease} = & C_M + C_{T\rightarrow} + \frac{1-\alpha^t}{1-\alpha}(C_A + C_{R1}) + c.\alpha^t.C_{T\leftarrow} + \\ & + r.c.\alpha^t \left[C_R + C_{T\rightarrow} + \frac{1-\alpha^t}{1-\alpha} \left[C_A + C_{R2} + c.\alpha^t.(C_{T\leftarrow} + C_D) \right] \right] \end{aligned}$$

Revenues for the lease system are calculated similarly, monthly leasing fees P_{L1} and P_{L2} are collected during $t = \{0, ..., t-1\}$ and $t = \{t, ..., 2t-1\}$. A deposit (P_{I1} and P_{I2}) is paid at $t = 0$ and $t = t$ by the customer, and it is returned at $t = t$ and $t = 2t$ for the machines that were collected (c). This results in the total discounted revenue of leasing one washing machine in two periods as:

$$TR_{Lease} = (1 - c.\alpha^t).P_{I1} + \frac{1-\alpha^t}{1-\alpha} P_{L1} + r.c.\alpha^t \left[(1 - c.\alpha^t) P_{I2} + \frac{1-\alpha^t}{1-\alpha} P_{L2} \right]$$

Consequently, the net present value of leasing one washing machine in two periods to two customers, dependent on the monthly leasing fees is found as:

$$\begin{aligned} NPV_{Lease}(P_{L1}, P_{L2}) = & (1 - c.\alpha^t) P_{I1} + \frac{1-\alpha^t}{1-\alpha} P_{L1} + r.c.\alpha^t \left[(1 - c.\alpha^t) P_{I2} + \frac{1-\alpha^t}{1-\alpha} P_{L2} \right] \\ & - C_M - C_{T\rightarrow} - \frac{1-\alpha^t}{1-\alpha}(C_A + C_{R1}) - c.\alpha^t.C_{T\leftarrow} \\ & - r.c.\alpha^t \left[C_R + C_{T\rightarrow} + \frac{1-\alpha^t}{1-\alpha}.(C_A + C_{R2}) + c.\alpha^t.[C_{T\leftarrow} + C_D] \right] \end{aligned}$$

3.1.2 Sales System

In the sales system, the total cost of selling one washing machine is comprised of the manufacturing, forward transportation and maintenance and repair costs. The discounted total cost of selling one washing machine is calculated as:

$$TC_{Sales} = (C_M + C_{T\rightarrow}) + \left(\frac{1-\alpha^t}{1-\alpha}C_{R1} + \frac{\alpha^t - \alpha^{2t}}{1-\alpha}C_{R2}\right)$$

Apart from the selling price, the company also has the maintenances and repairs as a source of revenues in the sales system, since the customer has to pay for these after the warranty period. Therefore, the total discounted revenue of selling one washing machine is given by:

$$TR_{Sales} = P_S + \left(\frac{\alpha^w - \alpha^t}{1-\alpha}P_{A1} + \frac{\alpha^t - \alpha^{2t}}{1-\alpha}P_{A2}\right)$$

Consequently, the net present value of selling one washing machine is written as:

$$NPV_{Sales} = P_S - (C_M + C_{T\rightarrow}) + \left[\left(\frac{\alpha^w - \alpha^t}{1-\alpha}P_{A1} + \frac{\alpha^t - \alpha^{2t}}{1-\alpha}P_{A2}\right) - \left(\frac{1-\alpha^t}{1-\alpha}C_{R1} + \frac{\alpha^t - \alpha^{2t}}{1-\alpha}C_{R2}\right)\right]$$

In this analysis, we take the parameters of the sales system as given and aim to determine the values of monthly leasing fees P_{L1},P_{L2}. Here, the manufacturer can choose to either have the same value of profits from leasing to sales or to have more/less profits per machine. Therefore, we define Δ as the ratio of NPV of lease to NPV of sales. In other words, Δ denotes the level of profits on which the manufacturer is willing to accept for leasing a washing machine, in comparison with selling the machine.

$$NPV_{Lease}(P_{L1}, P_{L2}) = \Delta.NPV_{Sales} \tag{3.1}$$

The decision to use Δ instead of simply equating the NPV_{Lease} to NPV_{Sales} is made also for the sake for the sake of the statistical analyses of the data from the survey (See Section 3.2.). To differentiate between P_{L1} and P_{L2}, we assume a ratio, β, due to the depreciation of the machine:

$$P_{L2} = \beta.P_{L1} \tag{3.2}$$

β is calculated simply by using the diminishing value method for the depreciation of the machine. Every year, the machine has a start value and it depreciates by a percentage of its start value, and it has a residual value at the end of the year. We calculate the start and residual values per year over the expected lifetime of the machine and find the average values per leasing period (i.e., during $t = (0, ..., t]$ and $t = (t+1, ..., 2t]$). Then, β is the ratio of the average value of the machine in leasing period 2 over that in leasing period 1. In other words, this means that the manufacturer prices the washing machines according to their average values during the times that they are leased. Finally, we choose the leasing fee levels P_{L1}, P_{L2} by taking all other parameters as exogenous to the model and simultaneously solving the equations 3.1 and 3.2.

Using data from a European white goods manufacturer, we calculated several P_{L1},P_{L2} pairs, dependent on the value of Δ. Table 3.2 presents these pairs. Appendix A shows the input values we took for the calculations, and Appendix B explains the calculation of the depreciation rate, β.

3.2 Hypotheses

Prior to describing our survey design and data analyses, in this section, we state our hypotheses resulting from the previous learnings in the literature.

Understanding the decision-making structure of consumers is a crucial first step to explaining the consumer behavior and demand for different alternatives. The marketing literature has shown that consumers follow hierarchical processes in some situations. For instance, when shopping for peanut butter, some consumers (especially the “hardcore loyals”) first decide on the brand and then on the type of product (e.g., crunchy or smooth) (Kamakura, Kim, & Lee, 1996). This exemplifies a “nested decision-making process” where the consumer makes her choice by first choosing her favorite nest and then choosing her favorite alternative among the chosen nest, rather than evaluating all alternatives separately at once. It may be detrimental to the demand predictions to neglect the patterns in the decision-making structure (Kamakura et al., 1996), hence we check for the potential nested structure in decision-making. In our case, we find two behaviorally interpretable models: (i) nests per product condition, (ii) nests per the business model. To the best of our knowledge, this thesis is the initial step to understand consumer behavior towards repeated leasing, and we were unable to find studies in the literature that suggests a nested structure in repeated leasing. We thus hypothesize that:

Hypothesis 1. *Consumers follow a compensatory decision-making structure and evaluate all alternatives separately at once.*

After understanding the decision-making structure, it follows to find out the potential influencing factors in the decision. In our design, we manipulate the leasing fees (for both the new and used machine options) while keeping the retail price fixed and observe the changes in demand for leasing versus purchasing. Following from general economic theory, we expect the price of the alternative to negatively affect the demand for it.

Hypothesis 2. *Price of an alternative is a significant factor in the decision and it is inversely related to the demand for the alternative.*

In this thesis, we investigate the consumer preferences between leasing and purchasing and the potential market segmentation. Our hypothesis on heterogeneity in consumer preferences is based on the learnings from two strands of literature: (i) the CLSC research on consumer preferences of remanufactured products, (ii) marketing research buying patterns in the automobile industry. As discussed in the literature review, for remanufactured products, recent research has shown that consumers were heterogeneous in their preferences with a segment strongly preferring new products, and another roughly indifferent between new and remanufactured products (Abbey, Blackburn, & Guide, 2015; Guide Jr & Li, 2010). Considering the three alternatives of leasing new, leasing used, and purchasing new products in our survey design, we would expect consumers to differ in their preferences between leasing new or used products. To understand the consumer choice for leasing versus purchasing new products, we rely on the marketing literature. In a study examining consumer personality and buying patterns for automobiles, Parmer and Dillard (2015) found that about 10% of consumers lease new cars for a fixed duration, instead of purchasing. This finding also suggests heterogeneity in consumer perceptions towards leasing new products and purchasing new products. In the light of these two learnings from the literature, we hypothesize that:

Hypothesis 3. *Consumers are heterogeneous in their preferences between leasing and purchasing (new or used) washing machines.*

We move on to the potential factors that may affect consumer valuations and drive the segmentation. Disgust, pride of ownership and perceived convenience of leasing are strong psychological antecedents that may influence consumer perceptions of leasing washing machines (See Chapter 2). Hence we expect that:

Hypothesis 4a. *Disgust is a significant factor in the consumer decision to purchase or lease (new or used) washing machines.*

Hypothesis 4b. *Pride of ownership is a significant factor in the consumer decision to purchase or lease (new or used) washing machines.*

Hypothesis 4c. *Perceived convenience of leasing is a significant factor in the consumer decision to purchase or lease (new or used) washing machines.*

Note that Hypotheses 4a-4c do not make claims on the trade-off between disgust, pride of ownership and convenience of leasing. To our knowledge, these factors have not been analysed in the same context in the literature. We therefore are yet unable to comment on the trade-off between these three factors.

Leasing may be regarded as a more affordable option than purchasing since it avoids the upfront retail cost. In a pilot study of leasing baby prams, the participants expressed that they liked the opportunity to access high-end brands without paying the high selling prices (Catulli et al., 2013). Durgee and O'Connor (1995) noted that the largest group of leasers came from lower-income groups. Other researchers have warned that attracting the lower-end consumers with low credit ratings may pose higher risks to the company (Bardhi & Eckhardt, 2012; van Loon et al., 2017). Thus, we asked for the respondent's income and the price they paid for their current machine (if they owned one), and we hypothesize that:

Hypothesis 5. *Consumers who prefer to lease come from lower-income groups that have paid lower prices for their current machines.*

Lastly, we asked the respondents' ages in our survey. In addition to interpreting the degree to which our sample matches the overall U.S. population, we examined if the consumers' leasing behavior was affected by their age. There is conflicting evidence in the literature about the effect of age in preferring leasing. With the development in technologies and the success of sharing/leasing systems, ownership may not be as important anymore for the young affluent consumers as it was for their parents (Durgee & O'Connor, 1995), which implies a higher likelihood of leasing a washing machine for younger consumers. On the other hand, the psychology literature has suggested that disgust sensitivity decreases as people age (Quigley et al., 1997), thus the younger the consumer is, the more disgusted he would feel towards repeated leasing. In the case of automobile buying patterns, even though the mean age of participants who lease their cars were lower than the ones who purchase, the effect of age was not found statistically significant (Parmer & Dillard, 2015). Thus, from the literature, we are unable to formulate a hypothesis on the effect of age and we simply hypothesize that age is insignificant.

Hypothesis 6. *Age does not have a statistically significant effect on the decision to lease* *or purchase a washing machine.*

In the next sections, we explain the survey design, the data collection, and analyses used to test our hypotheses.

3.3 Survey Design

We designed a consumer survey to gain an empirical understanding of the consumer acceptance of circular business models and the drivers behind the consumer behavior. The survey included a mix of discrete choice experiments (DCE) and queries to assess the antecedents of the respondents' choice. We utilized discrete choice experiments (DCE), a common consumer behavior elicitation technique in the marketing literature. In DCE-type questions, the respondent is given a set of alternatives and is asked to choose his/her favorite. DCEs were preferred over other techniques such as attractiveness ratings due to their higher resemblance of a realistic choice making process. Additionally, DCEs rely on a psychological theory of choice making mechanism, as suggested and analyzed by the Multinomial Logit Model (MNL) and its variants (Louviere, Hensher, & Swait, 2000; Louviere, Flynn, & Carson, 2010).

In the survey, the respondents were asked to imagine that they needed a washing machine, and after reading an information page about the leasing scheme, they were requested to make decisions between three alternatives as (i) purchasing a new washing machine, (ii) leasing a new washing machine at a monthly leasing fee P_{L1}, (iii) leasing a used washing machine at a monthly leasing fee P_{L2}. A "none of the above" option was also added to all choice sets as the status quo alternative. Each respondent answered seven discrete choice questions, where the leasing fees (P_{L1} and P_{L2}) were manipulated and all other attributes were kept fixed. Each choice situation corresponded to a Δ level, i.e., the ratio of profits from selling versus leasing a washing machine (See Section 3.1). In the dataset, the prices of different alternatives must be comparable, which is not possible in monetary values since the leasing alternatives include a monthly fee whereas the purchasing alternative requires an upfront retail price to be paid. Thus, to have a meaningful comparison between the prices of leasing and purchasing, we took the manufacturer's point of view as explained in Section 3.1, and compared the net present values of selling one washing machine to leasing one washing machine in two periods. We define the ratio of NPV_{sales} to NPV_{lease} as the "price level" and code the price attribute of leasing new as the price level while the sales price is simply coded as 1. We selected seven levels as 0.25, 0.5, 0.75, 1, 1.25, 1.5, 1.75, with each of the seven choice situations accounting for one level. That is, the company makes the same NPV of profits when the price level is 1 and makes half the profits from leasing than selling when the level is 0.5, etc.

The leasing fee levels we used in the discrete choice situations are presented in Table 3.2. By manipulating the leasing fees, the survey accounted for the effects of price. All respondents were given the same questions in the same order: from the lowest price for leasing to the highest. Another important point in the survey design is that the discount for the used machine was fixed. As Appendix B explains, β was calculated as 0.5. Hence, in all choice situations, leasing a used machine was 50% cheaper than leasing a new machine.

Aside from the economic factors, we aimed to understand the psychological factors affecting the consumer's decision between leasing and purchasing. From the literature, the possible underlying factors were identified as disgust, pride of ownership, and perceived convenience of leasing. Consequently, we added 12 statements into the survey, each relating to one of the

Table 3.2: Prices asked in discrete choice questions

Choice Situation	Price level Δ	Purchasing a new machine	Leasing a new machine	Leasing a used machine
1	0.25	$800	$13.00/month	$6.50/month
2	0.5	$800	$14.50/month	$7.25/month
3	0.75	$800	$16.00/month	$8.00/month
4	1	$800	$17.00/month	$8.50/month
5	1.5	$800	$18.50/month	$9.25/month
6	1.75	$800	$20.00/month	$10.00/month
7	2	$800	$21.00/month	$10.50/month

aforementioned psychological factors, and asked the respondents to rate their views on these statements on a Likert scale of 0 (not agree at all)-10 (totally agree). For instance, a statement to measure the feelings of disgust read: "I would never use laundromats or a shared washing machine, I think they are dirty." A score of 10 means that the respondent highly agrees with this statement, i.e., feels very disgusted towards shared machines.

Finally, to get additional insights into the current segmentation in the market and which segments are more likely to adopt circular business models, the survey also included questions about the brand and model of the respondent's current washing machine (or if they use laundromats) and the price they had paid for it. We checked for the respondents' familiarity with leasing by asking if they had leased any consumer product before (other than an apartment). They were also asked to give basic demographical information such as age and income. The complete survey is given in Appendix C.

3.4 Data Collection

We used Qualtrics online software to design the survey and Amazon Mechanical Turk (MTurk) to collect survey data. Qualtrics is a private market research company that offers online subscription software to conduct survey research, collect and analyze data (Qualtrics, 2018). MTurk is an online platform run by Amazon that brings "requesters" (task creators) and "workers" (paid task completers) together for tasks that require human intelligence (Human Intelligence Tasks or HITs) and cannot be fulfilled by computers (Buhrmester, Kwang, & Gosling, 2011; Turk, 2018). It has become increasingly popular among researchers for the immediate and inexpensive access it provides to a large subject pool of over 500,000 workers (Lee, Seo, & Siemsen, 2018), and has been the most commonly used crowdsourcing website for behavioral experiments since its introduction in 2005 (Mason & Suri, 2012; Lee et al., 2018).

There are several steps involved in the use of MTurk for experiments: The requester designs and creates the job with a description of the task and the amount that the worker will be paid for taking the HIT. She also determines the number of workers required to take the task, i.e., the number of participants needed, and has the choice of filtering the workers based on their demographics or qualifications. When workers accept the HIT, they are directed to the related interface of the experiment (such as Qualtrics), which presents them the instructions and records their data. After completing the task, workers are redirected to the MTurk website to submit their work. Once the predetermined number of data points is reached, MTurk removes the task from the list of available HITs at the moment, and the requester can download the collected data. Upon the completion of the data collection, the requester has an option to reject and erase data points with poor quality, in which case the worker does not receive payment for the task. Rejections also affect workers' score, which is calculated by the total number of accept/rejects they have collected. Before accepting a requester's HIT, workers can read reviews and ratings about the requester on the Turkopticon website. These ratings and reviews are posted by other workers who have previously taken a HIT of the requester, on such criteria as fair payment, accept/rejection speed, etc.

The major strengths of MTurk for experimenters lie in the high speed and low cost of data collection. HITs are usually completed within hours, and in our case, we reached 925 respondents in 2.5 hours. Compared to other traditional ways of running surveys, this speed is a major advantage for researchers. Moreover, it comes at a low cost: MTurk workers find a wage of $6 per hour acceptable (Hunt, 2015), while lower payments do not seem to harm data quality, only to decrease the speed of data collection (Buhrmester et al., 2011; Mason & Watts, 2009). For every accepted data point, a commission of $0.40 is paid to Amazon. Our survey was made visible only to the respondents based in the U.S., each of whom received $0.60 each for an average completion time of 4.82 min.

In addition to high data collection speed at a low cost, use of MTurk can help alleviate a sampling problem that has troubled the research for a long time: the samples from traditional studies consisting mainly of Western, educated, industrialized, rich, and democrat (WEIRD) participants (Landers & Behrend, 2015). MTurk has workers from 190 countries and from various income groups, which creates an advantage of a demographically more diverse subject pool than of a typical university subject pool (Lee et al., 2018) as well as other Internet samples (Buhrmester et al., 2011). Nevertheless, it is worth noting that 90% of this pool is based in the U.S. or in India (Ross, Zaldivar, Irani, & Tomlinson, 2009), and although technically possible, employing workers from other countries would require a longer time for data collection.

Skeptics of MTurk often question the quality of data collected. The concern is that respondents might be inattentive since they are unsupervised and anonymous, in contrast with participants in more traditional experiments. Also, given that workers are usually paid little, one might question if they take experiments seriously. However, there is little evidence for poorer data quality: both for Internet samples in general, and for MTurk samples in particular (Buhrmester et al., 2011). On the contrary, several studies found MTurk workers to be attentive to instructions: Paolacci, Chandler, and Iperirotis (2010) stated that MTurk workers pay attention to the tasks at least as much as the participants of traditional experiments, while Buhrmester et al. (2011) found that the quality of data from MTurk subjects exceeds the limits for psychometric research. More recently, Lee et al. (2018) used MTurk to replicate behavioral experiments from the literature. They compared MTurk workers with traditional participants on the showing the effects of individual biases and concluded that the biases were successfully reproduced, but the learning process in the experiments that required learning was slower for MTurk participants. This is not a concern for our study since our survey does not involve a learning process.

After designing the survey, we first ran a test by publishing the HIT to 400 workers. It became apparent that one of the statements that was meant to relate to the pride of ownership was not clear to the workers, and the ratings collected did not correlate with the other pride of ownership queries. We, therefore, reframed the statement in the final version of the survey.

Additionally, the first design of the survey included a statement as an attention check to make sure that the respondent has carefully read the information on the first screen and was well-informed about the leasing model. The statement read: "If you lease a washing machine you need to pay for maintenances yourself." It was expected from an attentive respondent to rate this question 0. However, since the instruction for all 13 statements asked the respondents to "rate how much they agree with the statements", it was realized after the test run that the respondents had understood the question to be about their *personal views on how it should be* instead of *how the leasing system works.* As a consequence, the attention check was found invalid, and it was removed from the final version of the survey.

Instead of an attention check, we manually inspected the answers of the respondents to the DCE-type questions and rejected workers with unreasonable answer patterns. Namely, responses were deleted if they presented one (or more) of the following patterns:

- The respondent chooses to purchase a new machine (alternative A) in the first discrete choice situation, but then switches to leasing (alternatives B or C) in the following questions: This pattern is illogical because in the survey the sales price was kept fixed and while the leasing fee was increased from one question to the next. That is, the DCE-type questions were presented from the lowest leasing price to the highest. Therefore, we expect from an attentive respondent who chooses to purchase even when the leasing prices are low to continue with his choice when the leasing prices are increased.

- The respondent switches back to his previous choice: It is reasonable for a respondent who chooses to lease (alternatives B and C) in the first DCE set to switch to purchasing (alternative A) when the leasing prices are increased. However, it is irrational to switch back to his previous choice (leasing) at any later point when the leasing fees are even higher.

- The respondent has clear answer patterns such as repetitive A-B-C's: This response pattern signals reckless respondent behavior.

It is advised in the literature to use the response time along with the response pattern for attention checks (Meade & Craig, 2012; Abbey & Meloy, 2017). We eliminated the workers who have completed the task in less than 100 seconds. The average response time was 290 seconds and it does not seem plausible for a worker to have carefully read and completed the survey in less than 100 seconds. In the end, responses from 852 workers were accepted.

3.5 The Data and Descriptive Statistics

For the 852 respondents, the data includes the choices each respondent made in the seven discrete choice situations that s/he faced, and the price as the only alternative specific attribute, coded as the price levels Δ. At all price levels, the overall choice frequencies for the alternatives were 54.35%, 10.26%, 34.45% and 0.9% for purchasing a new machine (alternative A), leasing a new machine for 5 years (alternative B), leasing a used machine for 5 years (alternative C), and none (alternative D), respectively.

In addition to the DCE-type questions, the respondents also rated on a scale of 0-10 how much they agreed with 12 statements relating to feelings of disgust, perceived convenience of leasing and pride of ownership. After running a confirmatory factor analysis (See Section 3.6.1), the ratings to the statements that were statistically proven to be in the same factor were used to calculate average scores of feelings of disgust, perceived convenience of leasing and pride of ownership for each respondent. The average scores for the total sample were 3.14 for feelings of disgust, 5.12 for the perceived convenience of leasing, and 5.66 for the pride of ownership.

The data also included relevant demographic information of the respondents such as location, age and annual household income. All respondents were based in the U.S. The age of the respondents ranged between 15-84, with the median age of 35. Our sample seems to be younger than the U.S. population that has a median age of 37.7 (US Census Bureau, 2018). There were 4 classes in terms of annual household income: 34.5% of the respondents earn less than \$40,000, 28.8% earn between \$40,000-\$80,000, 17.8% earn between \$80,000-\$120,000, and 8.8% earn more than \$120.000 a year. Our sample is slightly more weighed in the center in comparison with the whole U.S. population: in 2014, the percentages of these classes for the U.S. population were 38.33%, 28.26%, 15.4%, and 18.01%, respectively (US Census Bureau, 2018).

To get an understanding of the current market segmentation and which segments are more likely to adopt leasing, in addition to the average income question, we also asked the participants about the current machine they own and the price they paid for it. In total, 15.2% of the respondents use laundromats, and 10.4% got their washing machine with the apartment they bought/rented. The rest of the respondents paid on average \$612.27, with the price ranging from \$10-\$4500. In terms of the familiarity with leasing, 64.55% of the respondents stated that they had not leased a consumer product before (other than an apartment or a house), while the rest of the sample had leased such products at least once.

3.6 Data Analysis

All data analyses explained below were coded and run on **R** statistical software. We firstly ran a confirmatory factor analysis (CFA) to check if the statements in the survey are statistically grouped together under the relative psychological factor. We discuss this analysis in Section 3.6.1. Using the results of the CFA, we used the ratings of each individual to calculate disgust, pride of ownership, and perceived convenience of leasing scores, and we modified the data accordingly to run discrete choice models. We explain the Multinomial Logit Models (MNL) and the Nested Logit (NL) models in Sections 3.6.2 and 3.6.3, respectively, to test the potential nested decision-making structure. In Section 3.6.4, we use the Mixed Logit Model (MIXL) to check for taste heterogeneity in the population. Due to space limitations, we report only the models with a satisfactory fit to the data and refer to the Appendix D for a detailed discussion on the other models. These models lead us to Latent Class Multinomial Logit Model (LC-MNL), which identified the distinct segments in the market and satisfactorily predicted the demand, as discussed in Section 3.6.5.

3.6.1 Confirmatory Factor Analysis

We used CFA to ensure that the 12 statements (each relating to one psychological antecedent) were statistically in their relative group. Table 3.3 shows these statements and the relating factors as disgust, pride of ownership, and convenience of leasing. Although the table presents the statements in groups, they were asked in random order in the survey. The statements marked with an asterisk are taken from the survey in Moeller and Wittkowski (2010).

[7] The responses to this statement were coded negatively as 10-rating.

Table 3.3: Statements used in the survey

	Disgust:
1	I would never use laundromats or a shared washing machine, I think they are dirty.
2	I find sharing my belongings with other people disgusting.
3	Knowing that someone has previously used a product that I am using would bother me.
4	I am not the kind of person who would buy a second-hand item, I believe they are contaminated.
	Convenience of leasing:
5*	I would be inclined to consume durable goods, but I am not prepared to pay for maintenance.
6*	Having to think about repair and maintenance of consumer goods can restrict my consumption.
7	I find it tedious having to think about what to do with my possessions that I am not using anymore (e.g., sell on the second-hand market or dispose of).
8	I would rather have the washing machine company take care of the repairs of my machine than having to arrange and pay for it myself every time.
	Pride of ownership:
9*	Possession is important to me.
10	Knowing that an item is "mine" is important to me.
11	To me, it is not the possession of a good that is key, but the consumption of the item.[7]
12	I would prefer to own a product than having access to it without ownership.

Supporting the design, both the scree plot of Eigenvalues and Velicer's MAP test confirmed the use of 3 factors (O'Connor, 2000; Velicer, 1976), we ran a CFA with the 3 factors and used the assignments to groups as given above in Table 3.3. The column "CFA 1" in Table 3.4 presents the results of this analysis. As can be seen, the results are not satisfactory: the absolute fit indices RMSEA and SRMR are greater than the widely accepted cut-off scores of 0.10 and 0.08, respectively (Hu & Bentler, 1999). Although the Cronbach's alpha values for the three factors were moderately satisfactory (close to the cut-off score of 0.80), the Cronbach's alpha value for the pride of ownership suggested that dropping statement 11 would increase the reliability. Therefore, we tried another model by only including the statements 9,10,12 in the pride of ownership factor (See Column "CFA 2"). The fit has improved: with RMSEA$<$0.10, SRMR$<$0.08 and CFI, TLI scores greater than the CFA1 model. However, the standardized loading of statement 12 was 0.568 ($<$0.70), and the Cronbach's alpha for the pride of ownership suggested that it should be dropped from the analysis. This led us to "CFA3", which only includes the statements 9 and 10 in the pride of ownership factor (See Column "CFA3"). The fit of this final model was satisfactory: RMSEA$<$0.10, SRMR$<$0.80, and all loadings were greater than 0.70, as required by Hair et al. (2010). In all models tried, the composite reliability and average variance extracted (AVE) figures were acceptable, with composite reliability greater than 0.70 and AVE less than 0.70 (Hair, Anderson, Tatham, & William, 2010). Consequently, all statements except for 11 and 12 above in Table 3.3 were used to calculate the average disgust, convenience of leasing, and pride of ownership scores.

Table 3.4: Confirmatory factor analyses

Estimates	**CFA1**	**CFA2**	**CFA3**
P-value (Chi-square)	0.000	0.000	0.000
RMSEA [P-val]	0.012 [0.000]	0.090 [0.000]	0.083 [0.000]
SRMR	0.098	0.074	0.061
Comparative Fit Index (CFI)	0.915	0.944	0.959
Tucker-Lewis Index (TLI)	0.890	0.925	0.943
Cronbach's alpha disgust	0.89	0.89	0.89
Cronbach's alpha convenience	0.77	0.77	0.77
Cronbach's alpha pride of ownership	0.80	0.87	0.94
Composite reliability	0.964	0.945	0.945
Average Variance Extracted (AVE)	0.701	0.616	0.635

3.6.2 Multinomial Logit Models

McFadden's (1973) Multinomial Logit Model (MNL) has been the workhorse model of discrete choice analysis since its introduction to the literature. The model assumes that consumers are homogenous in their preferences, and estimates the utility functions from the observed choices via Maximum Likelihood Estimation (MLE) procedure. That is, the values for the utility weights are estimated such that the probability of obtaining the observed choices are maximized.

MNL defines the utility of alternative i to individual q at choice situation t as:

$$U_{itq} = \beta.X_{itq} + \epsilon_{itq}$$

for $i = 1, ..., I, q = 1, ..., Q, t = 1, ..., T$.

where X_{itq} is a vector of observed attributes of alternative i, β is a vector of the utility weights in the population, i.e., the value consumers associate with each attribute in X_{itq}. The X_{itq} may include alternative specific constants (ASC) to account for the unobserved attributes of each alternative i. ϵ_{itq} is the error term, assumed to be an independent and identically distributed (i.i.d.) extreme value. Hence, MNL assumes that the unobserved portion of the utility for one alternative is independent of the unobserved portion of another alternative.

Following from the i.i.d. assumption, the probability that consumer q chooses alternative i at choice situation t is logit and is given by:

$$P(i|X_{qt}) = \frac{exp(\beta.X_{itq})}{\sum_{i'=1}^{I} exp(\beta.X_{i'tq})}$$

where X_{qt} is the vector of attributes of all alternatives $i = 1, ..., I$. Since MNL assumes that the error terms are i.i.d. and preferences are homogenous, it imposes the independence of irrelevant alternatives (IIA) assumption. The IIA assumption implies that the preferences between alternatives x and y depend only on the individual preferences between x and y, and not the other alternatives in the menu. The model is criticized for this restrictive assumption, and while it is still widely used, many models that allow for unobserved taste heterogeneity and/or avoid the IIA assumption have been developed. In the following sections, as appropriate to our data, we discuss Nested Logit Model, Mixed Logit Model, and Latent Class Model. [8]

We use the MNL as a base model to compare with the other models. The first column in Table 3.5 shows the results, taking the "none" alternative (D) as a reference. The results make intuitive sense: price has a negative and statistically significant estimate, as expected. The intercepts for the alternatives suggest that A has the highest probability to be chosen over D, followed by the alternatives C and B. These values are in accordance with the overall choice frequencies: 54.35%, 10.26%, and 34.45% for A, B, and C respectively. The results also show that these choices are driven by the individual characteristics: an increase in the respondent's income, the disgust and pride of ownership scores increase the probability of the respondent choosing alternative A; whereas an increase in the convenience score decreases the probability. In other words, consumers are more likely to purchase if they have more means to afford, if they feel disturbed by used products, value ownership, and do not necessarily find leasing convenient. Similarly, the probability of choosing alternative B is significantly positively affected by an increase in the income, the disgust score and the convenience score. A consumer's probability of leasing used machines (alternative C) is also positively affected by an increase in the income but with a lower effect (and at a lower confidence interval), compared to the alternatives B and C. This is logical considering that C is the most affordable alternative in most cases. Moreover, the consumers who prefer to lease used machines do not experience significant feelings of disgust, find leasing very convenient, and do not necessarily take pride in ownership. In addition, age is only significant for the choice of B at 95% confidence level with a small estimate, signifying that younger respondents have a slightly higher probability of leasing new washing machines.

Finally, observe the high and statistically significant standard error for the disgust factor of alternative A, rendering the goodness of the prediction of this variable open to question. The standard errors for the intercepts of alternatives may seem high at the first glance, but note that the estimates for these intercepts are also high, so the errors are low compared to the estimates. Similarly, the standard error for the disgust factor of alternative C is high but insignificant. This leaves the disgust factor for alternative A as the only variable with an unsatisfactory estimation. We pay special attention to this issue when trying the other models below.

The results of this model highlight that both the price of the alternative and the income of the respondent have significant effects on the consumer's decision. The base model takes these effects separately from each other and includes both as distinct factors. However, it might be the case that rather than having an isolated effect on its own, income affects how much value a respondent attaches to the price of an alternative. That is, respondents might value the prices of alternatives relative to their incomes. To test this idea, we ran another MNL model by coding price relative to income. In terms of the goodness of fit to the data, this model was outperformed by our base MNL model, indicating that income has an isolated significant effect (See Appendix D). Consequently, the MNL model whose results are given in the first column of Table 3.5 is chosen as benchmark for other models below.

3.6.3 Nested Logit Models

The base MNL model assumes that consumers make decisions according to the IIA property, following a compensatory decision process. Put differently, they see and evaluate all alternatives separately at once. However, it might be that consumers follow a hierarchical decision-making

[8] Some other models that avoid the IIA assumption and/or allow for heterogeneity are the generalized extreme value (GEV), the multinomial probit (MNP), the generalized multinomial logit (G-MNL), the scale heterogeneity logit (S-MNL) and the mixed-mixed logit (MM-MNL).

process, that is, the consumer makes smaller decisions in an order rather than a single decision. This type of choices is analyzed by Nested Logit Models (NL). NL assumes IIA for the alternatives in the same nest, and avoids it in general for alternatives in different nests. NL is consistent with utility maximization (Daly & Zachary, 1978; McFadden, 1978; Williams, 1977). Following from the notation presented in Section 3.6.2 for MNL, let the set of alternatives q be partitioned in K nests denoted as $B_1, B_2, ..., B_K$. NL is developed by assuming that the vector of unobserved utility, i.e., the error term ϵ_{itq} in the utility function has a distribution of type generalized extreme value (GEV), with the cumulative distribution:

$$exp\left(-\sum_{k=1}^{K}\left(\sum_{i\in B_k} e^{-\epsilon_{iqt}/\lambda_k}\right)^{\lambda_k}\right)$$

In this specification λ_k is a measure of the degree of independence in unobserved utility among the alternatives in nest k, such that when $\lambda_k = 1$ for all k, the GEV distribution reduces to the product of independent extreme value terms, and the NL becomes standard MNL (Train, 2009).

We have identified two behaviorally interpretable nested decision-making structures. The first one assumes nestedness according to the business model, such that the consumers first decide whether to lease or not. The goodness of fit of this model was not satisfactory in comparison to the benchmark MNL model, as reported in Appendix D.2. Therefore we reject the hypothesis that consumers make hierarchical decisions according to the business model. The second NL model assumes nestedness according to the product condition, such that the consumers first decide on the product condition (new or used) and then the specific alternative among the chosen group. This means that the alternatives are grouped in three nests according to the product condition as: 1. new (alternatives A and B), 2. used (alternative C), 3. none (alternative D). The results of this model are shown in Table 3.5 in column "NL". The results predicted by this model appear reasonable: it estimates the intercept of alternative B lower than the other models, but the estimates for intercepts of alternatives A, B, and C are in line with the overall choice frequencies of these alternatives. Also note that the standard error of disgust factor for alternative A compared to its estimate has decreased. Furthermore, the log likelihood and AIC scores suggest that NL explains the data better than the MNL. This claim is supported by the likelihood ratio test at the 99% confidence interval ($\chi^2 = 6.68 > 3.841$, Δdf=1). Therefore, we reject **Hypothesis 1**, that the consumers follow a compensatory decision-making process as implied by the MNL, and conclude that the decision-making structure is nested with respect to the product condition.

3.6.4 Mixed Logit Models

In order to test the hypothesis that there is heterogeneity in consumer preferences, we relax the condition of the base MNL models and switch to a mixed logit model (MIXL). MIXL overcomes the homogeneity assumption of MNL by allowing the taste parameters, β_q, to be randomly distributed across individuals. To achieve this, the model requires an assumption for the random distribution, and a simulation method.[9] In our case, we first need to assume a reasonable random distribution for the price parameter. Normal, lognormal, triangular, and uniform distributions are the most common in practice (Hensher & Greene, 2003; Keane & Wasi, 2013). The selection of the distribution is dependent on the nature of the parameter

[9]For a good intuitive explanation to these requirements, see Hensher and Greene, 2003.

and the researcher's expectations of it. Observing the choice frequencies, as 51% of our sample chose to purchase, we expect a large group of consumers to be similar in their choices and hence, probably also in their valuations of price. This large group would have a big effect on the mean, and their data points would be located around the mean. In addition, our base models MNL and NL predict low standard errors for the price parameter, indicating a low standard deviation. Therefore, we would expect to be mainly centered around the mean and with fewer data points along the tails. Triangular and uniform distributions have large standard deviations. The lognormal distribution is useful when the response parameter is non-negative, while our price parameter must be negative. Finally, the normal distribution appears as a good candidate for the price parameter.

The simulation can be done by draws of pseudo-random points or Halton (i.e., intelligent) sequences which use non-random more uniformly distributed sequences instead of pseudo-random points (Hensher & Greene, 2003). Train (2000) compared the uses of these methods and found the simulation variance in the estimated parameters to be lower using 100 Halton numbers than 1000 random numbers. Bhat (2003) also measured their relative performances and agreed with the results of Train (2000)[10] We therefore use Halton sequences to simulate the price parameter.

Lastly, the number of draws to use for the simulation needs to be determined. In the literature, using 100 Halton draws was suggested to be enough to simulate a choice model with three alternatives and one or two random parameters (Hensher & Greene, 2003). Although our model is close to these specifications, including four alternatives and one random parameter, it is always the best practice to run models over a range of draws to ensure that the estimates stabilize (Hensher & Greene, 2003). So, we estimated the MIXL model with 50, 100, 200, and 500 Halton draws. We report the results in Appendix D, Table D.2. It seems that the estimates stabilize after $n = 300$, which is selected as the MIXL model to compare with the other models.

Analyzing the results of MIXL in comparison with our benchmark MNL model, we see that they produce similar insights, although the parameter estimates in MIXL are amplified to a degree. As for the intercepts of the alternatives, MIXL appears to estimate the choice of alternative B closer to alternative C, i.e., a smaller difference between the estimates of the alternatives. Considering the choice frequencies 10.26% and 34.45%, we would expect the estimates of the intercepts to differ more, as in the MNL model. However, the standard errors remained approximately the same while the estimates increased, thus, compared to the MNL, the MIXL model estimates the data with lower standard errors relative to its estimates. This signifies a better model fit, which is also supported by the log likelihood values, the AIC scores, the BIC scores. The results of the LRT also confirm this claim at a 0% level of significance ($\chi^2 = 1695.3 > 10.828$, Δdf=-1) . We therefore fail to reject **Hypothesis 3**, and conclude that consumers are heterogeneous in their choices between leasing and purchasing new or used washing machines.

Some estimates differ from the estimates of the MNL model in terms of significance. First, the estimates and standard errors of the disgust factor are significant also for alternative C, though with a smaller estimate than for A and B. Though it seems strange at the first glance, note that the estimate needs to be interpreted relative to the "none" alternative. Second, the pride of ownership score is only significant for alternative A, signifying that pride of ownership is only important in the decision for consumers who purchase. Lastly, the effect of age is significant

[10] A detailed explanation of how Halton sequences achieve better estimation in shorter time can be found in Hensher and Greene (2002).

for all consumers who choose to lease (alternatives B or C), suggesting that younger respondents in the sample are significantly more likely to lease. In conclusion, all of these observations from the MIXL model make intuitive sense.

Table 3.5: Results of base models (Bold estimates are statistically significant at 5% or less.)

	MNL		**NL**		**MIXL**	
	Estimate	Std.Error	Estimate	Std.Error	Estimate	Std.Error
A (intercept)	**4.818**	0.633	**5.208**	0.702	**9.981**	0.826
B (intercept)	**1.757**	0.665	1.009	0.823	**6.326**	0.834
C (intercept)	**2.829**	0.630	**3.011**	0.689	**6.709**	0.773
Price	**-1.323**	0.094	**-1.738**	0.186	**-3.745**	0.145
A: income	**0.654**	0.185	**0.653**	0.178	**1.805**	0.211
B: income	**0.641**	0.189	**0.645**	0.187	**1.763**	0.214
C: income	**0.461**	0.185	**0.457**	0.178	**1.493**	0.203
A: disgust	**0.328**	0.806	**0.320**	0.125	**0.820**	0.180
B: disgust	**0.456**	0.081	**0.508**	0.127	**0.955**	0.179
C: disgust	0.129	0.809	0.135	0.125	**0.631**	0.173
A: ownership	**0.147**	0.049	**0.162**	0.065	**0.206**	0.086
B: ownership	**-0.115**	0.052	**-0.195**	0.075	-0.107	0.086
C: ownership	**-0.113**	0.049	-0.121	0.065	-0.137	0.081
A: convenience	**-0.329**	0.063	**-0.356**	0.062	**-0.289**	0.083
B: convenience	**0.195**	0.066	**0.342**	0.094	**0.377**	0.084
C: convenience	**0.265**	0.063	**0.281**	0.062	**0.484**	0.080
A: age	-0.019	0.011	-0.018	0.012	-0.029	0.019
B: age	**-0.028**	0.011	**-0.032**	0.013	**-0.044**	0.019
C: age	**-0.015**	0.011	-0.016	0.012	-0.032	0.018
iv			**1.412**	**0.173**		
sd.price					**5.099**	0.166
LL	-4396		-4392		-3548	
McFadden R^2	0.244		0.245		0.390	
AIC	8830		8822		7354	
BIC	8957		8854		7660	

Having concluded that consumers are heterogeneous in their preferences, in the next section, we use Latent Class models to gain a deeper understanding into the drivers of heterogeneity.

3.6.5 Latent Class Model

The Latent Class model (LC-MNL) is useful for understanding the structure and causes of heterogeneity in the dataset (Keane & Wasi, 2013) and have often been used in the marketing literature instead of random parameter formulations (Louviere et al., 2000). LC-MNL models are similar to MNL with a discrete number of segments with distinct preferences. As opposed to the MIXL which requires a continuous distribution, LC-MNL assumes that a discrete number of points (say, S) are enough to describe the joint density function. These points are used to characterize the segments with similar preferences (i.e., individuals in segment s having the same vector of taste weights B_s). In other words, LC-MNL assumes heterogeneity across segments and homogeneity within segments.

Given that individual q is in segment s, then, his utility of alternative i at choice situation t is:

$$U_{iqt|s} = \beta_s.X_{itq} + \epsilon_{itq|s}$$

The choice probability is of logit form, written as:

$$P_{iqt|s} = \frac{exp(\beta_s.X_{itq})}{\sum_{i' \in I} exp(\beta_s.X_{i'q})}$$

Finally, with W_{qs} as the probability of individual q belonging to segment s, the unconditional choice probability is: [11]

$$P_{iqt} = \sum_{s=1}^{S} P_{iqt|s}.W_{qs}$$

The latent class models require the number of classes, S, as input, which is determined by information criterion scores of potential models with different numbers of segments. AIC and/or BIC are commonly used for this purpose. Models with lower AIC and BIC scores are preferred for lower complexity and higher fit to the data. Through the process explained in Appendix D.3, we choose the appropriate number of segments, $S = 3$.

Table 3.6 presents the results of LC-MNL with 3 classes. For comparison with previous models, we use the BIC as the primary selection criterion, as it was found to be the most reliable criterion for choosing the correct model for choice data with heterogeneity (Keane & Wasi, 2013; Fiebig, Keane, Louviere, & Wasi, 2010). As can be seen, the BIC score has significantly improved: from 7660 for the MIXL to 5279 for the LC-MNL. Results from other criteria agree: MIXL has a higher log-likelihood score (-2535.4 versus -3557.3) and a lower AIC (5118 versus 7354). The better fit to the data for the LC-MNL implies that it is reasonable to assume that there are 3 distinct classes whose preferences are similar within classes, and different across classes. Since it is the best-fitting one among the models we tried, we use the results of LC-MNL to evaluate the remaining hypotheses.

The results of this model seem reasonable and reliable with low standard errors compared to their estimates. As expected, the price coefficient has a negative coefficient for all classes. Note that this is the same for all models we tried. Using these results, we fail to reject **Hypothesis 2** which predicted the price of the alternative to be a significant factor in the decision and inversely related to demand.

The estimates of alternative specific constants (ASC) for alternative A and C suggest that consumers in Class 1 are most likely to lease a used machine among the given alternatives, followed by the choice of purchasing a new machine. The high and very significant estimate for price signifies a price-sensitive segment which is, as would be predicted, likely to choose the cheapest option (alternative C). This class is used as a reference for class assignment, hence its estimates are normalized and not reported. Firstly, observe that all psychological factors are significant (shown in bold) for class membership, i.e., the consumers are segmented based on

[11] See Swait (1994) for the estimation procedure of an individual's membership to a class.

Table 3.6: Results of LC-MNL with 3 classes: Bold estimates are statistically significant at 5% or less.

	Class 1		**Class 2**		**Class 3**	
	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
			I. Mean and standard deviations			
Price	**-5.671**	0.452	**-2.033**	0.232	**-6.751**	0.713
ASC A	**7.145**	0.478	**6.220**	0.751	**12.245**	0.769
ASC B	**4.996**	0.498	**7.910**	0.766	**4.729**	0.403
ASC C	**7.371**	0.363	**4.908**	0.739	**4.339**	0.350
			II. Variables for class assignment			
Constant			**-1.555**	0.244	**1.696**	1.179
Disgust			**0.336**	0.0221	**0.209**	0.017
Convenience			**-0.112**	0.025	**-0.671**	0.021
Ownership			0.022	0.019	**0.274**	0.015
Income			**0.280**	0.049	**0.241**	0.040
Age			**-0.013**	0.004	**-0.011**	0.003
Shares for classes	35.6%		12.7%		51.6%	
LL			-2535.4			
AIC			5118			
BIC			5279			

their valuations of these factors. Recall that **Hypotheses 4a-4c** predicted that disgust, pride of ownership, and convenience of leasing would be influential factors in the decision. Thus we fail to reject **Hypotheses 4a-4c**.

Class 2 is comprised of individuals who most likely prefer to lease a new machine, followed by the option to purchase a new machine. This class is less concerned about the price. Rather, they make decisions based on the individual valuations: they find leasing highly convenient and they are significantly disgusted towards used products, which explains the behavior of shunning used washing machines. From the comments on Classes 1 and 2, we move on to discuss **Hypothesis 5**, which expected that leasing would be more attractive to consumers from lower-income groups. The results of LC-MNL agree with this hypothesis for leasing used machines: the income factor is significant in class membership, with lower-income consumers in Class 1 that prefer to lease used machines. Nonetheless, the class with the highest income, Class 2, prefers to lease new machines. Therefore, the evidence for this hypothesis is mixed: we conclude that leasing used machines are more attractive to consumers from lower-income segments, while the situation is the opposite for leasing new machines.

Class 3 includes consumers with a strong preference for purchasing new washing machines: they take a high pride in the ownership of products and find leasing less convenient than the other classes. The estimates also suggest that the individuals in Classes 2 and 3 are younger than in Class 1. Put differently, younger consumers are more likely to prefer new products (either to purchase or lease) and shun used products due to feelings of disgust. This finding appears to be at odds with the results of other models, but can be explained by younger consumers displaying higher disgust sensitivity, as stated in the psychology literature (Quigley et al., 1997). However, although significant, we also note here that the estimates of the effect are small (around 1%). We thus reject **Hypothesis 6**, which expected for age to not have an important effect on the consumer behavior towards leasing.

The shares for each class in the market predicted by the model make intuitive sense, as they produce values close to the choice frequencies of alternatives. For example, the model estimates that class 1 constitutes 35.6% of the population; this class has a preference for alternative C that had an overall choice frequency of 34.4% in the data. This holds also for the other alternatives and class percentages. To further demonstrate the quality of the model, we calculate the demand it estimates. Following the MNL model specifications, we calculate the demand of each alternative i from each segment s separately as:

$$d_{i,s} = M_s \cdot \frac{exp(U_{i,s})}{exp(U_{0,s}) + \sum_{j=1}^{n} exp(U_{j,s})} \tag{3.3}$$

where M_s is the class probability of segment s and the rest of the equation is the MNL equation for the probability of an individual choosing alternative i. Since LC-MNL assumes that segments are heterogeneous in their preferences, we use the valuations of a segment s instead of an individual. $U_{i,s}$ represents the utility of alternative i for consumers in segment s, and $U_{0,s}$ represents the utility of the outside choice, i.e., alternative D in our case. The utility $U_{i,s}$ is calculated as:

$$U_{i,s} = \beta_{price,s} \cdot price_i + \sum_{j=1}^{n} ASC_{j,s} \cdot Alt_j$$

$\beta_{price,s}$ is the valuation (estimate) of price for segment s and $price_i$ is the price of alternative i. The estimates of ASC's give us the valuations of an alternative for segment s, thus we add it to the utility equation for alternative i. To do this we multiply the ASC with a binary variable, Alt_j, that takes value 1 when alternative $j = i$.

We calculate the demand for each alternative from each segment in each choice situation[12]. Then we take the average demand for the seven choice situations for each segment. Finally, we multiply these averages with the segment sizes (i.e., the shares for classes) and calculate weighted average demands of each alternative from each segment. Summing these weighted demand values, we get the total demands for each alternative estimated by the LC-MNL model. The results are given in Table 3.7 in comparison with the actual choice frequencies. As can be seen, the model is able to predict the demand with low absolute errors around 1%. When we multiply these percentage demands with our sample size, we find that the model falsely predicts the choices of only 25 participants out of 852, hence has a 2.93% absolute percentage error.

Table 3.7: Demand estimated by LC-MNL vs demand observed in the survey.

Alternative	**Estimated % Demand**	**Observed % Demand**	**Abs.% Error**	**% Error**
A	53.88%	54.35%	0.47%	0.86%
B	10.22%	10.26%	0.04%	0.40%
C	33.42%	34.45%	1.03%	2.99%
D	2.37%	0.90%	1.48%	164.38%

[12] Price is coded as 'price level', instead of the monetary values, as in the dataset used for the model estimation.

Notice that the LC-MNL still assumes that consumers follow a compensatory decision process implied by the MNL models, even though the results from the NL models suggest that consumers make nested decisions. Ideally, we could have used a model that accounts for heterogeneity in both the decision-making structure and preference determined by individual characteristics. However, this is computationally troublesome: it requires finite mixture models to be estimated by non-linear optimization methods such as sequential quadratic programming (Kamakura et al., 1996). Although useful for integrating different types of heterogeneities, the use of finite mixture models in market segmentation research are still rare, which also makes it harder to find appropriate packages in data analysis software. In our case, implementing such models was not possible due to time limitations, and the insights gained from other models were found adequate. The results above also show that the LC-MNL model fits the data and predicts the demand reasonably well.

3.7 Calculation of the Total Profits for the Manufacturer

After experimentally assessing the demand, as shown above, LC-MNL affords us to estimate the demand for the different alternatives in the three strategies that a manufacturer can choose: (i) sales only, (ii) lease only, and (iii) hybrid strategy. In this section, using the estimated demand, we calculate the total profits per period in each of these strategies and analytically identify the best strategy among these.

3.7.1 Strategy 1: Sales Only

Under the sales only strategy, the manufacturer only sells machines. In terms of our survey design, the consumer then has two alternatives: "A: purchasing the washing machine at the retail price" or "D: none", and the total profits per period are simply calculated as the multiplication of the demand for sales and the NPV of selling one machine.

$$TotalNPV_1 = NPV_{Sales}.D^1(A)$$

where $D^1(A)$ denotes the total demand for sales in case 1. Following from Equation 3.3, $D^1(A)$ is calculated as:

$$D^1(A) = \sum_{s=1}^{3} d^1_{A,s} = \sum_{s=1}^{3} M_s.\frac{exp(U_{A,s})}{exp(U_{A,s}) + exp(U_{D,s})}$$

Here $d^1_{A,s}$ denotes the demand for the sales alternative (A) from segment s, $(U_{A,s})$ and $(U_{D,s})$ denote the utilities of alternatives A and D to segment s.

3.7.2 Strategy 2: Lease Only

Under the lease only strategy, the manufacturer offers leasing alternatives for new or used machines. In this case, the consumer has three alternatives to choose from: "B: lease a new machine", "C: lease a used machine", or "D: none". Note that the calculation of NPV_{Lease} assumes that the machine is leased in two periods, therefore the value of NPV_{Lease} holds only if there is enough demand for leasing the machine when it is new and used. If the demand for leasing used machines is not equal to the available supply (i.e., $D^2(C) \neq r.c.D^2(B)$), the manufacturer will incur additional overage (c_o) or underage (c_u) costs. As a result, the total profits per period in the lease only case are given as a piecewise function:

$$TotalNPV_2 = \begin{cases} NPV_{Lease}.D^2(B) + (NPV_{Lease} - c_u).(D^2(C) - r.c.D^2(B)), & r.c.D^2(B) < D^2(C) \\ NPV_{Lease}.D^2(B), & r.c.D^2(B) = D^2(C) \\ NPV_{Lease}.D^2(C) + (NPV_{Lease} - c_o).(r.c.D^2(B) - D^2(C)), & r.c.D^2(B) > D^2(C) \end{cases}$$

The total demands for leasing new and used machines are denoted by $D^2(B)$ and $D^2(C)$ respectively, and calculated similarly to $D^1(A)$, following from Equation 3.3. Thus, to calculate the $TotalNPV_2$, one first needs to determine the c_o and c_u.

3.7.2.1 Case 1: $r.c.D^2(B) < D^2(C)$, calculation of the overage cost, c_o

The overage cost is needed when the supply for used machines (resulting from a high demand for new machines) exceeds the demand for used machines. Put differently, there will be a number of machines which will be leased when they are in the first half-lifetime (period 1) but not when they are in the second half-lifetime (period 2). In this case, the company simply needs to dispose of these machines without making revenues in the second period. Thus, the overage cost, c_o, is the difference between the profits made from a machine that is leased in both periods (i.e., NPV_{Lease}) and the profits made from a machine that is leased only in the first period (i.e., NPV^*_{Lease}):

$$\begin{aligned} NPV_{Lease} =& (1 - c.\alpha^t)P_{I1} + \frac{1-\alpha^t}{1-\alpha}P_{L1} + r.c.\alpha^t. \left[(1 - c.\alpha^t)P_{I2} + \frac{1-\alpha^t}{1-\alpha}P_{L2}\right] \\ & - C_M - C_{T\rightarrow} - \frac{1-\alpha^t}{1-\alpha}(C_A + C_{R1}) - c.\alpha^t.C_{T\leftarrow} \\ & - r.c.\alpha^t \left[C_R + C_{T\rightarrow} + \frac{1-\alpha^t}{1-\alpha}.(C_A + C_{R2}) + c.\alpha^t.[C_{T\leftarrow} + C_D]\right] \end{aligned}$$

$$\begin{aligned} NPV^*_{Lease} =& (1 - c.\alpha^t)P_{I1} + \frac{1-\alpha^t}{1-\alpha}P_{L1} - C_M - C_{T\rightarrow} \\ & - \frac{1-\alpha^t}{1-\alpha}(C_A + C_{R1}) - c.\alpha^t.[C_{T\leftarrow} + r.C_R + \alpha^t.C_D] \end{aligned}$$

$$\begin{aligned} c_o =& NPV_{Lease} - NPV^*_{Lease} \\ =& r.c.\alpha^t \left[(1 - c.\alpha^t)P_{I2} + \frac{1-\alpha^t}{1-\alpha}P_{L2}\right] + \\ & - r.c.\alpha^t \left[C_{T\rightarrow} + \frac{1-\alpha^t}{1-\alpha}.(C_A + C_{R2}) + c.\alpha^t.C_{T\leftarrow}\right] + (1 - r.c).c.\alpha^{2t}.C_D \end{aligned}$$

The calculation of NPV^*_{Lease} assumes that the manufacturer collects and refurbishes as many machines as he can ($r.c$) at the end of their leases in period 1. Since the demand for used machines is not yet realized, he refurbishes the machines and supplies the highest possible number of used machines to be leased ($r.c$). At the end of the second lease period, when the demand is realized and a number of machines (i.e., ($r.c.D^2(B) - D^2(C)$) have not been leased, all machines are disposed of together, hence, the C_D in the calculation of NPV^*_{Lease} is discounted by α^t.

3.7.2.2 Case 2: $r.c.D^2(B) > D^2(C)$, calculation of the underage cost, c_u

The calculation of the underage cost, c_u, is more complicated. This is because the available supply for used machines depend on the manufactured machines to be leased in the first period, and hence, the demand for leasing new machines. If there is more demand for used washing machines than the available supply resulting from the collected and refurbished machines, then the manufacturer has to make a decision on how to handle the problem. One idea might be to simply not serve the customer who would like to lease a used machine when the supply is not available. This idea is unlikely to be implemented in practice, especially in a competitive market, as a company would fear to lose the customer in the long term. To prevent this, a company might choose to provide a customer who demands a used machine with a new machine instead at the leasing fee of a used machine. It would mean manufacturing more new machines at the beginning of the period and leasing some of them at the leasing fee for used machines, and making less profits. Even though this idea is likely to derive greater consumer satisfaction, it poses a dynamic problem and makes the calculation of the optimal c_u and the total profits per period more complex. The example situation below illustrates the dynamic nature of the problem.

Example. Assume that the demand per period is stable at 50 for leasing new machines, and 100 for leasing used machines. For the sake of illustration, further assume that 90% of the machines can be collected at the end of the lease, and all collected machines can be refurbished, i.e., $c = 0.9$ and $r = 1$. At the beginning of period 0, the system starts with the supply of 50 machines collected to be refurbished. Hence, to cover for the demand of $50 + 100$ machines in total, $150 - 50 = 100$ new machines need to be manufactured. At the end of period 0, $c = 0.9$ of the machines are collected: $50 * 0.9 = 45$ machines are at the end of the lifetime, thus they are disposed of; while $100 * 0.9 = 90$ machines are at half-lifetime and are sent to refurbishment. Consequently, period 1 starts with 90 machines to be refurbished and $150 - 90 = 60$ new machines to be produced, and the system continues. Table 3.8 shows the flow of machines over time. For convenience, new machines in each period are shown in blue.

Table 3.8: Flow of machines in each period if $D^2(B) < D^2(C)$- dynamic situation.

	Period 0	**Period 1**	**Period 2**	**Period 3**
Manufacture	100	60	96	64
Refurbish	50	90	54	86
$D^2(B)$	50	50	50	50
$D^2(C)$	100	100	100	100
Collect	45+90	81+54	48+86	77+57
Dispose	45	81	48	77
Send to refurbishment	90	54	86	57

As can be seen, the system is dynamic because the number of machines that need to be manufactured and refurbished is not stable over time. The total profits that the company makes in each period fluctuates, rendering it troublesome to calculate the optimal average profits per period to compare with the sales only and hybrid cases. It was not possible under the constraints of a Master's thesis to optimally solve this dynamic problem [13] Instead, to still get an idea about

[13] The supply restriction is an issue also present in CLSCs, and leasing new machines as used ones is similar to the practice of "seeding": At early stages of product introduction, the firm cannot start remanufacturing since the product cores have yet to re-enter the system. "Seeding" is the practice of selling new products as remanufactured ones, to enter the market earlier and feed the system with more new products to have a higher

the profit level in this situation, we take a best/worst case approach and determine upper and lower bounds on the average total profits per period. Also, as will be seen in the numerical analysis in Section 3.7.4, these bounds help find the best strategy while avoiding the exact calculation of the total profits.

3.7.2.2.1 Best Case Scenario: If the demand for leasing used washing machines is at the exact same level that the manufacturer can supply, i.e., $r.c.D^2(B) = D^2(C)$, then the overage and underage costs are avoided, and the manufacturer makes the highest total profits per period. This gives an upper bound on the profits per period, calculated simply as:

$$TotalNPV_2^{Upper} = NPV_{Lease} \cdot D^2(B)$$

3.7.2.2.2 Worst Case Scenario: For the worst case scenario, we can avoid the dynamic nature of the problem when the demand for leasing used products is higher than the demand for leasing new products, by assuming a rather unintelligent strategy for the manufacturer. If the manufacturer uses the same strategy as in the calculation of c_u and disposes of the machines when they are not needed, then the dynamic structure can be eliminated. In other words, the manufacturer ignores the actual age of the machines when they are returned, and disposes of all machines that were leased as used machines. To illustrate, consider again the example above. Under this unintelligent strategy, the flow of machines are as given in Table 3.9. In this case, the manufacturer only sends for refurbishment the machines that have been leased as new to cover for the demand $D^2(B)$ and disposes of all machines that have been leased as used to cover for the demand $D^2(C)$, even though some of them are only at half-lifetime. The number machines that were disposed of unintelligently at the half-lifetime are shown in red. As seen in Table 3.9, this strategy stabilizes the flow of machines and eases the calculation of c_u.

Table 3.9: Flow of machines in each period if $D^2(B) < D^2(C)$- the unintelligent strategy.

	Period 0	**Period 1**	**Period 2**	**Period 3**
Manufacture	100	105	105	105
Refurbish	50	45	45	45
$D^2(B)$	50	50	50	50
$D^2(C)$	100	100	100	100
Collect	45+90	45+94	45+90	45+90
Dispose	45+55	45+55	45+55	45+55
Send to refurbishment	45	45	45	45

With a stable flow of machines, the calculation of c_u is straightforward from the calculation of c_o. Let NPV_{Lease}^{**} denote the net present value of profits made when a machine is manufactured and leased at the fee of a used machine for one period, and then disposed of. Then the underage cost, c_u, is the difference between NPV_{Lease} and NPV_{Lease}^{**}:

supply of cores later (Yoruk, 2004).The research on seeding in the CLSC literature may provide an inspiring starting point to analyze the dynamic problem in our total profit calculations as an extension of this thesis in future.

$$
\begin{aligned}
NPV_{Lease} =& (1-c.\alpha^t)P_{I1} + \frac{1-\alpha^t}{1-\alpha}P_{L1} + r.c.\alpha^t\left[(1-c.\alpha^t)P_{I2} + \frac{1-\alpha^t}{1-\alpha}P_{L2}\right] \\
& - C_M - C_{T\rightarrow} - \frac{1-\alpha^t}{1-\alpha}(C_A + C_{R1}) - c.\alpha^t.C_{T\leftarrow} \\
& - r.c.\alpha^t\left[C_R + C_{T\rightarrow} + \frac{1-\alpha^t}{1-\alpha}(C_A + C_{R2}) + c.\alpha^t.[C_{T\leftarrow} + C_D]\right] \\
NPV^{**}_{Lease} =& (1-c.\alpha^t)P_{I2} + \frac{1-\alpha^t}{1-\alpha}P_{L2} - C_M - C_{T\rightarrow} - \frac{1-\alpha^t}{1-\alpha}(C_A + C_{R1}) - c.\alpha^t.[C_{T\leftarrow} + C_D] \\
c_u =& NPV_{Lease} - NPV^{**}_{Lease} \\
=& (1-c.\alpha^t)P_{I1} + \frac{1-\alpha^t}{1-\alpha}P_{L1} + (r.c.\alpha^t - 1).\left[(1-c.\alpha^t)P_{I2} + \frac{1-\alpha^t}{1-\alpha}P_{L2} - c.\alpha^t.C_D\right] \\
& - r.c.\alpha^t.\left[C_R + C_{T\rightarrow} + \frac{1-\alpha^t}{1-\alpha}(C_A + C_{R2}) + c.\alpha^t.C_{T\leftarrow}\right]
\end{aligned}
$$

When we use this c_u calculated under the unintelligent policy, we get a lower bound on the total profits per period:

$$TotalNPV_2^{Lower} = NPV_{Lease}.D^2(B) + (NPV_{Lease} - c_u).(D^2(C) - r.c.D^2(B))$$

Consequently, in the case that $D^2(B) < D^2(C)$, the best case scenario above gives an upper bound, $TotalNPV_2^{Upper}$, and the worst case scenario gives a lower bound, $TotalNPV_2^{Lower}$, on the optimal total profits.

3.7.3 Strategy 3: Hybrid

When the manufacturer adopts a hybrid strategy and offers both leasing and selling options, the consumer has all four alternatives in our survey design: "A: purchasing a new machine", "B: leasing a new machine", "C: leasing a used machine", and "D: none". In a similar vein to the lease only strategy, his total profits per period are given as a piecewise function due to the demand-supply constraint for leasing new and used machines:

$$
TotalNPV_3 = \begin{cases}
NPV_{Sales}.D^3(A) + NPV_{Lease}.D^3(B) + (NPV_{Lease} - c_u).(D^3(C) - r.c.D^3(B)), & r.c.D^3(B) < D^3(C) \\
NPV_{Sales}.D^3(A) + NPV_{Lease}.D^3(B), & r.c.D^3(B) = D^3(C) \\
NPV_{Sales}.D^3(A) + NPV_{Lease}.D^3(C) + (NPV_{Lease} - c_o).(r.c.D^3(B) - D^3(C)), & r.c.D^3(B) > D^3(C)
\end{cases}
$$

where $D^3(A)$, $D^3(B)$ and $D^3(C)$ denote the demand for purchasing a new machine, leasing a new machine and leasing a used machine under the hybrid strategy, respectively. Their calculation follows from Equation 3.3.

Note that $TotalNPV_3$ differs from $TotalNPV_2$ only by the addition of the profits from sales and the fact that demand values for each alternative are different since the consumer has more options. Therefore, the ideas as explained for the determination of c_u and c_o allows us to calculate the $TotalNPV_3$ (See Sections 4.7.2.1 and 4.7.2.2). Then, in the case that $r.c.D^3(B) < D^3(C)$, we identify upper and lower bounds on the total profits under the hybrid strategy:

$$TotalNPV_3^{Upper} = NPV_{Sales}.D^3(A) + NPV_{Lease}.D^3(B)$$

$$TotalNPV_3^{Lower} = NPV_{Sales}.D^3(A)+NPV_{Lease}.D^3(B)+(NPV_{Lease}-c_u).(D^3(C)-r.c.D^3(B))$$

In the next section, we conduct a numerical study using the data gathered from an European white goods manufacturer and the demand values we assess using the LC-MNL model resulting from our survey.

3.7.4 Numerical Study

We start by determining the demand in each strategy for each price level offered in the survey, as given in Table 3.2. Table 3.10 shows the total demands for different alternatives under different strategies and leasing fees.

Table 3.10: Demand shares for each alternative in different strategies

Leasing Fees		**Sales Only**		**Lease Only**			**Hybrid Strategy**			
PL1	PL2	$D^1(A)$	$D^1(D)$	$D^2(B)$	$D^2(C)$	$D^2(D)$	$D^3(A)$	$D^3(B)$	$D^3(C)$	$D^3(D)$
\$13.00	\$6.50	0.852	0.147	0.325	0.657	0.026	0.425	0.166	0.402	0.006
\$14.50	\$7.25	0.852	0.147	0.221	0.707	0.070	0.487	0.125	0.379	0.008
\$16.00	\$8.00	0.852	0.147	0.157	0.689	0.153	0.516	0.109	0.363	0.011
\$17.00	\$8.50	0.852	0.147	0.125	0.606	0.267	0.537	0.097	0.347	0.016
\$18.50	\$9.25	0.852	0.147	0.111	0.504	0.383	0.563	0.085	0.325	0.025
\$20.00	\$10.00	0.852	0.147	0.103	0.418	0.477	0.598	0.073	0.288	0.039
\$21.00	\$10.50	0.852	0.147	0.096	0.351	0.552	0.644	0.058	0.235	0.061

As seen in Table 3.10, the demand for leasing used machines is greater than the demand for leasing new machines at all leasing fee levels in both lease only and hybrid strategies (i.e., $r.c.D^2(B) < D^2(C)$). Therefore, we use the equations in Section 3.7.2.2 to calculate the total NPVs in different strategies. The results are presented in Table 3.11.

Table 3.11: Comparison of weighed profits in different strategies

Leasing Fees		**Sales Only**	**Lease Only**		**Hybrid Strategy**	
PL1	PL2	$TotalNPV_1$	$TotalNPV_2^{lower}$	$TotalNPV_2^{upper}$	$TotalNPV_3^{lower}$	$TotalNPV_3^{upper}$
\$13.00	\$6.50	265.51	-74.14	45.11	75.69	158.64
\$14.50	\$7.25	265.51	-87.19	84.67	107.16	197.56
\$16.00	\$8.00	265.51	-76.58	114.99	132.10	224.83
\$17.00	\$8.50	265.51	-54.96	121.37	148.05	241.16
\$18.50	\$9.25	265.51	-19.09	129.76	170.19	261.88
\$20.00	\$10.00	265.51	9.91	133.38	194.17	278.71
\$21.00	\$10.50	265.51	25.53	127.61	213.52	284.48

Firstly, observe the discrepancies between the lower and upper bounds in the lease only and hybrid cases. The high differences demonstrate the significance of the supply-demand constraint in a repeated leasing model: if the demand for used products is not in accordance with the available supply, offering leasing only may result in dramatic decreases in profits (or even losses in some cases under the lease only strategy) for a manufacturer who fails to handle the situation well. Moreover, since there is a high difference between the lower and upper bounds on the total profits per period, for further research it appears worthwhile to solve the dynamic problem to determine the exact total profits to compare with other strategies. Nonetheless, the upper and lower bounds still allow us, to some degree, to make comparisons of the strategies.

The results show that with the data and leasing fees we used, leasing only is never the best strategy: at all leasing fee levels, the upper bound on the total profits under the lease only strategy is less than the NPV of sales only and the lower bound of profits under the hybrid strategy. We also observe that the lower bound on the profits under the lease only strategy, $TotalNPV_2^{lower}$, first decreases and then increases with increasing leasing fees, while the upper bound, $TotalNPV_2^{upper}$ first increases and then decreases. This behavior is a result of the trade-off between the leasing fees and the demand: the first increase is due to the increase in the leasing fees, while the decrease is due to the sharp decrease in demand when the leasing fees are very high. Note that, $TotalNPV_2^{lower}$ is also influenced by the difference between the demand for leasing new and used products (Columns $D^2(B)$ and $D^2(C)$ in Table 3.10).

Comparing the sales only and hybrid strategies, we see that including leasing alternatives in a company's offers have a potential to be profitable only under very high leasing fees ($PL_1 =$ \$20.00 and $PL_2 =$ \$10.00 and higher), since $TotalNPV_3^{lower} < TotalNPV_1 < TotalNPV_3^{upper}$. As opposed to the case for the lease only strategy, we do not see the effects of the trade-off between the leasing fees and the demand for leasing on the upper and lower bounds of the profits in hybrid strategy. This is because of the addition of the purchasing alternative to the company's offerings. From Table 3.12, notice that when the leasing prices increase, consumers switch from leasing alternatives to the sales alternative, and the company still makes profits from sales, whereas, in the lease only strategy, an increase in the leasing fees means switching to the "none" alternative. In other words, in the hybrid strategy, the company is protected from losing customers when the leasing fees are high. It further means that the company can charge higher leasing fees in a hybrid strategy: Table 3.11 shows that both the upper and lower bounds on the total profits from a hybrid strategy increase with increasing leasing fees. Therefore, we conclude that in all strategies with the given leasing fee levels, either the sales only or the hybrid strategy with the highest fees ($PL_1 =$ \$21.00 and $PL_2 =$ \$10.50) should be chosen as the best strategy. We acknowledge the necessity for further analysis is to determine the exact value of the total profits (i.e., when the company handles the dynamic situation).

Although our numerical study is unable to identify the best strategy with certainty, it is noteworthy for underlining the importance of consumer demand on the profitability of offering leasing. We demonstrated that even when the manufacturer makes the same NPV from leasing as he does from selling one machine (i.e.,$NPV_{Lease} \geq NPV_{Sales}$ for $P_{L1} \geq 17.00$, $P_{L2} \geq 8.50$), it is far from safe to assume that offering leasing alternatives will not harm the economic performance. His expected total profits are less for leasing than selling when the consumer is included in the picture due to the segment of consumers that prefer to purchase (as also seen from the results of the LC-MNL model) and the potential detrimental effects of the discrepancies between the demand for leasing new and used machines.

Chapter 4

Discussion

One interesting finding that may be unfavorable to a firm that seeks to transition to circular business models is the unpopularity of leasing. To better comprehend the reason behind, we investigate the possibility of consumers finding the leasing alternatives expensive by calculating the total cost of ownership (TCO) in Section 4.1. The calculations demonstrate the challenge in making leasing an appealing alternative to a consumer and profitable for a manufacturer. Following from these results, in Section 4.2., we investigate the ways in which the manufacturer can alleviate the situation (Section 4.2.1) and the necessary changes in the market shares of the three consumer segments (Section 4.2.2).

4.1 Consumer's Total Cost of Ownership

From the analyses in Chapter 3, we concluded that the demand for leasing alternatives are low, especially for leasing new machines: in more than 50% of the choice situations the respondents selected the purchasing alternative, while the leasing new alternative was chosen only about 10% of the time. We note that the low choice frequency for leasing new machines may be due to the discount for used machines (fixed at 50%). That is, at all leasing fees offered in our survey, the price for leasing a used machine was always 50% cheaper than leasing a new machine. A manufacturer who seeks to get roughly equal demands for leasing new and used machines, and thus avoid the detrimental effect of overage/underage costs should try to use different discount levels. The investigation of optimal discount levels to offer is a promising way to further extend this thesis.

Nevertheless, to gain a deeper understanding of the reasons behind the unpopularity of leasing, we calculate the total cost of ownership of the leasing prices offered to the respondents. This section investigates if consumers avoid leasing because they perceive it as more expensive than purchasing in the long term.

We took the manufacturer's point of view while determining the leasing fees to ask in the survey. That is, using cost and revenue data from a European manufacturer, we solved for the leasing prices that make the NPV of leasing one machine in two periods with refurbishment in between equal to (or a ratio of) the NPV of selling one machine. Therefore, we ensured from the start that the manufacturer can choose the level of profits per machine that he will make. Here, we take the consumer's point of view and evaluate the economic attractiveness of the leasing alternatives in comparison with the purchasing alternative at different leasing fee levels.

To understand the economic attractiveness of the alternatives, one needs to know how a respondent evaluates these offers. It is hard to guess how a consumer evaluates the prices and estimates the TCO considering the costs of maintenances and repairs (if he considers at all). For instance, it might be that one respondent underestimates the repair costs that he would need to pay if they purchase the machine, and thus chooses the purchasing option, while another respondent overestimates these costs and thus finds leasing very convenient. In addition, consumers may also differ in their evaluations of the time value of money. Therefore, rather than calculating an average TCO, we analyze the situation for two “extreme” types of consumers in terms of predicting and comparing the TCOs of different alternatives. At one extreme stands the “primitive” consumer who does the simplest calculation possible, whereas the “omniscient” consumer, at the other extreme, makes a detailed calculation by perfectly guessing all cost elements.

4.1.1 Primitive Consumer

The primitive acknowledges neither the time value of money nor the costs of maintenances and repairs to be paid in the sales system. This consumer type represents the simplest way of decision-making and appraises his TCO of leasing easily by multiplying the leasing fee he is given with the leasing duration.For leasing a new washing machine in the first period for t months, the TCO equation is:

$$TCO^P_{Lease1} = P_{L1}.t$$

For leasing a used washing machine in the second period for t months, the TCO equation is:

$$TCO^P_{Lease2} = P_{L2}.t$$

Hence, if the consumer decides to lease the same machine in two periods, his total TCO is:

$$TCO^P_{Lease} = TCO^P_{Lease2} + TCO^P_{Lease1}$$

For the purchasing alternative, since the primitive consumer neglects the repair and maintenance costs, his TCO is:

$$TCO^P_{Sales} = S_P$$

Using the equations above, Table 4.1 presents the results of the calculations for each price level, Δ.

Table 4.1: Total cost of ownership calculations of a primitive consumer

P_{L1}	P_{L2}	TCO^P_{Lease1}	TCO^P_{Lease2}	TCO^P_{Lease}	TCO^P_{Sales}
\$13.00	\$6.50	780	290	1170	800
\$14.50	\$7.25	870	435	1305	800
\$16.00	\$8.00	960	480	1440	800
\$17.00	\$8.50	1020	510	1530	800
\$18.50	\$9.25	1110	555	1665	800
\$20.00	\$10.00	1200	600	1800	800
\$21.00	\$10.50	1260	630	1890	800

The results show that a rational consumer who makes a primitive calculation would never choose to lease if he compares the TCO of purchasing with the TCO of leasing the same machine for 10 years (two periods). Overlooking the time value of money, the total lease fees he pays over 10 years is higher than the retail price of the machine, even at the lowest leasing fees. If the consumer compares the TCO of the leasing alternatives for 5 years (one period) with the purchase alternative, then he would choose leasing a new machine only at the lowest leasing fees offered (P_{L1} = \$13.00 and P_{L2} = \$6.50). At any leasing fee offered, we would expect a reasonable consumer to choose the leasing used alternative, as the TCO of leasing used for one period is lower than the retail price. This analysis demonstrates that the leasing alternatives may appear expensive to a primitive consumer, and may help to explain the unpopularity of leasing, especially for new machines.

4.1.2 Omniscient Consumer

The omniscient consumer represents the other extreme type in terms of decision-making: he is well informed about all costs included in his TCO calculations and acknowledges the time value of money. The TCO calculation for purchasing incorporates the costs of forward transportation, maintenances and repairs during lifetime after the warranty period, and the disposal costs at the end of the lifetime.

Similarly to the NPV calculations of the manufacturer, instead of using a one-time cost for maintenances and repairs, we distribute to months and use a monthly average cost. Assuming that the omniscient consumer perfectly guesses these costs, we use the values that were included in the manufacturer's NPV as revenues from maintenances and repairs (Section 4.1): P_{A1} when the machine is new (years 0-5) and P_{A2} when the machine is old (years 5-10). Thus, the omniscient consumer computes his discounted TCO of purchasing a new machine as:

$$TCO^O_{Sales} = S_P + C_{T\rightarrow} + \frac{\alpha^w - \alpha^t}{1-\alpha}P_{A1} + \frac{\alpha^t - \alpha^{2t}}{1-\alpha}P_{A2} + \alpha^{2t}(C_{T\leftarrow} + C_D)$$

We assume that the consumer pays for the forward transportation of the machine when he purchases it. The sales price and the forward transportation costs are not discounted as they are paid at $t = 0$. The company takes the responsibility for the maintenances and repairs during the warranty period, $t = (0, ..., w]$. After the warranty period, the consumer pays for maintenances and repairs: the third and fourth terms in the equation above is the discounted cost during the first half-lifetime of the machine, and the second half-lifetimes, respectively. Finally, we assume a responsible consumer who handles the disposal at the end of the lifetime and also pays the transportation fees to the disposal facility.

In the leasing alternatives, the consumer only pays the relative deposits and monthly leasing fees. The discounted TCO of leasing in the first and second periods is simply calculated as:

$$TCO^O_{Lease1} = \frac{1-\alpha^t}{1-\alpha}P_{L1} + (1-\alpha^t)P_{I1}$$

$$TCO^O_{Lease2} = \frac{1-\alpha^t}{1-\alpha}P_{L2} + (1-\alpha^t)P_{I2}$$

The total TCO of leasing the same washing machine in two consecutive periods (10 years in total) is computed as:

$$TCO^O_{Lease} = TCO^O_{Lease1} + \alpha^t(TCO^O_{Lease2})$$

The evaluations of an omniscient consumer depend also on the discount rate he uses since he realizes the time value of money. We analyzed for different monthly discount rates (DR), Table 5.2 presents the results for $DR = 0.01$, $DR = 0.005$, and $DR = 0.0033$.

Table 4.2: Total cost of ownership calculations of an omniscient consumer

P_{L1}	P_{L2}	TCO^P_{Lease1}	TCO^P_{Lease2}	TCO^P_{Lease}	TCO^P_{Sales}
DR=0.01					
\$13.00	\$6.50	635.21	317.61	810.04	839.95
\$14.50	\$7.25	703.32	351.66	896.89	839.95
\$16.00	\$8.00	771.42	385.71	983.74	839.95
\$17.00	\$8.50	816.83	408.41	1041.6	839.95
\$18.50	\$9.25	888.94	442.47	1128.5	839.95
\$20.00	\$10.00	953.04	476.52	1215.3	839.95
\$21.00	\$10.50	998.45	499.22	1273.2	839.95
DR=0.005					
\$13.00	\$6.50	701.66	350.82	961.75	852.59
\$14.50	\$7.25	779.63	389.81	1068.6	852.59
\$16.00	\$8.00	857.61	428.8	1175.5	852.59
\$17.00	\$8.50	909.59	454.79	1246.8	852.59
\$18.50	\$9.25	987.57	493.78	1353.6	852.59
\$20.00	\$10.00	1065.5	532.77	1460.5	852.59
\$21.00	\$10.50	1117.5	558.76	1531.8	852.59
DR=0.0033					
\$13.00	\$6.50	726.84	363.42	1025.1	858.71
\$14.50	\$7.25	808.64	404.32	1140.4	858.71
\$16.00	\$8.00	890.44	445.22	1255.8	858.71
\$17.00	\$8.50	944.97	472.48	1333.3	858.71
\$18.50	\$9.25	1026.8	513.38	1448.1	858.71
\$20.00	\$10.00	1108.6	554.28	1563.4	858.71
\$21.00	\$10.50	1163.1	581.55	1640.3	858.71

These calculations demonstrate that a rational omniscient consumer would choose to lease a machine in two consecutive periods rather than purchasing it only at the highest discount rate ($DR = 0.01$) and lowest leasing fees ($P_{L1} = \$13.00$, $P_{L2} = \$6.50$). If he evaluates the leasing alternatives for 5 years in comparison with the TCO of purchasing, then he might choose to lease new (at $P_{L1} = \$17.00$, $P_{L2} = \$8.50$ and less) or used (at all leasing prices) at $DR = 0.01$. As DR decreases, the TCO for leasing increases, and hence it renders the leasing offers less attractive to the consumer.

The TCO calculations for both types of consumers reveal that in most cases, leasing new machines appears more expensive than purchasing or leasing used machines. This helps to understand the low demands for the leasing alternatives. It further shows that it is challenging to make leasing appealing to both the consumer and the manufacturer. When the manufacturer makes the same or higher profits per machine from leasing and selling (at $P_{L1} = \$17.00$, $P_{L2} = \$8.50$ and higher), the consumer's TCO of leasing a machine for the lifetime is higher than the TCO of purchasing the machine. Moreover, in most cases (except for at $P_{L1} = \$17.00$,

P_{L2} = \$8.50 for an omniscient consumer with $DR = 0.01$) even the TCO of leasing a new machine for 5 years is higher than the TCO of purchasing the machine for a lifetime of 10 years. Therefore, we conclude from these analyses that with the given cost estimates (as seen in Appendix A) and the market demand, the leasing offer is not appealing to both parties. In the next section, we run sensitivity analyses on the cost elements and the market demand to investigate the requirements to improve the circular business model for washing machines.

4.2 Sensitivity Analyses

This section examines the effects of changes in various elements of the leasing offer on the total profits for the manufacturer, and on the total cost of ownership for the consumer. In Section 4.2.1, we analyze the potential actions that the manufacturer can take to improve the offer: namely, through better financing schemes and/or a more durable product design for leasing. Another change that may improve the situation for both parties is in the structure of the consumer market, i.e., consumer preferences. Although the estimated current consumer demand with more than 50% of the consumers preferring to purchase does not seem very promising to a manufacturer, this situation may change in the future by raising more awareness to the circular economy and working to alleviate the consumer concerns. In Section 4.2.2, we analyze the effects of an increase in the consumer demand for leasing. Throughout the analyses in this section, we assume an omniscient consumer with $DR = 0.003$. Unless otherwise stated, the manufacturer's discount rate is $DR = 0.001$. [14]

4.2.1 Financing and Product Design

Here we discuss the elements of the offer on which the manufacturer has rather direct control over. The manufacturer can ameliorate the situation mainly in two ways (i) by a better financing scheme and (ii) by a more durable product design. A better financing scheme, which can be achieved through engagement of governments and/or private banks, would help improve the offer by (a) decreasing the lease administration cost and (b) decreasing the discount rate of the manufacturer. In a similar vein, a more durable product design would help improve the offer by (a) decreasing the cost of refurbishment and (b) decreasing the monthly costs of maintenances and repairs.

4.2.1.1 Financing Scheme

We analyze the sensitivity of the offer to changes in the financing scheme in two steps. Firstly, we assume that the manufacturer has already started offering leasing under the current condition (i.e., with the estimates given in Appendix A and the previous analyses) with $\Delta = 1$ (i.e., $NPV_{sales} = NPV_{lease}$ per machine) and now after improving the financing scheme he does not change the leasing fees yet. That is, we examine the effect on the total profits by keeping the leasing fees constant at P_{L1} = \$17.00 and P_{L2} = \$8.50. Therefore, the consumer clearly does not observe any difference. Secondly, we assume that the manufacturer changes the leasing fees while keeping the Δ constant at 1, and we examine the effects of a better financing scheme on the consumer's TCO.

By improving the financing scheme, a manufacturer can decrease the lease administration costs and the discount rate. The lease administration cost is an important element, for the

[14] These values are chosen to make the effects of the mentioned cost elements more explicit. See Sections 4.2.1 and 4.1.2 for discussions on different DR levels for the manufacturer and the consumer, respectively.

fact that it is an "additional" cost: only realized by the manufacturer in the leasing system and not incurred on the consumer in the purchasing system, while other cost elements (such as transportation, disposal, maintenances and repairs) affect the consumer's TCO. Assuming that the manufacturer keeps the leasing fees constant at $P_{L1} = \$17.00$ and $P_{L2} = \$8.50$, Figure 4.1 below shows the changes in the expected total profits under each strategy. As can be seen, the lease administration cost has a significant impact on the expected total profits. A high lease administration cost ($C_A > 2.07$) may even result in losses under the lease only strategy ($TotalNPV_2^{Lower} < 0$), whereas with a low lease administration cost ($C_A < 0.86$), the lease only strategy may have a potential to result in higher profits than the sales only strategy ($TotalNPV_2^{Upper} > TotalNPV_1$). As for the hybrid strategy, while it always appears as a better strategy than the lease only strategy ($TotalNPV_3^{Upper} > TotalNPV_2^{Upper}$ and $TotalNPV_3^{Lower} > TotalNPV_2^{Lower}$) the comparison with the sales only strategy is more impacted by the lease administration cost: at very high values ($C_A \geq 3.30$), it does not seem worthwhile to offer leasing at all (i.e., sales only is the best strategy).

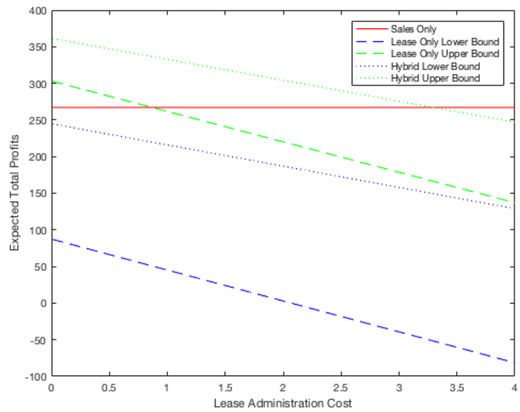
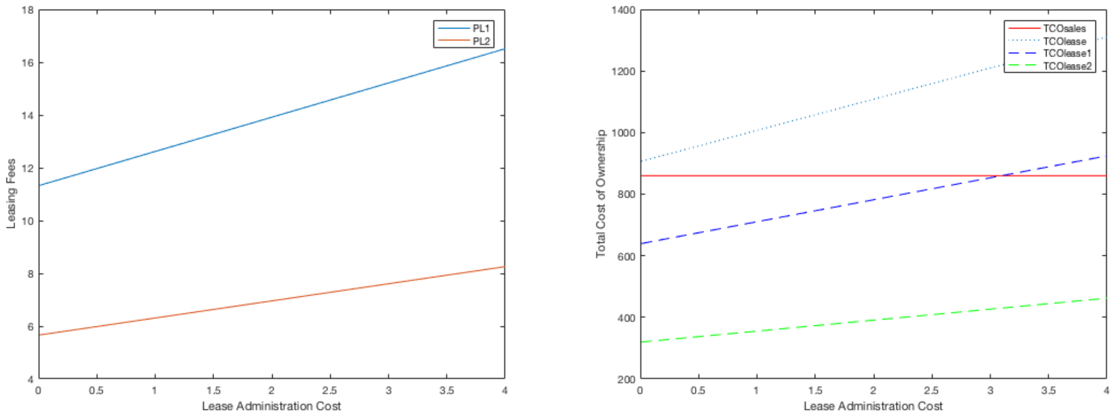


Figure 4.1: Expected Total Profits vs. Lease Administration Cost, $P_{L1} = \$17.00$ and $P_{L2} = \$8.50$.

Figure 4.2. presents the situation from the consumer's point of view, if the manufacturer decides to change the leasing fees. Figure 4.2.a shows the high impact of the lease administration cost on the leasing fees that allow the manufacturer the same level of profits per machine in the lease and sales options. From Figure 4.2.b, it can be seen that the changes in the leasing fees significantly affect the consumer's TCO as well: while the TCO of leasing the same machine for 10 years, TCO_{lease}, is always higher than purchasing the machine,TCO_{sales}, the difference between the two values increase drastically with increasing lease administration cost. Also, at very high values ($C_A \geq 3.10$), even the TCO of leasing a new machine for 5 years is unrealistically high (even $TCO_{lease1} > TCO_{sales}$). Such an increase in TCO_{lease1} may dramatically decrease the demand for new machines and cause an even higher discrepancy (than the currently observed levels) between the demand for leasing new and used machines, in turn, leading to less total profits from the lease only or hybrid strategies for the manufacturer.

Another way that a better financing scheme may ameliorate the leasing offer is through the discount rates of the manufacturer. Figure 4.3. shows the changes in expected total profits under different strategies, assuming that the leasing fees are fixed at $P_{L1} = \$17.00$ and $P_{L2} = \$8.50$). As can be seen, the discount rate has a very high impact, with values $DR \geq 0.005$ rendering



(a) Leasing Fees (b) Consumer's TCO

Figure 4.2: Leasing Fees and Consumer's TCO vs. Lease Administration Cost, $\Delta = 1$.

it unreasonable to offer leasing at all. When the discount rate is lower, the hybrid strategy may have a potential to result in higher profits than the sales only strategy. In Figure 4.4. we examine the case from the consumer's vantage point: 4.4.(a) shows the leasing fees that allow the manufacturer to make equal profits from leasing as from selling, 4.4.(b) shows the resulting TCO values. We observe that an increase in the discount rates of the manufacturer ($DR \geq 0.005$) may quickly cause the lease offer to be highly unattractive to consumers who make reasonable decisions based on price, i.e., even the TCO of leasing a new machine for 5 years is higher than the TCO of purchasing.

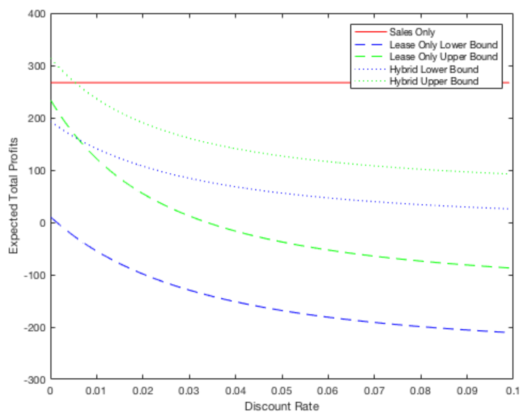
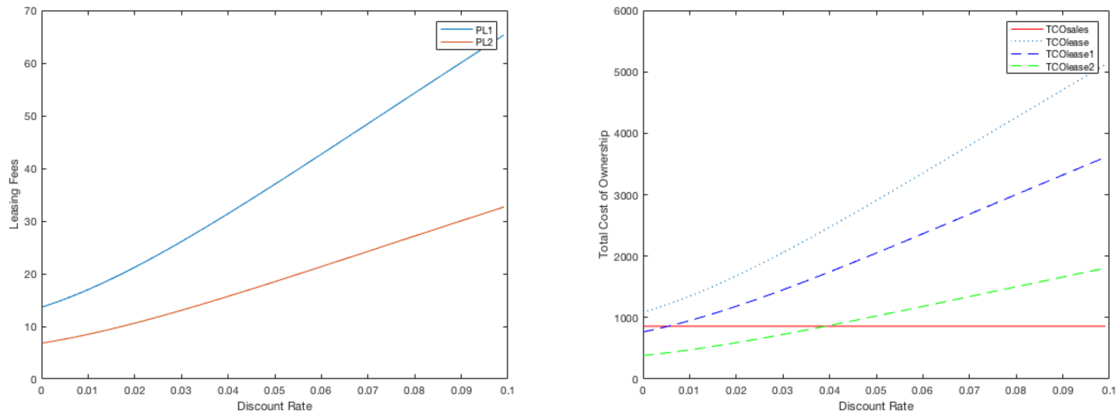


Figure 4.3: Expected Total Profits vs. Discount Rate, $P_{L1} = \$17.00$ and $P_{L2} = \$8.50$.

4.2.1.2 Product Design

By improving the product design in terms of durability, a manufacturer can decrease the refurbishment cost and the costs of maintenances and repairs. In this section, we assume that the manufacturer designs a new, more sturdy machine specifically for leasing while keeping the product design and the offer for sales the same. We start with the impact of the refurbishment cost, C_R. Similar to the lease administration cost, the refurbishment cost is also an "additional" cost of leasing to the manufacturer thus requires special attention. In our data, the refurbishment



(a) Leasing Fees (b) Consumer's TCO

Figure 4.4: Leasing Fees and Consumer's TCO vs. Discount Rate, $\Delta = 1$.

cost was estimated at \$100, for a washing machine that costs \$470 to manufacture, signaling a rather unsturdy design. Figure 4.5 presents the changes in the total expected costs in each strategy with respect to changes in the refurbishment cost.

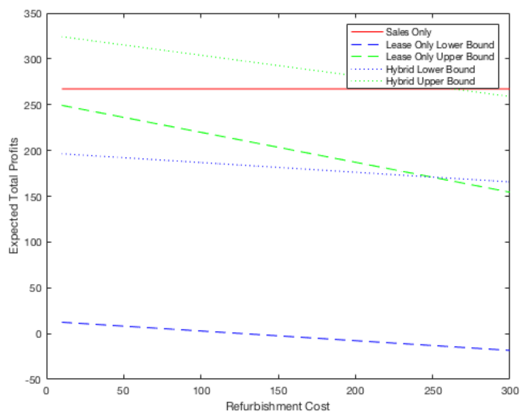
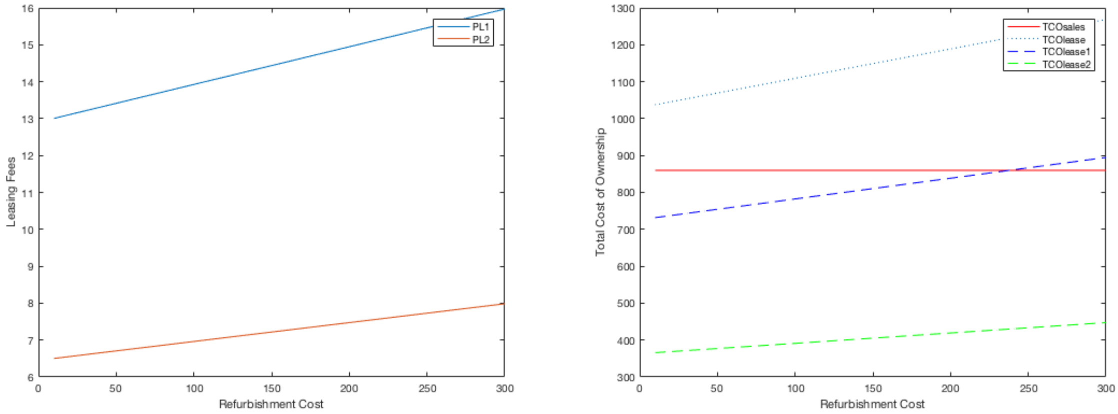


Figure 4.5: Expected Total Profits vs. Refurbishment Cost, P_{L1} = \$17.00 and P_{L2} = \$8.50.

As seen in Figure 4.5, similar to previous cases, the lease only strategy is always less profitable than sales only. When $C_R \leq 263$, the hybrid strategy has still a potential to be worthwhile. We also check how the leasing prices that allow the manufacturer to make the same profits per machine in sales and leasing systems (i.e., $\Delta = 1$) are changed when C_R is decreased. Figure 4.6.(a) shows the changes in leasing prices and 4.6.(b) presents the changes in consumer's TCO. Similarly, when $C_R \geq$ 239, the alternative to lease new machines becomes very high, i.e., $TCO_{lease1} > TCO_{Sales}$. Under such conditions, it would require a consumer to either highly overestimate the TCO of sales (on the contrary to our "omniscient" consumer), or to have a strong preference for leasing for the convenience of leasing or for other reasons, so that he is willing to pay a high premium. Without the presence of such consumers in the market, the demand may be very low for leasing new machines.

A more sturdy product design would also decrease the monthly costs of maintenance and



(a) Leasing Fees (b) Consumer's TCO

Figure 4.6: Leasing Fees and Consumer's TCO vs. Refurbishment Cost, $\Delta = 1$.

repairs. We change the monthly cost of maintenances and repairs in the first period, C_{R1}, between \$0.01 and \$1, and assume that it costs twice in the second period, $C_{R2} = 2.C_{R1}$.

The effects of changing the cost of maintenance and repairs on the manufacturer's expected total profits are seen in Figure 4.7. As C_{R1} approaches 1, the upper bound of the profits in the hybrid strategy get closer to the profits of sales only, thus it becomes illogical to add a leasing alternative in the offer. Even when the C_{R1} is close to 0, lease only strategy is less profitable than others, and the hybrid strategy requires further analysis to ensure that it is worthwhile. Figure 4.8. illustrates the situation from the consumer's point of view, in the case that the manufacturer changes the leasing fees. We observe that if $C_{R1} \geq 0.84$, the offer becomes unappealing, i.e., $TCO_{lease1} > TCO_{Sales}$, to consumers who are not willing to pay a high premium for leasing new machines.

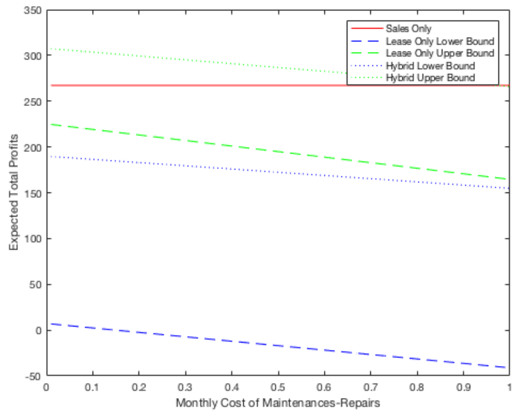
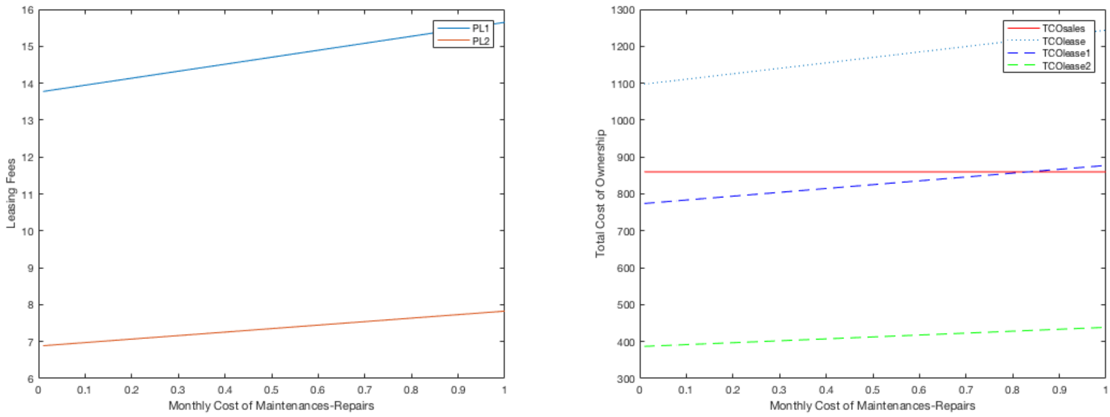


Figure 4.7: Expected Total Profits vs. Cost of Maintenances and Repairs, $P_{L1} = \$17.00$ and $P_{L2} = \$8.50$.



(a) Leasing Fees (b) Consumer's TCO

Figure 4.8: Leasing Fees and Consumer's TCO vs. Cost of Maintenances and Repairs, $\Delta = 1$.

To conclude this section, we comment on the importance of each cost element in comparison with each other. Table 4.3 presents the sensitivity of the upper bound on the total expected profits from the hybrid strategy and the leasing fees to each cost element, namely: the monthly lease administration cost, the manufacturer's discount rate, the refurbishment cost, and the monthly cost of maintenances and repairs. As can be seen, among the given cost elements, the monthly discount rate has the highest impact on the profitability and the leasing fees: a 1% increase in the monthly discount rate causes 2.45 % decrease in the upper bound on the total profits from hybrid strategy, and a 2.28 % increase in the leasing fees if the manufacturer decides to reflect the change on the leasing fees offered. Next, we observe that the monthly lease administration cost also has a high effect. In general, this analysis implies that the financing of the leasing model is crucial to the economic performance of the circular business model: by decreasing the DR or the lease administration costs, the expected profits from a hybrid (and lease only) strategy can be substantially increased.

Table 4.3: Sensitivity analyses

Cost element	**Change in** NPV_3^{Upper}	**Change in** P_{L1}
Lease administration cost, C_A	0.086%	0.102 %
Monthly discount rate, DR	2.45%	2.28%
Refurbishment cost, C_R	0.074%	0.074 %
Monthly cost of maintenances and repairs, C_{R1}	0.014%	0.014 %

4.2.2 Market Demand

This section analyzes the effects of the market demand, on which the manufacturer does not have direct control over. The current segmentation in the market may not seem promising to a manufacturer, with a high ratio of consumers preferring to lease, and a high discrepancy between the demands for leasing new and used machines. However, with help from government bodies and non-governmental organizations, promoting circular economy and alleviating consumers' concerns may improve the situation and boost the demand for leasing. In Section 3.6.5, we found that the market is segmented into three classes: Class 1 comprises 35.6% of the market

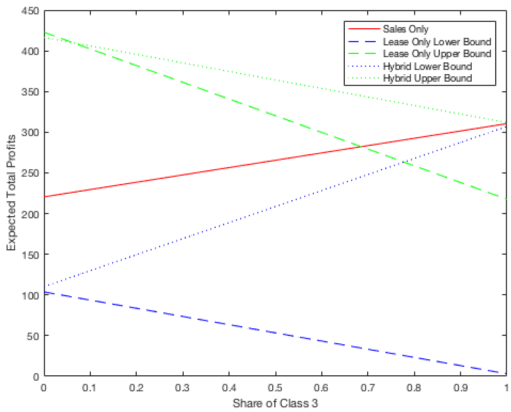


Figure 4.9: Expected Total Profits vs. Share of Class 3, $P_{L1} = \$17.00$ and $P_{L2} = \$8.50$.

and prefers leasing used machines, Class 2 comprises 12.7% and prefers leasing new machines, and Class 3 comprises 51.6% and prefers purchasing. We investigate the impacts of a potential change in the market segmentation by changing the share of Class 3. Figure 4.9 shows the expected total profits from different strategies, with the class share of Class 3 varying from 0 to 1. The lower bounds on the profits in the lease only and hybrid strategies are estimated by assuming that Class 1 and Class 2 make up 3/4 and 1/4 of the remaining population, roughly in accordance with the current segmentation. The upper bounds are estimated as explained in Section 3.7.2.2.1, i.e., assuming that the demand for leasing used machines is equal to the supply from the refurbishment of machines that have been leased as new. From Figure 4.9, we observe that the hybrid strategy has almost always a potential to be more profitable than the sales only strategy. The upper bound on the profits from the lease only strategy has very close values to (or even higher than) the upper bound on the profits from the hybrid strategy when the share of Class 3 is very low (< 0.06), hence the demand for leasing is very high. With these cost estimates and $DR = 0.001$, it may still be worth to offer leasing in a hybrid model, if the share of Class 3 is less than 65%. Also, note the dramatic increase in the differences between the upper and lower bounds on the profits from the hybrid strategy. Even though it always requires further analysis of the exact profits from a hybrid strategy, ($TotalNPV_3^{Upper} > TotalNPV_1 > TotalNPV_3^{Lower}$) when the share of Class 3 is lower, the hybrid strategy appears much more promising since the difference between $TotalNPV_3^{Upper}$ and $TotalNPV_1$ increases. Overall, we conclude that the structure of the market segmentation has drastic effects on the choice of the best strategy and the total expected profits.

Chapter 5

Managerial Insights and Conclusion

The circular economy is currently a popular topic of discussion in both industry and academia. However, the consumer side of the equation has not been adequately researched in the literature. In this thesis, we took an initial step to investigate the consumer perception of circular business models and the economic performance of adding leasing alternatives to a firm's offerings, taking the consumer demand into account. We took the case of washing machines and focused on repeated leasing with refurbishment in between. Our study was comprised of three main steps. We first analytically determined the leasing fees that would allow the manufacturer to make (roughly) the same profits from leasing versus from selling one washing machine. Through this analytical model, we identified several levels of leasing fees to include in the second step of our study, which included designing a consumer survey to gain understanding of consumer behavior. We collected the data through Amazon MTurk and analyzed by well-established discrete choice models. Thirdly, incorporating the consumer demand that was estimated in the second step, we analytically examined the profitability of offering leasing and commented on the potential drivers of the results.

The first and foremost contribution of this thesis is in establishing the importance of the consumer in circular business models. We started with an analytical model comparing the profits from leasing and selling one machine, and ensured that the manufacturer makes equal (or a ratio of) the profits per machine when he offers leasing. Neglecting the consumer part of the equation and assuming enough demand for leasing, this analytical model would suffice to assure that offering leasing would be profitable. However, when we included the experimentally assessed consumer demand into the analysis, our calculations of the total profits revealed that providing a leasing alternative is not always profitable. Using the cost estimates from our case company, we showed that switching to a hybrid model may have a potential for better economic performance than a sales only model only at high leasing prices, while a lease only model is never more profitable, even when the manufacturer makes twice the profits from leasing than selling per machine. Therefore, comparing our analytical model and total profits calculations leads us to caution managers in the transition to circular business models: consumer demand is a crucial part of the picture that deserves close attention. While a circular economy is an appealing idea, it may only be an effective and profitable solution with consumer support, which is not always certain.

The results from the experimental study demonstrated the uncertainty of consumer demand. For the case of washing machines, we found segmentation in the market with three distinct classes each having a preference for one of the alternatives they were given in the survey as (i) purchasing a new machine, (ii) leasing a new machine, (iii) leasing a used machine. The shares for these classes may appear as disadvantageous for a manufacturer that seeks to offer leasing alternatives: the group that chooses to purchase the new machine was approximately 52% of the market, while the groups that favor leasing new products and used products make up of about 13% and 35%, respectively. First of all, the segment that purchases being so large explains why a lease only strategy is not profitable, because in that case a big group of consumers is lost. Losing these consumers may be very dangerous for a firm especially in the case of competition, which we do not explicitly analyze in our study. Second, the discrepancy between the demand for leasing new and used machines is alarming due to the supply-demand interdependency in a repeated leasing model. If the demand for leasing new and used machines are not (roughly) equal, the manufacturer must adopt a smart strategy to minimize the overage/underage costs. Though we do not solve for optimality, our best/worst case analyses illustrate the importance of such a strategy: failing to handle the situation well may result in detrimental effects on the profits.

A firm may also aim at bridging the gap between the demands for leasing new and used machines. We examined three psychological antecedents in our survey, found that the market segmentation is a result of these antecedents of consumer behavior. Some consumers shun leasing used products due to disgust, while some others shun leasing altogether because they take high pride in ownership. We also found that the consumers who prefer leasing find it significantly more convenient than purchasing, as the firm is responsible for the maintenances and repairs in a leasing scheme. Consequently, we advise a firm that would like to transition to a more circular business model to pay attention to these aspects when marketing the offer.

We further analyzed the reason behind the unpopularity of leasing and looked into the economic attractiveness of leasing to a consumer by computing the total cost of ownership of leasing and purchasing options. It was found that under the cost estimates we used, it is possible that a consumer finds leasing more expensive than purchasing. Our calculations of the total cost of ownership of the consumer demonstrated the challenge in making the leasing offer attractive to both the manufacturer and the consumer at the same time. We ran sensitivity analyses on various cost elements and the market demand, to investigate the ways in which this challenge can be overcome. The sensitivity analyses showed the importance of financing in a circular business model: through decreasing manufacturer's discount rate and the monthly lease administration costs (which were estimated high in our data), a manufacturer can substantially increase his profits, and/or make the offer more appealing to consumers by decreasing the leasing fees. Another way to ameliorate the situation is by designing a more durable product for leasing, which would result in less refurbishment and monthly maintenance/repair costs. We thus advise a manufacturer to pay close attention to these cost elements, especially the financing of the business model. Although the current market segmentation and consumer demand may not appear promising, with successful marketing and promotion of circular economy, this structure may be improved in the future. We examined the impact of a smaller consumer segment that prefers to purchase and concluded that even a small increase in the segments that prefer leasing can quickly make the business model successful. This change would obviously require beyond the marketing efforts of a company, help from governments and non-governmental organizations would be essential to alter the negative consumer perceptions towards circular business models.

Lastly, our study informs a firm on the type of consumers that are interested in leasing. Previous research argued that consumers from low-income groups would be more attracted to leasing (Durgee & O'Connor, 1995; Catulli et al., 2013; van Loon et al., 2017), and they may potentially be delinquent consumers that might harm the firm's profits by failing to pay the leasing fees and to return the products at the end of the leasing period (van Loon et al., 2017). We contribute to the literature by differentiating between leasing new and used products. Our findings agree with the previous literature for leasing used products: we find that consumers with lower income are more likely to lease used washing machines. However, the situation is different for new products: we find that the class with the highest income level prefers to lease new products because they find leasing very convenient and they experience disgust towards used products. This is a noteworthy finding since it indicates that while a leasing strategy may pose higher risks on the firm by attracting low-income consumers, it may also create a strategic advantage for extracting more profits from high-income consumers. Successful marketing of the leasing alternatives is of utmost importance to attract the desired consumer type.

All in all, we believe that this research is valuable for demonstrating the significance of consumer behavior and the potential implications of low consumer acceptance. As well as contributing to the literature by integrating the consumer into the picture for circular business models, the present research has also produced significant insights for a firm that would like to transition to more circular business models. Nevertheless, our work has some limitations. Most importantly, understanding consumer behavior and demand is a very challenging task in itself, and the marketing academics have long debated over different methodologies. Our method for assessing the consumer behavior was through a stated choice experiment, which is of lower validity in comparison with a revealed choice experiment. Nonetheless, revealed choice data is hard and usually expensive to gather especially for products/business models in the introduction stages, thus stated choice methods are widely preferred in the literature for the ease of use. Furthermore, our findings from the stated choice data make intuitive sense. Future research may design a pilot study, which was not possible in our situation, and compare the results.

Moreover, we only examined a restricted group of potential drivers of consumer behavior, namely affordability, disgust, pride of ownership and convenience of leasing. Our experiment was limited for not appraising the potential effects of culture, environmental consciousness, gender, generation, etc. Though it is never possible in one study to investigate all drivers behind consumer behavior, future research may extend our study to include more factors. Also, our survey included only one discount level for leasing used products, i.e., β, calculated by the depreciation rate of a washing machine. Offering different discounts might help alleviate the difference between the demands for leasing new and used washing machines, which may be interesting for future research.

As for the analytical analyses of economic performance, we assumed a monopolist manufacturer. We expect the harmful effects of low demand for leasing to be more detrimental in a competitive setting, but we acknowledge the necessity for further analyses before making serious claims. Furthermore, to gain deeper insights into the total profits of the manufacturer and the total cost of ownership of the consumer, we took best/worst case approaches rather than solving the situation for exact values. Our results are encouraging for future research in calculating the exact values since there is a significant difference between the upper and lower bounds on the expected total profits in lease only and hybrid strategies.

Finally, a straightforward extension of our research is through applying the idea to different consumer products. Although we examined the case only for washing machines, our study design presents a roadmap for assessing the consumer demand and economic performance of circular business models for other types of consumer products.

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Appendix A

Data used in the calculations

Notation	**Explanation**	**Value**
t	Leasing duration (in months)	60
w	Warranty period (in months)	24
C_M	Manufacturing cost	\$470
C_R	Refurbishment cost	\$100
$C_{T\rightarrow}$	Forward transportation cost	\$20
$C_{T\leftarrow}$	Return transportation cost	\$20
C_{R1}	Monthly average costs of maintenances and repairs during $t = (0, t]$	\$0.09
C_{R2}	Monthly average costs of maintenances and repairs during $t = (t, 2t]$	\$0.16
C_A	Monthly lease administration costs	\$2
C_D	Dismantling cost	\$15
S_P	Sales price	\$800
P_{I1}	Deposit for the first leasing period	\$100
P_{I2}	Deposit for the second leasing period	\$50
P_{L1}	Monthly leasing fee for the first leasing period	Decision variable
P_{L2}	Monthly leasing fee for the second leasing period	Decision variable
P_{A1}	Monthly average revenues from maintenances and repairs during $t = (0, t]$	\$0.14
P_{A2}	Monthly average revenues from maintenances and repairs during $t = (t, 2t]$	\$0.24

Appendix B

Calculation of the depreciation rate

It is common to assume 13% diminishing value depreciation for washing machines (Inland Revenue Department, 2018). Although the starting value of the machine does not change this calculation, for demonstration purposes, we take the manufacturing cost of \$470 as the starting value of the machine. We compute the depreciation and the values of the machine at the end of each year, over a 10-year period. The calculation is shown in the table below.

Year	**Start Value**	**Diminishing Value Rate**	**Depreciation**	**End Value**
1	470	13%	61.1	408.9
2	408.90	13%	53.16	355.74
3	355.74	13%	46.25	309.49
4	309.50	13%	40.23	269.26
5	269.26	13%	35.01	234.26
6	234.26	13%	30.45	203.80
7	203.80	13%	26.49	177.31
8	177.31	13%	23.05	154.26
9	154.26	13%	20.05	134.21
10	134.21	13%	17.44	116.76

Next, to determine the ratio of leasing fees, i.e., the discount that the company needs to make on the leasing fee of a used machine, we calculate the ratio of the average of the start values of the machine during the first and the second leasing periods.

$$\beta = \frac{\sum_{i=1}^{5} StartValue_i}{\sum_{i=6}^{10} StartValue_i}$$

This calculation results in $\beta = P_{L1}/P_{L2} = 0.498 \approx 0.5$.

Appendix C

Complete Survey

Screen 1
In the first screen of the survey, the participants saw an information page explaining the research and the differences between leasing and purchasing. The page read:

In this survey, we are interested in your views on leasing versus purchasing washing machines. Before continuing, we would like to give you basic information on the differences between how leasing and purchasing works.

Purchasing

You buy the machine at the retail price and pay the price upfront. The company transports the machine to your house and bears the cost of transportation. This machine has a limited warranty period. During this period, the company handles and covers for the maintenances and repairs of the machine, under the condition that the machine was installed and operated according to the guidelines. After the warranty period, you need to pay for all maintenance and repair costs during the lifetime of the machine.

Leasing

The company owns the machine, and the machine needs to be returned to the company at the end of the leasing period. You pay a deposit at the start of the leasing period. The company transports the machine to your house and bears the cost of transportation. Throughout the fixed leasing period, you pay a monthly leasing fee. During the leasing period, there is no constraint on the use frequency (number of wash cycles). The company takes care of the regular maintenances and repairs of the machine and bears all costs. The machine is returned to the company at the end of the leasing period. The company arranges and pays for the return transportation. You get your deposit back when the machine is returned to the company.

Leased machines that are returned to the company will be properly cleaned and refurbished by the company before they are leased again to new customers. In this case, the customer is also informed about the used condition of the machine.

Screen 2

In the next screen, the respondents were presented with the description of a washing machine and the alternatives to access the use of it.

Now that you know more about how leasing works, we would like you to consider the following situation:

Assume that you are in need of a washing machine. You go to a store and pick the high-end washing machine described below.

- Front load, 8 kg wash capacity
- A+++ Energy Class
- Conventional programs: Fast, Intensive, Cotton, Delicate, Mixed, Synthetics
- Special programs: Dark colors, Hand wash
- 1600 RPM maximum spin
- LCD display

You are offered 3 alternatives for accessing the use of this machine:

Alternative A: Purchase a brand-new washing machine at a retail price to be paid upfront. In this case, the machine has a two-year limited warranty, and the expected lifetime is 10 years.

Alternative B: Lease a brand-new washing machine at a monthly subscription fee for 5 years. You need to pay a $100 deposit, which is refunded when the machine is returned at the end of the 5 years. All maintenance and repair costs are covered by the company during the fixed leasing period.

Alternative C: Lease a previously-used washing machine at a monthly subscription fee for 5 years. The machine has been previously leased and professionally refurbished by the company.

You pay a $50 deposit, which is refunded when the machine is returned. All maintenance and repair costs are covered by the company during the fixed leasing period.

In the following questions, we are interested in knowing which alternative you would choose. In each choice set, you are offered different leasing fees.

Screens 3-9

In these screens the respondents saw the seven discrete choice situations as given in Figure 4.2, and stated their choices. The questions were ordered from the lowest leasing fee to the highest, with the leasing fees presented in Table 4.2. For the sake of completeness, we repeat the first DCE question below.

	Alternative A	**Alternative B**	**Alternative C**
Option	Purchasing	Leasing	Leasing
Condition	New	New	Used
Duration	10 years (expected lifetime)	5 years	5 years
Deposit	N/A	$100	$50
Maintenances and repairs	Included during the two-year limited warranty period	Included	Included
Price (leasing fee)	$800	$13.00/month	$6.50/month

Which one of the above options would you choose?

- Alternative A: Purchasing the new washing machine at the regular retail price of $800.
- Alternative B: Leasing a new washing machine at $13.00 monthly subscription fee.
- Alternative C: Leasing a new washing machine at $6.50 monthly subscription fee.
- None of the above.

Screen 10

Here we assessed the respondent's level of disgust, pride of ownership, and convenience of leasing through the statements given in Table 4.3.

On a scale of 0-10, how much do you agree with the statements below? (0: not at all agree, 10: totally agree)

- I would never use laundromats or a shared washing machine, I think they are dirty.
- I would be inclined to consume durable goods, but I am not prepared to pay for repair and maintenance.
- I find sharing my belongings with other people disgusting.
- Possession is important to me.
- Knowing that an item is "mine" is important to me.

- To me, it is not the possession of a good that is key, but the consumption of the item.
- Knowing that someone has previously used a product that I am using would bother me.
- I would prefer to own a product rather than having access to it without ownership.
- Having to think about repair and maintenance of consumer goods can restrict my consumption.
- I am not the kind of person who would buy a second-hand item, I believe that they are contaminated.
- I find it tedious having to think about what to do with my possessions that I am not using anymore (e.g., sell on the second-hand market or dispose off)
- I would rather have the washing machine company take care of the repairs of my machine than having to arrange and pay for it myself every time.

Screen 11

On the last screen, we asked for additional information on the demographics of the respondents and their current washing machines. After this page the respondents were redirected to MTurk website to submit their work.

Have you ever leased a product before (other than an apartment or a house)? (Yes/No)

What type of washing machine do you currently have (from which brand)? If you use laundromats instead, please also state. (Open question)

Approximately how much have you paid for your current washing machine? If you use laundromats, please enter N/A. (Open question)

How old are you? (Open question)

What is the approximate income for your household?

- Less than $40,000
- $40,000-$79,999
- $80,000-$119,999
- Greater than $120,000

Please enter your MTurk Worker ID. Note that survey responses with incorrect or invalid Worker IDs will not be accepted since the quality of the work cannot be checked.

Appendix D

Other Discrete Choice Models

D.1 Multinomial Logit Model 2

The results of the base MNL model (MNL1) in Section 3.6.2 highlight that both price of the alternative and the income of the respondent have significant effects on the consumer's decision. The base model takes these effects separately from each other and includes both as distinct factors. However, it might be the case that rather than having an isolated effect on its own, income might affect how much value a respondent attaches to the price of an alternative. That is, respondents might value the prices of alternatives relative to their incomes. To test this idea, we ran another MNL model by coding price relative to income. In Table D.1. we compare the results of all base models. Column 2 presents the results for MNL2.

As can be seen, the estimates of alternative intercepts and individual specific variables give similar insights to the first MNL model, although some estimates are slightly different. To compare models, we use the Log Likelihood (LL) value, the Akaike's Information Criterion (AIC) and the Bayesian Information Criterion (BIC). AIC punishes model complexity (number of parameters) while favoring better model fit (higher log-likelihood value): $AIC = -2.LL + 2.K$, where LL is the log-likelihood estimate of the model and K is the number of model parameters. BIC is similar, with a different punishment approach for model complexity: $BIC = -2.LL + K.log(n)$, where n is the number of observations in the dataset.

Comparing MNL2 to MNL1, all our criteria supports the claim that MNL1 outperforms MNL2: with higher LL, and lower AIC and BIC scores. We also used the Likelihood Ratio Test (LRT) between these two models. LRT compares the fit of two related models (one must be a special case of the other) using their Log-Likelihood values and degrees of freedom. The test concludes that at 0.1% level of significance, MNL1 outperforms MNL2 ($\chi^2 = 60.09 > 16.266$, Δdf=3). Thus, we reject the idea of coding price relative to income, and use MNL1 as the base model to benchmark with other models from now on.

D.2 Nested Logit Model 2

It is probable that a consumer follows a hierarchical decision making process: she first makes a decision between leasing or purchasing, and then decides on the product condition (lease new or used) only if she has already chosen to lease. Put differently, the respondents might be making the decision in two steps by first choosing the nest (lease or do not lease) and then choosing one of the alternatives in the given nest. Therefore, we test the possibility of a nested structure in the decision-making process of the respondents by running a nested logit model. The model has two nests: 1. lease (alternatives B and C), and 2. do not lease (alternatives A and D). Column 3 in Table D.1 shows the results of this model.

The insights gained from this model are mostly similar results to MNL1 model, except that NL1 predicts higher probabilities (estimates) of alternatives A, B, and C being chosen over D. A strange result is the estimate of the income factor for alternative C being the highest estimate, meaning that consumers with higher incomes would choose to lease a used washing machine. As C is seemingly the most affordable alternative[1], this outcome is contrasting with our expectations as well as the results from other models. Also differently from MNL1, NL1 estimates that pride of ownership is not significant for choosers of alternative B, and convenience of leasing is not significant for leasers (alternatives B and C). Further note that the standard error for the disgust factor of alternative A decreased. Other than these observations, the results of NL1 are logical and in line with MNL1.

We used the Likelihood Ratio Test (LRT) between these two models to test the hypothesis that the decision-making structure is nested (i.e., the hypothesis that $\lambda_k \neq 1$) (Train, 2009). LRT compares the fit of two related models (one must be a special case of the other) using their Log-Likelihood values and degrees of freedom. The test concludes that on 95% confidence level there is not enough statistical evidence to suggest that the decision-making structure is nested, i.e. the nested logit model (NL) does not fit to the data significantly better than the MNL model ($\chi^2 = 1.978 < 3.841$, Δdf=1). This result can also be seen by the slight difference between the LL scores of the two models (-4396 vs. -4395). AIC and BIC scores also support this claim. Consequently, we fail to reject **Hypothesis 1** which stated that consumers would make compensatory choices as assumed by the MNL.

[1]See Section 4.1 for a discussion on the consumer's total cost of ownership.

Table D.1: Comparison of all base models (Bold estimates are statistically significant at 5% or less.)

	MNL1		MNL2		NL1		NL2	
	Estimate	Std.Error	Estimate	Std.Error	Estimate	Std.Error	Estimate	Std.Error
A (intercept)	**4.818**	0.633	**5.707**	0.575	**5.696**	1.194	**5.208**	0.702
B (intercept)	**1.757**	0.665	**2.671**	0.606	**2.179**	0.987	1.009	0.823
C (intercept)	**2.829**	0.630	**3.502**	0.571	**3.635**	1.154	**3.011**	0.689
Price	**-1.323**	0.094	**-1.599**	0.119	**-1.390**	0.102	**-1.738**	0.186
A: income	**0.654**	0.185	-	-	**0.824**	0.271	**0.653**	0.178
B: income	**0.641**	0.189	-	-	**0.847**	0.292	**0.645**	0.187
C: income	**0.461**	0.185	-	-	**0.612**	0.261	**0.457**	0.178
A: disgust	**0.328**	0.806	**0.332**	0.080	**0.418**	0.178	**0.320**	0.125
B: disgust	**0.456**	0.081	**0.461**	0.082	**0.601**	0.204	**0.508**	0.127
C: disgust	0.129	0.809	0.136	0.080	0.194	0.167	0.135	0.125
A: ownership	**0.147**	0.049	**0.145**	0.049	**0.190**	0.087	**0.162**	0.065
B: ownership	**-0.115**	0.052	**-0.113**	0.052	-0.080	0.088	**-0.195**	0.075
C: ownership	**-0.113**	0.049	**-0.114**	0.049	-0.070	0.087	-0.121	0.065
A: convenience	**-0.329**	0.063	**-0.331**	0.063	**-0.409**	0.107	**-0.356**	0.062
B: convenience	**0.195**	0.066	**0.182**	0.066	0.106	0.117	**0.342**	0.094
C: convenience	**0.265**	0.063	**0.261**	0.063	0.194	0.101	**0.281**	0.062
A: age	-0.019	0.011	-0.179	0.011	-0.023	0.016	-0.018	0.012
B: age	**-0.028**	0.011	**-0.027**	0.011	**-0.034**	0.017	**-0.032**	0.013
C: age	**-0.015**	0.011	-0.015	0.011	-0.018	0.015	-0.016	0.012
iv					**1.267**	**0.234**	**1.412**	**0.173**
LL	-4396		-4426.1		-4395		-4392	
McFadden R^2	0.244		0.239		0.244		0.245	
AIC	8830		8884		8830		8822	
BIC	8957		8991		8977		8854	

Table D.2: Results of MIXL models with different numbers of Halton draws (Bold estimates are statistically significant at 5% or less.)

Mixed Logit Model										
Number of draws	n=50		n=100		n=200		n=300		n=500	
	Estimate	Std.Error	Estimate	Std.Error	Estimate	Std.Error	Estimate	Std.Error	Estimate	Std.Error
A (intercept)	**10.257**	0.775	**9.784**	0.802	**9.950**	0.807	**9.981**	0.826	**9.855**	0.823
B (intercept)	**6.591**	0.785	**6.124**	0.810	**6.292**	0.816	**6.326**	0.834	**6.198**	0.831
C (intercept)	**6.968**	0.720	**6.527**	0.745	**6.660**	0.753	**6.709**	0.773	**6.582**	0.769
Price	**-3.790**	0.145	**-3.815**	0.147	**-3.760**	0.145	**-3.745**	0.145	**-3.736**	0.144
A: income	**1.879**	0.205	**1.859**	0.207	**2.106**	0.208	**1.805**	0.211	**1.900**	0.212
B: income	**1.835**	0.207	**1.817**	0.209	**2.063**	0.210	**1.763**	0.214	**1.858**	0.214
C: income	**1.557**	0.196	**1.539**	0.197	**1.782**	0.199	**1.493**	0.203	**1.584**	0.203
A: disgust	**0.697**	0.153	**0.758**	0.169	**0.782**	0.172	**0.820**	0.180	**0.806**	0.174
B: disgust	**0.833**	0.153	**0.894**	0.168	**0.917**	0.171	**0.955**	0.179	**0.941**	0.174
C: disgust	**0.513**	0.162	**0.571**	0.162	**0.595**	0.165	**0.631**	0.173	**0.617**	0.167
A: ownership	**0.214**	0.082	**0.249**	0.082	**0.213**	0.083	**0.206**	0.086	**0.212**	0.085
B: ownership	-0.099	0.082	-0.066	0.082	-0.100	0.083	-0.107	0.086	-0.102	0.085
C: ownership	-0.131	0.077	-0.097	0.077	-0.129	0.078	-0.137	0.081	-0.133	0.079
A: convenience	**-0.357**	0.078	**-0.341**	0.079	**-0.320**	0.081	**-0.289**	0.083	**-0.296**	0.083
B: convenience	**0.311**	0.079	**0.327**	0.081	**0.347**	0.082	**0.377**	0.084	**0.371**	0.085
C: convenience	**0.420**	0.074	**0.434**	0.076	**0.455**	0.077	**0.484**	0.080	**0.479**	0.080
A: age	**-0.035**	0.016	-0.031	0.018	**-0.040**	0.018	-0.029	0.019	-0.031	0.019
B: age	**-0.049**	0.016	**-0.045**	0.018	**-0.055**	0.018	**-0.044**	0.019	**-0.045**	0.019
C: age	**-0.037**	0.015	**-0.033**	0.017	**-0.043**	0.017	-0.032	0.018	-0.033	0.018
sd.price	**5.099**	0.166	**5.154**	0.17	**5.095**	0.167	**5.099**	0.166	**5.083**	0.166
LL	-3557.8		-3557.3		-3552.7		-3548.4		-3550.5	
McFaddenR^2	0.388		0.388		0.389		0.390		0.390	

D.3 Number of Segments for LC-MNL

The latent class models need the number of classes, S, as input, which is determined by information criterion scores of potential models with different number of segments. AIC and/or BIC are commonly used for this purpose. Models with lower AIC and BIC scores are preferred for lower complexity and higher fit to the data. For our dataset, the AIC and BIC scores of LC models with different number of segments are reported in Table D.3 below.

Table D.3: LC-MNL with various number of classes

Q	**AIC**	**BIC**	**LL**	**Class probabilities**[2]	**Error**
2	6855	6948	-3413	0.47, 0.52	No
3	5118	5279	-2535	0.35, 0.12, 0.50	No
4	6828	7055	-3380	$2.2.10^{-14}$	Yes, r.c.[3] $=10^{-19}$
5	5158	5453	-2535	10^{-17}	Yes, r.c.=$.4.10^{-24}$
6	4552	4913	-2222	$2.5.10^{-48}$	Yes, r.c.= 6.10^{-64}
7	4563	4992	-2217	$3.3.10^{-24}$	Yes, r.c.= 7.10^{-32}

The models with more than 3 classes encounter singularity errors with the given reciprocal condition numbers ($< 10^{-6}$). This problem indicates singularity of the information matrix in the model and hence, model non-identification (Masyn, 2013) and may signal class over-extraction (Geiser, 2012; Berlin, Williams, & Parra, 2014).

Another signal of using too many classes is the models with more than 3 classes having at least one class with a class probability close to 0. Masyn (2013) states that such models are not trustworthy and advises against further consideration of them. Moreover, after Q=3, the goodness of fit measures AIC, BIC and LL start to have strange behaviors against expectations: AIC and BIC do not have a minimum point, LL first increases and then decreases. So, these measures cannot be used to select the optimal number of classes. Nevertheless, the fact that models with a singularity problem are not reliable leaves the estimates of goodness of fit measures open to question and may explain these strange values.

Consequently, we only compare the models with 2 and 3 classes which do not return the singularity issue. Among these, the model with 3 classes is selected because it fits the data significantly better with a lower log likelihood value, and has lower AIC and BIC scores. Furthermore, as will be discussed below, the results are interpretable, which is the most essential criterion for the final model selection according to Geiser (2012).

[2]For models with more than 3 classes, we only report the lowest class probability that indicates class over-extraction.

[3]r.c.: reciprocal condition number.