摘　要

动力电池回收利用作为新能源产业可持续发展的重要环节，对实现“双碳”目标具有重要意义。依照动力电池 4 年至 8 年的使用寿命估算，2017 年前后国内大规模装机的新能源车动力电池已经在 2023 年迎来了回收放量期。大规模电池“退役潮”的来临使得动力电池回收利用体系完善迫在眉睫。对于退役动力电池的回收利用，主要有再生利用和梯次利用两种方式。相较于再生利用，梯次利用已经退役的动力电池，可延长电池使用寿命，充分发挥其剩余价值。但在梯次利用环节，由于受到电池信息不透明等因素影响，退役电池梯次利用还未能获得长足发展。因此，本文从区块链信息共享、数据不可篡改的技术特性出发，通过细分梯次产品内部竞争和外部竞争两种场景，对如何实现区块链赋能退役动力电池梯次利用领域进行了研究。

针对区块链技术赋能下考虑梯次产品内部竞争的问题，首先，根据是否引入区块链技术，分别构建了区块链技术赋能前后由授权处理商和电池制造商组成的博弈模型。随后，通过对比两种情形下的最优决策，研究了区块链技术引入对电池制造商运营决策以及区块链技术采纳决策的影响。研究结果表明：（1）电池制造商引入区块链会促使厂商提升两类梯次产品的保底批发价格和零售价格。（2）电池制造商的参与决策取决于区块链技术引入成本，当区块链技术引入成本过高时，电池制造商没有参与区块链的动机。（3）区块链技术的引入有助于社会福利和消费者剩余增长。

针对区块链技术赋能下考虑梯次产品外部竞争的问题，首先，基于末端消费市场中新产品与再制造产品存在的质量－价格竞争，构建了一个由梯次处理商和新产品厂商组成的博弈模型。随后在此基础上探讨了相关成员的区块链技术引入策略和市场竞争策略。最后，通过两种情形对比可知：（1）区块链技术的引入会激励梯次处理商提升梯次产品的质量和价格水平，但新产品质量水平是否提升取决于质量投资边际成本和新产品生产成本大小。仅有当新产品生产成本较小且质量投资成本适中时，新产品厂商有动力提升产品质量，当质量投资成本过大时，新产品厂商更倾向于选择保守性的市场策略。（2）梯次处理商引进区块链技术并不一定会损害新产品厂商利润，当新产品生产成本较大且质量投资成本适中时，新产品厂商也能在引入区块链的情形中获得收益。（3）在与同类新产品厂商存在质量-价格竞争的情形下，梯次处理商能否受益于区块链技术的引入主要取决于产品质量投资成本以及区块链投资成本。

本文以退役动力电池梯次利用所面临的现实困境为切入点，通过融合区块链技术与退役动力电池梯次利用，具体研究了区块链技术对于相关厂商运营决策的影响以及适宜区块链技术引入的最佳条件。研究成果一定程度上为区块链技术与动力电池管理结合的

理论探索提供了新的视角，具有一定借鉴意义。

关键词：退役动力电池；区块链技术；梯次利用；供应链；产品竞争

Abstract

The recycling and utilization of power batteries, as an important link in the sustainable development of the new energy industry, is of great significance for achieving the "dual carbon" goal. According to the estimation of the service life of the power battery from 4 to 8 years, new energy vehicle power batteries installed on a large scale in China around 2017 have entered a period of recycling and increasing production in 2023. The arrival of a large-scale battery retirement wave has made it urgent to improve the power battery recycling and utilization system. There are two main ways to recycle retired power batteries: regeneration and echelon utilization. Compared to recycling, echelon the use of retired power batteries can extend their service life and fully utilize their remaining value. In the process of echelon utilization, due to the influence of factors such as opaque battery information, the cascade utilization of retired batteries has not yet made great progress. Therefore, starting from the technical characteristics of blockchain information sharing and immutability of data, this article studies how to achieve blockchain empowerment in the field of retired power battery echelon utilization by segmenting the internal and external competition scenarios of tiered products. The main research content is as follows.

Aiming at the problem of considering the internal competition of echelon products under the empowerment of blockchain technology, firstly, game models were constructed before and after technology empowerment, consisting of authorized processors and battery manufacturers, based on whether blockchain technology was introduced. Subsequently, by comparing the optimal decision-making in the two scenarios, the influence of the introduction of blockchain technology on the operation decision of battery manufacturers and the adoption decision of blockchain technology is studied. The research results indicate that: (1)the introduction of blockchain by battery manufacturers will encourage them to increase the guaranteed wholesale and retail prices of two types of tiered products; (2)The participation of battery manufacturers in decision-making depends on the cost of introducing blockchain technology. When the cost of introducing blockchain technology is too high, battery manufacturers do not have the motivation to participate in blockchain; (3)The introduction of blockchain technology contributes to social welfare and consumer surplus growth.

In order to consider the external competition of echelon products under the empowerment of blockchain technology, firstly, based on the quality-price competition between new products and remanufactured products in the terminal consumer market, a game

model composed of echelon processors and new product manufacturers is constructed. Then, on this basis, the blockchain technology introduction strategy and market competition strategy of relevant members are discussed. Finally, by comparing two scenarios, it can be concluded that: (1)the introduction of blockchain technology will motivate tier processors to improve the quality and price level of tier products, but whether the quality level of new products is improved depends on the marginal cost of quality investment and the production cost of new products. Only when the production cost of new products is low and the quality investment cost is moderate, new product manufacturers have the motivation to improve product quality. When the quality investment cost is too high, new product manufacturers are more inclined to choose conservative market strategies. (2)The introduction of blockchain technology by tier processors does not necessarily harm the profits of new product manufacturers. When the production cost of new products is high and the quality investment cost is moderate, new product manufacturers can also benefit from the introduction of blockchain. (3)In the case of quality price competition with similar new product manufacturers, whether tier processors can benefit from the introduction of blockchain technology mainly depends on the investment cost of product quality and blockchain investment.

This article takes the practical difficulties faced by the echelon utilization of retired power batteries as the starting point. By integrating blockchain technology with the echelon utilization of retired power batteries, it specifically studies the impact of blockchain technology on the operational decisions of relevant manufacturers and the optimal conditions for introducing blockchain technology. To a certain extent, the research results provide a new perspective for the theoretical exploration of the combination of blockchain technology and power battery management, and have certain reference significance.

Key Words: Retired power batteries; Blockchain technology; Echelon utilization; Supply chain; Product competition

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