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The impact of a repair subsidy on repair prices, demand and repair company profitability

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ABSTRACT

Repair is a critical contributor towards a more sustainable circular economy by prolonging the lives of consumer products. However, compared with purchasing new products, consumers perceive repair as expensive and inconvenient. Consequently, repair demand is low. To overcome this problem and stimulate demand, public authorities have introduced financial incentives in the form of different funding schemes for electric and electronic products. Clearly the design of these schemes will affect how repair companies set repair prices and how this affects consumer demand for repair. However, at a micro-level, this relationship between repair funding and repair prices as well as demand has not been studied before. In this paper we analyze and compare two designs of a funding scheme for electric and electronic products as implemented in Austria. Using a stylized model, we show that while such schemes lead to increasing prices, they can indeed enhance demand and improve repair company profits. Moreover, we find that preferences of consumers and repair companies with respect to the design of the funding scheme may diverge. Thus, public authorities need to prioritize demand or supply side benefits of the funding scheme.

1. Introduction

The second half of the last century saw a fast-paced move to throw-away societies in many developed economies (Cooper, 2013; Hellmann and Luedicke, 2018). One indicator for this is the decline in both demand and supply for repair of consumer products. For example, the number of specialized firms in electronics repair in the Netherlands went down from 4 500 to 2 500 over a 10-year period, while in Poland it decreased by 16% between 2008 and 2010. On the demand side, around a third of consumers would never consider repair (Makov and Fitzpatrick, 2021; EPRS, 2019; Jaeger-Erben et al., 2021). There are different reasons for that Laitala et al. (2021), Güsser-Fachbach et al. (2023a). First, while cheap, low-quality new products are easily available, repair suffers from an unfavorable cost structure due to its labor-intensity. Second, the convenience of online shopping with home-delivery of new products is in contrast with the hassle of finding and visiting an appropriate repair company. Third, waiting for a repair which may be unsuccessful after all also makes repair inconvenient.

On the other hand, repair is seen by many as a key enabler of a circular economy, see e.g. Stahel (2016). Being the innermost loop of re-use activities it preserves the product's integrity and uses little extra (virgin) resources. As such it preferably compares with approaches like recycling or remanufacturing, which are technology intensive. Moreover, recycling only restores value on the material level.

Yet, while over the last 20 years a reversal of the consumerism trend can be observed and sustainability is gaining traction, this is particularly pronounced in terms of recycling. Nowadays, separate collection of different wastes, a key preparatory step for efficient recycling, is common practice in (western) households (Agovino et al., 2020). Firms market their products by indicating their recyclability or even the recycled content that has gone into the product itself (see e.g. Apple (2023)). Governments have enacted legislation, mandating collection and recycling volumes of products like waste electric and electronic equipment, plastic or batteries (see e.g. European Parliament (2018)).

Compared to that repair is only beginning to recover. While more and more consumers are well-intentioned, demand for repair is still low and growing at a slow rate (see e.g. European Commission (2018), Fachbach et al. (2022)). Right-to-repair initiatives (Right to Repair Europe, 2020) are starting to influence legislators in shaping regulations that lay the basis for more circular business models and ultimately more sustainable product design (Ecodesign UK, 2023; BMK, 2023a; European Commission, 2023). Thus, while some success has been achieved, particularly in terms of recycling, there is still a long way to cover to achieve a truly circular economy. Consumers, repair companies but also

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manufacturers as well as legislators and public administrations need to contribute.

Understanding the crucial role of consumers in holding on to their products for a longer time and demanding repair in case of defects, financial incentive schemes have been put in place in several countries. These schemes address repair prices as the main barrier for consumers to take up repair (Güsser-Fachbach et al., 2023b). Reduced value-added-tax (VAT) rates on repair are in place across Europe. Sweden offers income tax-deductability of expenses for repair (Svensson-Hoglund et al., 2021). These measures affect consumers only indirectly (VAT rate reductions) or with a significant time delay (income tax-deductability). A third approach is offering a direct subsidy to consumers undertaking repair. Starting in 2017, different implementations of such repair subsidy schemes have been used on a municipal, regional or national level across Austria. For example in Graz, the second largest city in Austria, citizens could re-claim 50% of their expenses for repairs of electric and electronic equipment by submitting the invoice together with the proof of payment to the city administration. In April 2022, a national Austria-wide scheme was introduced that replaced all the regional funding schemes (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2023). While being similar to its predecessors in many aspects, the scheme differed from them by transferring the burden of re-claiming the expenses from the consumers to the repair companies. Thus, consumers only paid the subsidized price to the repair companies and the latter subsequently submitted the invoices for reimbursement. Within one year of its inception at the national level almost 600,000 repairs have been undertaken under the scheme, far exceeding the government's expectations (BMK, 2023b). While the success justifies the national scheme practically, it remains unclear what the effect of the design of the scheme was, and whether it compares preferably with its predecessors.

To get a basic understanding of the perception of the different funding scheme designs we organized focus group discussions with consumers as well as interviews with repair companies in Graz. Based on the gathered insights we build a stylized economic model of the two funding schemes for electric and electronic products — the national Austria-wide system and its municipal predecessor in Graz. In our model we consider the subsidy rate, the disutility of waiting for the reimbursement and the repair company's administrative cost associated with dealing with the funding scheme in a monopolistic setting. We compare both schemes with each other as well as with a benchmark without subsidy. The guiding research questions are: (i) What is the impact of the design of the funding scheme on repair prices and demand? (ii) Which of the two schemes is preferable from a repair company and/or consumer perspective?

Our model therefore does not provide decision support in the narrow sense, but identifies structural dynamics between repair funding and the resulting repair prices. By using the stylized, economic model and abstracting from cultural, sustainability-related or similar topics, we can properly isolate and attribute observed effects. In general, we find that the impact of a repair subsidy on demand and company profits depends on the design of the scheme and the repair cost structure. In particular, we show that a scheme where repair companies are reimbursed is only preferable under high subsidy rates and for expensive repairs. When subsidy rates or repair cost are low, such a system can even be inefficient, in that it reduces consumer demand for repair as well as repair company profits. We further demonstrate that preferences of consumers and repair companies with respect to the design of the funding scheme may diverge, necessitating public authorities to prioritize demand or supply side benefits when implementing a funding scheme.

The remainder of the paper is organized as follows. In the next section we present an overview of related work and position our contribution. Section 3 describes our model formulation, while we analyze and compare the two different designs of the funding scheme with each other as well as with a benchmark without subsidy in Section 4. Section 5 concludes the paper with a summary of our findings, as well as their practical implications, and a discussion of the limitations of our research.

2. Related work

In this section we will briefly review the relevant related work. We employ a traditional (narrative) literature review to provide a broad overview and describe and discuss the extant body of work from a contextual point of view. Our paper is mainly related to three different streams of research, namely investigations on public policies, consumer behavior in terms of repair as well as strategies and operations of repair companies.

Reviews of public policies for circular economy can be found in McDowall et al. (2017), Milios (2018) and Uusitalo et al. (2020). Different national initiatives like the repairability index in France or the Swedish strategy for repair in general are elaborated on in Almén et al. (2021) or Monier et al. (2016). Financial and fiscal incentives for repair are rather new phenomena and consequently have not been analyzed extensively (Almén et al., 2021; Dalhammar, 2019). In a comparative law study Heselhaus (2020) analyzes VAT reductions on repair services. Almén et al. (2021) focuses mainly on the Swedish repair incentives and only briefly touches upon other schemes in different countries. The effects of tax-deductability of repair expenses have also been studied in Ramezani et al. (2018). Using a macro-economic lens, Köppl et al. (2019) analyze different mechanisms including a VAT reduction and tax-deductability. Measures like a subsidy and its impact on different stakeholders have not yet been analyzed in the context of repair but for remanufacturing or recycling (see e.g. Liu et al. (2016), Yu et al. (2020). Mitra and Webster (2008) analyze the effect of a public subsidy on the competition between an OEM and an independent remanufacturer. Liu et al. (2021) found that subsidizing consumers leads to better results in terms of welfare than supporting the remanufacturers. This latter results has also been multiply confirmed by studies in more general contexts, including the use of solar panels Myojo and Ohashi (2018) or the development of new technologies Sun et al. (2019). Our paper contributes to this stream of literature by providing the first micro-level assessment of different versions of repair funding schemes. By focusing on the effects of the schemes on consumers and repair companies, it also enhances our understanding about who should be targeted with the funding scheme.

The second stream of literature this paper builds on is concerned with consumer repair behavior. A recent review, highlighting the relative scarcity of works dealing with repair and reuse as compared to disposal and recycling behaviors, can be found in Islam et al. (2021). Several studies from this literature point at the importance of the financial viability of repair (see e.g. Adler and Hlavacek (1976), Banaszkiewicz et al. (2022), Laitala et al. (2021), or Fachbach et al. (2022)). Apart from that, the necessity to turn intentions into actual behavior, and the role of public interventions as a means to achieve this have been addressed in, e.g. Borthakur and Govind (2019), Gobert et al. (2021), and Baker et al. (2022). Güsser-Fachbach et al. (2023a) highlights the importance of convenience in shaping repair intentions of consumers and Güsser-Fachbach et al. (2023b) links willingness-to-pay for repair to service convenience. We contribute to this stream of literature by analyzing the effect of (different types of) repair funding schemes on repair demand of consumers.

Finally, our paper relates to the supply side of repair services. Repair time as a crucial aspect of the service affecting repair acceptance by consumers has been addressed through studies on the organization and logistics of warranty services (Murthy et al., 2004; Buczkowski et al., 2005), the design of the reverse logistics for repair in general (Blumberg, 1999; Amini et al., 2005; Du and Evans, 2008), or spare parts management (Blumberg, 1999; Mamer and Smith, 1985; Cohen and Lee, 1990; Tiemessen and van Houtum, 2013). More recently, the focus has shifted on the impact of customer tolerance for waiting on spare parts management (e.g. Dreyfuss and Giat (2017)) or on the interaction between spare parts and service engineer capacity (e.g. Sleptchenko et al. (2003, 2018), Rahimi-Ghahroodi et al. (2019)). This literature highlights the importance of designing repair services as a means to keeping repair cost down and protecting profit margins. A different stream of research focuses on the pricing of repair services. Cohen and Whang (1997) consider a product life-cycle model where they integrate a manufacturer's pricing decisions for the new product and the after-sales repair services. Sabbaghi et al. (2017) undertook a survey study among more than 2000 repair technicians to obtain empirical data on repair services that were then fed into a pricing model to determine the optimal hourly repair charge as a function of spare parts prices. Very recently, Jin et al. (2022) have analyzed the impact of right-to-repair legislation – through reduced repair cost and lower entry barriers for independent repair companies – on repair prices. Our paper contributes to this field by describing the impact of repair funding schemes on the pricing decision of the manufacturer.

3. Methodology

We consider a monopolist repair company that offers repair services for a durable product to satisfy consumer demand in a single period. The single period can be viewed as the maturity stage of the product, where repair demand and prices over time are stable. This is a common assumption in models looking for structural insights in decision making (see e.g. Atasu and Souza (2013)). Our assumption to consider a single product also makes sense in the context of repair. While repair companies likely offer repair services for a potentially large number of different products, any individual consumer is unlikely to observe repair demand for more than one product at the same time. Thus, arguably repair prices of different products are not closely linked with each other strategically. Finally, considering a monopolist keeps the model simple, but it can also be justified from a practical standpoint. First, convenience has been shown to be an important aspect of repair services (Güsser-Fachbach et al., 2023a). As such there is not much shopping for the cheapest possible repair service. Rather, reachability and accessibility drive the choice, if the price is acceptable in principle. Moreover, for our specific setting in the city of Graz, Austria, which is a medium-sized city with a population of about 300.000 inhabitants, there is indeed only a single repair company for certain types of products.

Our modeling of consumer preferences also follows the extant literature (see e.g. Atasu and Souza (2013)). Without loss of generality, we normalize market size to 1. Consumers are heterogeneous in their willingness to pay for repair θ, which we assume to be uniformly distributed, i.e. $\theta \in \{0, 1\}$. Consumer demand for repair is driven by the utility consumers derive from having functional products. Given the repair price p, consumers derive a net utility $U[\theta, p] = \theta - p$. Normalizing the value of the outside option to zero, repair demand originates from consumers with a positive net utility, leading to the demand function $D[p] = 1 - p$.

To stimulate demand, the public authorities offer a subsidy f on the repair price. For example, it has been 50% of the repair price across all previous schemes and also in the current scheme in place in Austria for electric and electronic products (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2023). Thus, we assume that f is independent of the actual scheme used, but to keep our model more general we let $0 < f < 1$. Also, a common feature of all the systems is that the repair subsidy is paid out after the repair and upon submission of the supporting documents including invoices and confirmation of payment. Consequently, there are two issues that need to be considered. First, there is a time lag between the repair service and its payment and the reimbursement of the subsidy. Second, as repair and regular maintenance are sometimes hard to distinguish or even separate, there is a certain probability, that the service used by the consumer turns out not to be eligible for the subsidy, which is then denied. Alternatively, such a denial can also happen when the available budget for the funding scheme runs dry. To account for those two issues we introduce an interest rate $0 \leq r$ capturing the discounted value of the future reimbursement at the time of repair.

Finally, the third stakeholder in our model is the repair company. It has per-unit cost c associated with providing the repair and charges a price p_r for its repair service. It also has to pay VAT at a rate $0 \leq t$. Note that without a subsidy, i.e. when $f = 0$, the price p consumers pay is the same as the repair price p_r charged by the repair company, i.e. $p = p_r$. We will use this situation below as a benchmark (denoted with superscript B).

With a subsidy, i.e. when $f > 0$, the actual difference between p and p_r will depend on the design of the subsidy. Once again inspired by the real world system in Austria, we consider two variations of the subsidy. In the first scheme, consumers pay the full price p_r to the repair company and subsequently have to claim their reimbursement of the subsidy from the public authorities. In that scheme (which we call *Scheme C* and denote by superscript C in the following) the price p^C affecting consumers' demand decision is given by $p^C = (1 - \frac{f}{1+r})p_r^C$. Note that the reimbursed amount $f p_r^C$ is discounted by $(1+r)$ to mimick the time consumers wait to receive the subsidy. The associated demand is given by $D^C = D[p^C] = 1 - p^C = 1 - (1 - \frac{f}{1+r})p_r^C$. In that scheme the repair company is not directly affected by the subsidy process (only indirectly by its effect on demand), and maximizes its profit which is given by $\pi^C = (\frac{p_r^C}{1+t} - c)D^C$.

In the second scheme (which we call *Scheme F* and denote by superscript F in the following), the consumers are granted the subsidized price $p^F = (1 - f)p_r^F$ directly by the repair company which is subsequently reimbursed by the public authorities. The associated demand is given by $D^F = D[p^F] = 1 - p^F = 1 - (1 - f)p_r^F$. In that scheme the repair company has to deal with the paperwork and waits for its reimbursement. The first aspect is captured in the model by an administrative cost $0 \leq c_a$ that companies face in addition to the unit repair cost c. The second aspect affects the repair company's income stream over time. Specifically it earns $\frac{(1-f)p_r^F}{1+t}$ immediately when the consumer pays for repair. Once the reimbursement is issued, the repair company receives its remaining money $\frac{f p_r^F}{(1+t)(1+r)}$. Note that, as in *Scheme C* above, the cash-flow of the reimbursement is discounted by $(1 + r)$ to mimick the time the repair company waits to receive the subsidy. Given those cash-flow components, the profit of the repair company is given by $\pi^F = (\frac{(1-f)p_r^F}{1+t} + \frac{f p_r^F}{(1+t)(1+r)} - c - c_a)D^F$.

Finally, to account for the fact that companies may be used to a decoupling of physical and financial flows in their supply chains, we allow the discount rate r to differ between the two schemes. Specifically, we replace r with r_C and r_F in *Scheme C* and *Scheme F*, respectively, and let $0 \leq r_F \leq r_C$.

4. Analysis

In this section, we analyze our models for the two schemes to generate insights on how the design of the scheme affects the consumers and the repair company. We first consider a benchmark scenario (Section 4.1) without subsidy. Next, we consider *Scheme C* and *Scheme F* separately in Sections 4.2 and 4.3, respectively. In those sections we also compare these schemes with the benchmark scenario. Finally, we compare the two schemes (Section 4.4). The proofs for all our analytical results are sketched in Appendix A.[1]

4.1. Benchmark: No subsidy ($f = 0$)

Without subsidy, where $p_r^B = p^B$, our model simplifies to $D^B = D[p^B] = 1 - p^B$ and $\pi^B = (\frac{p_r^B}{1+t} - c)D^B$.

Maximizing π^B yields the optimal repair price of $p_r^B = \frac{1+c(1+t)}{2}$ and the associated repair demand $D^B = \frac{1-c(1+t)}{2}$. The repair company's profit is given by $\pi^B = \frac{(1-c(1+t))^2}{4(1+t)}$. These results are also summarized in Table 1.

[1] The underlying Wolfram Mathematica® file is available upon request.

Table 1
Optimal prices, demands and repair company profits under different funding schemes.

	Repair price charged by repair company p_r
Benchmark	$\frac{1+c(1+t)}{2}$
Scheme C	$\frac{1+c(1+t)}{2}+\frac{f}{2(1+r_C-f)}$
Scheme F	$\frac{1+c(1+t)}{2}+\frac{f+(1-f)(c_a(1+r_f)(1+t)+(1+c(1+t))r_f f)}{2(1-f)(1+r_f(1-f))}$
	Repair price paid by consumers p
Benchmark	$\frac{1+c(1+t)}{2}$
Scheme C	$\frac{1+c(1+t)}{2}-\frac{cf(1+t)}{2(1+r_c)}$
Scheme F	$\frac{1+c(1+t)}{2}-\frac{(cf-c_a(1+r_f)(1-f))(1+t)}{2(1-f)(1+r_f(1-f))}$
	Repair demand D
Benchmark	$\frac{1-c(1+t)}{2}$
Scheme C	$\frac{1-c(1+t)}{2}+\frac{cf(1+t)}{2(1+r_c)}$
Scheme F	$\frac{1-c(1+t)}{2}+\frac{(cf-c_a(1+r_f)(1-f))(1+t)}{2(1-f)(1+r_f(1-f))}$
	Repair company profit π
Benchmark	$\frac{(1-c(1+t))^2}{4(1+t)}$
Scheme C	$\frac{(1+r_c-c(1+t)(1+r_c-f))^2}{4(1+t)(1+r_c)(1+r_c-f)}$
Scheme F	$\frac{(1+(1-f)(r_f-(c+c_a)(1+r_f)(1+t)))^2}{4(1+r_f)(1-f)(1+r_f(1-f))(1+t)}$

Table 2
Functional expressions of thresholds.

$$T_0 = \frac{1}{1+t}$$

$$T_1 = \frac{1+(1-f)r_f}{(1-f)(1+r_f)(1+t)} - c_a$$

$$T_2 = \frac{c_a(1-f)(1+r_f)}{f}$$

$$T_3 = \frac{c_a(1-f)(1+r_f)}{f} - \sqrt{\frac{(1+(1-f)r_f)(f-c_a(1-f)(1+r_f)(1+t))^2}{(1-f)f^2(1+r_f)(1+t)^2}}$$

$$T_4 = \frac{c_a(1-f)(1+r_c)(1+r_f)}{f(r_c-(1-f)r_f)}$$

$$T_5 = \frac{c_a(1-f)(1+r_c)(1+r_f)}{f(r_c-(1-f)r_f)} - \sqrt{\frac{(1+r_c)(1+(1-f)r_f)(f(r_c-(1-f)r_f)-c_a(1-f)(1-f+r_c)(1+r_f)(1+t))^2}{(1-f)f^2(1-f+r_c)(1+r_f)(r_c-(1-f)r_f)^2(1+t)^2}}$$

To ensure that demand is non-negative, i.e. there exists a market for repair even without subsidy, repair cost must not be too high, specifically $c < \frac{1}{1+t}$. In all our further analyses, we assume that this condition holds and we express the threshold as $T_0 = \frac{1}{1+t}$. This threshold, together with all the other thresholds used in our further analysis, is also captured in Table 2.

4.2. Scheme C – reimbursing consumers

Let us now consider the case where the funding scheme is based on reimbursing consumers.

Lemma 1. *Under consumer reimbursing the optimal repair price is given by $p_r^C = \frac{1+c(1+t)}{2} + \frac{f}{2(1+r_c-f)}$. It ensures non-negative demand whenever $0 \leq c \leq T_0$. The associated repair demand D^C and the repair company's profit π^C are shown in Table 1.*

Corollary 1. *The optimal repair price p_r^C*

- *decreases in discount rate r_c, and*
- *increases in VAT rate t, repair cost c and subsidy rate f.*

Repair demand D^C

- *decreases in discount rate r_c, VAT rate t, repair cost c and*
- *increases in subsidy rate f.*

Lemma 1 and Corollary 1 explain how the economic environment including the funding scheme affects repair price and demand. First, we observe that the subsidy always increases repair price compared with the case without subsidy. Second, the results confirm our intuition that a higher repair cost and VAT rate drive repair price upwards and consequently reduce demand. Third, they explain the effect of the subsidy rate and the consumers' disutility of waiting for the reimbursement (measured by the discount rate r_c) on repair price and demand. Looking at the subsidy rate, we find that increasing f leads to a higher repair price, yet it also induces higher demand. Thus, the repair company extracts some of the benefit of the subsidy, but little enough to ensure that repair demand is not hurt. Considering the other aspect of the funding scheme, namely the consumers' disutility of waiting for the reimbursement, we observe that an increase in r_c, i.e. an increase in disutility, reduces repair demand and price. In other words, the repair company adjusts its price downwards to offset some of the consumers' disutility, but not enough to stabilize demand. While the subsidy rate f and the discount rate r_c induce opposing effects, the success of the funding scheme clearly depends on the combination of those two aspects. Proposition 1 provides a strong result on the preferability of the funding scheme over the benchmark without subsidy.

Proposition 1. *Reimbursing consumers always increases repair demand and repair company profits compared with the benchmark without subsidy.*

This result shows that reimbursing consumers always has a positive effect on consumers, in terms of increased repair demand, despite the increased repair price it induces. Jointly, higher price and demand increase the profit of the repair company. In other words, the benefits induced by the funding scheme are always shared between the repair company and the consumers. Put differently, even though the funding scheme directly targets the consumers and affects the repair company only implicitly, the repair company extracts some of the subsidy for its own profitability, by anticipating the demand effect.

4.3. Scheme F – reimbursing repair companies

In this section we will consider the case where the scheme is based on reimbursing repair companies.

Lemma 2. *Under repair company reimbursing the optimal repair price is given by $p_r^F = \frac{1+c(1+t)}{2} + \frac{f+(1-f)(c_a(1+r_f)(1+t)+(1+c(1+t))r_f f)}{2(1-f)(1+r_f(1-f))}$. It ensures non-negative demand only if $0 \leq c \leq T_1$. The associated repair demand D^F and the repair company's profit π^F are shown in Table 1.*

Corollary 2. *The optimal repair price p_r^F increases in all parameters.*
Repair demand D^F

- *decreases in discount rate r_f, VAT rate t, repair cost c, administrative cost c_a, and*
- *increases in subsidy rate f.*

Analogously to Lemma 1 and Corollary 1 above, Lemma 2 and Corollary 2 explain how repair price and demand are affected by the economic environment. As was true in *Scheme C*, the funding scheme always increases repair price compared with the case without subsidy. Like in *Scheme C* higher repair cost and VAT rate also increase repair price and reduce demand under repair company reimbursing. The effect of the subsidy rate is also the same, in that an increase in the subsidy rate leads to a higher repair price, but also induces increased repair demand. The big difference between *Scheme F* and *Scheme C* lies in the effect of the discount rate. As in *Scheme F* the company only earns the subsidized repair price directly and has to wait for being reimbursed the remaining amount, an increase in r_f, implying an increase

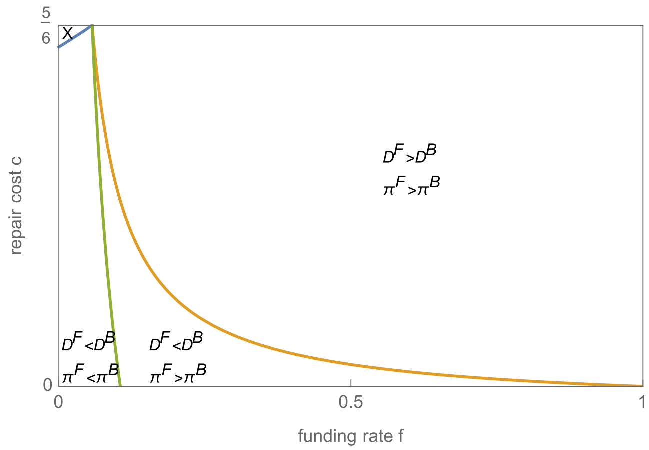

Fig. 1. Effect of reimbursing repair companies on repair demand and repair company profit ($t = 0.2, c_a = 0.05, r_c = \frac{1}{70}, r_f = \frac{1}{140}$).

in the repair company's disutility of waiting for the reimbursement, now increases the repair price and this directly affects repair demand negatively. Finally, under repair company reimbursing, the additional administrative cost c_a affects repair price and demand in the expected way, i.e. an increase in those administrative cost increases repair price and consequently reduces repair demand. It is this administrative cost c_a that also leads to the threshold T_1. As c_a essentially contributes to the unit-cost for the repair company, the actual repair cost c must not be too high to ensure positive demand.

Different from *Scheme C*, in *Scheme F* the repair company increases its repair price not only to divert some of the extra benefit induced by the funding scheme away from the consumers, but also to (i) cover its additional administrative cost, and (ii) offset the disadvantage of receiving part of the payment only in the future. Given those extra components influencing the repair price, Proposition 2 lays out an interesting finding on the preferability of the funding scheme over the benchmark without subsidy.

Proposition 2. *Compared with the benchmark without subsidy, reimbursing repair companies always decreases repair demand and repair company profits when* $0 < f < \frac{c_a(1+r_f)(1+t)}{1+c_a(1+r_f)(1+t)}$.

When $f > \frac{c_a(1+r_f)(1+t)}{1+c_a(1+r_f)(1+t)}$ *the effect of the funding scheme on repair demand and repair company profit depends on repair cost c:*

- $0 < c \leq T_3$: *reimbursing repair companies decreases repair demand and repair company profits*
- $T_3 < c \leq T_2$: *reimbursing repair companies decreases repair demand, but increases repair company profits*
- $T_2 < c < T_0$: *reimbursing repair companies increases repair demand and repair company profits*

Corollary 3. *The two thresholds* T_2 *and* T_3

- *increase in* r_f *and* c_a*, and*
- *decrease in* f.

T_3 *increases in* t.

These results are also visualized in Fig. 1, where the underlying data on VAT and discount rates reflect the economic background in Austria at the time of the study. They imply that different from *Scheme C* which always benefits consumers and the repair company, *Scheme F* actually requires a minimum subsidy rate f to be efficient. When f is too small, the subsidy does not sufficiently offset the price increase due to administrative cost c_a, and repair company disutility of waiting r_f. The consumers face a higher price than without subsidy and consequently demand is reduced. For the repair company the per-unit margin is smaller than without subsidy. As a result both the consumers and the repair company would be better off without the funding scheme. The minimum subsidy rate also depends on repair cost c. When c is small the proportion of the repair price induced by repair cost is small, while the proportion induced by the funding scheme is large. Consequently, even for a larger subsidy rate f, the inefficiency of *Scheme F* remains.

Conversely, when f and c are large enough ($f > \frac{c_a(1+r_f)(1+t)}{1+c_a(1+r_f)(1+t)}$ and $T_2 < c$), the repair price markup due to the funding scheme is proportionally low. Consequently, the repair company can increase repair price to fully offset the negative effect of the administrative cost c_a and the disutility of waiting for the reimbursement (r_f). Additionally the high subsidy rate still ensures that the subsidized price consumers pay is below the price p^B without subsidy. As a result, both consumers and the repair company benefit from *Scheme F*.

Proposition 2 provides another intriguing result. When f is sufficiently large $f > \frac{c_a(1+r_f)(1+t)}{1+c_a(1+r_f)(1+t)}$, but repair cost c falls in an intermediate range $T_3 < c \leq T_2$, *Scheme F* is beneficial to the repair company despite decreasing demand compared to the benchmark without subsidy.

In such a setting the repair price markup due to the funding scheme is proportionally large and the subsidy rate f is not sufficient to ensure that the subsidized price consumers pay is lower than the unsubsidized repair price. Consequently repair demand is lower under *Scheme F* than in the benchmark situation without subsidy. Yet, as long as c is not too small, the repair price increase is large enough to ensure that the increased per-unit revenue outweighs the reduced demand.

Finally, Corollary 3 confirms that an increase in the repair company's disutility associated with the funding scheme (measured by increasing c_a or r_f) reduces its preferability over the benchmark without subsidy.

In summary, contrary to *Scheme C*, *Scheme F* requires a sufficiently large subsidy rate f to benefit at least the repair company and an even larger f to also benefit consumers.

4.4. Comparison of the two schemes

So far we have seen that *Scheme C* always benefits both, consumers and the repair company, while *Scheme F* may even lead to a lose-lose situation when compared with the benchmark without subsidy. When such a case occurs for *Scheme F*, it is clear that *Scheme C* is strictly preferable over *Scheme F*. Proposition 3 presents the more general answer for all possible market conditions and is visualized in Fig. 2, where the underlying data on VAT and discount rates reflect the economic background in Austria at the time of the study.

Proposition 3. *For any given subsidy rate* f*,*

- *reimbursing repair companies always leads to a larger repair price than reimbursing consumers.*
- *Repair demand is higher with repair company reimbursing than with consumer reimbursing if* $T_4 < c < T_0$*. Otherwise (if* $0 < c \leq T4$*), it is lower.*
- *Repair company profit is higher with repair company reimbursing than with consumer reimbursing if* $T_5 < c < T_0$*. Otherwise (if* $0 < c \leq T_5$*), it is lower.*

Corollary 4. *The threshold* T_4

- *increases in* r_f *and* c_a*, and*
- *decreases in* r_c *and* f.

Corollary 5. *The two thresholds* T_4 *and* T_5 *satisfy* $0 < T_5 < T_4$.

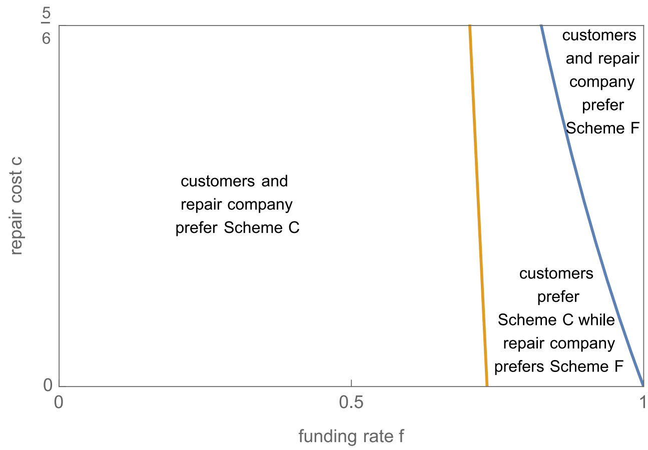

Fig. 2. Comparison of consumer and repair company preferences for type of funding scheme ($t = 0.2, c_a = 0.05, r_c = \frac{1}{70}, r_f = \frac{1}{140}$).

The result again highlights the more extreme behavior of *Scheme F* compared with *Scheme C*. In fact, while we know that for sufficiently small f (or sufficiently small c), *Scheme F* is even dominated by the benchmark without subsidy, Proposition 3 shows that for sufficiently high f (or sufficiently high c), *Scheme F* outperforms *Scheme C* in that it not only benefits the consumers but also the repair company. This is particularly interesting, given that *Scheme F* always lead to higher repair prices. When repair is sufficiently expensive and the subsidy rate is high enough, the benefit of ultimately paying a nominally lower price under *Scheme C* is offset by the consumers' disutility of waiting for the reimbursement in that scheme. Corollary 4 supports this logic, as the preferability of *Scheme F* over *Scheme C* from a consumer perspective goes up when r_c increases, while it is reduced when r_f or c_a increase.

Corollary 5 indicates that there is a third case, for intermediate levels of the subsidy rate f (or c), where consumers would prefer *Scheme C* over *Scheme F*, while the repair company prefers *Scheme F* over *Scheme C*. The higher price in *Scheme F* yields a larger per-unit revenue for the repair company which offsets the reduced demand. Conversely, given the lower level of the subsidy rate f, for consumers the benefit of directly paying the subsidized price no longer outweighs the disutility of waiting for the reimbursement in *Scheme C*. Finally, there can never be a situation where consumers would prefer *Scheme F* over *Scheme C* while the repair company simultaneously prefers *Scheme C* over *Scheme F*.

In closing, it is worth mentioning that for the funding rate of 50% (i.e. $f = 0.5$) and given the economic conditions in Austria as captured in the figures, *Scheme C* always benefits both consumers and repair company. As this is the discontinued scheme, our results suggest that the current scheme is inferior to its predecessor.

5. Discussion and conclusions

Despite its importance for the establishment of a more sustainable circular economy repair currently suffers from limited supply and low demand. To overcome this problem, public authorities have introduced financial incentives in the form of different funding schemes for electric and electronic products. Clearly the design of these schemes will affect how repair companies set re- pair prices and how this affects consumer demand for repair. However, at a micro-level, this relationship between repair funding and repair prices as well as demand has not been studied before. Our paper contributes to the literature by addressing this gap.

This study presents a stylized model, in order to capture the important trade-offs regarding how a subsidy for repair affects repair supply and demand. Specifically we compare two designs of the subsidy as implemented in Austria. The key ingredients of our model are based on observations made during focus group discussions with consumers as well as interviews with repair companies in Graz. As expected any type of funding scheme was appreciated by consumers. However, in the municipal scheme used in Graz consumers criticized the fact that they had to pay the full repair price and subsequently wait for their reimbursement. In that context they also perceived uncertainty about the process and the outcome, i.e. whether and how much they would be reimbursed. Conversely, in the national system consumers appreciated the fact that they have to pay the subsidized price only. Yet, they voiced the fear that repair companies, when being in charge of administering and claiming the subsidy, would raise repair prices to internalize some (or all) of the benefits of the funding scheme. When talking with repair companies, they complained about their administrative effort and associated cost of dealing with the funding scheme in the national system, and confirmed that this cost would be included in repair prices.

In comparing the two designs of the funding scheme, our results demonstrate that, regardless of its design, repair prices always increase, while depending on the market conditions and the characteristics of the scheme itself, either design may be preferable from the perspective of consumers and repair company.

The critical trade-off in our study is driven by the relationship between the benefits of a funding scheme and its administrative burden, measured by the disutility of waiting for the reimbursement as well as the cost of repair companies for handling the scheme's process. In particular we argue that reimbursing consumers always leads to increased demand, despite increased repair prices, through which the repair company extracts part of the extra benefit of the scheme. Conversely, any extra cost associated with administering the funding scheme under repair company reimbursing may increase prices in a way that repair demand actually decreases. Remarkably such a situation, while detrimental to consumers, may still be preferable for the repair company.

These results have important implications for policy-making and the design of the funding scheme. First, when choosing repair company reimbursing, the subsidy rate needs to be sufficiently large to ensure a positive demand effect and increased repair company profits. Clearly, a higher subsidy rate implies greater cost for the public authorities, which needs to be taken into account as well. However, if the scheme stimulates the repair market, VAT income may also increase and this could lead to a fiscal multiplier effect (Hagedorn et al., 2019), i.e. a situation where the cost of the funding scheme is more than offset by the additional tax income for the public authorities. Second, repair company reimbursing is only efficient for more expensive repairs. Arguably, this is the case for some electric and electronic products, like large household appliances, smartphones or laptops. However, for less expensive appliances like microwaves, blenders, earphones, which are also covered by the currently existing funding schemes, this may no longer be true. Moreover, if such funding schemes were to be extended to other product categories, like e.g. clothing or bicycles, the design question becomes even more pronounced. For those product types a scheme based on consumer reimbursing seems preferable. Third, we find that when subsidy rates and repair cost both are moderate a tension exists between the repair company and consumers on the preferability of the funding scheme design. Both actors may prefer to be the reimbursed party. For the public authorities this raises the question whose interests are more important. While at the forefront, the idea of the funding scheme is to stimulate demand BMK (2023b), the supply side is important to ensure that repair services are offered adequately (ORF.at, 2022).

In conclusion, our study, like all research, is not without its limitations. First, we used a stylized demand model. Specifically, consumer valuations for repaired products are uniformly distributed, which is in keeping with the closed-loop supply chain literature, and necessary for analytical tractability. This assumption implies linear demand curves, which have been shown to approximate reality when prices vary in narrow ranges. Moreover, appropriately for strategic-level models such as ours, our model is completely deterministic. However, uncertainty about the funding scheme can play an important role, and experiences deviating from the expectations can affect future decisions to repair or not. Second, and related to this, we assume a single period model, mimicking a stable market. In reality, repair prices and times will depend on available capacities and their operational planning. Consequently, the interaction of the funding scheme with demand and supply of repair services may dynamically evolve over time. This would require a multi-period model. Our single-period model suggests that this would be very challenging analytically.

CRediT authorship contribution statement

Marc Reimann: Writing – review & editing, Writing – original draft, Validation, Software, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

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

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jclepro.2024.143102.

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