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Service innovation for sustainability: paths for greening through service innovation

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Abstract:

The purpose of this work is to examine the extent to which services and service innovation can contribute to sustainable development in its environmental dimension. The supposed immateriality of services seems to argue in favour of their natural sustainability. This is actually just a myth – one we examine the roots of, and which we refute. This calling into question of the naturally-green-services myth does not, however, mean that the greening of the economy cannot rely on services. On the contrary, greening also fundamentally depends on innovation dynamics being implemented in or by services.

Introduction

More than two decades of research in economics and management science, have helped to make service innovation a relevant, legitimate and increasingly important issue in the field of innovation studies. The (recent) maturity of this field of research is illustrated, to some extent, by the rising number of both qualitative and quantitative literature reviews covering the topic of innovation in services, in both its general and its specific (sectoral or thematic) aspects. A recent review of these reviews is provided in Gallouj and Djellal (2015).

Research efforts have naturally mainly focused on two (often related) issues, namely the nature of innovation in services, and its production modes. Does innovation in services (in terms of form, how it is produced) differ from innovation in goods? This is the main question that has long guided the emerging field of service innovation studies. Depending on how this question is answered, the literature considers three analytical perspectives used to address innovation in services: a technologist/industrialist or assimilationist perspective (negative response to the question), a demarcation/differentiation perspective (positive response) and an integration/synthesis perspective (reconciling goods and services, their differences and similarities, within a single analytical model) (Gallouj 2010). A fourth perspective, labelled inversion perspective, focuses on the strategic role played by certain services (KIBS) in the their customers' innovation.

In recent years, innovation studies have been bolstered, in various ways, through the exploration of new themes (e.g. KIBS in innovation, social innovation, public-private innovation networks, public policies for service innovation, etc.) and through empirical investigation in new sectors. They have also been reinforced by complementary qualitative work using quantitative surveys, relying in particular on the revision of OECD Manuals (Oslo

and Frascati Manuals) as well as on the launch of national surveys (see Community Innovation Surveys in particular).

However, the maturity and legitimacy of service innovation studies also depend on their ability to be in line with the great contemporary socio-economic issues. From this point of view, sustainability is undoubtedly a key issue. Contemporary economies are certainly *service economies*, and if they are - or truly aspire to be - *sustainable development economies*, then the question of the relationship between *services* and *sustainable development* has to be addressed. However, in spite of certain notable exceptions - such as reporting on the adverse effects of transport and tourism on the environment - little attention has been paid to this question so far. Sustainability is still seen as a predominantly industrial issue (Djellal and Gallouj, 2010, 2015).

The purpose of this chapter is to examine - mainly from a theoretical angle at this stage - to what extent services and service innovation can contribute to sustainability in its environmental dimension (in other words to 'economic greening') - that is, to the satisfying social needs while leaving the smallest possible ecological footprint. Our focus in this work is thus not (or at least not directly) on the economic and social dimensions of sustainability.

Some intrinsic characteristics of services - especially their immateriality - seem to argue in favour of their natural sustainability. This is actually no more than a myth¹ - and one we propose, in Section 1 of this chapter, to examine the foundations of, achieving its deconstruction. This calling into question of the myth of 'naturally green' services does not mean that the greening of economic activity (at either micro or macro level) cannot rely on services. On the contrary, in section 2 we show that greening also fundamentally depends on innovation dynamics implemented *in* or *by* services.

1. Services are green by nature: the foundations of a myth, and its deconstruction

The idea that services would be greener and more sustainable, that is, less damaging to the environment than goods, is not uncommon in the literature (Claval, 2006; Illeris, 2007; Rifkin 2000; OECD, 2000; Ellger and Scheiner 1997). It even seems to be confirmed by some statistical analyses at both international and national level. For example, the International Energy Agency (2008) estimated that, in 2005, services (excluding the transport sector) accounted for 12% of CO₂ emissions and 9% of total final energy consumption, worldwide. In the case of France, although the services sector (excluding transport) accounted for almost 75% of GDP and employment, it was responsible for only 7% of CO₂ emissions in 2008² and consumed 15% of total energy in 2010 (CEREN, 2012).

This idea of the 'natural greenness' of services is based on their immateriality, which is meant to provide a relatively satisfactory criterion with which to distinguish services from goods (§ 1.1). Because they are supposed to be immaterial, services would, the thinking goes, be less harmful to the environment than material goods - whose manufacturing process gobbles up natural resources and is a source of pollutant emissions, etc. The tertiarization processes at work in contemporary economies should therefore automatically lead us to more

¹ It should be noted that this is a positive myth, while the service economy is more verbose in negative myths: for a discussion of these myths, see Gallouj (2002)

² Data from CITEPA: Centre Interprofessionnel Technique d'Etudes de la Pollution Atmosphérique [interprofessional technical center for the study of atmospheric pollution] concerning CO₂ emissions, excluding LULUCF (Land Use, Land-Use Change and Forestry).

immaterial/intangible - and therefore more sustainable economies (Ettighoffer 1992; Romm et al., 1999).

This attractive hypothesis is, however, debatable. It is possible, for example, to note that the most tertiarized contemporary economies are also the biggest polluters, and that certain service sectors (transport in all its forms, for example) are among the top sources of negative environmental externalities. Beyond simple fact, our purpose is to reconsider the myth of immaterial and therefore green services, from an analytical angle. Step 1 in this reconsideration process is an attempt to identify a certain number of (forgotten or neglected) sources of service materiality (from a static point of view) (§ 1.2). Step 2 is the highlighting of the socially-constructed (and therefore changing) nature of service materiality/immateriality, depending on the output convention adopted (§ 1.3) and Step 3 consideration of the search for materiality as the subject of active strategies carried out by service organizations (§ 1.4). Inverse dematerialization strategies will be considered in the second section of this work, which is exclusively devoted to them.

1.1. The foundations of the green services myth

Across the board, from economics to management science, works on services ritually recall a list of technical characteristics that are supposed to be intrinsic to services, namely: Intangibility (immateriality), Heterogeneity, Interactivity and Perishability. This is particularly true in marketing, where the IHIP acronym is common knowledge. These characteristics have long been considered quasi-genetic criteria (a kind of DNA) serving to distinguish services from goods.

This definition of the essence of services by their immateriality is rooted in the history of economic thought, particularly among classical economists (Smith, 1960 [1776]; Say, 1972 [1803])³.

He does not explicitly use the term ‘immaterial’, yet Adam Smith is considered the precursor of the definition of services by their immateriality. This intrinsic technical characteristic of services comes from the distinction Smith made between ‘productive’ and ‘unproductive’ labour. Only productive labour (for example, the labour of the workman in a factory) creates wealth, because it adds value to the material it processes and it brings about material results, which are likely to lead to accumulation. In contrast, services⁴ are performed by unproductive labour, that is to say, which “does not fix or realize itself in any permanent subject, or vendible commodity, which endures after that labour is past, or for which an equal quantity of labour could afterwards be procured” (Smith, 1960 [1776]). The immaterial nature of services is often derived (in a way that is perhaps somewhat unsatisfactory) from the idea formulated by Smith (and taken up by Alfred Marshall) that the “work of all [the services] perishes in the very instant of its production” (ibid.). Admittedly with some ambiguity, then, the unproductivity of service work (its inability to create wealth) is, in Smith’s words, a synonym for immateriality.

It was another classical economist, Jean-Baptiste Say (1972 [1803]), who first explicitly introduced the ‘immaterial’ qualifier to the definition of services. Jean-Baptiste Say called into question the implicit and ambiguous identity established between *unproductivity and*

³ For a review of the debates on services in economic thought, see Delaunay and Gadrey (1992).

⁴ Smith provides a number of examples of service providers including domestic servants, servants of the state, servants of the church, artists, lawyers, doctors...

immateriality (the evanescent nature of the output). According to him, services, while immaterial, are not unproductive, since they are useful, the source of visible and enduring (accumulative) results (changes) - for example the healing produced by the work of doctors. In Smith's analysis, Gadrey (2000) identifies the premises of a distinction between immediate or direct output on the one hand, and the mediate output on the other - the outcome or long-term or indirect result ('change of state' in the reality subjected to the services provided). Only the immediate output is evanescent, the outcome itself is lasting: for example health, education and culture have durable effects on the mind or body. To take another example provided by Smith himself, though the immediate work of the domestic servant may be evanescent, the resulting cleanliness does not vanish once the work is done, but endures some time.

The reasoning which, in modern economies, involves translating this genotype (that is, these technical characteristics) into an environmentally-friendly phenotype is obvious. Since the output of services is immaterial, evanescent and transient, it is supposed not to harm the natural world, unlike industrial and agricultural production which transforms raw materials into physical goods, damaging the environment in both their production and their consumption. Such reasoning is clearly mistaken. Services are both less immaterial, and less green than they seem – it all depends on how the materiality issue is addressed. Services are of course immaterial in the sense that they are not intended to produce tangible goods as final output. However, their relationships with materiality may take a range of forms, in line with the types of services envisaged. In the following paragraphs, we examine these different relationships.

1.2. The (neglected) sources of service materiality

Given the link established between the level of materiality and the sustainability of services, in calling into question the principle of intrinsic immateriality of services (genotype), we also query its supposed positive effects in terms of sustainability (phenotype). We therefore propose, in this paragraph, to seek to identify neglected sources of service materiality which undermine the myth of its natural sustainability.

Service materiality may manifest itself in different places: (a) in the service medium or target; (b) in various estate facilities, that is the physical spaces of production/consumption; (c) in the production factors deployed in the service relationship. While it is important not to neglect the (physiological) materiality of the human factor, it is of course on the capital factor that we focus here. A further significant source of (direct and indirect) materiality stems from another intrinsic characteristic attributed to the service - its interactivity, its coproduced character (d). Indeed, interactivity is often associated with mobility, which requires implementation of a certain number of transport facilities and infrastructure – these being highly material and damaging to the environment.

a) Materiality of the service medium

The diversity of services in their relationship to materiality is obvious. Even intuitively, it escapes no-one that transportation, waste processing, cleaning, catering, hostelry, and car repairs are more 'material' services than are consultancy, training, insurance or psychotherapy. Even within the confines of these few examples alone, we might add that nothing is more material than the dishes prepared in a restaurant's kitchen, whereas psychotherapy is primarily a verbal exchange.

Beyond plain intuition, by mobilizing theoretical works devoted to definition of the service concept (Hill, 1977; Gadrey, 2000), this difference in materiality between services can be interpreted by the difference in materiality between their mediums. Indeed, drawing on Hill, Gadrey (2000) defines the service as a “set of processing operations seeking to change the state of the service medium”. The service medium is in turn defined by the target or reality modified or worked upon by the service provider on the customer’s behalf. It may take different, more or less material forms: (i) a material good, (ii) codified information, (iii) individuals (customers, users) themselves having physical, intellectual or locational characteristics, and (iv) organizations, again in their various aspects (technologies, structures, collective competences and knowledge).

The ‘change of state’ effected by the service can be considered immaterial (healing for the sick, satiety for the guest of a restaurant, repairs to a car, improved cultural awareness, knowledge and employability for a student). Such a change of state can neither be stored nor surrendered, regardless of the medium to which it is consubstantially linked. The service medium may, however, be more or less material, leading to the service itself in turn being considered more or less material.

The degree of materiality of the medium is the basis for a number of service typologies. Thus—when focusing on the difficulty of defining and measuring productivity in services—Gadrey (1996) has proposed a typology which can be extrapolated without difficulty to the services sustainability issue. This typology includes three groups of services whose differences are marked by their main medium:

- 1) Services that mainly involve the physical processing of technical mediums. These differ little from the conventional production of physical goods, which is the category to which the statistical conventions would in any case have assigned them (passenger and goods transportation, repair of goods, catering, hostelry, retailing, various rentals, standardized processing of codified information (e.g. some functions of banks and insurance companies...)).
- 2) Intellectual services applied to organized productive knowledge - often referred to as ‘intangible’ or ‘pure’ services because, unlike those of the previous group, these services are not primarily focused on goods (engineering, consultancy services, R&D, software production, advertising/PR services, etc.).
- 3) Services applied to individuals’ knowledge and capabilities, in final consumption, and posing significant problems with regard to the identification and measurement of output (education, health, leisure, culture, etc.).

In the previous typology, the service is defined by the *main* medium that is the subject of the ‘state change process’. This means that in reality every service activity operates, to varying degrees, on *several mediums*, so that every service activity is in fact a combination of functions associated with these different mediums (material, informational, cognitive, relational, etc.). These combinations vary across space, and especially over time (we will return to this issue in point 2.1a).

b) The materiality of service production/consumption spaces

Another key expression in the materiality of services is the materiality of their production/consumption spaces. The service economy is often associated with the absence of factories and heavy-duty production lines. However, services do also require production/consumption spaces such as offices, classrooms, hospitals, railway stations, and

airports. It would clearly be wrong to conclude that these spaces are environmentally benign – one has only to consider the space taken up by such service facilities as supermarkets, airports, logistics platforms, university campuses, hospitals, landfills, etc. The environmental damage attributable to these production/consumption spaces manifests itself in a variety of ways: use of space, energy consumption, waste generation, emissions, noise, visual and olfactory disturbances, etc.

From an organizational perspective, the question of the production space materiality is often considered via making a distinction between two different spaces: the back office and the front office. The back office is where the material or informational transformations of service medium take place in the absence of the customer (for example, the restaurant kitchen or the various departments within a company). The front office is the customer-facing area (for example, the floor of a restaurant, the bank counter or the hotel lobby).

In management science, and in marketing in particular, an extensive literature has developed in recent years, seeking to take full advantage of these production/consumption spaces and enhance their materiality. This aspect of materialization strategies will be discussed in paragraph 1.4.

c) Materiality of the production factors deployed

Even though the labour factor has an evident physical existence, here we are addressing the issue of capital materiality. The third sector theory is built upon the idea that services are low capital-intensive, and primarily based on the mobilization of labour. Colin Clark, a founding father of the theory of the third sector, observes that “most service businesses require far less in the way of capital goods than industry or agriculture” (Clark, 1940). This low capital-intensity lies at the heart of the first positive (rather than residual) definition of the tertiary sector. According to Fourastié (1949), the service sector includes activities for which productivity growth rate is low due to weak mechanization. Baumol (1967) relies on the same assumption in his unbalanced growth model which defines services as a stagnant sector, whereas goods belong to a progressive sector. It should however be noted that in a later work, Baumol et al. (1985) qualified this analysis by introducing an asymptotically stagnant sector combining a progressive and a stagnant component. An example of this is provided by the IT sector, whose hybrid nature (hardware + software), starts out progressive, while the hardware element is proportionately dominant, then evolves towards stagnation as the software component grows stronger.

This negative assessment of the capital-intensity (and materiality) of the services (and conversely, the positive assessment of their sustainability) must be qualified and called into question – both statically and dynamically. First of all, it is undeniably true that some services have long been characterized by their high capital-intensity: this is the case not only of transport in all its forms (passenger and goods transport, air, rail, land and sea transport, etc.), but also of energy and water supply activities (public utilities) for which the question of their belonging to ‘industry’ or ‘services’ continues to be a matter of debate (Broussole, 2014). Yet it is clear, from a dynamic perspective, that services are increasingly capital-intensive. They fall within the scope of natural technological trajectories in the sense of the evolutionary theory (Nelson and Winter, 1982), i.e. trajectories of increasing mechanization. We will return to this point in paragraph 1.4.

d) The material dimensions of interactivity

Interactivity is another essential (intrinsic) technical characteristic of services. It refers to the different forms of interaction between service consumer and service producer (different modalities of the service relationship), which reflect various levels of co-production of the service by the consumer. Like immateriality, this technical characteristic of services also has its roots in the history of economic thought. Storch (1823) is often cited as its precursor.

This service interactivity is also a source of materiality - and therefore of adverse effects to the environment. It often presupposes a physical encounter, which entails travelling on the part of service relationship protagonists. These journeys are material-intensive because they mobilize not only transport infrastructure and technical systems, but also different countervenues, depending on the nature of the mobility in question. Interactivity thus has an effect on materiality, especially through the two above-mentioned vectors of materiality (see § b and c) - namely the factors of production and production/consumption spaces.

Several types of journeys can be distinguished (Gadrey, 2010; Fourcroy et al., 2015): (i) journeys by consumers or users to the place of service production/consumption (for example, in trade, catering, hostelry, education or health, at least in their traditional dominant form); (ii) journeys by service providers to the customer, be this a firm or an end consumer (e.g., consultancy, certain sales formulas, home services); (iii) simultaneous journeys by service providers and clients (passenger transportation in all its forms); (iv) journeys made by service organization employees to their workplace.

These different types of journeys involve individuals whose mobility is required for the establishment of the service relationship, that is the encounter between client and provider. The mobility can however also concern material goods: material inputs required to produce the service, as well as the goods that are the subject of the service transaction (e.g. supply to stores in retailing, delivery of goods to customers in mail-order selling).

Service-associated journeys are a major source of energy consumption. In 2007, in France, they represent approximately 40% of official tertiary sector energy consumption (Fourcroy et al., 2012). The scale of these journeys and their impact on sustainability are such that Gadrey (2010) has no hesitation in predicting the decline - and even the demise - of whole swathes of the tertiary sector, unless appropriate solutions (innovations) are found. Examples of such activities are transportation and all services relying heavily on transportation - including international tourism and business travel, hostelry, postal services, etc.

1.3 A materiality/immateriality that depends on the output convention adopted

Immateriality is not an (objective) intrinsic technical characteristic of services, just as materiality is not anymore always seen as a fundamental dimension of goods (see § 2.2). The degree of materiality is a social construction, which depends on the output conventions adopted. The materiality of the service and its impact on the environment differs, depending on the delineation of the border of the service, according to its topographical and temporal coordinates.

In the following paragraphs, we consider the output convention at three different levels:
 - the technical (topographic) delimitation of the boundaries of the service activity as such (this level essentially reflects the direct materiality of the service);

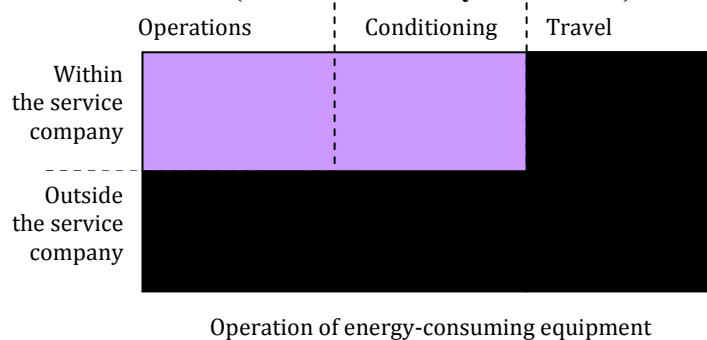
- the focus on the indirect dimensions of the materiality of the service, particularly (but not exclusively) from a time perspective, involving an analysis in terms of life cycle;
- the focus on the universal nature of the "service provided" as an ontological characteristic of both services and goods.

a) *The physical scope of the service*

It is obvious that, depending on the border that is drawn to delimitate the service, the level of its materiality and therefore of its sustainability can vary considerably. This relationship between the output convention adopted and sustainability can be illustrated in the case of the evaluation of energy consumption. Such an exercise was performed by Fourcroy et al. (2012), who propose to break down the service into three components (basic services), which give rise to different energy needs (see Figure 1): conditioning, service operations and travel.

According to the definitions of the service previously mentioned (§ 1.2a), *service operations* consist in the mobilization of competences and techniques in order to make transformations on the various mediums of the service (material object, information, knowledge, the individual). These operations require technologies, particularly technologies for material and information processing, which are energy consuming. *Conditioning* refers to the whole set of energy-consuming activities achieved for the preparation of the physical space of the service activity (fitting out, cleaning, heating, air conditioning, lighting, etc.). These activities take place upstream of the service operations, but also during the operations and partly after them. *Travel* refers of course to the different configurations of the journeys made by the service protagonists before, during or after the service operations (see section 1.2d). It is a major source of energy consumption and pollution. It should be noted that conditioning activities and service operations could take place in the premises of the company or outside the company.

Figure 1. The Scope of Energy Consumption in the tertiary sector as assumed in CEREN statistics (source: Fourcroy et al. 2012)



Key:

■ Consumption excluded in the CEREN energy statistics

However, the official energy statistics (for example, in France those of CEREN⁵) limit the scope of energy consumption to *conditioning activities* and *service operations within the service firm*. The only energy consumption taken into account are those of the equipment used

⁵ CEREN: Centre d'Etude et de Recherches Economiques sur l'Energie [Centre for study and research into energy economics]. This is the major French organization supplying energy statistics on the tertiary sector.

within the premises of the service organizations. Therefore, the measurement conventions underestimate the energy consumption and more generally the negative environmental externalities in the tertiary sector. They exclude, in fact, on the one hand, the energy consumption of conditioning activities and of service operations performed outside the service firm, and on the other hand, the consumption related to travel activities.

By adding to the official statistics, the energy consumption generated by the whole set of journeys related to the consumption or production of services (journeys the service consumers in order to consume the service, journeys by service organizations employees from home to their workplace, journeys by service providers for professional reasons), Fourcroy et al. (2012) estimate, in the case of France, and for 2007, that the energy consumption is multiplied by a factor of 1.4.

b) The direct and indirect sources of materiality

The discussion of the materiality of services (and of its negative effects in terms of sustainability) is often restricted to its *direct* sources. But there are also *indirect* sources of materiality. Taking them into consideration would contribute to scale up the adverse environmental effects of services.

Direct sources of materiality (and corresponding negative externalities) are those which appear immediately within a given service provision. They reflect the negative externalities directly generated by the use of the different material elements (service medium, production factors, production/consumption spaces, etc.), within the different component of a service (operations, conditioning, travels).

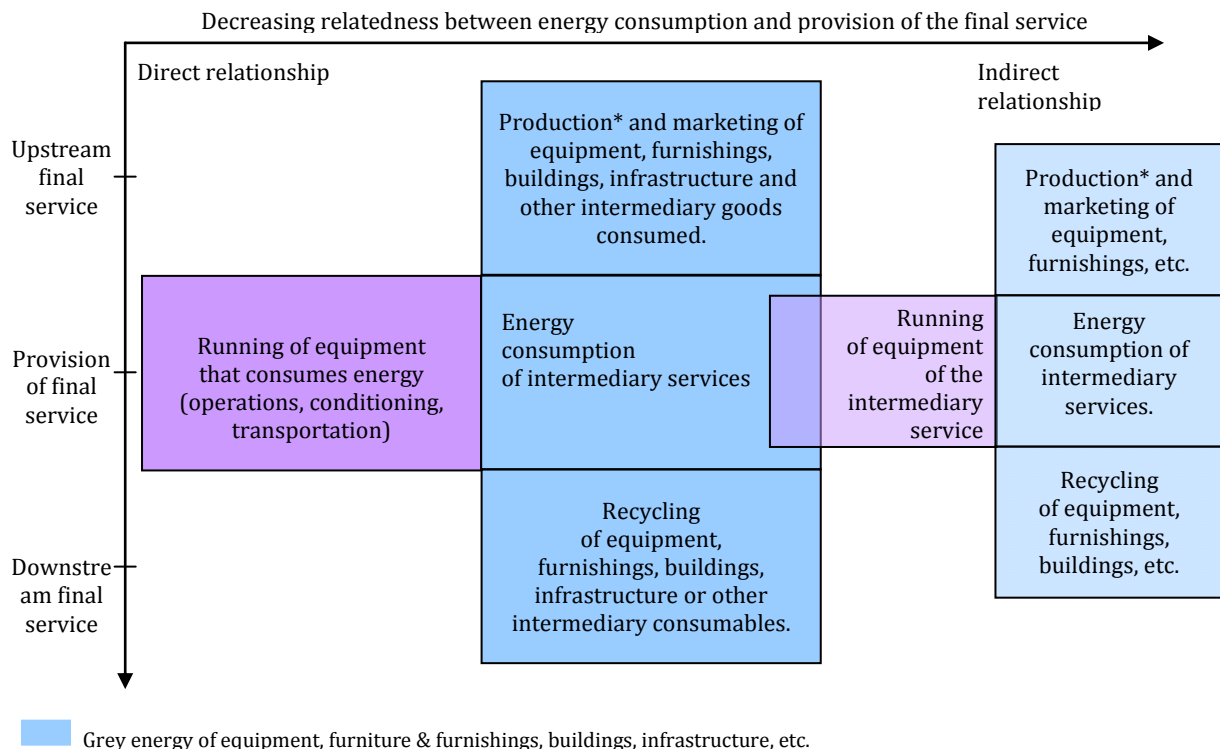
Indirect sources of materiality, for their part, are those that are induced by the service in question in the rest of the economy and/or at other times, upstream or downstream the service. There are (at least) two different types of indirect sources of materiality (Fourcroy et al., 2012).

The first type can be addressed by an analysis in terms of life cycle, applicable to the whole set of material goods mobilized during the service provision: technical equipment of course, but also buildings, furnishings, intermediate consumption of various goods, goods sold (e.g. in retailing). These different material goods are not only sources of materiality (and externalities) during their use (direct materiality previously mentioned), but also, upstream, at the moment of their own design, production and selling, and downstream, when they are maintained or repaired and possibly recycled at the end of their life. By analogy with grey energy, this incorporated materiality can be labelled "grey materiality".

The second type of indirect source of materiality of the service corresponds to the materiality associated with the different types of intermediary services, necessary for the provision of the final service in question. These may include, for example, cleaning services, catering services, consultancy services. These intermediary services also, recursively, involve direct and indirect sources of materiality. The former correspond to the negative externalities that appear immediately during the delivery of the intermediary services in question and which are generated by the different vectors of materiality of these intermediary services (equipment, furnishings, buildings, etc.). The latter correspond to the grey materiality of these intermediary services themselves and, recursively, to the materiality of the intermediate services necessary for the provision of these intermediate services themselves, etc.

Figure 2 provides an illustration of the distinction between direct and indirect sources of materiality, in the sole case of energy consumption. It can easily be generalized to all direct and indirect sources of materiality. Using an input-output method, Fourcroy et al. (2015) estimate that in France, for 2009, taking into account grey energy multiplies the energy consumption in services by a factor of 1.6 (it is even doubled in certain service sectors such as the information and communications sector).

Figure 2 The total direct and indirect sources of energy consumption in a final service



*Production in the broad sense. This includes: the design of the project, the extraction and transportation of the necessary raw materials, the processing of raw materials and fabrication of the product.

c) The service as a common ontological characteristic of both goods and services

The idea of the subjective and conventional nature of the border of services (of the difference between goods and services) probably culminates in the recent theoretical work, which consider that the search for specificity (materiality of goods vs. immateriality of services) is counter-productive, since in fact "everything is service".

These works share the idea of a certain (observed or desired) blurring of the boundaries between goods and services and the need for common theoretical models. They actually rediscover the principles of consumer microeconomics: the utility, the value in use, the service or final characteristic as an ontological characteristic of both goods and services. This common immaterial nature of goods and services, which militates in favour of integrative or unifying theoretical analyses, is at the heart of all the following theoretical constructs: the functional economy theory (Stahel, 1997; Du Tertre, 2007; Boutillier et al. 2014), which defines any output (goods or services) by the function (service) it provides, the experience economy theory (Pine and Gilmore, 1999), which defines the output by the experience it provides to the consumer, the "Service-Dominant Logic" (SDL) (Vargo and Lusch, 2006)

which defines the value by the value in use, therefore erasing the difference between goods and services, and the "Service science" (Maglio and Spohrer, 2008) which is a science of both goods and services. Another formulation of this integrative theoretical perspective is more directly focused on the innovation issue. This is the approach (of the product and of innovation) in terms of characteristics developed by Gallouj and Weinstein (1997) and extended by a number of other works (De Vries, 2006; Garcia-Goñi and Windrum 2008; Gallouj and Toivonen, 2011, etc.).

However, if they share a common desire of theoretical synthesis, these integrative theories do not pursue the same key objectives. Thus, the main initial project of the functional economy theory (Stahel, 1997) is to develop a theory of sustainable development. Therefore environmental issues occupy a central place in this theory. The analysis in terms of SDL (Vargo and Lusch, 2006) and the experience economy theory (Pine and Gilmore, 1999) essentially fall into the scope of a perspective of service marketing. They rediscover and operationalize the use value, and the new consumer economics (Lancaster). The approach in terms of characteristics (Gallouj and Weinstein, 1997) is also of Lancasterian inspiration. Its main purpose is to provide a theoretical model that accounts for the diversity of the innovation dynamics in both services and goods. But of course, these theories can add (or have already added) to their research agenda, purposes other than their original purpose. Thus, for example the functional economy theory and SDL are increasingly addressing innovation issues (Ordanini and Parasuraman, 2011; Vargo et al., 2014). The approach in terms of service characteristics strives to integrate environmental and more generally sustainability issues (Djellal Gallouj, 2015; Cruz et al, 2015).

1.4 The rise in materiality as an active strategy of service organizations

In management sciences, real or supposed immateriality of services has long been regarded as a weakness to be corrected. This immateriality of the service and its associated heterogeneity/variability character, are the origin of performance evaluation issues (service quality, cost or labour productivity) concerning both the client and the service provider (Gadrey 1996; Djellal and Gallouj 2008a). Therefore different (innovation) strategies have been implemented to introduce material elements in services or optimize existing ones. Some authors (especially Levitt, 1972) established this rise in materiality as a strategic imperative for service organizations, advocating for a systematic "industrialization" of services.

The increase in material intensity of services and their industrialization can take different forms that are closely related, but that we present separately, in order to highlight the different materialization (and industrialization) mechanisms at work.

The first form of materiality rise is the introduction of material technical systems in service companies and organizations. The information and communications technologies that spread invasively in services are (especially in their hardware dimension) an essential source of this materialization process. But other technologies also play a key role (often by hybridization with ICTs): cooking, cooling and ventilation technologies, transportation technologies, medical technologies, etc. As highlighted by a certain number of works (Berkhout and Hertin 2001; Faucheux et al., 2002; Gadrey, 2010), these technical systems are intensive consumers of exhaustible natural resources (rare metals) and energy. They also raise formidable problems related to the treatment of waste. Their development is often artificially supported by extremely short life cycles associated with quasi-programmed obsolescence (Desmarchelier et al., 2011).

The second form of materiality rise is, paradoxically, the implementation of what may be called soft or "immaterial" technologies. This is the standardization of work processes, the implementation of industrial production methods, models, blueprints (Levitt, 1972; Lovelock, 1992; Kingman-Brundage, 1992), which are veritable production "manuals" of the service. These invisible technologies lead to a standardization of the service itself. The product, in this case, is not a good, but a quasi-product: for example, a standard insurance contract or a standard financial product, a tourist standard package, a standard menu item identical throughout a fast food chain (McDonald's is often cited as the archetype of the industrialization of catering). Industrialization means, then, eliminating cases that are not standard cases.

The third form of materiality rise involves the physical spaces of production/consumption of the service. It can be addressed in two different ways. The first reflects the development, in possibly innovative forms of these spaces defined as architectural entities (*external or 'property' materiality*). The icons of this property materiality are large shopping centres, logistics platforms, transportation hubs, etc. It should be noted that this property materiality can even, in certain cases, rely on industrial production processes, since some modules of the building infrastructure are pre-fabricated in a factory (this is the case, for example, of Hotel Formule 1 of Accor Group). The second way to address the rise of materiality of the physical spaces is to look at the materiality that manifests itself within the infrastructures. This *internal materiality* is critical to customers, who are sensitive to the aesthetic and functional qualities of the internal architecture and of the furnishings: accessibility to spaces, signage, appearance, decor, comfort, ergonomics, etc. All these elements contribute to make tangible the immaterial and the heterogeneous, and are the subject of intense innovation efforts. The strategies implemented to optimize the internal materiality may have different but complementary goals: communication/advertising, improving access and mobility, optimizing the client-provider interaction, reducing uncertainty about the quality, etc.

The last form of materiality rise that we evoke does not concern the production but the consumption sphere. It manifests itself by the rise of the self-service in Gershuny's meaning (1978), that is to say the replacement of services by industrial goods used at home: for example, the replacement of the laundry service by the use of one's own washing machine, the replacement of the cinema by the DVD at home, etc.

2. Greening the economy by innovation *in* services and *by* services

In the first part of this work, we have argued that, contrary to an old assumption, the service is not green and sustainable by nature, but that it includes direct and indirect sources of materiality, which serve to increase its ecological footprint. We have raised the innovation issue only in addressing these sources of materiality in dynamic terms, that is to say by focusing on the materialization/industrialization strategies implemented in service companies and organizations.

In this second part, we address innovation from a different angle, that of dematerialization strategies. In a service economy, innovation in services and by services plays a key role in the process of dematerialization and greening. This greening of the economy by services and service innovation can take two different but complementary paths: first, the greening of the services themselves through the implementation of dematerialization strategies and green

innovations trajectories within services sectors (§ 2.1); then, the greening of goods by services and services innovation (§ 2.2).

2.1 The greening of services themselves: the green innovation trajectories in services

We consider here how, through appropriate innovations strategies, services can dematerialize and green themselves. To account for these *internal or endogenous dematerialization* strategies, we rely on the different dimensions of the materiality of the service previously considered, namely the materiality of (i) the service medium, (ii) the production/consumption spaces and (iii) the production factors. We will not discuss here separately dematerialization strategies associated with the interactivity of the service, to the extent that they are actually special cases of dematerialization strategies related to production factors (transport systems) and production and encounter spaces. This analytical approach is simplifying since the different materiality sources separately addressed here are interdependent in reality.

a) Dematerialization and greening of the service medium

As we mentioned in paragraph 1.2, the medium of the service can take different more or less material forms: a (material) good, the individual himself, codified information, knowledge. If, in theory, a service activity may be defined by the nature of its main medium (therefore several types of services are distinguished: material, informational, cognitive, relational services...), a service organization is mostly processing simultaneously these various mediums, combined in varying proportions. These combinations are not static but dynamic, and in particular, they may evolve according to dematerialization trajectories.

Depending of the analytical level adopted (macro, meso, micro), the dematerialization of services, considered in terms of the dematerialization of their mediums, can be interpreted in different ways.

At the macro or mesoeconomic level, the dematerialization of the medium may manifest itself by a rise of informational, cognitive and relational services at the expense of material services. This structural change is reflected by concepts such as ‘information economy’ or ‘knowledge economy’. It is also at the heart of the post-industrial society as defined by Daniel Bell (1973), namely, a society that is moving towards the higher-level services in which the mediums of service provision are human beings and knowledge (in particular health, culture, leisure, research and public administration) to the detriment of so-called lower-level services characterized by the processing of tangible goods (transport, retailing, etc.).

At the micro level, this dematerialization is expressed by the rise, within a given organization (or activity), of processing operations of immaterial mediums (information, knowledge and relationship with the individual) to the detriment of processing operations of physical mediums. The outsourcing of certain material services activities (e.g., catering, transportation, cleaning) can contribute to this process of dematerialization. However, as highlighted by Djellal and Gallouj (2008b), the various mediums of the service and the various corresponding functions (operations) can be associated with different technology families: material processing technologies (robotics, mechanics,...), information processing technologies (IT, telecommunications), knowledge processing technologies (soft technologies, methods...). Thus, in a given activity (or service organization), the rise of the immaterial mediums and functions with respect to material mediums and functions is bound by a reciprocal causality to the change of relative weights of technological families and corresponding innovations

trajectories. The dematerialization of the service is thus associated with the rise of immaterial innovation trajectories (pure service, cognitive (methodological) and informational (in its software dimension) at the expense of material innovation trajectories (see section c).

b) Dematerialization and greening of production/consumption spaces

The dematerialization and greening process of production/consumption spaces fall into the scope of two distinct groups, which are not fully independent. The first group includes the different operating modalities of the dematerialization and greening of traditional production/consumption spaces, while the second group consists of "alternative spaces" to these traditional spaces.

In the first group, dematerialization and greening of the traditional production/consumption spaces can be operated in different ways, which, essentially, refer to building engineering and architecture (including interior architecture). Thus dematerialization and greening cover, first of all, innovation efforts to build sustainable property infrastructure (ecoconstruction, HQE approach) whether these efforts focus on the nature of the materials used, the non-intrusive inclusion of infrastructure (the buildings) in the natural environment or the configuration of interior spaces, etc. They also cover, in some respects⁶, "architectural and spatial" facets of the so-called low-cost or service regression strategies (Djellal and Gallouj, 2005, 2008b). Indeed, these service regression strategies simplify not only the service offer (by limiting it to the central service and eliminating peripheral services), but also the physical environment of this offer. They are less demanding in volume and quality of reception areas (see, for example, the frugal reception areas of low-cost airlines companies at airports, the Spartan material organization of shelf spaces in discount retail chains) and, according to Fourcroy (2015), less energy consuming. Dematerialization and greening of traditional production/consumption spaces finally also covers the experience of "smart buildings", reflecting a hybridization of real estate techniques and information technologies (see following item c).

In the second group, dematerialization and greening of production/consumption spaces are obtained by the introduction of spaces, alternative to traditional production/consumption spaces. Some of these alternative spaces are not new, but they are experiencing a significant development. These include, for example, alternative spaces associated with the following services: 1) home services (e.g., home care services, especially elderly care); 2) remote services relying on post mail, telephone, but especially Internet; 3) services in shared space (e.g. village shop that provides postal services). These alternative spaces can contribute, in varying proportions, and all things being equal, not only to reduce the production/consumption spaces but also the amount of travel.

c) Dematerialization and greening of the production factors

The process of dematerialization/greening production factors (limited here to technical systems) can be addressed by focusing on the different ways that innovation trajectories at work in service organizations may evolve: (i) the rise of immaterial innovation trajectories at the expense of material trajectories; (ii) the strengthening of the immaterial dimension within a given innovation trajectory; (iii) the hybridization of several trajectories. The process of the

⁶ In other respects, and primarily, regression strategies aim more, as we have already stated (see § 1.4) to industrialize the service, to make it less intangible, less interactive.

dematerialization of production factors can also be addressed (iv) through changes in material goods ownership and use regimes.

Changing relative weight of innovation trajectories in favour of immaterial trajectories

First, within a given service company or service activity, the dematerialization/greening process can be considered (as we have already pointed out above) to be a rise in immaterial innovations and technologies at the expense of material innovations and technologies, alongside the rise of the intangible components of the service provision, which is at the expense of its tangible components. In other words, material innovation trajectories reflecting technological developments relating to the transport and transformation of material substances, whether human or physical⁷, become less important than immaterial innovation trajectories which reflect, on the one hand, the production and evolution of formalized methods of knowledge processing⁸ and, on the other, the implementation and evolution of 'pure' services innovation, independent of any technical medium.

Strengthening of the immaterial/green dimension within a single innovation trajectory

The dematerialization process may also be considered at the level of any one component of the service (material, informational, cognitive, or relational) or at the level of the corresponding innovation trajectory, whether material or immaterial. The idea here is that the innovation trajectories, whatever form they take (material or immaterial), are becoming more environmentally-friendly, meaning that efforts are being made to develop and adopt cleaner, more energy-efficient technologies. For example, within the logistics material innovation trajectory, efforts are made in favour of cleaner transport technologies (electric and hybrid vehicles). Within the material and information innovation trajectories, efforts are also made to reduce the volume (materiality) of new technical systems, so that they are more compact. This trend towards miniaturization and integration is not, however, new. Though evolutionary economics (Foray and Zuscovitch, 1988) has described it as a specific natural technological trajectory insofar as it characterizes the technological evolution of a particular sector (electronics), it is tending to become a generic natural technological trajectory (concerning many sectors). In the specific case of the informational trajectory describing the dynamics of information systems, it is generally assumed that (immaterial) 'software' dimensions tend to outweigh the (material) 'hardware' dimensions as the trajectory evolves. Acceptance of this hypothesis thus means that the informational trajectory will evolve in line with a growing dematerialization process. It is on the basis of this hypothesis that Baumol et al. (1985) introduced an asymptotically stagnant sector in the so-called unbalanced growth model.

Hybridization of material and immaterial innovation trajectories

Dematerialization and greening can also happen through the hybridization of innovation trajectories. In the most common case - the hybridization of material and informational innovation trajectories - the question arises as to whether hybridization helps reduce the level of materiality of the new hybrid technical systems formed (to which the answer is probably yes, assuming that the software dimension overrides the hardware dimension). However, beyond this hypothetical dematerialization, there is no doubt that some hybridization strategies, all other things being equal, do have a greening effect: this is the case where the introduction of ICT helps streamline use of a technical system with a view to sustainability - and in particular to energy-saving (smart grid solutions) (Hyytinen and Toivonen, 2015). This

⁷ For example, passenger or goods transportation systems, cooking and refrigeration systems, cleaning systems, various kinds of dispensing machines, visitor attractions, bio-medical or bio-pharmacological innovations, etc.

⁸ For example, new consultancy methodologies, new health or cleaning protocols.

is also the case where ICTs are used to carry out service transaction without travel (e.g. remote surgery). Conversely, it should be noted that the hybridization of immaterial (pure service and methodological) innovation trajectories and informational innovation trajectories—that is, the introduction of ICTs to both pure service and methodological innovations, contributes to the pro-materialization dynamic in services (see § 1.4).

Changes in production factor ownership and use regimes

Dematerialization of production factors (and more generally of material goods) may be achieved through changes in ownership and use regimes. Within the sphere of production, as in that of consumption, individual ownership and private use may give way to different service consumption patterns that do not include ownership (or do not include exclusive ownership) of the goods: leasing, renting, sharing, pooling (see also § 2.2c below). Examples include car sharing (such as BlaBlaCar), shared use of certain sophisticated and expensive technologies, possibly within the context of public-private partnerships (e.g. scanners in hospitals), etc. This fall in materiality, voluntary though it may be, can also be fortuitous, a joint by-product of the pursuit of other objectives. This is, for example, the case of the pooling of heavy equipment in hospitals, which primarily pursues an economic objective.

2.2 Dematerialization/greening of goods (and of the whole economy) through services

As we noted in the previous paragraph, services (as activities or organizations) may themselves be subject to dematerialization and greening dynamics. Here we look at another relationship between services and greening, namely the potential role these activities may play in the greening of other economic activities than their own. These greening (dematerialization) strategies can be described as *external or exogenous*. Within the framework of the so-called economy of functionality, and within a servitization perspective (Vandermerwe and Rada, 1988), the concept of Product-Service System (PSS) (for a literature survey, see Goedkoop et al., 1999; Mount, 2002; Tischner et al., 2002; Tukker, 2004; Baines et al., 2007; Beuren et al., 2013) occupies an important place in this issue of the greening *by (rather than of) services*. Although it is becoming catch-all and ambiguous as it seeks to gain theoretical consistency, this concept has undeniable heuristic value. Indeed, the concept of PSS (initial, pared-down definition: a combined offering of goods and services) has extended to cover more abstract content, and in particular the idea that everything is service.

In this section, we begin by discussing the analytical ambiguities introduced by enriching the concept of PSS (§ a). We then examine the implications in terms of the dematerialization/greening of different PSS formulations, distinguishing two cases: (i) Product-oriented PSS and dematerialization through the addition of services to products (§ b); (ii) Use-oriented PSS and dematerialization through the substitution of services for products (§ c).

a) Different PSS concepts, and some ambiguities

Strictly speaking, Product-Service System can be defined as the association (the joint supply) of products and services to meet consumer needs. Such systems existed long before the concept of PSS was explicitly introduced. Although other denominations reflecting the same idea (the combination of products and services to meet consumer needs) preceded PSS, these have been less successful (Bryson 2010). Examples include ‘goods-services complexes’ (Barcet, 1987) and ‘compacts’- a neologism (from ‘complex packages’) coined by Bressand,

1986, (see also Bressand et al., 1989), comprising ‘bundles of services and manufactured inputs’.

In the literature, the ‘mechanical’ definition of PSS soon gave way to a more complex definition, going beyond the combination of products and services to include utility and environmental issues. Thus, according to Manzini and Vezzoli (2002), “the concept of PSS promotes a focus shift from selling just products to selling the *utility*, through a mix of products and services while fulfilling the same client demands with less environmental impact”.

On the whole, in recent literature, the PSS concept seems to be a heterogeneous category, covering various modalities of the (real, theoretical or even rhetorical⁹) integration of products and services. These modalities are described in the following terms (Mont, 2002; Tukker, 2004; Bryson 2010 Vandermerve and Rada, 1998 Boutillier et al., 2014): the association of physical products with intangible services; the definition of the product by the services it renders; the sale of the use of a product rather than the product itself (leasing, renting); the sharing or pooling of the use of a product, and repair rather than disposal. Such a broad and open definition of PSS introduces an ambiguity related to the confusion between the service as an activity (as opposed to a product) and the service as utility or use in the sense of economic theory. A PSS connects products and services. But the ambiguity arises, on the one hand, out of the semantic shift that characterizes the term ‘service’, and on the other, out of the nature of the relationship which causes a system to exist.

In an attempt to formally summarize these semantic ambiguities, Let’s call P the product, S the service, s the final characteristic (utility, use value, service characteristic), σ the general (generic) function attributed to a product, a service or a combination of products-services, Σ the service uses that can be made of the product P.

In contemporary literature, as we have just stressed, the PSS concept now, in an ambiguous and catch-all way encompasses a broad set of relationships (which are not always systemic), associating a product (P) and an expression of the service from among those just mentioned (S, s, σ , Σ). The main relationships in question areas follows:

- P + S. This is the PSS in the strict sense, combining tangible products with intangible services.
- Σ (P), which expresses the service uses of a product. These service uses include leasing, renting, sharing, pooling, etc. While a relationship between Σ and P does exist here, it can only be called a PSS via erroneous use of language.
- P (σ) or S (σ), which formalize the idea that a product or service is defined by the general function it performs: mobility, leisure, health, or education, for example. The relationship between P and σ and S and σ is not itself systemic. In reality a system exists only when P and S are combined to satisfy a function, which can be formalized as follows: (P + S) (σ).
- P (s) or S (s), which, in the Lancasterian tradition, reflect the idea that any product and service is defined by the service characteristics it provides. As in the previous case, the general idea is that products (like services) are defined by the service provided. The difference lies in the fact that the service is not approached in general terms (as a function), but rather broken down into more specific basic service characteristics (e.g. the transport or mobility function is replaced by a vector of service characteristics: speed, security, comfort, etc.). Both approaches to the relationship between products and services can have critical

⁹ This is sometimes a marketing discourse

implications on both perception of the level of materiality and the definition of innovation. However, the relationship between P and s or S and sis not systemic. Indeed the service characteristics (s) are consubstantial to P and S; these are not external components capable of creating a system.

The first of the above relationships (P + S) reflects what the literature on PSS (Tukker, 2004) calls ‘Product-oriented PSS’, while all the other relationships fall within the scope of the ‘Use-oriented PSS’.

b) Product-oriented PSS: dematerialization and greening through the addition of services to products

Product-oriented PSS are established by the addition of services to products. They may, however, take more or less sophisticated and integrated forms, featuring more, or fewer, added services. Within this product-oriented PSS diversity, it is possible to distinguish two main sub-categories, according to the knowledge-intensity of added services.

The addition of (relatively) low knowledge-intensive services: services around the product

The best-known form of product-oriented PSS is that which entails adding traditional services (generally those having (relatively) low knowledge-intensity) to a product. These PSS are similar to what Furrer (1997, 2010) calls “services around the product”. Examples include the addition of different pre- and after- sales services, financial and insurance services, etc. which made Fordist economies so successful. Such PSS may be considered at micro level (the same company provides the combined supply of products and services) or at meso level (the joint offer is the result of a partnership between different actors). In the latter case, the PSS is more than just a design and product engineering concept since it also reflects a production and innovation network dimension.

It should be acknowledged that the original purpose of such a system is not ecological. By adding services to products, the objective pursued by companies is to gain a competitive advantage. Companies seek to improve the quality of goods, reduce costs, boost sales and thus increase profits. In some cases, the services added to the product can even be more profitable than the products themselves (Furrer 1997). By adding services to products, companies may also seek to lock down the relationship with the customer - in other words, to generate customer loyalty (Bryson 2010). The multiplication and tightening-up of service relationships (i.e. customer interaction) help keep the provider attentive to client needs, favouring adaptation and innovation. It is now possible to state that the addition of services to products, and the concept of PSS, have enriched innovation theory, ahead of sustainable development theory. The two fields (innovation and sustainability) are now reconciled within this concept.

In this PSS approach, dematerialization arises out of multiple sources. First and foremost, it is mechanical (passive), a result of the rise of intangible services in the PSS. In other words, by adding services or service to products, the degree of immateriality of the entire PSS rises. In this way, the ratio between the ‘volume’ of material products and the ‘volume’ of intangible services serves as an indicator of the degree of the service’s materiality/immateriality. Within the supply of a given industrial firm, the volume of intangible services may increase, outweighing the volume of material products. This development, which raises sectoral allocation issues, is illustrated by the case of iconic industrial companies (particularly

in IT) that have essentially become service providers. It should be noted that in this simple PSS approach, the reverse process of adding products to services also contributes to the creation of aPSS. Such a process, however, helps increase materiality, rather than reduce it.

Dematerialization is also active for some added services. This is, of course, the case of repair and maintenance services, as well as of take-back and recycling services at the end of product life. All of these contribute to dematerialization through the expansion of the lifespan of either the products or some of their components, and by reducing use of virgin materials in the production process (Agri et al., 1999).

The addition of KIBS: the P-KIBS System

A product-oriented PSS can also be constituted through the addition of Knowledge-Intensive Business Services (KIBS) (various types of consultancy services, engineering, training, and research) to products (and services). The Product-KIBS system also contributes to dematerialization of the system, in a mechanically (passive) way, by the simple juxtaposition of intangible services and physical products. This is not, however, the most important dematerialization/greening mechanism. Above all, KIBS contribute via an active role. Indeed, in this type of PSS, KIBS are primarily mobilized as agents of change. They can accompany and support the greening/dematerialization efforts of a business and corresponding innovations, whether technological or non-technological. A number of consulting companies have thus either specialized in providing greening services, or included this expertise in their service supply.

c) Use-oriented PSS: dematerialization through the real or theoretical substitution of services for products

The currently dominant PSS approach is broader than the previous one, since - beyond the systemic dimension (linking products and services), it is the distinction between products and services (and paradoxically between components of the system) that is called into question. Indeed, the main idea here is that, by nature, everything (including the product) is service and that material goods are subject to service uses. This PSS approach is called 'Use-oriented PSS'.

- From the theoretical (and sometimes rhetorical) point of view, this PSS approach falls within the scope of a perspective that reflects a radical change in perception of the nature of goods and services. In this vision "everything is service". Agricultural products, industrial products and services alike are of value only based on the service(s) or function(s) they provide.
- From the operational point of view, this PSS approach reflects, then, a change in the way products are used by consumers, associated with a change in the producer's business model. The company no longer provides products, and the consumer no longer acquires ownership of a product - rather, both respectively sell and buy the use of the product and the service it provides. From this perspective, products (such as cars, photocopiers, and machines) are no longer what are sold, but rather kilometres travelled, the number of photocopies made, hours of operation, and so on. This purchase of the service provided by the products can take many forms: renting and leasing (potentially even going as far as a 'pay per service unit' model¹⁰), as well as sharing and pooling.

¹⁰ An illustration is provided in the area of rental and leasing photocopiers.

In this PSS approach, dematerialization and greening are not limited to the rise of mechanical immateriality through the addition of intangible services. Here the sources of immateriality and greening are more complex and difficult to grasp. They are linked to the decline in consumption of durable goods and the efforts made by producers to upgrade durable goods (sources of the services they sell) or extend their lifespan.

Though it reflects a blurring of the traditional analytical ‘product and service’ categories, PSS also questions (scrambles) our analytical categories in the field of innovation (whether or not related to sustainable development): its nature, its actors, its appropriation regime and its evaluation systems. In a PSS, therefore, innovation in products can come out of innovation in complementary services (this is well known in mature sectors, such as the automotive industry). Innovation takes systemic, architectural form. It concerns not only products as such, but also their consumption or use modes. It also raises appropriation issues, given the multiplicity of stakeholders (and in particular the role of the user). It requires innovations in our innovation and performance measurement apparatus, in order to reflect - beyond industrial and technical performance - environmental and social performance (Hyytinen et al., 2015).

Conclusion

Insofar as it is through their material dimension that economic activities damage the environment, the alleged immateriality of services is often seen as a guarantee of their natural sustainability. Unlike goods for which the production process swallows up exhaustible natural resources and harms the environment, services, by dint of their evanescent nature (long since emphasized by the founders of classical economics) are supposed to have a smaller environmental footprint.

In this work we have sought, firstly, to refute this myth of the immateriality of services. Even though a service outcome may be (or seem) immaterial, we must not forget the many materiality sources that the service conceals: materiality of the service medium, the production factors deployed and the production/consumption spaces, as well as materiality relating to interactivity (which is integral to the previous two vectors of materiality).

Moreover, the materiality/immateriality of a service is not an objective, intrinsic, technical characteristic. It depends, firstly, on the output convention adopted - that is, the scope agreed upon for definition of the service, whether this is its topographical delimitation or its time horizon. Massive underestimation of service materiality often results from the exclusion (as often practiced by official statistics conventions) of certain components (such as travel) from the scope of a service. The materiality of the service is similarly underestimated when it is limited to direct materiality, excluding indirect (‘grey’) materiality, which is ‘incorporated’ to buildings, furnishings, intermediate goods and technical systems in particular, as well as to intermediary services mobilized in the course of the service transaction. This service materiality also depends on the materialization/dematerialization strategies being implemented by service organizations.

Thus, while the service is not intrinsically intangible, innovation strategies can be implemented that will make it more or less material/immaterial. In this chapter, we have only

briefly touched on service materialization (industrialization) strategies in order to focus on dematerialization and greening strategies.

In their relationships to services, such dematerialization strategies can take two forms, each covering different sustainable innovation trajectories. The first of these internal dematerialization/greening approaches describes a set of innovation strategies entailing services dematerializing and greening themselves through actions designed to affect the vectors of materiality: service mediums, production/consumption spaces, and production factors. The second form, known as an external materialization/greening strategy, encompasses a set of innovation strategies which comprise the dematerializing/greening of goods (and of the whole economy) through services and service innovation. The PSS concept occupies an important position in these dematerialization/greening strategies. It reflects (though sometimes ambiguously) various mechanisms: mechanical (passive) dematerialization via the simple association (juxtaposition) of goods and services; more complex dematerialization, based on a unified ontological conception of goods and services (everything is service) and on changing production and consumption patterns and ownership regimes, and dematerialization/greening through active KIBS intervention.

Overall, we can conclude that services are not by nature intangible and green, but that they are capable of dematerializing and greening themselves via the implementation of appropriate innovation strategies. This process of dematerialization and greening, supported by sustainable service innovation, must however be qualified by a number of remarks, some of which may be considered interesting avenues for a research agenda:

- In this work, we have focused on the dematerialization dynamics of services and of PSS. However, in contemporary economies, the two often go hand in hand with the contradictory dynamics of materialization. These are the two inseparable faces of Janus. Gallouj et al. (2015) describe the industrialization/servitization dialectic as one of the most powerful megatrends at work in contemporary economies. We might also ask to what extent these two contradictory processes lead to a zero sum game in terms of materiality and sustainability.
- Analyses of dematerialization must take into account what is called the rebound effect. Indeed, the success of eco-friendly solutions can induce increased production and consumption, thus reducing the overall benefit.
- The two remarks above refer to the fundamental question of measurement systems. Most of our analyses remain theoretical or qualitative. The dematerialization issue raises formidable measurement problems. Thus, the idea of PSS sustainability - that is, their less material-intensive nature (though considered acceptable in theory) is not validated by measurement. This is an important research issue.

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