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Predicting the value of Product Service-Systems for potential future implementers: results from multiple industrial case studies

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Abstract

The great impact played by Product/Service-Systems (PSS) on industry and academia can be motivated by the need for modernizing business models, carrying out internal companies' reconfiguration, enhancing environmental sustainability. Despite the large number of objectives pursued by PSS, sparks of criticism have recently emerged, as well as the results ensuing from PSS adoption have not been rigorously assessed. In particular, the authors highlight a lack of quantitative analysis concerning the service aspects of PSS and hurdles in service modeling and evaluation. The paper's objective is to contribute in this field by individuating factors, advantages and disadvantages that are not directly measurable in monetary terms by companies. This kind of assessment might result crucial, as the implementation of PSS-oriented strategies require a not negligible amount of commitment, besides propensity to risk. A first activity was carried out thanks to a pilot group of firms that have not implemented any PSS initiative so far, which have been exposed to business reconfiguration scenarios underpinning PSS. A model for generalizing pros and cons of future PSS implementation has been subsequently experimented by a larger group of industrial organizations. Such a model has represented the backbone for the creation of a tentative quantitative estimation tool, which assesses and forecasts the added value of services featured by the introduction of PSS and hence represents a candidate criterion for undertaking decisions concerning the implementation of PSS strategies. The paper clarifies which assumptions are introduced in order to achieve this result.

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Keywords: Product Service-Systems; service modelling; value forecasting; quantitative service estimates; decision-making

1. Introduction

PSS domain clearly represents a dynamic context. The paradigm behind PSS, whose launch has taken place in the 1990s, is attracting increasing interest in the last few years, as witnessed by the bibliometric study described in [1], which underlines, among the others, the growing collaboration opportunities across research groups. The fast-evolving literature production has attracted many scholars, who have contributed to the field through updated state-of-the-art works by focusing on the expanding body of objectives, perspectives and relevant characteristics pertaining to PSS experiences. Reim et al. [2] provide an overview of industrial applications implementing the different articulations of business models underpinning PSS, i.e. product-, use- and result-oriented practices. The systematic review described in [3] is more concerned on design, evaluation and operations management issues, laying bare the most recent advancements. The reading of the state-of-the-art proposed by Annarelli et al. [4] seems to bridge diverse perspectives. The scholars highlight to which degree different scientific areas, e.g. economy and engineering design and management, focus on common PSS' primary objectives and strive to individuate fundamental research issues to be prioritized. Although presenting a different starting point, all the mentioned surveys share visions about the large variety of opportunities that the future developments of PSS can help to open up. Moreover, the intrinsic value of PSS introduction is actually crossing the traditional borders of sustainability and competitiveness goals.

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For instance, [5] claims PSS capability to accelerate customers' acceptance of technological innovations.

Not surprisingly, as the reach of and interest for PSS are expanding, new challenges emerge. At the same time, weak methodological guidance affects, among the others, the chances of a further diffusion of PSS, which are conversely observing some unsuccessful experiences [6]. Sutanto et al.'s [7] work is also rooted in the remark that some PSS implementations have failed to deliver expected results in terms of both profitability and sustainability; a design method is illustrated that is supposed to support firms in shifting from product-intensive to service-oriented business gradually. Different design and modelling standards inherent to product and service engineering represent a primary source of concern in the view expressed by Trevisan and Brissaud [8]. Contextual factors are likely to strengthen the difficulties faced by PSS in terms of wielding its full potential. Song and Sakao [9] stress the importance to customize PSS and propose modular designs in order to match customer orientations and preference changes, which considerably affect both the product and the service dimensions [10]. Moreover, the fluctuations of the most relevant customer requirements and complex network of stakeholders determine particularly severe management problems in PSS [11]. In order to understand the complexity connected with PSS, it is worth mentioning the effort made by Kim et al. [12], who identified a non-exhaustive list of 94 items that should be used to characterize and evaluate the performances of PSS.

Consistently with these remarks, the implementation of PSS strategies require great internal commitment, structured processes, as well as the creation of a proper climate within the organization, e.g. [13].

Despite the large number of critical factors concerning PSS, the possible advantages outweigh risks based on literature scrutiny. In authors' vision, the PSS paradigm is currently underexploited in a large number of industrial domains (at least with regard to authors' national context). The industrial fields, whose investigation is illustrated in the next sections, range among the ones for which the introduction of PSS is seen as particularly valuable, especially from the viewpoint of the differentiation of the commercial offer. The understanding of what hinders the design and implementation of PSS strategies in these branches represents a complementary aim of the present study. Actually, the main goal of this research activity is to facilitate manufacturing firms' decisions concerning the introduction of PSS-driven design initiatives. The support the paper provides consists of an evaluation roadmap and a tentative quantitative estimate of the value provided by service aspects that can be easily overlooked because of the lack of acknowledged measurement processes, e.g. [14]. Whereas standard routines and tools are capable of evaluating and anticipating measurable product performances and monetary flows (like in [15]), the present contribution focuses on other characteristics, which are supposed to play a likewise relevant role in the success of PSS introduction.

The paper is structured as follows. Section 2 clarifies the objectives of the paper based on insights from the literature. Section 3 illustrates how the proposed tools have been developed in a multi-stage fashion through the involvement of a sample of industrial companies that currently do not leverage PSS-based business models. The results are presented in Section 4 concerning the estimation of added value potentially ensuing from implementing PSS scenarios. Section 5 discusses the findings, draws conclusions and introduces future work.

2. Background

The Introduction section has already remarked the complexity of tasks that aim to model PSS and assess their performances. Many different aspects have to be considered that refer to diversified spheres [16]. Some of them are deemed as the most critical according to several scholars. In [14], it is claimed that the poor adoption of Modelling & Simulation techniques in the field of PSS is mostly due to the intangible and unquantifiable nature of services. In addition, [14] asserts that the non-deterministic behavior of customers represents a further cause of complexity. This vision is widely shared by [17], in which customer demand and the service supply chain constitute the major sources of uncertainty. Furthermore, still in the perspective of modelling and assessing PSS expected outcomes, [18] focuses on the interdisciplinary nature of service design, which has repercussions in terms of agreeing upon a common point of view for what concerns the definition of value. Eventually, [19] points out the difficulties in taking into account the dynamic aspects involved in PSS, among which some have been already highlighted in the Introduction.

The literature illustrates several contributions that deal with the necessity to model, evaluate and simulate PSS. However, no convergence has been reached yet. The authors argue that the existing contributions, although valuable, fail to provide a global view of PSS scenarios, focus on peculiar aspects only, or are difficult to use for a preliminary evaluation of the goodness of PSS proposals. A brief list follows of relevant contributions, for which limitations in the above perspective are highlighted.

- Allen Hu et al. [20] propose Fuzzy Delphi Method and Fuzzy Analytic Hierarchy Process to model PSS business models, but their aim is limited to the identification of the most impacting success determinants.
- Bertoni et al. [21] provide a technique that is capable of delivering value information across the various phases of PSS design, but the value flow is limited to the hardware dimension.
- Lee et al.'s [22] contribution is particularly appropriate for considering how dynamic effects influence the functional performance of PSS, but the proposed framework results in a complex scheme whose validation through industrial case studies has not been performed yet.
- Chen et al. [23] consider random effects and uncertainty in order to evaluate PSS with a particular focus on sustainability issues, but the proposed approach requires a large amount of historical data, which are not always available (particularly within result-oriented business models).

3. Research aim and methodology

Given the aforementioned literature gaps, we focused on the identification of "problematic" aspects in PSS forecasting and, more specifically, on the quantitative evaluation of advantages and disadvantages implied by PSS adoption beyond economy-related factors. The consideration of said pros and cons is the backbone for determining how these circumstances might affect economic accounts concerning the adoption of PSS. Therefore, the research question the paper addresses is:

RQ: How can Product Service System's value forecasting take into account those variables that are overlooked in quantitative measures because of their non-monetary nature?

The proposed approach to tackle the RQ is described in the followings.

3.1. Advantages and disadvantages

Based on previous experiences and an investigation in the literature, we formulated an initial set of aspects that commonly characterize the implementation of PSS policies. The scope was providing a general set of factors that could be considered relevant across many industries. This sample has been refined thanks to the participation of partner firms for which some PSS scenarios were illustrated. In particular, these industrial subjects helped us individuate whether the considered aspects could be affecting PSS adoption in different circumstances. Still thanks to these partner firms, terms considered overlapping were eliminated. The list of these aspects is not provided due to space reasons; anyway, the tables reported in Section 4 that document advantages and disadvantages for various case studies include illustrative factors.

This allowed us to build a semi-structured interview, with the aim to understand the potential repercussions of PSS adoptions for the firms to which the questionnaire has been administered (see Section 4). Of course, interviewees were in charge of defining whether the described PSS scenario would affect their business in terms of the recalled aspects. This explains the difference of the items reported in Table 4 vs. Table 6 and Table 5 vs. Table 7.

More in details, the interview is introduced by a questionnaire of six initial questions, which helped in classifying cases according to acknowledged variables. The main unstructured part is divided in five sections (Technical and Design considerations, Market demand, Organizational aspects, Considerations on economic feasibility, and Stakeholders-related aspects) to guide the interviewee and to make emerge their point of view and perception about PSS strategies.

After the information gathering process, the most important aspects emerging from the interviews have to be classified as advantages or disadvantages. The stakeholders that are affected are highlighted as well, because, according to a first assumption that is necessary for quantification issues, they play a different role in light of companies' decisions. In particular, stakeholders can be classified through a matrix (reported in Table 1), that assigns priorities among the actors affected by PSS introduction. Stakeholders are therefore categorized according to the degrees of interest and power, obtaining a set of 4 types. Interest represents the degree of influence the project has on stakeholder's business in terms of objectives and results; decision-making power (Power in Table 1) accounts for the level of influence a stakeholder can have on a project.

Table 1: Stakeholders' categories.

	Power	
Interest	*Low*	*High*
Low	Minor Stakeholders	Useful Stakeholders
High	Weak Stakeholders	Important Stakeholders

According to this categorization and the internal/external role of stakeholders within the firm, a scale of priorities was defined. Quantitative scores were proposed for each kind of stakeholder, as shown in Table 2. Higher scores were (arbitrarily) given to external stakeholders, because of the difficulties in coping with them and the assumed major magnitude of possible (positive or negative) effects that might follow a PSS introduction.

Each time an aspect affects positively (negatively) the introduction of a PSS strategy with reference to a given stakeholder, this is considered as an increase of advantages (disadvantages) in terms of the corresponding score. As already pointed out, just involved firms can establish aspects affecting their business. This enables a rough estimation of advantages and disadvantages as for non-monetary aspects of PSS implementations. Assigning to each advantage a "plus" and to each disadvantage a "minus" sign, we can sum up the Total Score (*TS*) of each PSS scenario. The provided overall framework about pros and cons (from a qualitative viewpoint) and the corresponding score (from a quantitative viewpoint) can represent per se a further variable for tackling decisions about the opportunities behind the design of PSS propositions.

Table 2: Scale of stakeholders' priorities.

Stakeholder	**Score**
Important stakeholder (external)	1
Important stakeholder (internal)	0,9
Useful stakeholder (external)	0,7
Useful stakeholder (internal)	0,6
Weak stakeholder (external)	0,4
Weak stakeholder (internal)	0,3
Minor stakeholder	0,1

3.2. Service Added Value Estimate

The calculations that follow are based on further assumptions, which are necessary to build a tentative quantitative equation capable of considering non-monetary aspects and other factors contextually.

In a company's perspective, *TS* might be interpreted as a moderator or multiplier of expected profits. In other terms, there is a relationship between sums calculated as in 3.1 and this multiplying coefficient, which we named *k*. In particular,

the coefficient amplifies or reduces the supposed gap between Service Fee (*SF*, requested by the provider of the PSS) and Service Costs (*SC*, due to service implementation/expansion). We propose the following formulation of a variable named Service Added Value Estimate (*SAVE*), which is a function of *k*, *SF* and *SC*. The explanation of *SAVE* as a piecewise function is clarified below.

In case *SF* are higher than *SC*, a profit is expected from a PSS introduction, being their difference the expected marginality. In these circumstances, the presence of a positive (negative) value of *TS* results in boosting (moderating) the prospects of a positive margin. The authors assume that the maximum value of *k* might be 1.5 when a very good score of *TS* is achieved, near to 0 when disadvantages are largely predominant and they can jeopardize the positive economic prospects of a PSS introduction. Of course, when *TS* is equal to 0, the value of *k* has to be 1 – this means that equal advantages and disadvantages do not affect economic forecasts at all. Simulations were performed for pilot case studies and *TS* was calculated accordingly. Its value is expected to range in the interval between -6 (unsustainable or even absurd PSS propositions) to 3 (convincing PSS scenarios mirroring successful examples already experimented in other countries). Whereas, the former value would totally jeopardize financial benefits (*k*=0, as above), the latter might be seen as a significant growth of said benefits (*k*=1.5). By relating these extremes and the 0 value to the corresponding magnitudes of *k*, the proposed formulation for the *k* coefficient follows (1).

$$k = 1 + 0.17 \times TS \tag{1}$$

In case the marginality is negative, the coefficient *k* should work in the opposite way; therefore, instead of being a multiplier, it becomes a divisor. The formulation of SAVE follows according to these remarks, which is expressed as (2), which holds when the margin between *SF* and *SC* is positive, or (3), in the opposite case.

$$SAVE = k \times (SF - SC) \tag{2}$$

$$SAVE = k^{-1} \times (SF - SC) \tag{3}$$

4. Results

According to the Research Question, we structured our activity as a multiple case study.

Case studies were considered as the most appropriate method to investigate an empirical topic by following a set of pre-specified rules and procedures; it allows a holistic and contextualized analysis, tailored to exploratory research purposes, because it enables the identification of crucial variables while exploring a given phenomenon. In particular, this research employed a multiple case study design, because "it allows both an in-depth examination of each case and the identification of contingent variables that distinguish each case from the other" [24; 25].

We carried out 6 different cases (2 for each PSS category [26], i.e. the recalled product-, use- and result-oriented) of possible PSS implementation scenarios. 5 firms of different size and market orientation were involved in this activity, covering a diversified sample of industrial fields, so that observations emerging from questionnaires were not affected by domain-specific biases. Table 3 summarizes the case studies and the most important features of involved companies. Cases 1 and 2 involve Product-oriented PSS scenarios; cases 3 and 4 regard Use-oriented PSS implementations; the residual cases concern Result-oriented PSS propositions.

Table 3. Case studies constituting the testing activity

	Business	**Net sales**	**Channel**	**PSS type**
Case_1	Wood Flooring	1,6 – 5 mln €	B2B	Prod. Or.
Case_2	Wood-fired Ovens	<0,5 mln €	B2B/B2C	Prod. Or.
Case_3	Electric Bicycles	1,6 – 5 mln €	B2B	Use Or.
Case_4	3D Printers	<0,5 mln €	B2B/B2C	Use Or.
Case_5	Wood Flooring	1,6 – 5 mln €	B2B	Res. Or.
Case_6	Steel Tanks	>5 mln €	B2B	Res. Or.

The interviewees, one for each firm, were all at the managerial or at a higher hierarchical level: we contacted a commercial director (Case_1 and Case_5), a sales manager (Case_3), a country manager (Case_6), an owner (Case_2) and a chairperson (Case_4).

The information emerging from interviews was used to estimate the amount of advantages, disadvantages, and, subsequently, the *k* coefficient, as shown in two illustrative examples. In the former (4.1), the value of *TS* is positive, while disadvantages are predominant in the latter (4.2). The main results emerging from the residual investigations are summarized in 4.3.

4.1. Case_3: Bike sharing

This case has been selected as an illustrative example in which advantages are predominant. Advantages are shown in Table 4, while disadvantages are displayed in Table 5. Issues reported in italics represent the modification aspects that are considered impacting by the firm.

Table 4: List of advantages, Case_3.

Environment	*Interest*	*Power*	*Stakeholder*	*Score*
New customers				
External	High	High	Important	1
Customers satisfaction				
External	High	High	Important	1
Higher visibility for the company				
External	High	High	Important	1
Positive impact on customers' loyalty				
External	High	High	Important	1
Enforced relationships with suppliers				
External	Low	High	Useful	0.7
			Total advantages	4.7

Table 5: List of disadvantages, Case_3.

Environment	*Interest*	*Power*	*Stakeholder*	*Score*
Maintenance (frequent substitutions of components)				

Internal	Low	High	Useful	-0.6
Need of parking spaces (for bikes)				
External	High	Low	Weak	-0.4
Installation of charge stations				
External	High	Low	Weak	-0.3
Logistics				
Internal	Low	Low	Minor	-0.1
Need for process re-engineering				
Internal	High	High	Important	-0.9
Need for new studies on the product				
Internal	Low	High	Useful	-0.6
Need for new competences				
Internal	Low	Low	Minor	-0.1
Competition (potential new entrants)				
External	High	High	Important	-1
Need for legal permissions				
External	High	Low	Weak	-0.4
			Total disadvantages	-4.2

In this case, the total sum of advantages and disadvantages (*TS*) results in a positive score (+0.5); according to (1), the estimated value of *k* coefficient is roughly 1.1.

4.2. Case_1: Wood Flooring

This case has been selected as an illustrative example in which disadvantages are predominant. Tables 6 and 7 show advantages and disadvantages individuated by the involved firm with the same formalism as in 4.1. The nature of involved stakeholders is checked as well, like in all the other case studies.

Table 6: List of advantages, Case_1.

Environment	*Interest*	*Power*	*Stakeholder*	*Score*
Lack of competitors				
External	High	Low	Weak	0.4
Opportunity for re-engineering and enhancing internal processes				
Internal	High	High	Important	0.9
Enforcing relationships with suppliers				
External	Low	High	Useful	0.7
			Total advantages	2

Table 7: List of disadvantages, Case_1.

Environment	*Interest*	*Power*	*Stakeholder*	*Score*
Product durability				
External	High	High	Important	-1
Impact on customers (lack of customers' loyalty)				
External	High	Low	Weak	-0.4
Non-reusable / non-recyclable product				
Internal	Low	High	Useful	-0.6
Changes in products turnover				
External	High	High	Important	-1
Maintenance (causal and on long term perspective)				
Internal	Low	Low	Minor	-0.1
Higher stocks (higher costs)				
Internal	High	High	Important	-0.9
Need for new competences				
Internal	High	Low	Weak	-0.3
Need for new machinery				
External	High	Low	Weak	-0.4
Customers' sensibility to price change				
External	High	High	Important	-1
			Total disadvantages	-5.7

In this case, the total sum of advantages and disadvantages results in a negative score (-3.7); with the same procedure, the computed *k* coefficient is about 0.4.

4.3. Other cases

Table 8 summarizes the main data concerning the residual case studies.

Table 8: results from other case studies

Case	*Total advantages*	*Total disadvantages*	*TS*	*Estimated k*
_2: Ovens	2.5	-3.1	-0.6	0.9
_4: 3D printers	5.6	-2.6	3	1.5
_5: Wood Flooring	2	-4.7	-2.7	0.5
_6: Steel tanks	1.9	-2.4	-0.5	0.9

5. Discussion and conclusions

The present paper attempts to fill a gap in the PSS field and, more specifically, in services' stream of literature, by introducing a procedure that provides a larger view of opportunities and problems when predicting services' value. The applicability of said procedure has been verified through a series of case studies, described in Section 4. In order to pursue the research objectives, several activities were performed. The outputs of each of them can be seen as partial results, applicable also in different circumstances than value forecasting and decision-making. The final outputs are affected by some assumptions, which provide evidence of the difficulty of the quantification task. While these assumptions seem reasonable to the authors based on their experience, this aspect could be argued and future work is required to overcome ambiguities. As a result, the last outcomes that follow are characterized by a minor degree of confidence.

First, the gathering was required of a list of diffused impacting aspects that emerge when putting PSS proposals into practice. These aspects relate to very different expertise domains within an organization, ranging from design issues (e.g. necessity of co-creation practices) to managerial problems (e.g. relationships with suppliers), from technological factors (e.g. new machinery) to market outlooks (e.g. customer fidelity) and legal/regulatory aspects. It is worth noting that, given the difficulties of an effective evaluation and consideration of these aspects, companies might tend to overlook them. This can imply undesired effects, especially in case of underestimated disadvantages, which, moreover, resulted predominant in the majority of treated cases.

Second, a questionnaire was built swiveling on the above aspects, which are not measurable in common monetary terms. The questionnaire can be used (or self-administered) in order to point out relevant issues with regard to the adoption of PSS strategies.

Third, the proposed model introduces an original criterion, based on a specific assumption, to "quantify" qualitative variables that could not be addressed (or difficultly addressed) before. The criterion is based on the typologies of stakeholders that are affected by a prospective PSS adoption, who can experience benefits or drawbacks. This leads to estimate whether the considered aspects give rise to greater advantages or disadvantages. The difference between the two, addressed as *TS*, can be used as a metric for undertaking decisions about shifts towards PSS business models. For instance, one of the participating firms has been exposed to two PSS introduction scenarios (product- and result-oriented, respectively). Thus, it can benefit from the outcomes of the activity in terms of *TS*, in order to establish which kind of PSS proposition is the most suitable beyond profit forecasts.

Fourth, at an operational level, the *k* factor is introduced to "adjust" the marginality according to the predominance of advantages or disadvantages in PSS adoption. It is based on an assumption that establishes the relationship between extreme values of *TS* and *k*. The employment of the *k* factor is supposed to provide new insights and applications to forecast PSS value, as proposed through the final index named *SAVE*. The latter has not been actually calculated due to the unavailability of information about margins in the exposed case studies, but the mere employment of *k* as a multiplier is not supposed to be a troublesome issue.

As recalled, the model needs to be tested with more cases and streamlined, as well as fully validated through actions in which the adoption of PSS will truly take place. Besides, the model is biased by the use of ordinal variables as addends, as for advantages and disadvantages, beyond the recalled assumptions that are necessary for calculating quantitative indicators. These limitations have not hindered the application of the proposed procedure in several industrial contexts, which can potentially benefit from the shift towards PSS business models in the future. Interested readers willing to contribute to the numerical fine-tuning of the model, which is preliminary and tentative in essence, or to replicate the experiment can contact the corresponding author to receive more material.

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