# Digital dark matter within product service systems

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Author 1 Name: Ferran Vendrell-Herrero

Department: Birmingham Business School

University/Institution: University of Birmingham

Town/City: Birmingham

Country: United Kingdom

Author 2 Name: Vasileios Myrthianos

Department: Management department

University/Institution: Polytechnic University of Catalonia

Town/City: Barcelona

Country: Spain

Author 3 Name: Glenn Parry

Department: Department of Strategy

University/Institution: University of the West of England

Town/City: Bristol

Country: United Kingdom

Author 4 Name: Oscar F. Bustinza

Department: Department of Management/Aston Centre for Servitization

University/Institution: University of Granada/Aston University

Town/City: Granada/Birmingham

Country: Spain/United Kingdom

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**Ferran Vendrell-Herrero**, Ph.D.(Universitat Autonoma de Barcelona) is a lecturer in managerial economics in Birmingham Business School, University of Birmingham, UK. His work has a strong industrial orientation and takes a quantitative approach. His research interests are mostly devoted to the economic analysis of organizations, with special focus on innovation and operations management topics. Dr. Vendrell-Herrero's research has been published in a variety of journals, including among others the International Journal of Production Economics, Technovation, Small Business Economics, Regional Studies and Supply Chain Management.

**Vasileios Myrthianos,** PhD.(University of Granada) is a teaching fellow in management, at the Polytechnic University of Catalonia, Spain. He has extensive experience of working as an associate researcher at the Autonomous University of Barcelona and Open University of Catalonia, both in Spain. His current research interests include strategy and operations management in the creative industries.

**Glenn Parry**, Ph.D.(Cantab) is an Associate Professor of Strategy and Operations Management at the University of the West of England, UK. His research is characterised by a strong industrial focus on process combined with the rigour of academic analysis. His work aims to capture leading practice, moving companies forward through transformations based upon data driven analysis. He has been published in a number of international journals and has published the books, "Build to Order: The Road to the 5-day Car", "Complex Engineering Service Systems" and "Service Design and Delivery" which was ranked in The IIJ top 20 upcoming books for innovators. He is currently involved in Enterprise Transformation, studying the move of complex engineering companies from product to service provision.

**Oscar F. Bustinza**, Ph.D.(University of Granada) is an Associate Professor of strategy and operations management at the University of Granada (Spain) and Visiting Research Fellow at the Aston Centre for Servitization (Aston University). His work aims to analyse drivers of firm's boundaries choice, servitization, and demand chain management based upon data driven analysis. Dr. Bustinza's research has been published in the International Journal of Operations and Production Management, International Journal of Production Economics, Journal of Supply Chain Management, Supply Chain Management, International Journal of Production Research, and British Journal of Management among other outlets.

## Abstract

**Purpose –** The unobserved benefits of digital technologies are described as digital dark matter. Product service systems (PSS) are bundles of products and services that deliver value in use; which is unobserved but generates benefits. This article empirically quantifies digital dark matter within product service systems and correlates that measure with national competitiveness.

**Design/methodology/approach –** A novel methodology establishes the link between customer needs and a product & digital service portfolio offered across ten developed economies. The case context is the music industry where product and services are often substitutes – a cannibalistic PSS. Consumer information is obtained from a unique database of more than 18,000 consumer surveys. Consumer demand for digital formats is modelled and predicted through logistic regressions.

**Findings –** The work provides inverse estimations for digital dark matter within product service systems by calculating the gap between supply and demand for digital offers - described as the business model challenge. The USA has the lowest business model challenge; the home of major companies developing digital technologies. Digital dark matter is shown to be positively correlated with national competitiveness and manufacturing competitiveness indices.

**Practical Implications –** The success of a cannibalistic PSS requires good understanding of market demand. Governments embarking on soft innovation policies might incentivise the development of service orientated business models based on digital technologies.

**Originality/Value –** Work expands theory on the concept of digital dark matter to the PSS literature. Empirically, a novel method is proposed to measure digital dark matter.

**Keywords –** Business model, Digitalization, Music industry, Product-Service portfolio, National Competitiveness.

**Article Classification** – Research paper.

## Introduction

Aggregate productivity is the key determinant of the level of prosperity and value generation a territory can sustain over time (Porter, 2004) but links to the digital economy and competitiveness are still unclear. Digitalization of productive resources has raised firm productivity yet the rate of employment has decreased (Brynjolfsson and McAfee, 2011; Veliyath and Fitzgerald, 2000). Social science lacks the appropriate concepts and methodological tools for measuring directly what we only see indirectly today. Greenstein (2011) employs a metaphor using the astrophysics term "dark matter" which defines the unobservable parts of the universe. He argues that digitalization of resources has unobservable benefits (or drawbacks) for the economy and he coins the term "digital dark matter" to refer to those unseen impacts. Some examples of 'unvalued' digital resource are open access software like Linux, the building blocks of the World Wide Web such as HTML, URL or HTTP, open access encyclopaedias like Wikipedia, or other Ethernet extensions like Wi-Fi. No one pays license fees to use these research outputs, but they do gain benefits from them. Is it possible to get precise estimates of these benefits? Greenstein and Nagle (2014) offer a figure of the economic impact of open access web server software 'Apache' in US. They find that 22% of web servers in US are running Apache, and estimate that the use of Apache has an economic value between $2 and $12 billion, which is not included in the GDP.

Digital technologies aid the development of new business models. Following Chesbrough and Rosenbloom (2002) new business models unlock latent value from existing technology, linking technical potential and realization of economic value. The success of new business models reflects the extent to which firms understand what their customer wants, how the value proposition is delivered, and the way to capture value and make a profit (Teece, 2010).

The Resource-based view suggests that resource bundles may be combined to create value propositions and capture value (Barrales *et al.*, 2013; Mills *et al.*, 2003; Vargo and Lusch, 2004, 2008). A firm may provide a number of different product-service offerings using their portfolio of resources, creating Product-Service Systems –PSS– (Baines *et al.*, 2007; Neely, 2008). Successful PSS introduction requires an epistemological shift in value, from understanding the 'value in exchange' of product ownership business models to understanding 'value in use' created through access to resources in a service system business model (Barnett *et al.*, 2013; Macdonald *et al.*, 2011; Thenent *et al.*, 2014). This transition can generate unobservable benefits (or losses) to the economy, and where servitization involves digital innovations it may produce digital dark matter.

Analysis of PSS and digital business models usually takes a qualitative perspective, and hence literature on PSS is open to further theoretical development through quantitative approaches providing robust assessment of the phenomena (Tukker, 2004). Studies are limited due to a scarcity of reliable consumer databases which allow analysis of service-orientated business models (Sampson, 2012).

The aim of this article is to identify unseen benefits, or digital dark matter, in the implementation of new digital business models. This paper contributes to theory by filling a gap in literature through the development of a methodology that establishes the link between customer demand and the product and digital service portfolio offered across 10 developed countries in the context of the music industry. The work exploits a combination of real market sales and survey data from 18,000 customers provided by a major music-licensing firm (Bustinza *et al.*, 2013a). Information related to consumers permits the estimation of demand functions based on logistic regressions. In each country estimated demand functions are compared graphically with the structure of music offered – from a continuum of pure product offering to a diverse portfolio of digital services. The analysis presented allows the estimation of the business model challenge for each country.

Our method gives a reliable measurement for the unseen benefits (or losses) of the implementation of digital business models. Countries with a low business model challenge are expected to have realised benefit from the implementation of digital technologies, but the potential value of the benefits is not fully realised. It is proposed that the digital business model challenge is an inverse measure of digital dark matter within PSS, since at the extreme case a country with no digital offering has a significant business model challenge and little to no digital dark matter. Digital dark matter represents the inverse of the digital business model challenge.

By definition digital dark matter is not included in a country's GDP, but the work presented here attempts to make at least a proportion of dark matter visible as we hypothesize that it is positively correlated with more comprehensive measures of economic development and welfare, such as the Global Competitiveness Index (Sala-i-Martin *et al.*, 2012) or the Manufacturing Competitiveness Index (Deloitte, 2013).

In sum, this paper has three general research goals. The first one is to understand the extent to which digital business models and bundles of products and services satisfy consumer needs. This is investigated by matching digital supply with consumer preference for digital goods. The second general objective is to describe and measure digital dark matter in countries with digital business models and product-service offerings. This is investigated

by providing an estimation of the digital dark matter in each country. Finally, the third objective is to better understand the association between digital dark matter and economic development/welfare. This is done by correlating the estimated digital dark matter with measures of national competitiveness and manufacturing competitiveness.

The order of the article is as follows. The next section builds upon theoretical frameworks for business models, servitization and competitiveness to position research questions and the empirical hypothesis. The following sections present the context of the study, the data and the results. Conclusions close the work.

## Theoretical underpinning and model development

*Business models, PSS, and consumer needs*

Vandermerwe and Rada (1988) define servitization as an increment in the entire market package of customer focused combinations of products, services and knowledge offered by a firm searching for additional value to their base product offerings. This has resonance with the Resource-based view of the firm which suggests that resource bundles may be combined to create value propositions (Barrales *et al.*, 2013; Vargo *et al.*, 2008). Smith et al. (2012) define service value propositions as multiple, simultaneous and iterative connections between provider and customer systems. From a resource perspective PSS is a concept closely related to servitization (Baines *et al.*, 2009). Servitization has been defined as creating product-based services while PSS is considered a specific product-service offering (Tukker, 2004); therefore discussions of PSS may be considered as placing more focus on integrated solutions.

Baines et al. (2007) defined PSS as a unified mix of products and services that deliver value in use. This is consistent with the paradigm shift for manufacturing firms to compete through value-in-use and differentiation instead of cost (Porter *et al.*, 2003). Based on the generic strategies for competitive advantage (Dobbs, 2014; Porter, 1979) the concepts of PSS and servitization are linked to differentiation strategies obtained by knowing the requirements of a customer base and creating barriers to entry through adding services which enable products to be differentiated.

Neely (2008, pp. 110) states that one of the main challenges associated with PSS is the "business model and customer offering". This challenge is related to the lack of knowledge of how to design and deliver complex services and the organisational capabilities required to do so (Neely, 2010). Further, a PSS co-ordinating firm may erroneously assume homogeneous customer capability in accessing the value of the PSS portfolio on offer (Bustinza *et al.*,

2013b; Suarez *et al.*, 2013), particularly when they provide a spectrum of possible product and service regimes (Ng *et al.*, 2011).

By definition a PSS requires the coexistence of product and service. This coexistence can be complementary and Ahamed et al. (2013) provide a detailed case study of how the IBM Corporation successfully combined a physical product (i.e. hardware), a digital product (i.e. software, applications) and services (i.e. consulting, training). For IBM digital product and service combinations provide the main source of revenues, but this capability was developed over two decades. PSS revenue grew from a marginal contribution to the firms' product dominant offering in the early 90s, to 58% of revenue in 2001 and 90% in 2011. In contrast the coexistence of product and service may be cannibalistic (Greenstein, 2010), as in the case of the music industry when the sale of a product substitutes for the sale of service (Koukova *et al.*, 2012). Parry et al. (2012) propose that the PSS offer of the music industry can be broken down and catalogued under the headings "product" (physical product), "service - pay as you go" (digital product-service) and "service - pay monthly" (streaming service). Figure 1 shows the distribution of sales for these three offerings as well as other minor sources of music industry revenues including video, mobile and performance rights. It can be seen that in 2010 the majority of revenues are associated with the physical-tangible product and digital-intangible product-service combination. For this reason the research presented here focuses only on this physical/digital dichotomy.

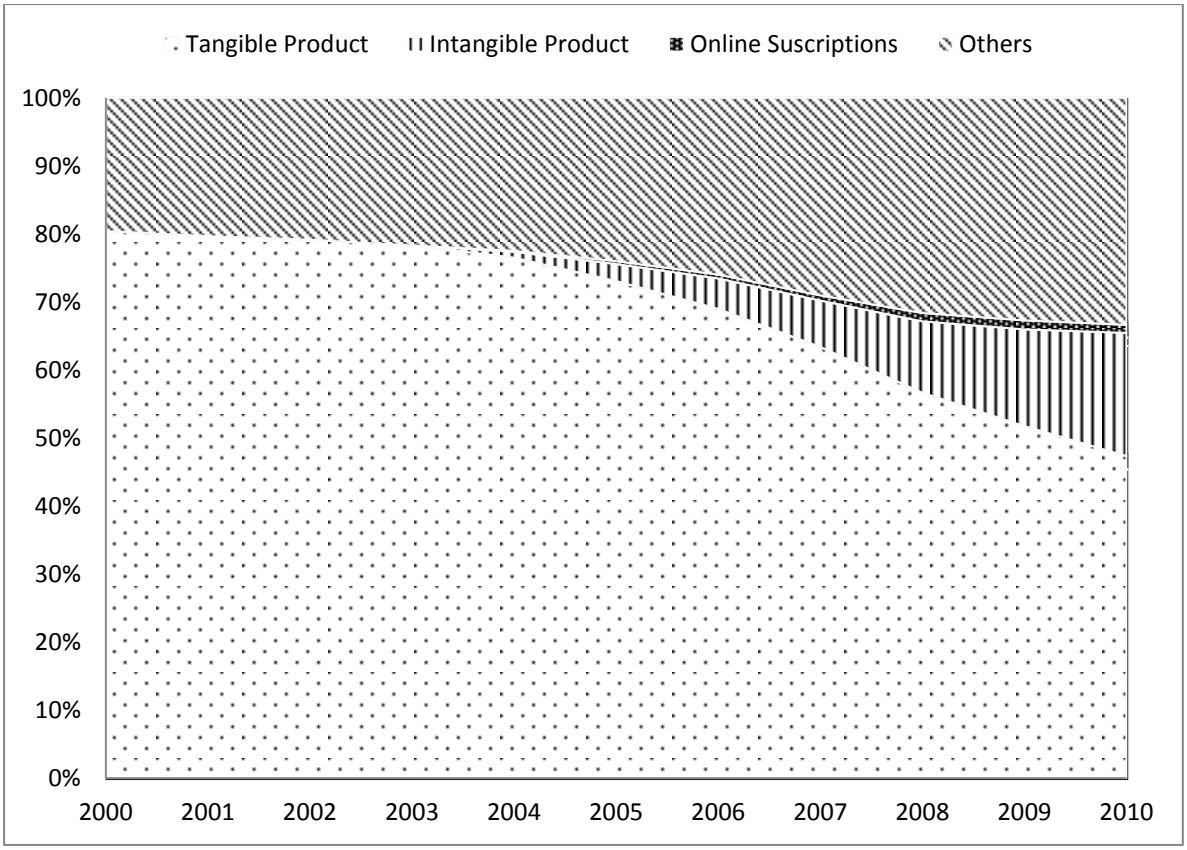


**Figure 1.** Evolution of format sales in the countries selected.

Source: IFPI. Online subscriptions include only online streaming. Others include the rest of formats such as mobile content, video, other physical formats different from CD or vinyl and especially performance rights.

In the complementary PSS scenario customers select combinations of service offerings to support their use of the product. In the cannibalistic PSS scenario this does not happen, which suggests the provider must develop different business models to generate market revenue and meet customer needs (Teece, 2010). A strategy of customer needs linked to business model is required to provide PSS which enable value-in-use to be realised by customers (Vargo and Lusch, 2004, 2008). Business models emerging from the process of servitization in manufacturing sectors with complementary PSS develop the firm's innovative capabilities in creating value at the customer level by creating the correct balance of products and services (Visnjic and Van Looy, 2013). The examples are from PSS which have complementary product and service offers, and does not give indication as to if this is also happening or even possible in cannibalistic PSS. This leads to the first research question to this article.

RQ1: To what extent do digital business models and bundles of Product-Service offers satisfy consumer needs?

*How can we assess digital dark matter in cannibalistic PSS?*

From an economic perspective, the theory of consumer behaviour –see Kreps (1990) for detail– explains how the consumer allocates income between goods and services. Due to assumed rational consumer behaviour money is utilized in order to get as much satisfaction as possible by maximizing utility, which depends on prices and income. At given prices in the economy the optimal allocation of income can differ between individuals due to their preferences. The process of maximization of utility entails the consumer allocating income in such a way that the amount spent on each product provides the same marginal utility. Consequently, taking a purely economic perspective, there are three factors that determine the decision of the consumer: price, budget constraints and individual preference. Given this information the consumers' willingness to pay can be computed (Wertenbroch and Skiera, 2002). Subtracting price from the value the consumer is willing to pay gives a value for an individual's consumer surplus.

In Figure 2 we graphically report the relationship between supply and demand of product and service portfolios within a cannibalistic PSS, measured as the percentage of intangible format revenue, shown in the vertical axis and the relative consumer surplus, expressed as consumer preference for these formats, shown in the horizontal axis. For simplicity this framework categorises formats offered as either tangible, to represent the physical offer, and intangible to represent digital.

Market *A* in Figure 2 represents a context in which the industry offers a PSS with a relatively high number of intangible formats. Consumers in market *A* have greater preference for tangible format. The proportion of the population that receives a consumer surplus when purchasing tangible format is larger than the population receiving consumer surplus when purchasing intangible formats. Therefore, market *A* has an excess of intangible format offering and industry may correct for this through developing the tangible offering in the PSS or reducing the proportion of intangible offering. In contrast the average consumer surplus of the consumers in market *B* is higher for intangible formats, but the PSS of the industry has prioritised tangible offerings. *A* market deficit exists in the intangible format offerings and analysis highlights an opportunity for firms to develop businesses which provide intangible digital offers in market *B*. Finally, market *C* represents a situation in which the PSS is perfectly equilibrated with consumer needs, and hence total value is higher in point *C* than in points *A* or *B*.

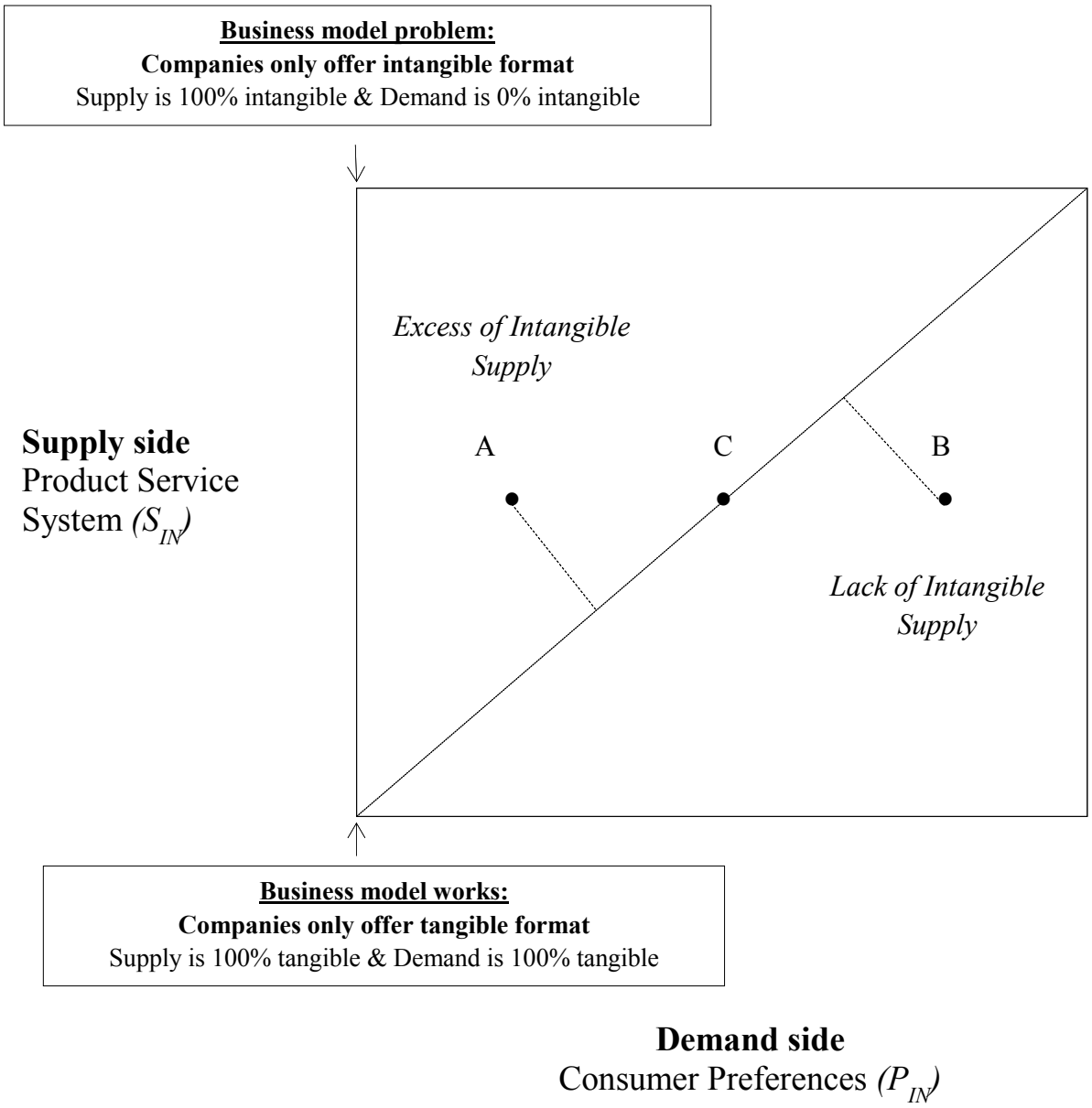


**Figure 2.** A two-dimension framework for identifying business model challenge.

Source: self-elaborated. The distance between points A or B and 45 degree line is a measure of the business model challenge in cannibalistic PSS. The inverse of this measure can be seen as digital dark matter. In this sense, when product service supplied matches with consumer preference the benefits of digitalization of resources is maximized.

Following this model digital dark matter increases as markets move closer to the 45 degree line, as *A* or *B*, get closer to the line, demonstrating firms are producing digital offers which better satisfy consumer needs and create more value which increases the likelihood of value 'spillover' into dark matter. In that sense digital dark matter within cannibalistic PSS is maximized when the market is situated on the line, such as market *C*. The distance between the position of the market and the line also determines the business model challenge; which following our definition is an inverse measure of the digital dark matter. It is acknowledged at this point that the constructs are based on a number of assumptions and these will be

critically discussed at the end of this article. First we derive the empirical measure and study its relevance and robustness.

*Deriving a measure of digital dark matter within cannibalistic PSS*

Any point in space on Figure 2 is associated with a given level of demand and supply. The demand is represented by the horizontal axis in Figure 2 and is measured by the Normalized Consumer Needs for intangible format ($P_{IN}$). The supply is represented by the vertical axis in Figure 2 and is measured by the Normalized Intangible supply ($S_{IN}$). The business model challenge in a given market is determined as the distance between the current point of the market in the 2-dimensionsional axis ($P_{IN0}$,$S_{IN0}$) and the line defined from $P_{IN}$=$S_{IN}$. We follow the work of Luenberger (1992) and choose the Euclidean distance between two points to construct a measure for the business model challenge. The advantage of this measure is that it is more flexible than the horizontal (demand oriented) or vertical (supply oriented) measures alone. Theoretically the measure shows that changes in the business model challenge can be produced indistinctively from changes in supply or demand of digital formats. According to Euclidean geometry the distance between a point ($P_{IN0}$,$S_{IN0}$) and the 45 degree line is:

$$Distance(a \cdot P_{IN} + b \cdot S_{IN} + c = 0, (P_{IN0}, S_{IN0})) = \frac{|a \cdot P_{IN0} + b \cdot S_{IN0} + c|}{\sqrt{a^2 + b^2}}$$

Therefore in this case we calculate the Business Model Challenge for each country using the formula:

$$Business\ model\ challenge = \ Distance(P_{IN} - S_{IN} = 0, (P_{IN0}, S_{IN0})) = \frac{|P_{IN0} - S_{IN0}|}{\sqrt{2}}$$

But, how can we obtain a precise estimation of the point ($P_{IN0}$,$S_{IN0}$) for a given country? The supply side ($S_{IN0}$) can be directly observed by the distribution of revenues in tangible and intangible formats. As shown in Figure 2 other minor formats can coexist with main tangible and intangible formats, so any index of intangible format supply will need to be normalized. In particular if $R_I$ are aggregated industry revenues for intangible format and $R_T$ are aggregated revenues for tangible format, $S_{IN0} = R_I/(R_I + R_T)$.

The empirical estimation of the demand side is not directly observable and far more complex. The research presented here seeks to estimate the individual value placed on a tangible or intangible format depending on a consumer's characteristics (gender, status, etc.), beliefs and country of origin. We estimate consumer likelihood to purchase ($p_i$) in either tangible ($Y_T$) or intangible format ($Y_I$) through discrete choice models. Theoretically, a given

consumer has a probability to buy music $y_i$*, linearly related to a vector of observable variables, $x_i$ and non-observable factors collected in the error term, $\varepsilon_i$:

$$y_i^* = \beta x_i + \varepsilon_i$$

When $y_i$* is greater than 0 the consumer decides to buy music. A consumer's propensity to buy cannot be observed, only their actual choice, which is called $y_i$ and gives a value of 1 when the consumer buys and 0 otherwise. Logit models can be derived from utility maximization and predicted probabilities have a simple closed form expression (McFadden, 1980). Empirically the probability that $y_i=1$ is given by equation below, where $\beta$ is the vector of coefficients to be estimated and the individual lineal predicted probabilities are given by the formula $p_i = F(x_i'*\beta)$, where $F$ is the cumulative logistic distribution.

$$P(y_i = 1|x_i) = \frac{\exp(x_i'\beta)}{1+exp(x_i'\beta)}$$

This methodology allows an estimate of an individual's predicted probability of purchasing, which can be aggregated at country level and gives precise estimators for $Y_T$ and $Y_I$. Once this information is achieved, $P_{IN0} = Y_I/(Y_I + Y_T)$.

The measurement of the business model challenge is an inverse measure of the digital dark matter in cannibalistic PSS; *Digital dark matter = 1/Business Model Challenge = 1/Distance* ($P_{IN} - S_{IN} = 0$, ($P_{IN0}$, $S_{IN0}$)). In this regard it is useful to know in which markets digital dark matter is more relevant, and how it manifests when there is an excess or lack of intangible formats. This gives rise to the second research question of this article.

RQ2: What is the nature of digital dark matter in those countries with digital business models and Product-Service offerings?

*Digital dark matter and territorial competitiveness*

Competitiveness is a concept that goes beyond economic transactions included in GDP. Competitiveness is what underpins wealth creation and economic performance (Aiginger, 2006; Porter, 1990), which ultimately is directly linked to aggregated productivity (Porter, 2004), and it is the central driver of cross-country differences in prosperity (Lewis, 2004).

The World Bank 'Doing Business' index and IMD 'World Competitiveness' measure national competitiveness and provide institutional metrics for legal systems and a nation's infrastructure. However, the most comprehensive measure for national competitiveness in the context of this study is the 'Global Competitiveness Index' developed by the World Economic Forum. Published every year since 2004, the measure integrates the macroeconomic and the micro/business aspects of a country's competitiveness into a single

index. The Global Competitiveness Index is based on a productivity-focused approach to national competitiveness and captures the main factors that explain the growth and development agenda for countries (Sala-i-Martin *et al.*, 2012). The theoretical framework that underpins this index considers that key factors to enhance competitiveness for innovation-driven economies –or broadly speaking developed economies– are innovation and business sophistication.

Further to this, based on the analysis of Baines and Shi (2015) who argue that digital technologies impact the way that business and production are organized and therefore affect the competitiveness of manufacturing firms, we include a measure of manufacturing competiveness. The most comprehensive measure is the Global Manufacturing Competitiveness Index developed by Deloitte (Deloitte, 2013). This index is based on more than 550 survey responses from senior manufacturing executives around the world and takes into account the digital revolution and pace of technological change that profoundly impacts the competitiveness of manufacturing firms.

Service business dynamics require the implementation of business models which capture value through consumer understanding (Bustinza *et al.*, 2013a; Vargo and Lusch, 2008). Digital technologies are facilitators of consumer interaction as they can passively gather relevant and informative consumer data e.g. the pages a consumer looked at, personal details, what they clicked on, what they purchased etc. which may be analysed and used to reposition a firm. It is therefore proposed that digital dark matter, or benefits of digital technology not included or captured in monetary transactions (Greenstein, 2011; Greenstein and Nagle, 2014), are positively linked to National Competitiveness –a comprehensive measure of economic development and welfare that also accounts for benefits beyond economic transactions (Sala-i-Martin *et al.*, 2012). In addition, it is proposed that the introduction of digital technologies in manufacturing industries as part of the servitization process has a direct effect on the competitiveness of manufacturing firms, which in turn contribute to the enhancement of the welfare of the society in which those firms are located. According to Baines and Shi (2015) and Arnold et al. (2015) this forms part of a virtuous circle that creates employment and economic development; therefore an economic incentive potentially exists for policy makers to establish service reforms. All these elements lead to the following research question:

RQ3: Is digital dark matter positively associated to national and manufacturing competitiveness?

## Cannibalistic PSS in the music industry

*Industrial context*

The music industry is led by 3 major music-licensing firms who hold over 60% of the market share in terms of property rights to music resource (Informa Telecoms & Media, 2010). The companies and their artists may influence the final combination of products and services, tangible and intangible formats, which are offered in each market through distribution and promotion channels (Bockstedt *et al.*, 2005). The music industry represents a sector where revenues were in sharp decline between 1999 and 2012 (Bustinza *et al.*, 2013a; Liebowitz and Watt, 2006; Myrthianos *et al.*, 2014). The music industry was the first creative market to suffer significantly from piracy, which has been attributed as one of the main factors for explaining the observed decrease in revenues (see Parry *et al.*, 2014a, for a comprehensive summary of the literature). As shown explicitly in Figure 1 the industry adapted to piracy with the implementation of new digital business models, finding early success selling downloads from platforms such as iTunes (Parry *et al.*, 2012). The experience of the music industry is instructive to other industries digitalizing their resources and transiting from a product-centric business model to PSS (European Commission, 2011).

*The data*

A unique music industry dataset comprising information for 10 countries in 2010 was employed. The countries selected cover different geographical locations and legal systems (Djankov *et al.*, 2002). In particular information from three independent sources is used for ten innovation-driven economies: US, Canada, Australia, Japan, UK, Germany, France, Italy, Netherlands and Spain.

Supply side information to measure the vertical axis in Figure 2 comes from market aggregated data containing details of the sales of the different music formats available in 2010. This information was provided by the industry trade body, the International Federation of the Phonographic Industry (IFPI, 2012). Consumer data to measure the horizontal axis in Figure 2 comes from extensive surveys collected by one of the 'Big 3' global music companies providing information on individuals characteristics, beliefs, file sharing activity and music consumption patterns. The survey contains 18,842 observations and a more detailed description can be seen in Bustinza et al. (2013a).

Tangible formats considered are CD and Vinyl, which provide music via a physical support. Tangible sales per capita are measured as the sum of sales of CD and Vinyl over total population and Percentage of tangible sales ($R_T$) is measured as the sum of sales of CD

and Vinyl over total sales. Intangible formats are defined as commercialized music provided without a physical support; in the years studied these are digital downloads in the form of singles and albums (i.e. iTunes) as streaming service revenue were insignificant. Even in 2012, though growing rapidly, streaming represents only 13% of intangible digital revenues (IFPI, 2013). Intangible sales per capita is measured as the sum of sales for digital albums and digital tracks over total population and Percentage of intangible sales ($R_I$) is measured as the sum of sales of digital albums and digital tracks over total sales.

For the estimation of the aggregated predicted consumption of tangible ($Y_T$) and intangible ($Y_I$) format we run discrete choice analysis. The binary dependent variables are *Buy tangible* that takes a value 1 if the consumer claims to buy music in physical format and 0 otherwise. Similarly, *Buy intangible* takes a value 1 if the consumer claims to purchase music files from digital stores and 0 otherwise. The vector of observable variables, $x_i$, is composed of customer specific characteristics (gender, age, working status), consumption behaviour (willingness to pay, budget constraint, file sharing behaviour, hours listened per week), and country specific effects (Legal origin and continent). Table I gives information for the average and dispersion of the variables and details of how they have been constructed. Finally, as a measure of national and manufacturing competitiveness we take values from the Global Competitiveness Index (Sala-i-Martin *et al.*, 2012) and the Global Manufacturing Competitiveness Index (Deloitte, 2013). Whilst Digital Dark Matter is measured in 2010, territorial Competitiveness is measured in 2013. Digital Dark Matter is lagged three periods based on the finding of Schilling (2015), who conclude that there is a non-immediate causality between technological implementation and technological outcomes, and that the social and economic impact of implementing IT technologies only starts to be significant after three years.

**Table I.** Descriptive statistics.

| | Variable construct | Obs. | Mean (St. Deviation) |
|---|---|---|---|
| **Supply side*** | | | |
| Sales per capita Tangible | (Sales CD + Sales Vinyl) / Total Population | 10 | 9.02 (4.43) |
| Sales per capita Intangible | (Sales digital and album tracks) / Total Population | 10 | 2.12 (1.80) |
| Percentage of Tangible Sales | (Sales CD + Sales Vinyl) / Total Sales | 10 | 0.60 (0.07) |
| Percentage of Intangible sales | (Sales digital and album tracks) / Total Sales | 10 | 0.14 (0.11) |
| **Technological** Infrastructure** | | | |
| Connectivity | Connectivity of people and firms executive survey based on an index from 0 to 10 at a country level for the year 2010 | 10 | 7.97 (0.85) |
| Computer per capita | Number of computers per 1000 people for the year 2010 | 10 | 764.98 (129.81) |
| **Demand side** *** | | | |
| Buy Tangible | Buyers of CD and/or Vinyl | 11529 | 0.52 (0.49) |
| Buy Intangible | Buyers of digital files and/or albums | 17550 | 0.68 (0.46) |
| Gender | Dummy variable ( 1 for male and 0 for female) | 18842 | 0.53 (0.50) |
| Age | Consumer`s age with a range 15-99 | 18842 | 36.10 (15.10) |
| Income Full-Time | | 18842 | 0.37 (0.48) |
| Income Part-Time | Consumer's answer to the question: | 18842 | 0.21(0.41) |
| Out of Job Market | *What is your working status/ occupation?* | 18842 | 0.16 (0.36) |
| Students | | 18842 | 0.08 (0.27) |
| Willingness to Pay | Dummy Variables for consumers who are willing to pay for music | 18842 | 0.51 (0.49) |
| Budget Constraint | Dummy variable for consumers that the lack of money is the main reason they don't buy music | 18842 | 0.49 (0.49) |
| File Sharers | Dummy variable for consumers who download digital music they didn't pay for | 18842 | 0.28 (0.45) |
| Hours per week | Hours of listening to music the consumer has chosen/bought per week | 18842 | 3.30 (3.40) |
| Passion for Technology | Dummy variable for consumers who love technology, and music is a big part of that technology | 18842 | 0.53 (0.50) |
| Passion for Music | Dummy variable for consumers that music is important in their life | 18842 | 0.85 (0.36) |
| America | Dummy variable for American consumers | 18842 | 0.24 (0.43) |
| Europe | Dummy variable for European consumers | 18842 | 0.55 (0.50) |
| AusiAsia | Dummy variable for Australian or Asiatic consumers | 18842 | 0.20 (0.40) |
| French LO | Dummy variable for consumers from countries with French legal origin system | 18842 | 0.37 (0.48) |
| English LO | Dummy variable for consumers from countries with English legal origin system | 18842 | 0.46 (0.50) |
| German LO | Dummy variable for consumers from countries with German legal origin system | 18842 | 0.16 (0.37) |

**Source:* IFPI
*** Source:* IMD WORLD COMPETITIVENESS ONLINE 2010
****Source:* One of the 'Big 3' global music companies. See Bustinza et al. (2013) for precise description. This research uses 1,702 less observations in respect to Bustinza et al. (2013) due to missing data. Continuous variables (Age and hours per week) are presented here in normal form but in the regression model are introduced in logarithms for normalizing the parameters.

**Results**

The first stage in the empirical design is to analyse consumer preference through logistic regressions. In line with Ortin-Angel and Vendrell-Herrero (2010) Table II reports the results of two logistic regressions and the percentage of correctly predicted cases. Column 1 analyses the propensity to purchase in tangible format compared to non-purchasing. The model has a good fit correctly predicting 72.14% of consumer purchasing choices. Column 2 analyses the propensity to purchase in intangible format and correctly predicts 73.95% of consumer purchasing decision.

**Table II.** The propensity to purchase in tangible and intangible form through logistic regression.

| Independent Variables | Tangible Buyer vs. Non Buyer | Intangible Buyer vs. Non Buyer |
|---|---|---|
| Passion for Technology | 0.751*** | 0.520*** |
| | (0.046) | (0.039) |
| File Sharers | -0.849*** | -0.928*** |
| | (0.049) | (0.041) |
| Willingness to Pay | 1.197*** | 0.942*** |
| | (0.044) | (0.037) |
| Budget Constraint | -0.205*** | -0.221*** |
| | (0.044) | (0.037) |
| Income Full-Time | 0.439*** | 0.237*** |
| | (0.073) | (0.060) |
| Income Part-Time | 0.342*** | 0.171*** |
| | (0.079) | (0.065) |
| Out of Job Market | 0.397*** | 0.174*** |
| | (0.083) | (0.067) |
| Students | 0.137 | 0.035 |
| | (0.093) | (0.075) |
| Passion for Music | 1.034*** | 0.487*** |
| | (0.070) | (0.050) |
| Ln(Hours per week) | 0.299*** | 0.155*** |
| | (0.028) | (0.024) |
| Gender | -0.004 | 0.088** |
| | (0.044) | (0.037) |
| Ln(Age) | 0.330*** | 0.110** |
| | (0.056) | (0.047) |
| Europe | 0.854*** | 0.650*** |
| | (0.084) | (0.072) |
| AusiAsia | 0.107 | 0.110* |
| | (0.076) | (0.065) |
| French LO | -1.569*** | -1.679*** |
| | (0.078) | (0.067) |
| German LO | -0.320*** | -0.205*** |
| | (0.081) | (0.067) |
| Cons | -2.933*** | -0.279 |
| | (0.236) | (0.189) |
| Log likelihood | -6303.3694 | -9125.4158 |
| $X^2$ | 3350.08 | 3561.31 |
| Number of obs. | 11529 | 17550 |
| Prob> $X^2$ | 0.0000 | 0.0000 |
| Pseudo $R^2$ | 0.2099 | 0.1633 |
| Correctly predicted | | |
| Buyers | 74.21% | 89.32% |
| Non-Buyers | 69.87% | 40.22% |
| Total | 72.14% | 73.95% |

Standard Errors in Parenthesis. Level of statistical significance: ***, ** and * denote statistically significance of 1%, 5% and 10% respectively. In the working status category the reference group is unemployed.

Consistent with most of previous literature using survey data (Parry *et al.*, 2014b) file sharers are found to exhibit a lower probability of purchasing music in tangible or intangible format, providing evidence of the purchase substitution phenomenon (Liebowitz and Watt, 2006). Ceteris paribus, file sharers are 19.8 percentage points (20.9 percentage points) less likely to purchase intangible (tangible) formats than non-file sharers. These results are statistically significant (p-value<0.01).The parameters in both columns are similar with one exception related to the variable 'gender'. While there is no significant difference in the propensity to purchase in tangible format between males and females, males are, ceteris paribus, 1.7 percentage points more likely to purchase music in intangible format than females. This result is significant (p-value<0.01).

The estimated demand functions show that the average likelihood to purchase digital music is highly heterogeneous across countries. There is larger preference for digital music in Anglo-Saxon countries (in this case, Australia, Canada, UK, and US). Latin countries like France, Italy and Spain have the lowest preference for digital music. Similar heterogeneity is found for physical format suggesting that Anglo-Saxon countries are more willing to purchase music.

The first research question asks whether bundles of product and service satisfy consumer needs and hence maximize consumer surplus. In terms of Figure 2 this would be translated through a perfect match between supply and demand. Figure 3 graphically shows the position of the countries analysed in the framework developed in Figure 2. Table III summarizes the business model challenge and digital dark matter for each country. As can be seen in Figure 3 consumer surplus is not maximised in any of the markets analysed. The consumers' willingness to purchase in digital format is unsatisfied as the observations are below the 45 degree line. This is in agreement with Rifkin (2014), who posits that the transition towards a digital economic system, with practically zero marginal costs, facilitates the shift of consumer preference regarding digital formats, whereas incumbent firms are resistant to change.

The finding answers the second research question by describing and measuring digital dark matter. The model identifies whether there is an excess or lack of intangible format offering, in markets *A* and *B* in Figure 2 respectively. According to the representation in Figure 3 all countries analysed lack intangible format offerings, suggesting that the industry needs to redefine their PSS, enhancing the digital offering. But, which are the countries with the largest business model challenge?

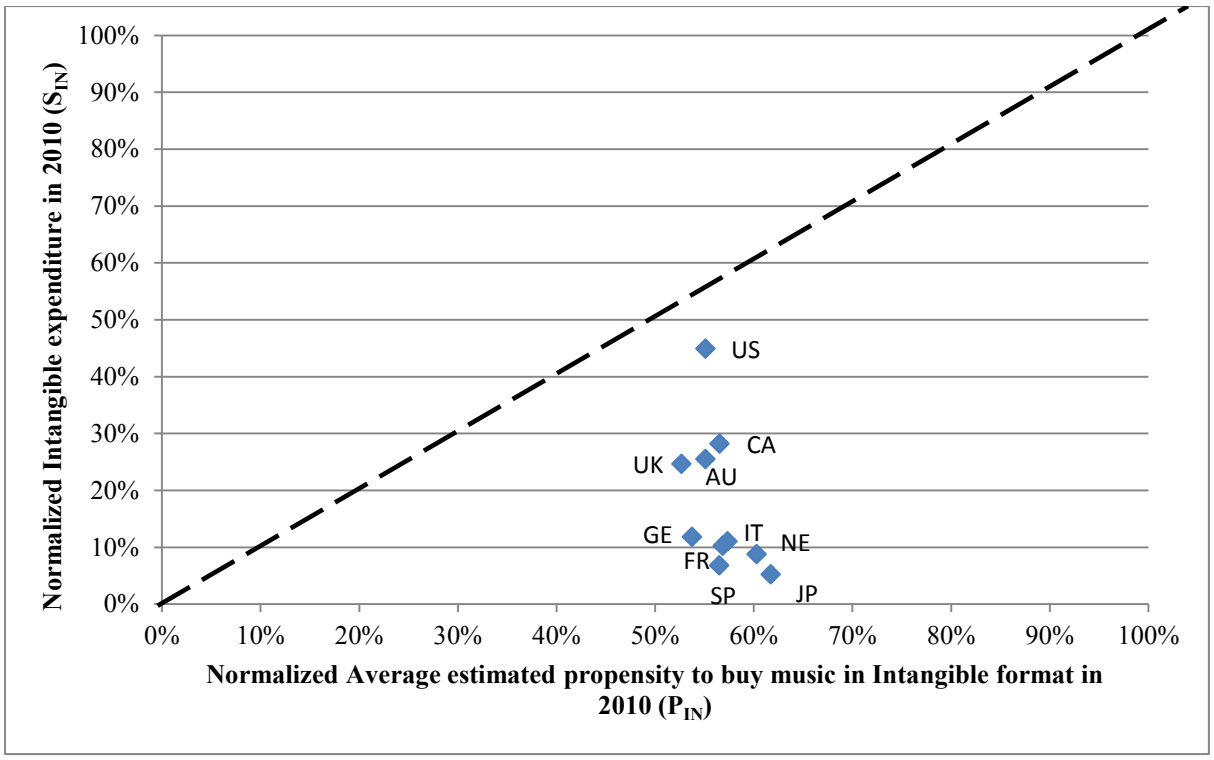


**Figure 3.** Measuring the digital dark matter within product-service systems.

Source: Self-elaborated. It shows the empirical development of the theoretical model in Figure 2. US is the country with the lowest business model challenge and hence the largest benefit of digitalization or digital dark matter.

**Table III.** Estimation of Digital dark matter at country level

| Country | Business model Challenge | Digital Dark Matter (= 1/Business model challenge) |
|---|---|---|
| Australia (AU) | 0.21 | 4.77 |
| Canada (CA) | 0.20 | 4.99 |
| France (FR) | 0.33 | 3.05 |
| Germany (GE) | 0.30 | 3.37 |
| Italy (IT) | 0.33 | 3.03 |
| Japan (JP) | 0.40 | 2.50 |
| Netherlands (NE) | 0.36 | 2.74 |
| Spain (SP) | 0.35 | 2.84 |
| United Kingdom (UK) | 0.20 | 5.05 |
| United States (US) | 0.07 | 13.91 |

The desire for increased intangible formats is relatively consistent among countries ($P_{IN0}$ ranges from 52.6% in UK to 61.7% in Japan) while the PSS offering has strong heterogeneity ($S_{IN0}$ ranges from 5.2% in Japan to 44.9% in US) suggesting the existence of an important business model challenge in many countries. From Table III and Figure 3 it can be seen that those countries with English as a first language and an English Legal origin [US, Canada, Australia and UK] (Djankov *et al.*, 2002) appear to more closely meet their consumer's needs.

It is proposed that the measure of business model challenge is inversely linked with digital dark matter, and the country with the smallest business model challenge by far is the USA. This is consistent with the fact that the companies leading software and digital technologies development (i.e. Facebook, Google, Microsoft, IBM, Apple) are located in the USA.

The third research question asks whether digital dark matter is positively associated with national and manufacturing competitiveness. This question is addressed using a correlation analysis. Table IV shows the linkage between digital dark matter, the Global Competitiveness Index and the Global Manufacturing Competitiveness Index where a positive correlation is observed with both indexes. Despite the fact that we have a small sample, which does not allow statistical significance to be obtained (*p-value* = 0.324 and *p-value* = 0.123 respectively), we consider that the observed positive link between Digital Dark matter and these two measures of competitiveness is strong as the size of the correlation parameter in absolute terms (0.348 and 0.520 respectively) is high and positive.

**Table IV:** Proposed table to examine the relationship between digital dark matter and competitiveness

| | **Estimated Digital Dark Matter** | **Competitiveness Index** | **Global Manufacturing Competitiveness Index** |
|---|---|---|---|
| **Panel A: English legal system** | | | |
| Australia (AU) | 4.77 | 5.09 | 5.75 |
| Canada (CA) | 4.99 | 5.20 | 7.24 |
| United Kingdom (UK) | 5.05 | 5.37 | 5.81 |
| United States (US) | 13.91 | 5.48 | 7.84 |
| **Panel B: French legal system** | | | |
| France (FR) | 3.05 | 5.05 | 4.64 |
| Italy (IT) | 3.03 | 4.41 | 3.75 |
| Netherlands (NL) | 2.74 | 5.42 | 5.27 |
| Spain (SP) | 2.84 | 4.57 | 3.66 |
| **Panel C: German legal system** | | | |
| Germany(GE) | 3.37 | 5.51 | 7.98 |
| Japan (JP) | 2.50 | 5.40 | 6.60 |

## Conclusion

*Implications of the results*

The transition towards service business models is not cost free (Bustinza *et al.*, 2013b; Suarez *et al.*, 2013) but can potentially enhance firm profitability and innovation (Visnjic and Van Looy, 2013). Cases such as IBM reflect those benefits (Ahamed *et al.*, 2013). However, previous literature has been silent with regards analysis of public policies encouraging the development of service-oriented strategies in firms or groups of firms as a means to driving forward national competitiveness.

In that regard in responding research questions 1 and 2 this paper provides a new empirical methodology to understand the gap between business models value propositions in PSS and consumer expectations. The context of the research (the music industry) is sector specific but the results and methods can be considered for use in other creative industries such as publishing or motion pictures (Parry *et al.*, 2014a) facing similar transitions towards a cannibalistic combination of physical and digital formats (Greenstein, 2010; Koukova *et al.*, 2012). Results are also relevant for the private sector. The methodology provides evidence of consumer demand exceeding supply of intangible digital format music, which suggests the music industry needs to examine its PSS market offering and increase the support given to firms providing digital content. The success of a product-service combination is determined by the level of understanding of market demand. Appropriate resource bundles can then be co-produced and dialog with customers undertaken to educate partners as to the value of the proposed offer (Vargo and Lusch, 2008).

One important objective of this research is to better understand the linkage between digital dark matter and territorial competitiveness (see RQ3). Our measure of digital dark matter is positively associated with national and manufacturing competiveness, as measured with the Global Competitiveness Index (Sala-i-Martin *et al.*, 2012) and Global Manufacturing Competitiveness Index (Deloitte, 2013). This does not demonstrate causation, however, it suggests that there may be relevance for governments embarking on soft innovation policies, incentivising and encouraging the development of product service portfolios in the private sector and introducing service reforms (Arnold et al., 2015). Some initiatives have been developed in that direction (see European Commission, 2011) but this is still in its inception stages.

This result contributes to the construct of digital dark matter (Greenstein, 2011). Digitalization of the economy not only increases aggregated productivity (Brynjolfsson and McAfee, 2011), which enhances competitiveness (Porter, 2004), it also produces

unobservable benefits for society, not included in monetary transactions. Our evidence suggests that those unobservable benefits come not only from developments in open access platforms (Greenstein and Nagle, 2014), they can also be found in the development of digital business models, like PSS. The value in PSS is not based on the 'value in exchange' of product ownership; instead PSS includes the 'value in use' of the provision of digital and/or service offerings (Barnett *et al.*, 2013; Macdonald *et al.*, 2011; Thenent *et al.*, 2014). The evidence provided here demonstrates that consumer needs in the digital domain are not fully met by current offerings, and hence managers need a better comprehension of digital business models. This managerial transition will benefit the process of value capture in their companies and will contribute to national competitiveness. In that respect the results suggest that US companies better understand the demand of digital formats; which is consistent with the international success of their companies in the digital domain (i.e. Facebook, Google, Microsoft, IBM, Apple).

This article also provides evidence supporting the negative relationship between file sharing and purchasing. The influence of business models and consumer demand enriches the academic debate on piracy as most literature highlights the requirement of specific regulation regarding file sharing activities and also proposes additional firm support for legal digital innovation –see Parry et al. (2014b) for more detail.

*Limitations and future research avenues*

The measure of digital dark matter is robust as it is positively linked with national competitiveness, and the country with the most experience with digital business models is found to have the greatest digital dark matter. However, we acknowledge the measure is based on a two relevant assumptions that will need to be covered in future research. First, the model assumes that an excess of digital business models reduces digital dark matter. In that respect, by inference it could be assumed that digital dark matter relates to customer satisfaction only when demand exceeds supply for digital services. A market with an advanced digital offering could have unseen benefits by consumers (i.e. spillovers). Unfortunately, our evidence does not find any country in this circumstance. Second, our method is specific for cannibalistic PSS, and hence does not provide information on how digital business models can facilitate the development of complementary PSS. Recent research has already related servitization strategies in manufacturing settings with digital business models (Carlborg *et al.*, 2013), which suggests that digital dark matter also could be present in those contexts.

The analysis focusses on a specific period in time and a single market sector, and we recognise that digital markets are very dynamic. Analysis here is based on 2010 data but in 2012, according to IFPI (2013), the music industry reaches an inflection point, changing to a path of revenue growth. Growth was based on the introduction of new formats, including streaming services. This is an example of the iterative and dynamic nature of consumer demand and industry PSS. This dynamism was not dealt with in this paper as the data presented is cross-section. Future research should examine the dynamic nature of markets and the evolution of digital dark matter within cannibalistic PSS. The evidence provided is also silent on the relationship between digitalization and competitiveness in developing countries and there are opportunities for further research in these markets. Future research will analyse how PSS transform and evolve over time with changes in context and consumer demand. In particular, future studies will seek to analyse how the PSS has changed since 2010, and look for insight into the success of strategy based upon PSS offer and economic, legal and infrastructure developments across different types of counties over time.

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