Product–Service System's Rebound Effect

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Contributor: Salman Alfarisi , Yuya Mitake , Yusuke Tsutsui , Hanfei Wang , Yoshiki Shimomura

A product–service system (PSS) is a concept concerning sustainability, as it offers the opportunity to decouple economic success from material consumption, thereby reducing the environmental impact of economic activities. However, researchers have identified significant barriers frequently impeding sustainability potential, which are called rebound effects.

product–service system | rebound effect | sustainability | mitigation strategy | consumer behaviour

1. Introduction

The origin of the product–service system (PSS) concept is a concern for sustainability. The discipline of PSS has evolved, and its focus has expanded beyond the environmental dimension to include economic and social dimensions. It is currently recognised as a potential catalyst for transitioning to a more sustainable society. Bocken et al. [1] described the significance of PSSs to the sustainable business model archetype as 'deliver functionality rather than ownership'. The nature of this altered relationship is crucial, as not all PSSs inherently result in sustainable solutions [2][3].

The achievement of sustainability is contingent upon a multitude of influencing factors. It is assumed that non-ownership modes of consumption are collaborative, prosocial, altruistic, and environmentally sustainable [4]. Nevertheless, previous research has shown that this is not always the case [5]. The change in ownership can make PSSs more sustainable by encouraging companies to produce superior products and reducing the number of products required to meet the same number of consumers [6][7]. However, this change in ownership has also been identified as a potential source of rebound effects (REs) [2][8].

2. Rebound Effect (RE)

To reduce carbon emissions, the majority of governments seek to increase energy efficiency in all economic sectors. In general, it is presumed that such enhancements will reduce overall energy consumption, at least in comparison to a situation in which no such enhancements are made. However, economists have learned that various mechanisms, typically grouped under REs, can reduce the energy savings obtained over time. RE and its theoretical arguments can be traced to Jevons and Brookes' work. Some economists contend that introducing certain energy-saving technologies in the past has increased overall energy demand. This outcome is known as a 'backfire'.

If this RE is significant, energy and climate policy will be profoundly affected [9]. Although cost-effective energy efficiency improvements should increase welfare and enhance economic outcomes, they may be ineffective or even counterproductive in combating climate change in certain instances.

The current debate on RE began with Khazzoom's [10] assertion, which was supported by theoretical logic and empirical evidence, that changes in fuel efficiency would lead to changes in the implicit price of energy services. Therefore, as long as the price elasticity of the demand for energy services is typically negative, it is reasonable to anticipate that efficiency improvements will contribute to upward pressure on the demand for energy services through increased usage levels.

Brookes added a macroeconomic viewpoint, monitored greenhouse gas and CO_2 emissions, and discovered that the RE theme responded to the green surge. Researchers have noted the complexity of the RE, with direct or first-order effects causing indirect or second-order effects [11]. Furthermore, the literature identifies three categories of REs: direct, indirect, and economy-wide [12][13][14]. Classical theory states that the RE is only concerned with energy issues. However, Giampietro and Mayumi [15] asserted that the RE is valid not only in relation to energy efficiency but also to resources in general, while other scholars, such as Vezzoli et al. [16] and Alfarisi et al. [17], argued that the RE should be extended to include systems involved in the life cycle.

Conversely, Hopkinson and James concluded that three distinct categories of REs (inside PSSs) had been observed: direct, indirect, and platform [18]. Platform effects emerge when new services are made available, influencing the underlying factors that determine production and consumption levels and patterns. REs have been extensively studied in economics and are typically defined as those resulting from changes in relative prices: when a product or service becomes more efficient, its operating costs per unit decrease, which may lead to greater utilisation [11].

Based on a search of the Scopus and Web of Science databases using the search terms 'rebound effect' and 'literature review', 72 documents were obtained. The first study in the literature review on the RE was discovered in 1968, disappeared, and then returned in 2010. In 1968, the term 'rebound effect' appeared in the health and medicine category for the first time, specifically in the pharmacology subject titled 'Chemistry, pharmacology, and clinical pharmacology of oral contraceptives'. At that time, the RE in the health and medical categories was defined as a secondary reaction of an organism to drug stimuli [19], and the withdrawal effect was defined as the development of new symptoms that are a temporary return of the prescribed drug's symptoms. Subsequently, this research buzzword ceased until it reappeared in 2010. While the REs in natural and environmental science and in engineering and technology overlap and are frequently used interchangeably to refer to an increase in demand for products due to a rise in efficiency [17], the terms are often used interchangeably in economics. The overall or economy-wide RE of energy efficiency improvements is the sum of direct and indirect effects [9].

3. Product–Service System (PSSs)

Companies increasingly integrate their products and services into today's globally competitive business environment [7]. This phenomenon is significant for product and service providers [20][21]. Consequently, the prospective benefits of offering integrated product and service solutions have economic, social, and environmental effects as firms increase resource utilisation and competitiveness [22][23][24][25]. PSSs are a generic term for research on this emerging phenomenon [20][22]. When defining PSSs, most articles cite Goedkop et al. [26], who define them as a set of marketable products and services that can satisfy customer needs cost-effectively and sustainably.

Product–service systems were inspired by environmental issues. PSSs are viewed as catalysts for the transition to a more sustainable society. Therefore, the concept of sustainability must be clarified for each PSS dimension. Mont [7] described how PSSs offer integrated products and systems of products and services to reduce environmental impacts through alternative product usage scenarios. PSSs consist of (i) products, (ii) services, in which an activity is executed without the need for tangible goods or systems, and (iii) the combination of products, services, and their relationships [26]. Environmental sustainability is attained when the PSSs' production and consumption patterns limit the depletion of natural resources and decrease pollution from existing products. Economic sustainability occurs when PSSs can sustainably maintain their economic objectives. Social sustainability occurs when PSSs can maintain quality of life without sacrificing social rights. Most authors view PSSs merely as competitive proposals to satisfy consumer demand [7][20][23]. Nonetheless, according to some authors [20][27], PSSs strive for sustainability by striking a balance between environmental, economic, and social concerns. In general, products are created in response to consumer demand and can be modified to incorporate services. Therefore, PSSs represent a competitive opportunity, which is significant because they can alter consumption standards.

In other words, PSSs aim to enhance competitiveness and establish an equilibrium between social, economic, and environmental concerns [28]. Manzini [2] defined a PSS as a strategic design integrating product, service, and communication systems based on new organizational forms, reconfiguring roles, consumers, and other stakeholders.

4. PSS-RE

Implementing PSSs does not guarantee sustainability; thus, PSSs must be meticulously designed, developed, and implemented. The emergence of REs in PSSs has been demonstrated to be a valid concern [16][17][29]. Jenkins et al. [30] defined the RE as the difference between anticipated and actual energy gains and broader environmental benefits due to a given efficiency improvement.

Although PSSs are a potential pathway to sustainable resource consumption, they necessitate a significant transformation at the value chain and industry levels for product- and service-oriented businesses [31]. Implementing effective and environmentally favourable PSSs is still limited [32]. Alfarisi et al. [17] found that PSSs have introduced numerous features that function well in one dimension but lead to other issues. This trade-off phenomenon has prompted a broader study of the RE, which is not limited to energy efficiency but encompasses the energy, materials, and transportation sectors and all sectors associated with the cycle. PSSs that are not developed with caution carry the risk of having their environmental potential mitigated by REs and less responsible behaviour [5][33]. The terminology of REs, as described in energy economics, is insufficient to indicate the various secondary effects of sustainable consumption that focus on technological measures to improve efficiency and behavioural changes. Several researchers have incorporated the concept of PSSs into the integrated study of REs, while others have incorporated the concept of REs into the concept of PSSs. These effects are defined as 'ecologically damaging second-order effects that sometimes originate from PSS' [34] and 'unintended impacts of PSS' [35]. Recent studies have emphasised several potential PSS benefits. However, comprehension of the causes and mitigation strategies for PSS-REs remains very limited.

In the context of PSSs, the RE occurs when production and consumption increases offset efficiency and production/service adequacy enhancements. This occurrence is known as the PSS-RE [36]. Systemic REs are unavoidable when implementing

PSSs. Vezzoli et al. [16] referred to these as negative consequences. Unfortunately, stakeholders have employed the RE as an excuse for inaction. Managing the RE is crucial when designing a PSS because it entails complex trade-offs that affect the system's overall direction. In addition, the change in ownership affects REs related to consumer behaviour. When consumers are no longer the owners of a product, they may behave irresponsibly with regard to it [2][5]. These types of behaviours can impede the long-term viability of the entire PSS and should be avoided. The premise is that adding a service to a product that focuses exclusively on a shift in property rights, responsibility, or the temporality of possession can decrease the (perceived) value of the product to the user, resulting in REs. Figge and Thorpe [37] identified the production system as a potential aspect of generating a RE. According to Figge and Thorpe [37], the changes in production, the price of items, materials, or commodities, the operational efficiencies, and the company's relationships are the primary factors contributing to the RE. However, as it overlaps with the concept of CE, the concept of a RE in PSSs has been underdeveloped. Even though they are distinct concepts, CE aims to create the highest possible value and sustain it for as long as possible using the fewest resources [38], and PSS is viewed as one of the approaches to accomplishing this objective [39]. Several studies have demonstrated that PSSs are one of the business model approaches that fall within the CE domain [40], and PSSs are expected to facilitate the accomplishment of CE. Nonetheless, other studies have contended that these two strategies are in accordance with Haber [41]. The consequence of this statement is that the phenomenon that occurs between the two, such as the RE, is considered identical.

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