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Electric Vehicle Owners' Perception of Remanufactured Batteries: An Empirical Study in China

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Abstract: The proliferation of electric vehicles (EVs) globally is remarkable progress in strides toward a low carbon society. However, the volume of end-of-life EV batteries will hit a critical mass in the future. Widespread adoption of EV battery remanufacturing is essential in achieving higher resource efficiency. The current study investigated Chinese EV owners' perceptions of remanufactured EV batteries: 420 respondents in China who own and drive EVs participated in the survey. This study modeled respondents' acceptance, purchase intention, and willingness-to-pay for remanufactured EV batteries by adapting the structural equation model (SEM). The results showed that consumers' price consciousness and perceived benefits both directly influence their purchase intention of remanufactured batteries. Unlike previous studies, this study found that consumers' perceived risks on remanufactured batteries do not directly influence their purchase intention. Instead, the influence of perceived risks on purchasing behavior is mediated by perceived benefits. The study also found that purchase intention affects willingness to pay and acceptance of remanufactured batteries. Drawing on our study results, this research suggests measures to promote markets for remanufactured EV batteries and provides corporate marketing options to accelerate proliferation of remanufactured batteries.

Keywords: remanufactured batteries; electric vehicles; Chinese consumers; consumer perceptions; purchase intention

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1. Introduction

Global environmental protection and conservation efforts have generated rapid growth and enthusiastic adoption of eco-friendly technologies. The proliferation of electric vehicles (EVs) worldwide signals significant strides toward cleaner transportation and a more environmentally sustainable society. Characterized by their eco-friendly aptitude, battery-powered EVs are celebrated for bringing remarkable environmental and social benefits, such as reducing carbon emission, lessening air and noise pollution [1], and increasing energy efficiency [2,3]. Paradoxically, the mounting demand for EVs comes with looming concerns over the potential environmental burden of EV batteries (EVBs). Particularly, large volumes of spent EVBs without proper treatment will likely be disposed of as solid waste and become a significant environmental liability [4,5]. Moreover, heavy reliance on virgin raw materials will hasten the depletion of natural resources such as cobalt and nickel, leading to roaring costs of EVB production and consequently, hindering more widespread adoption of EVs [2,6,7].

The market forecast suggests the volume of spent EVBs is expected to increase significantly in the coming years and will escalate with the continuous rapid growth of the global EV market [8,9]. On a yearly basis, in 2025, a survey forecast that 345,000 tons of end-of-life EVBs would be generated globally, of which 80% would be generated in China [10]. China is

the world's largest new-energy vehicle (NEV) market by sales volume since 2015 [9] and is expecting even faster growth rates for the years to come. The China NEV market is undoubtedly at the forefront facing the pressing challenge of managing EVBs upon retirement.

A practical solution addressing environmental and social issues in EVB management is remanufacturing [11]. Remanufacturing is an industrial process whereby the residual value of used products can be recaptured by restoring and reusing valuable working components [12,13]. This practical and logical approach enables used products to be restored and offered to consumers in "like-new" condition [14,15]. Remanufacturing has been well-documented as an efficient and responsible end-of-life manufacturing strategy [16] providing enormous economic, environmental, and social benefits [17,18]. Literature shows that remanufacturing alleviates negative impacts on the environment by minimizing premature waste disposal [14]. It promotes resource conservation by reusing materials and improving the effectual efficiency of natural resources [5].

Although the remanufacturing literature has seen blooming interest and productive research in the last decade, most extant literature has focused on supply chain and operational issues [13,19] or waste management considerations [4,5]. Despite emerging, research on consumer acceptance of remanufactured products and market demand issues remains very limited [18,20,21]. Previous studies suggest consumer "green" attitude [14,18,22,23], perceived benefits [11,24,25], product knowledge [11,18,22,24,26], and tolerance for ambiguity [27,28] contribute to greater purchase intention of remanufactured products. Lower price [12,13,20,29], quality assurance by certification [11,30], and brand reputation [20,22,25] are among effective marketing strategies to entice purchase. Perceived high risk generally is negatively associated with purchase intention with some mixed findings [18,22,25,28,31,32].

Research on consumer acceptance of remanufactured EVBs (REVBs) is practically missing. High market demand can inspire remanufacturing decisions [14], however, insufficient consumer purchasing can be a crucial obstacle to a successful circular economy [11]. To the best of our knowledge, no previous research has explicitly studied REVBs despite the crucial importance of EVB management. This study fills the research gap in understanding market demand of REVBs, or a lack thereof, by investigating current Chinese EV owners' perception and willingness to accept REVB. It also explores their purchase intention and willingness to pay (WTP) for REVBs. Empirical findings provide firsthand knowledge of consumers' perception of REVBs and valuable insights in critical business decisions such as pricing strategies and innovative business models. Moreover, this research draws on the risk perception theory [33] and studies the roles of uncertainty and perceived consequences in consumer risk assessment.

Specifically, the purpose of this research is three-fold. First, this study investigates consumer acceptance, purchase intention, and WTP of remanufactured EVBs and consumer perceptions. Previous studies have suggested that Chinese consumers are generally reluctant to buy remanufactured products [18,31], considering them defective and inferior in quality [18,22]. Answering the call for more research on improving WTP [21,34] and including both cognitive and affective measures [29], this study examines consumers' intention to purchase and their WTP for remanufactured EVBs comparable with new EVBs. This study also examines consumers' willingness to accept a new EV powered by the remanufactured battery pack, providing consumer insights and business implications for the rising battery-as-a-service (BaaS) models [9].

Second, this study investigates consumer price consciousness and its effect on perceptions and purchase intention. Recently, price-conscious behaviors have been increasingly observed in the marketplace [35] amidst economically challenging conditions. Financial vulnerability [35] and negative economic events [36] have propelled consumers to pay closer attention to price considerations. Importantly, literature alludes to an assumption that price-conscious consumers are more inclined to purchase remanufactured products because of perceived low prices. However, the underpinning mechanism that derives this assumption has never been studied explicitly [37]. Moreover, Chinese EV owners

are reported to be relatively price-conscious [13,38] and are highly concentrated in major metropolitan areas due to registration restrictions and emission rules [9].

Finally, consistent with extant literature, this study predicts a positive relationship between perceived benefits of remanufactured electric vehicle batteries (REVBs) and consumers' purchase intention, and greater willingness to accept and higher WTP for an REVB. Less evident in the extant literature is the effect of risk perception [20]. Although previous research has suggested a negative relationship, mixed findings [11,27,30] call for further investigation to untangle the effect. Previous studies show that Chinese consumers construct high-risk perceptions primarily associated with performance and quality [22] and high costs [18]. However, they are very receptive to the economic, environmental, and social benefits of remanufactured products [31] and appreciate the significant resource conservation and energy saving made possible by remanufacturing [18].

This research contributes to the remanufacturing literature by providing additional marketing perspectives and insights, specifically consumer price consciousness and risk perception. Meanwhile, we shed some light on the unique characteristics of REVBs and their effect on consumer decision-making behavior.

2. Literature Review and Hypotheses

Relevant studies were systematically searched using keywords including remanufacturing, electric vehicles, price consciousness, benefits and risks, and consumer purchase intention and WTP, while empirical studies were collected predominantly from the marketing literature, supply chain and operations research, and sustainability studies. A literature review suggests that consumer-attribute-based research is scant in the remanufacturing literature [11,12,25]. Particularly, relevant to remanufactured products, including electric vehicle batteries (EVBs), is consumers' price consciousness and its effects on product valuation and purchase decisions. Remanufactured products are often perceived to be associated with low-cost and price [12,39]; hence, they are often assumed to have great appeal to high-price-conscious (HPC) consumers. In a study of consumer perception of remanufactured auto parts in Japan, Matsumoto et al. [32] noted that Japanese consumers are largely low-price-conscious (LPC). When their product knowledge is limited, they likely perceive low benefits in remanufactured auto parts, providing an indirect but interesting observation for consumer price consciousness. This research draws on price consciousness literature and investigates the effects on consumers' perceived benefits and risks associated with REVBs and the impact on purchase intention, product acceptance, and consumer willingness-to-pay (WTP).

2.1. Price Consciousness, Perceived Benefits, and Purchase Intention

Consumer price consciousness has been studied extensively in the marketing literature [40–46]. Defined as "the degree to which the consumer focuses exclusively on paying a low price" [41] (p. 235), price consciousness reflects an enduring attitudinal propensity that consumers value financial savings as essential economic and utility benefits, and habitually seek lower prices when making purchase decisions [36,40,45]. Some studies have viewed this as an adaptive response to cope with personal financial vulnerability [35,40,41] and negative economic events such as unemployment [36]. However, the majority of extant research posits that price consciousness is an innate consumer characteristic and that price-conscious consumers enjoy the utilitarian value of saving money and derive psychological benefits like excitement and entertainment from shopping for low prices [40,42,43].

We predict that price-conscious consumers likely express greater intention to purchase REVBs because the pervasive low-price image of remanufactured products probably invokes a lower price assumption for REVBs, which HPC consumers generally find appealing. Extant literature has documented that remanufactured products are generally perceived as being of below-par quality with low prices [12,22,25,32] and competing based on price advantage [13,27,28]. Atasu et al. [14] observed that remanufactured products are less expensive than the comparable new products in most real-life cases, and many consumers

would buy only at lower prices. Meanwhile, Ferguson and Toktay [39] explained that the lower valuation might be attributed to consumers' perception of lower cost or lower quality in remanufactured products.

To reduce cognitive effort, consumers draw from a range of information to infer price level (e.g., [47]), including brand and quality [48], choice context (e.g., [44]), and perceived image of product origin [11,46] HPC consumers focus on paying low prices and often make hasty decisions [49]; thus, they predominantly rely on the most salient and pre-eminent price information available to judge prices and drive decisions [47]. We contend that HPC consumers are more likely to embark on the low-price image of the remanufacturing category and use it as a salient price cue that lowers the price of REVBs compared with new EVBs (NEVBs, i.e., new batteries for EVs). The signaling effect is particularly prevalent in the REVB market against the backdrop of relentlessly high battery production costs [9,50], which conjures an elevated internal reference point in the consumer price comparison. We hypothesize that the low-price perception of remanufactured products serves as a salient, pleasing, and sufficient price cue for HPC consumers to infer lower prices of REVBs, which in turn increases product attractiveness and induces greater purchase intention.

The environmental and social benefits are at the focal point of most extant remanufacturing studies [11,12,29,30]. They have documented the significant role remanufacturing plays in reducing negative environmental impacts, conserving resources and energy [5], facilitating closed-loop supply chains (CLSCs), and empowering a self-sustained circular economy [12]. Particularly intriguing are the perceived benefits associated with REVBs among current EV owners. Touting their eco-friendly power, EVs appeal to buyers through their anticipated environmental benefits, such as reducing carbon emission and air pollution [1] and improving energy efficiency [2,3]. The EV battery pack, the core EV component, is one of the most valuable and crucial technologies that deliver expected eco-friendly benefits. Therefore, in line with extant research, we predict that current EV owners, whether price-conscious or not, will express positive beliefs of environmental benefits associated with EVs, and by extension, perceived eco-friendly benefits of REVBs.

Notwithstanding, we predict that HPC consumers are more likely to evoke price implication from resource conservation and energy saving benefits. By doing so, they conceive additional economic and utility gain associated with environmental benefits, compared with their LPC counterparts. Driven exclusively by low prices and paying little attention to non-price attributes [41], HPC consumers likely consider the environmental benefits of REVBs in terms of price implications, specifically how such benefits contribute to lower EVB prices. Remanufacturing literature provides ample evidence that successful CLSCs and a sustainable circular economy may prevent price surges of raw materials and engender considerable cost savings in battery production [5,51], thereby further bringing down EV and EVB prices. Bloomberg News (25 October 2021) [50] reported that recycling valuable metals like nickel from retired EVBs can bring the cost of EVBs down by up to 20%. We contend that HPC consumers likely view resource conservation and energy savings as benefits leading to cost reduction and lower prices. The crucial importance of low-price in their purchase decisions further amplifies the magnitude of perceived eco-friendly benefits compared with LPC consumers.

Thus, we hypothesize the following:

Hypothesis 1a (H1a). *Consumers' price consciousness positively influences their purchase intention of remanufactured batteries.*

Hypothesis 1b (H1b). *Consumers' price consciousness positively influences their remanufactured batteries' perceived benefits.*

2.2. Perceived Benefits, Intention, WTP, and Acceptance

Consumer perception is an important antecedent to consumer purchase intention. A review of the literature reveals that consumers' intention to purchase remanufactured products and their WTP [11,27–29,32] are the most investigated outcome variables in the remanufacturing literature [20], followed by consumer perceptions and acceptance of remanufactured products (e.g., [11]). Matsumoto et al. [30] showed that the greater perceived benefits of remanufactured auto parts increased purchase rate in Southeast Asian markets. Moreover, economic exchange theory posits that greater perceived benefits positively contribute to consumers' utility gain in an economic exchange [48] and their WTP a premium price [52]. Choi and Johnson [53] further honed in on the perceived effectiveness of green products (e.g., EVs) and illustrated the positive relationship between consumers' perceived benefits and their increased purchase rate.

Greater purchase intention of REVBs is generally a result of a favorable view of such a product and a greater desire for product ownership, indicating greater willingness to accept REVBs [12] and providing the basis for greater WTP. Particularly, relevant to REVBs that go hand-in-hand with an eco-friendly appeal, research suggests that consumers are typically willing to pay a premium in purchasing a "green" product [53]. We postulate that price-conscious consumers are more inclined to purchase REVBs by direct price inference and heightened environmental benefits. Those who consider EVs and EVBs as eco-friendly products are likely to express higher willingness to accept EVs with REVBs and higher WTP. Thus, we hypothesize the following:

Hypothesis 1d (H1d). *Consumers' perceived benefits positively influence their purchase intention of remanufactured batteries.*

Hypothesis 1e (H1e). *Consumers' intention to purchase remanufactured batteries positively influences their WTP.*

Hypothesis 1f (H1f). *Consumers' purchase intention of remanufactured batteries positively influences their acceptance of EVs with remanufactured batteries.*

2.3. Perceived Risks, Price Consciousness, and Purchase Intention

Consumer risk perception is often associated with the uncertainty inherent in the remanufacturing process and the unknown prior use of products [12,20,25,27]. Extant literature showed that high perceived risk hampers consumer intention to purchase remanufactured products [12,32], as high-risk perception essentially embodies a negative attitude toward the product [18]. Chinen and Matsumoto [11] explained that a major perceived risk source is rooted in consumers' inability to verify quality before purchase, thus inducing ambiguity and potential loss. Consistently, Letmathe and Suares [26] posited that high credence attributes of EVBs (e.g., energy consumption, repair frequency, and degradation schedule) are difficult to verify even during product use. Conceivably, consumers are apprehensive of such ambiguity [25,54] and may choose to delay purchase or seek alternatives to avoid ambiguity risks [20,28]. In line with extant literature, we expect that risk perception is associated with the uncertainty and ambiguity inherent in the unknowable remanufacturing process and unverified outputs; greater uncertainty engenders higher perceived risk.

Extant research often equates perceived risk with uncertainty [20,25,55]. We draw on the theory of perceived risk that consumers' assessment of riskiness in purchasing decisions accounts for both uncertainty and consequences of negative outcomes [33,55,56]. Uncertainty is attributed to the unknown probability of an event occurring [57]; for example, the likelihood of an REVB breaking down within a year cannot be precisely specified, neither can the likelihood of resulting losses. As such, uncertainty induces an unsettling sentiment of threat, contributing to a higher level of perceived risk. Risk consequence consists of two considerations: perceived importance of the expected outcome [20,33]

and expected loss severity [25,29,58]. In our study, because price consciousness reflects consumers' "cognitive briefs about the importance of saving money" [42], the importance of consequence reflects consumers' desire for money-saving [33,36] or a "subjective feeling of negativity" [56] about financial loss. The severity of consequence denotes the amount of loss [56], a proxy seriousness measure of loss consequences [29]. Previous research has shown that consumers consider both uncertainty level and expected utility of loss consequences in risk assessment [25,31,42,58]. In particular, Sinha and Batra [42] studied price-conscious consumers' in-store brand purchasing and defined product category risk by multiplying the probability and perceived consequence. Hamzaoui-Essoussi and Linton [25] explored consumer purchase intention of remanufactured products and defined perceived risk as uncertainty, importance, and severity of consequences. Previous studies have also suggested a negative relationship between price consciousness and risk perception [42,59]. Motivated exclusively by paying lower prices, HPC consumers are deeply engaged in dollar-and-cent price comparison [43,60], paying little attention to non-price attributes [41] and lesser thought on the likelihood or severity of negative consequences. The perceived deficiency of remanufactured products mostly revolves around the uncertainty of product quality and performance. Therefore, we expect that such non-price relative risks are largely neglected among HPC consumers and have little bearing in their evaluation of REVBs. However, LPC consumers place greater importance on product quality and performance attributes [41,43] and are likely to interpret high perceived risks that both heighten likelihood of quality failure and elevate severity of a potential loss. This is consistent with the findings of Sinha and Batra [42], who stated that LPC consumers are more inclined to mitigate high ambiguous risks by purchasing higher-priced products, believing that high-priced products are of better quality and hence have lower risks. We hypothesize the following:

Hypothesis 1c (H1c). *Consumers' price consciousness negatively influences their perceived risks of remanufactured batteries.*

This reasoning further hypothesizes that perceived risk negatively, but indirectly, affects the purchase intention by diminishing consumers' perceived benefits of REVBs. Extant research supports a negative effect of perceived risk on consumer intention to purchase remanufactured products [11,20,23,32,58], although this effect is not always significant [27,30]. Matsumoto et al. [30] studied the purchase intention of remanufactured auto parts in Southeast Asia countries and reported a negative but insignificant effect of perceived risk on purchase intention. Wang et al. [27] also noted that perceived risk does not directly affect purchase intention. Further research was called upon to unravel the underpinning mechanism that drives this relationship.

Consistent with the extant literature, we hypothesize a negative mediation effect: perceived risks adversely affect consumer purchase intention by diminishing perceived benefits. Consumers who view REVBs as high-risk likely experience greater uncertainty, ambiguity, and lack of confidence that REVBs will deliver the stated environmental, social, and economic benefits. As we established earlier, we expect most EV owners to agree with the potential environmental and social benefits of REVBs and that remanufacturing helps conserve the natural resource and facilitate an efficient circular economy by demanding less raw material, reducing energy consumption, and alleviating potential negative impact on the ecosystem [11]. In this regard, expectations of negative consequences such as poor EVB performance, frequent repair, accelerated degradation schedule, and premature replacement may steer consumers to speculate if these post-purchase services may end up requiring as much or more raw material, energy use, and other resources during their lifetime. Consumers holding high perceived risk are more likely to question the efficacy of REVBs and, by extension, the practicality of remanufacturing to support sustainability. As such, perceived social and environmental benefits associated with REVBs may be undermined, resulting in increased hesitation to consider a purchase. Similarly, consumers taking an economic perspective likely expect resource conservation and energy savings to

lead to cost savings and lower prices; when post-purchase services associated with frequent repair and early retirement of REVBs are assumed to incur significant extra costs, it invites high-risk assuming consumers to challenge its ability to produce net economic savings effectively and in turn to discount the total perceived benefits associated with REVBs.

Although an insignificant relationship cannot be tested statistically, we do not expect an important direct effect of perceived risk on purchase intention, considering several factors potentially attributable to our research context, in which some are arguably unique to the Chinese EVB market. Our general contention is that the severity of risk consequences in purchasing REVBs may be effectively mitigated among Chinese EV owners by the well-documented effective risk relievers [56]: major brand image [20,22,29], government incentives, significant technology advancement, and resulting consumer confidence. Brand image is offered as one the most effective drivers that effectively ease perceived risk in reality. We argue this is because the overall weighted risk magnitude, albeit still important, diminishes as consumers develop trust and confidence due to these risk relievers. As such, the actual threat of loss is not seen as imminent or severe enough to affect purchase intention. Matsumoto et al. [24] alluded to the severity effect. They explained the insignificant direct effect, citing that "consumers may be taking the RAP risks lightly, and their purchase intentions are not as affected" (p. 1039).

Most Chinese consumers do not have much first-hand experience with EVB degradation and replacement, let alone REVBs. Automakers are also being modest, perhaps except for Tesla [46], about their remanufacturing engagement with only a handful of successful cases (e.g., Nissan Leaf providing REVBs as an option to consumers in Japan) [61]. The infancy of REVBs makes the severity of potential loss distant and less than compelling in deriving direct behavioral implications.

Therefore, we do not expect a direct effect but hypothesize full negative mediation:

Hypothesis 2a (H2a). *Consumers' perceived benefit negatively mediates the relationship between perceived risk and their product purchase intention of remanufactured batteries.*

3. Scope and Measurement

3.1. Scope of Products and Respondents

This study focuses on EV owners' perceived image of remanufactured batteries for EVs in China. The authors contracted a professional web survey company, which surveyed 420 respondents in early 2021 who met two conditions to complete the questionnaire. First, they were current owners of EVs. Second, they were the primary drivers of their EVs. We focused on the Chinese EV market because China is the world's largest EV market, with 2.3 million EVs in active use, or nearly 45 percent of the EV global stock [62]. Europe and the US are far behind, with 1.2 and 1.1 million EVs, respectively [63]. As China has become the largest carbon dioxide emitter globally, the government has begun introducing a series of policies to reduce carbon dioxide emissions with a specific focus on EV adoption [64].

Table 1 presents the summary statistics of demographics. Male respondents represent 50 percent. Approximately 20 percent of respondents were under 30 years old, 40 percent between 30 and 50 years old, 40 percent of 60 or older. Roughly 62 percent of respondents had a bachelor's degree or higher education level. Over 90 percent of respondents expressed their strong consideration of limited resources.

Table 1. Summary statistics of sample in the study.

		Frequency
Gender	Male	210
	Female	210
Age	Under 30	84
	30 to 39	84
	40 to 49	84
	50 to 59	84
	Above 59	84
Consideration of limited resources	Weak	19
	Neutral	20
	Strong	381

3.2. Scales of Measurement

Scales measuring benefit perception construct were adapted or slightly modified scales used in the study by Collins et al. [65]. Scales measuring perceived risk constructs were adapted or slightly modified scales used in the study by Matsumoto et al. [24]. This study measures price consciousness using scales from Lichtenstein et al. [41]. Our survey's purchase intention constructs consist of three questions used in the studies: two items by Klein [66] and Matsumoto et al. [24], and one-item developed for this study (desire to buy) by the authors. Respondents indicated their intentions for the two questions using a seven-point Likert scale with anchors ranging from (1) "strongly disagree" to (7) "strongly agree." "Willingness to pay" was a one-item question developed for this study. It asked respondents about their willingness to assign price (in unit) for a remanufactured battery assuming a new battery is priced at 100 units. We also included a one-item question developed for this study, asking if they can accept remanufactured EVBs for their new EVs. Table 2 summarizes the measurement scales used in this study.

Table 2. Scales of measurement.

Construct		Element (Seven-Point Likert Scale)
Perceived Benefits (PB)	PB1	Purchasing remanufactured EV batteries will help use less finite material resources.
	PB2	Purchasing remanufactured EV batteries will help reduce energy use in the manufacturing sector.
	PB3	Purchasing remanufactured EV batteries will help realize the circular economy.
	PB4	Purchasing remanufactured EV batteries will minimize negative effects on natural ecosystems.
Perceived Risks (PR)	PR1	One of the risks of remanufactured EV batteries is that they do NOT perform and function as new EV batteries.
	PR2	One of the risks of remanufactured EV batteries is of low value for money.
	PR3	I believe that I will have to return to the car repair shop to repair more frequently when I use a remanufactured EV battery.
Price Consciousness (PC)	PC1	Generally, I am willing to go to extra effort to find lower prices.
	PC2	The money saved by finding low prices is usually worth the time and effort.
	PC3	I shop at more than one store to find low prices.
	PC4	The time it takes to find low prices is usually worth the effort.
Purchase Intention (PI)	PI1	I am willing to purchase a remanufactured EV battery.
	PI2	The likelihood of buying a remanufactured EV battery is high.
	PI3	My desire to buy a remanufactured EV battery is strong.
Willingness to pay (WTP) (one-item question)		Assume a new EV battery is sold at the price of 100. How much are you willing to pay for a remanufactured EV battery?
Acceptance of remanufactured batteries (APT) (one-item question)		When I buy a new EV, I can accept the EV, which has remanufactured EV batteries.

For all construct items, 1: Strongly disagree, 7: Strongly agree. WTP 1: 30–50, 2: 51–70, 3: 71–80, 4: 81–89, 5: 90–99, 6: 100. APT 1: Strongly disagree, 7: Strongly agree.

3.3. Back Translation and Pretest

This study followed Craig and Douglas [67] and Brislin [68] to facilitate cross-cultural comparisons and ensure the comparability of questionnaire items. Items were translated and back-translated to assess cross-cultural equivalence. Then, we pretested the questionnaire among 92 students at a large US university before circulating it to a larger group of participants. This process ensured that the questionnaire was comprehensible in both cultures [68].

4. Results

4.1. Measurement Model: Confirmatory Factor Analysis

Cronbach's α scores of constructs (i.e., perceived benefits, perceived risks, price consciousness, and purchasing intention) all surpassed 0.8, ranging between 0.81 and 0.90, demonstrating that the scale used in this study has solid internal reliability (see Table 3). Convergent validity was assessed on the basis of the criterion that the indicator's estimated coefficient was significant on its posited underlying construct factor. We followed three standards recommended by Fornell and Larcker [69] to evaluate convergent validity.

Table 3. Convergent validity.

Construct	Item	Factor Loading	Construct Mean	Standard Deviation	Composite Reliability	AVE	Cronbach's α
Perceived benefits (PB)	PB1	0.83	5.93 **	0.91	0.87	0.62	0.87
	PB2	0.78					
	PB3	0.78					
	PB4	0.78					
Perceived risks (PR)	PR1	0.70	5.05 **	1.20	0.81	0.59	0.81
	PR2	0.81					
	PR3	0.79					
Price consciousness (PC)	PC1	0.80	5.45 **	1.06	0.88	0.66	0.88
	PC2	0.80					
	PC3	0.83					
	PC4	0.81					
Purchase intention (BUY)	BUY1	0.87	5.42 **	1.22	0.90	0.75	0.90
	BUY2	0.86					
	BUY3	0.87					
Price willing to pay (WTP), (one item)	WTP		4.15 *	1.41			
Acceptance of remanufactured batteries (APT), (one item)	APT		5.12 **	1.39			

** Significantly different from the neutral point (4) of the scale, $p < 0.01$. * Significantly different from the neutral point (4) of the scale, $p < 0.05$. AVE: Average variance extracted. For all construct items, 1: Strongly disagree, 7: Strongly agree. WTP 1: 30–50, 2: 51–70, 3: 71–80, 4: 81–89, 5: 90–99, 6: 100. APT 1: Strongly disagree, 7: Strongly agree.

1. All the indicator factor loadings should be significant and exceed 0.5
2. The construct reliability (Cronbach's α) should exceed 0.8
3. The average variance extracted (AVE) by each construct should exceed 0.5.

The results in Table 3 represent that all three conditions for convergent validity were met.

To demonstrate the discriminant validity, we must ensure that the square root of AVE for each factor or latent reflective construct is greater than the corresponding correlations between that and any other constructs (i.e., the AVE for each factor exceeds the square of the corresponding correlations between that and any other constructs), as recommended by Fornell and Larcker [69]. The results summarized in Table 4 demonstrate that the measurement model satisfies the requirement of discriminant validity. The results, therefore, confirm that the instrument has satisfactory construct validity.

Table 4. Discriminant validity.

	PB	PR	PC	BUY
Perceived Benefits (PB)	0.62			
Perceived Risks (PR)	0.00	0.59		
Price Consciousness (PC)	0.12	0.11	0.66	
Purchase Intention (BUY)	0.00	0.49	0.21	0.75

Diagonal elements are square root of AVEs. Figures are a square of the square of estimates between the constructs.

4.2. Structural Model: Structural Equation Analysis

After confirming the satisfactory fit for the measurement model, we assessed the structural equation model (SEM) and examined the research hypotheses using AMOS version 27. The SEM is an appropriate statistical tool to analyze the structural relationship between latent constructs. The SEM model is used because it allows us to estimate the multiple and interrelated dependence between constructs, such as perceived benefit, perceived risk, price consciousness, and purchase intention, in a single analysis. Figure 1 illustrates our hypothesized model for this study. The first step in evaluating the SEM was to compute the R2 statistic, which shows the dependent variable's variance explained by the predictor model variables. Overall, the model accounted for 52 percent of the variance in the purchase intention, 15 percent of the variance in perceived benefits, and 14 percent of perceived risks. The value of R2 for the model's construct variables exceeds the reference value of 0.1 [70].

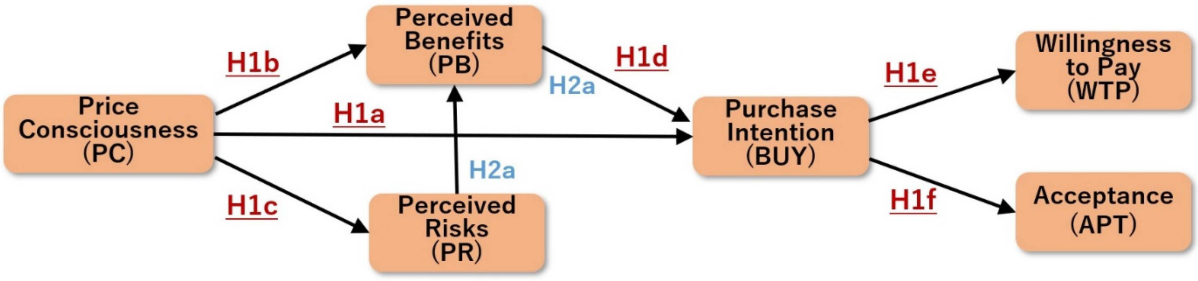

Figure 1. Hypothesized model. Note: H1a, b, c, d, e, and f represent direct effects. H2a represents indirect effect.

In the SEM measurement model, all constructs were allowed to correlate. The relative chi-square was 2.4 ($\chi^2(113) = 270.72$). The relative chi-square seems to have no universally agreed-upon standard to "what is considered a good and a bad fit" [71]. However, the relative chi-square of <5 is still acceptable [72]. Other fit-indices showed an acceptable level of fit: comparative fit index (CFI) = 0.96; Tucker–Lewis index (TLI) = 0.95; root mean square error of approximation (RMSEA) = 0.06. With evidence of acceptable fit, we proceeded to test the hypotheses. Table 5 summarizes the results of direct effects in the SEM model.

As predicted by H1a and H1b, the study found that the price consciousness positively influenced the purchase intention (H1a, BUY ← PC: $\beta = 0.26$, t = 5.63, $p < 0.001$); perceived benefits; H1b: PB ← PC: $\beta = 0.38$, t = 6.13, $p < 0.001$); and perceived risks (H1c, PR ← PC: $\beta = 0.36$, t = 6.23, $p < 0.001$). This study hypothesized the negative relationship between the price consciousness and perceived risk. However, the study found the positive relationship between the price consciousness and the perceived risk (H1b: PB ← PC: $\beta = 0.38$, t = 6.13, $p < 0.001$). We provide possible explanations for this result in the discussion section. The study found that perceived benefits positively influenced the purchase intention: the greater the consumers' perceived benefits, the greater their purchase intention of remanufactured batteries (H1d, BUY ← PB: $\beta = 0.60$, t = 11.17, $p < 0.001$). Expectedly, this study found a positive relationship between purchase intention and WTP (H1e, WTP ← BUY: $\beta = 0.30$, t = 6.08, $p < 0.001$). Expectedly, the study also found a positive relationship between the purchase intention and accepting remanufactured batteries to their new EVs (H1f, APT ← BUY: $\beta = 0.77$, t = 18.78, $p < 0.001$).

Table 5. The result of the structural model: Direct effects.

The Model Fitness Indicators	Value of Indicators		
χ^2 (df, probability level)	270.72 (113, $p < 0.001$)		
CFI	0.96		
TLI	0.95		
RMSEA	0.06		
Hypothesis	β	*t*-value	Support for hypothesis
BUY ← PC	0.26	5.63 ***	H1a: Supported
PB ← PC	0.38	6.13 ***	H1b: Supported
PR ← PC	0.36	6.23 ***	H1c: Not supported
BUY ← PB	0.60	11.17 ***	H1d: Supported
WTP ← BUY	0.30	6.08 ***	H1e: Supported
APT ← BUY	0.77	18.78 ***	H1f: Supported
PB ← Age	0.12	2.47 **	
PR ← Age	−0.10	−1.92 *	

*** Significant at $p < 0.001$; ** Significant at $p < 0.01$; * Significant at $p < 0.10$. WTP 1: 30–50, 2: 51–70, 3: 71–80, 4: 81–89, 5: 90–99, 6: 100. APT 1: Strongly disagree, 7: Strongly agree.

Although no predictions were made concerning age, our analyses showed that older consumers rated perceived benefits higher (β = 0.12, t = 2.47, $p < 0.001$). We also found that younger consumers tended to show higher perceived risks toward remanufactured batteries than younger consumers (β = −0.10, t = −1.92, $p < 0.10$).

To test the effect of a third valuable or mediating variable, we used the bootstrap confidence interval test method in AMOS version 27. Table 6 shows the results of the mediating effects in this study. In testing mediation using the bootstrap procedure, the null hypothesis (of no indirect effect) is rejected if zero is excluded from the specified confidence interval's lower and upper bounds. In this study, bootstrap analyses with 500 resamples (α = 0.05, i.e., the confidence interval at 95 percent) provided supports for the indirect effect for perceived risks on purchasing intention via perceived benefits (H2a supported, lower bound (−0.23) and upper bound (−0.05), $p = 0.019$). We observed full mediation because the direct effect of perceived benefit (PR) on purchase intention (BUY) was not significant in the presence of the mediator (PB) (BUY ← PR: β = 0.02, t = 0.34, $p = 0.733$).

Table 6. The result of the structural model: Mediation Effects.

	Estimate	Lower	Upper	*p*-Value	Support for Hypothesis
BUY ← PB ← PR	−0.12	−0.23	−0.05	0.019	H2a: Supported, full mediation

Readers should interpret the findings of this study carefully due to the smaller sample size relative to the actual number of EVs in the Chinese market. While a large sample may increase the detection of differences, a smaller sample can prevent the findings from being generalized.

5. Discussion

The findings of this study offer important insights to understand better customers' purchase behavior and perceptions toward REVBs, particularly in China, the largest EV market in the world. The results show that consumers' price consciousness positively influences purchase intention (H1a) and perceived benefits (H1b) of remanufactured EVBs. The analysis also demonstrates that consumers' perceived benefit positively affects purchase intention (H1d), and purchase intention positively influences both customers' WTP (H1e) and their acceptance of EVs with remanufactured batteries (H1f). The SEM also revealed that customers' perceived benefit fully mediates the relationship between their perceived risk and purchase intention of REVBs (H2a). This study primarily examined relationships

between endogenous variables (i.e., price consciousness, perceived risks, and perceived benefits) and exogenous variables (purchase intention). It also tested the mediation between perceived risks and purchase intention via a third variable: perceived benefits. This section primarily focuses on why the direct effect of price consciousness and perceived risks (H1c) was not supported.

The research on the psychology of consumption suggests that pricing drives risk and benefit perception. The higher the price a customer pays, the stronger the perceived benefits or the weaker the perceived risks a customer tends to develop, and vice versa [73]. This psychological effect also leads to a higher willingness to accept the risk perception due to the sunk cost effect [73]. Therefore, this research took a position that customers' price consciousness negatively influences perceived risk toward remanufactured batteries (H1c). However, our findings support a significant relationship between price consciousness and perceived risk. The effect, however, exhibits a positive association. High-price-conscious (HPC) consumers seem to identify greater risk associated with purchasing REVBs than low-price-conscious (LPC) consumers. This observation may be attributed to the significant financial consequences of purchasing REVBs as the perceived financial loss may trigger important price-related risks among HPC consumers.

First, vigilant on paying low prices, price-conscious consumers enjoy price comparison and are highly involved in the search and processing of price information [40]. Price-conscious consumers are deeply engaged in the dollar-and-cent calculation [43,60]; hence, they likely evaluate REVBs from the total ownership cost (TOC) [45], a notion characterized by considerations of expected future expenditures associated with repair and replacement [58,74]. The acutely expensive EVB repair and replacement [8], with the lower resale values due to battery degradation [4,26,75], clearly contribute to a greater likelihood of future monetary outlay and higher final price paid, increasing both the likelihood and magnitude of expected financial loss.

Second, financial loss, i.e., inability to save money, is clearly of greater importance to HPC consumers than to their LPC counterparts. The importance of perceived loss is the driving force that shapes consumers' overall risk perception [33,55]. Thus, the heightened risk of future financial setback can be distressingly exacerbated among price-conscious consumers as they overestimate the magnitude of loss. Peter and Ryan [55] showed that uncertainty strongly predicts brand preference if consumers view losses as highly important; Koschate-Fischer et al. [36] also noted that a strong desire to save money may lead to higher levels of uncertainty and higher risk perception regarding performance. Moreover, because TOC calculation of EVs and EVBs can be complex and overwhelming [26,52,75], price-conscious consumers may experience information overload when the lower ticket price of REVBs fades into an unreliable price cue, inadequate to drive decisions. Instead, the unsettling thought of future unknown financial losses looms larger in the minds of price-conscious consumers, inducing greater ambiguity and higher perceived risks.

However, LPC consumers place greater importance on product quality and performance attributes. As they become more knowledgeable about the "like-new" trait of remanufactured products, the perceived likelihood of product failure and potential loss diminishes. Additionally, previous research suggests a strong risk-aversion effect among LPC consumers [42] that LPC consumers are more willing to pay higher prices for better quality products to avoid uncertainty-related risk. The observed low-risk perception among LPC EV owners may partially be explained by their proactive risk-averse mitigation measures such as purchasing an extended warranty, subscription to worry-free service plans, and other assurance services.

Consumers' perceived risk of REVBs must be reduced. Consumers' concern over products' lower quality constitutes a major obstacle in diffusing remanufactured products in general [25] because EVBs are the most expensive components of EVs [76]. As we predicted, this study found that price-conscious consumers are likely to demonstrate greater purchase intention of REVBs. However, even if consumers value of the remanufactured

products is very close to new, they expect remanufactured products to be offered at a lower price, generally 30% less than new products [77]. Batteries are the most expensive and thus ranked high on reliability among all EV components [76]. Therefore, consumers may not expect a significant discount on REVBs. Indeed, our further analysis shows that 64.5% of respondents in this study expressed that they are willing to pay 81%–100% of the price of NEVBs for REVBs. Further, almost 74% of respondents expressed that they are willing to purchase EVs with REVBs.

6. Concluding Remarks and Implications for the Industry

The proliferation of EVs globally is remarkable progress in strides toward a low carbon society. However, the volume of end-of-life EVBs will hit a critical mass in the coming years and further in the future. Widespread adoption of EVB remanufacturing is essential in achieving higher resource efficiency. The current study investigated Chinese EV owners' perceptions of remanufactured EVBs.

Our empirical results show that consumers' price consciousness directly and positively influences their product purchase intention of remanufactured batteries. Additionally, consumers' price consciousness positively influences their perceived benefits of remanufactured batteries, which positively influences their product purchase intention. Although mediated by consumers' perceived benefits, consumers' perceived risks negatively correlate with their purchase intention toward remanufactured batteries. Consequently, consumers' price consciousness also indirectly increases their purchase intention of remanufactured batteries by reducing their perceived risks.

We offer some implications for the industry. Consumers' price consciousness plays a significant role in influencing their product purchase intention of remanufactured batteries; thus, a natural implication is for the suppliers of remanufactured batteries to focus on the HPC consumers. The suppliers of remanufactured batteries select the group buyers instead of the individual buyers as their initial target market. The group buyers are more likely to focus on cost control and the price–performance ratio, have more product knowledge and large purchase volumes, and are more willing to be the initial adopters of remanufactured products to gain a competitive advantage. All these characteristics make them the ideal buyers of remanufactured goods. For example, a taxi company with a large fleet of EVs is more likely to purchase remanufactured batteries than an individual consumer. More specifically, the suppliers of remanufactured batteries can focus on the potential buyers adopting a low-cost leadership strategy instead of a differentiation strategy, as the low-cost leaders are more price-conscious than their mid- or high-end counterparts. Once the suppliers have established a considerable market position in the segment of group buyers, they may start to penetrate the lower-end of the B2C segment, as the lower-end buyers are more price-conscious than the higher-end buyers. By then, their success in the segment will signal the quality of their products, facilitating the acceptance of their products in the segment.

The second implication for the industry is related to consumers' perceived benefits and risks of remanufactured batteries and their impact on consumers' product purchase intention toward remanufactured batteries. Our empirical results show that consumers' perceived benefits positively influence their product purchase intention of remanufactured batteries. Additionally, consumers' perceived benefits negatively mediate the relationship between their perceived risks and their product purchase intention of remanufactured batteries. Therefore, changes in consumers' perceived benefits and risks of remanufactured batteries will, directly and indirectly, affect their purchase intention. The suppliers of remanufactured batteries can increase consumers' product purchase intention by enhancing the perceived benefits and downplaying the perceived risks of remanufactured batteries. A few factors, including consumers' product knowledge, brand reputation, and warranties, can help achieve this goal.

Future research can systematically and empirically compare the buying behavior of the group buyers versus the individual buyers when remanufactured goods are involved.

Additionally, future research can empirically examine how suppliers' brand reputations and warranties influence consumers' perceived risks and product purchase intention.

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