**LINKING EFFICIENCY AND SUSTAINABILITY:
DYNAMIC PRICING AS SERVICE INNOVATION IN SMART FRIDGES**

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Abstract

This article analyzes dynamic pricing in IoT-enabled smart fridge, conceptualizing it as a service innovation policy rather than a retail tactic. Drawing on service-dominant logic and circular service design, we frame the smart fridge as a sociotechnical service actor that perceives, decides, and acts, coproducing value with users along the usage path.

Using a dataset of over 10,000 transactions, we aim to analyze how dynamic pricing aligns operational efficiency with sustainability outcomes. We hypothesize that dynamic pricing improves product turnover and stabilizes orders (efficiency), while also favoring the sale of products close to their expiration date (sustainability).

The findings will advance service research by reframing dynamic pricing as a service innovation integrated into IoT ecosystems, with implications for scholars and practitioners seeking to design sustainable services.

Keyword: Service Dominant Logic; Dynamic Pricing; Circular Service Design; Smart Services; Internet of Things (IoT)

1. Introduction

The growing diffusion of smart technologies is reshaping service design, enabling new forms of automation, interaction, and value co-creation (Mele et al., 2023). In this evolving landscape, connected devices such as smart fridges are no longer passive distribution tools, but act as autonomous service actors, capable of detecting inventory levels, assessing product freshness, applying dynamic pricing logic, and completing transactions in real time (e.g. see Dekoninck & Barbaccia, 2019). Their role within service ecosystems is increasingly strategic, especially in contexts where operational efficiency and environmental sustainability must be jointly pursued.

Among the various levers available for designing smart services, dynamic pricing is gaining renewed attention. Traditionally considered a short-term tactic in retail and revenue management (Bitran & Caldentey, 2003; Elmaghraby & Keskinocak, 2003), pricing strategies are now being reconsidered as components of broader service innovation policies. In the context of automated food services, where perishable goods and real-time operations coexist, dynamic pricing can be reimagined as a governance mechanism that improves system performance and reduces waste.

By reframing dynamic pricing as a mechanism that can be designed within smart service ecosystems, this research offers three key contributions. First, it aims to enrich the service management literature by conceptualizing pricing as a service design policy, not just a tactic. Second, it aims to provide empirical evidence of how IoT-enabled services can integrate efficiency and sustainability goals. Third, it aims to provide concrete insights for practitioners who wish to leverage technology and pricing innovation to promote circularity in food automation.

2. Background and research propositions

This study adopts a service-dominated logic perspective (Vargo & Lusch, 2004; 2008; 2016) to conceptualize smart fridge as actors that integrate resources and contribute to the operational and ecological outcomes of the service system. Service-dominated logic (S-D Logic) views value as cocreated through interactions between multiple actors within a service ecosystem (Vargo & Lusch, 2004; 2008; 2016). From this perspective, technologies are not neutral enablers, but resource integrators that participate in the exchange of services (Breidbach et al, 2013; Sklyar et al., 2019). Smart devices, such as IoT-enabled fridge, embody this logic by sensing inventory levels, making pricing decisions, and interacting with users throughout the service journey. These devices sense, decide, and act, effectively becoming autonomous service actors in the co-creation of value.

From this perspective, dynamic pricing is not simply a revenue optimization tool, but a valueconfiguration mechanism integrated into the smart service interface. It influences the user experience (e.g., price fairness, perceived control), operational flows (e.g., replenishment, waste), and long-term relationships between the user and the service system (e.g., trust, habit formation). Dynamic pricing has traditionally been studied in the retail industry (Bitran and Caldentey, 2003), yield management (Talluri and Van Ryzin, 2004), in the tourism industry (e.g. see Guizzardi et al., 2021; Abrate et al., 2012) and subscription services (Penmetsa et al., 2015). These studies highlight how dynamic pricing optimizes revenue under conditions of demand uncertainty, but often overlook its implications for service design, particularly in low-contact self-service environments such as smart vending. More recent research on automated food systems and vending interfaces suggests that design features (e.g., price visibility, product layout) influence not only purchasing decisions but also the speed and accuracy of those decisions (Rahi et al., 2022; Marinelli et al., 2021). From this perspective, dynamic pricing serves as a choice architecture tool that can be calibrated to promote both sales performance and social objectives (e.g., waste reduction, nutritional incentives). Furthermore, dynamic pricing strategies that consider network effects, consumer learning, and review-based adjustments (Masuda & Whang, 1999; TalónBallestero et al., 2022) expand the analytical lens from pure optimization to interactional dynamics. When integrated into IoT ecosystems, such as smart fridge, dynamic pricing strategies become part of a

feedback-rich environment in which consumer behavior, algorithmic decisions, and system performance reinforce each other.

2.1 Dynamic Pricing and Service Efficiency

Service efficiency can be defined as the system's ability to match supply and demand in a timely and cost-effective manner, minimizing unsold inventory and optimizing product availability. In intelligent vending systems, where human intervention is minimal, dynamic pricing contributes to efficiency by constantly adjusting prices based on real-time variables such as inventory levels, product expiration dates, and customer behavior patterns.

From an S-D Logic perspective, the smart fridge acts as an autonomous actor that co-produces efficiency by sensing contextual data and translating it into actionable pricing updates. This enables smoother inventory rotation and reduces operational imbalances (e.g., overstocking or out-of-stocks). Previous research supports the role of dynamic pricing in improving efficiency. For example, Kayikci et al. (2022) simulate how dynamic pricing based on product freshness increases sales rates and reduces operational obsolescence. We therefore hypothesize:

H1: The adoption of dynamic pricing in IoT-enabled smart fridge is positively associated with increased product turnover and more stable average order values.

2.2 Dynamic Pricing and Sustainability

While efficiency has traditionally been the primary objective of dynamic pricing (Talluri and Van Ryzin, 2004), recent studies highlight its sustainability potential when integrated into circular service models. Circular Service Design promotes service configurations that reduce waste, extend resource utility, and balance economic and environmental objectives (Kayikci et al., 2022; Karpen et al., 2023). Kayikci et al. (2022) demonstrate that intelligent service platforms, when combined with real-time data and dynamic pricing, can improve sell-through rates and reduce operational obsolescence, ultimately improving resource efficiency. Similarly, Karpen et al. (2023) conceptualize service ecosystems as designable structures that enable circularity by orchestrating flows of resources, data, and interactions between actors. These contributions support the idea that pricing logics embedded in IoT-enabled services can serve as design mechanisms to optimize both service performance and resource utilization. In this paradigm, dynamic pricing acts as a temporal coordination mechanism, synchronizing demand with product perishability. By adjusting prices based on real-time data (e.g., expiration date, inventory levels), smart fridges nudge users toward the consumption of products approaching their expiration date, thereby reducing food waste and operational losses.

Research on dynamic pricing in food retail provides strong evidence of the effectiveness of perishability-based price adjustments in reducing waste. Sanders (2023) shows that dynamic pricing reduces food waste by approximately 21% compared to static pricing, while also stabilizing operations and increasing margins. Crucially, these effects are stronger than those produced by regulatory bans, suggesting that market-based pricing mechanisms are particularly effective in shifting demand toward products approaching their expiration date. This is consistent with the logic of source reduction in circular services (Lieder et al., 2018), where waste is avoided upstream by incentivizing consumption before expiration.

Moreover, from a Circular Service Design standpoint, dynamic pricing operationalizes the principle of source reduction, reducing waste at its origin rather than managing it post-consumption.

We therefore propose:

H2: The adoption of dynamic pricing in IoT-enabled smart fridges is associated with a higher proportion of expiring products being sold before waste occurs.

These two hypotheses are complementary. Together, they frame dynamic pricing not just as a profit optimization mechanism, but as a policy lever that enhances both the economic and ecological performance of the service system.

3. Empirically testing the framework

To empirically test the proposed framework, our two hypotheses are translated into measurable constructs that allow for rigorous analysis within real-world service ecosystems. Expanding on existing research on dynamic pricing in the presence of inventory considerations (e.g., Elmaghraby & Keskinocak, 2003; Sanders et al., 2023), this study introduces an innovative model that positions dynamic pricing not only as a commercial tool, but as an operational logic embedded in sociotechnical service networks, with implications for both efficiency and sustainability.

We propose to test our framework in the emerging smart vending ecosystem for perishable goods, enabled by IoT technologies and AI-based decision logic. This empirical context is particularly relevant for two main reasons.

First, despite the proliferation of dynamic pricing research, little attention has been paid to its implementation in autonomous retail environments such as smart fridges. In such contexts, pricing logic is no longer centrally managed by humans, but implemented by smart devices that detect inventory levels, product lifecycles, and user interactions. These systems represent a frontier in service innovation, where pricing becomes a form of machine-mediated governance.

Second, the smart fridge is not simply a point of sale, but a service actor integrated into a circular and sustainable consumption infrastructure. It is designed to optimize the lifecycle of perishable products through dynamic pricing, while enabling real-time data flows on usage, preferences, and product expiration. By operating autonomously and interacting with consumers throughout the entire selectionpurchase-consumption-disposal cycle, the smart fridge implements the principles of Circular Service Design in a tangible and measurable way.

In our case study, we will analyze a network of smart fridges installed in a company cafeteria, where sensors collect telemetry data on product selection, payment, and inventory changes. The dataset includes: Product ID, category, and expiration time; Transaction time (month, day of the week, hour); Price, surcharge, and order value; Items sold and fridge location; Customer ID.

This operational data is complemented by inventory information (e.g., product categories, shelf life) and price rules to construct variables aligned with the two hypotheses:

- *Efficiency indicators:* Leverage data on items sold (count and value), customer counts, discounts, expiration dates, and other factors. Analyze these metrics by breakdowns such as fridge ID code, fridge type (interactive or non-interactive), product category, day and month of the week, and duration of product stay in the fridge. This detailed breakdown aims to optimize product turnover and stabilize order values

- *Sustainability indicators:* Use the same data dimensions as above (items sold, customers, discounts, expiration dates), adding consideration of nutritional content and a focus on controlling order variability through price monitoring. Stable orders with low variance between maximum and minimum orders are expected to lead to reduced waste. This approach promotes sustainable inventory and demand management by linking nutritional awareness and order consistency leveraging prices and discounts.

This practical experiment allows us to observe how designing pricing policies integrated into smart devices contributes not only to revenue optimization, but also to value co-creation and resource conservation, in line with the S-D Logic and Circular Economy frameworks.

4. Discussion and conclusions

This study makes three main contributions to the literature on service innovation, dynamic pricing, and sustainable operations in technology-based service ecosystems.

First, we contribute to the service management literature by conceptualizing dynamic pricing not only as a tactical mechanism for revenue optimization, but as a service design policy integrated into smart service infrastructure. By examining IoT-enabled devices, particularly smart fridges, as autonomous service actors capable of sensing, learning, and acting within service ecosystems, we respond to recent calls to reconceptualize service design through the lens of sociotechnical systems and value co-creation (Lusch & Nambisan, 2015; Patrício et al., 2018). This approach positions pricing as a structural feature of service delivery and ecosystem orchestration.

Second, we contribute to the dynamic pricing literature by providing empirical evidence that pricing rules embedded in smart devices can simultaneously improve operational efficiency and reduce resource waste, even in high-velocity environments such as the sale of perishable products. By shifting the focus from short-term profit maximization to price governance within smart systems, we extend existing models and reframe dynamic pricing as a sustainable and relational mechanism, aligned with the broader goals of the service system (Elmaghraby & Keskinocak, 2003; Talon-Ballestero et al., 2022).

Third, we contribute to the growing body of research on sustainability in services by integrating dynamic pricing into the principles of Circular Service Design. Our study shows how smart fridges, through real-time data and autonomous pricing logic, can align economic profitability with environmental responsibility, reducing food waste and promoting responsible consumption. This perspective is in line with current discussions on how can managers can leverage data-driven insights to align operational efficiency with sustainability goals (Fehrer et al., 2024; Karpen et al., 2023; Pugh & Subramony, 2016; Verleye et al., 2024).

Managerial implications: Our conceptual model has direct implications for managers operating in automated restaurant environments and broader service ecosystems. The findings suggest that dynamic pricing policies should be designed not only to respond to market fluctuations but also to integrate stewardship and sustainability values into daily service delivery. This requires a forward-thinking mindset, in which pricing is viewed as a strategic tool for balancing efficiency, user experience, and resource conservation.

Managers are encouraged to develop adaptive, transparent, and purpose-driven pricing systems, enabling autonomous technologies to make decisions that reflect both economic logic and environmental ethics. Furthermore, service designers and operations managers should consider the ecosystemic role of smart devices, not only as tools, but as co-creators of value within networks of human and non-human actors.

Future research avenues: This work opens several avenues for future investigation. First, empirical testing across different institutional or cultural contexts would enrich our understanding of how dynamic pricing policies are perceived and performed in different ecosystems. Second, further studies could explore the behavioral dimension of users interacting with AI-enabled pricing systems—examining, for instance, how perceptions of fairness, transparency, and agency affect purchasing behavior and waste reduction.

Finally, longitudinal and experimental research could assess how data-driven service policies evolve over time and how they contribute to broader shifts in consumer practices, operational models, and ecosystem dynamics. By doing so, scholars can better evaluate the transformative role of intelligent services in fostering resilient and sustainable futures.

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