DIGITAL BUSINESS MODELS AND NATIONAL COMPETITIVENESS

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Abstract
The benefits of digital technologies that cannot be quantified in monetary terms are described as digital dark matter. Product service systems (PSS) are unified mix or bundles of products and services that deliver value in use; which ultimately is an unobservable construct and hence generate non-pecuniary benefits. The aim of this article is to empirically quantify the digital dark matter within product service systems, and correlate that measure with national competitiveness. We implement a novel methodology that establishes the link between customer needs and the product and digital service portfolio offered across 10 developed economies. The context of analysis is the music industry; which has a cannibalistic PSS. The supply of physical and digital formats is calculated with industry revenues. Consumer information is obtained from a unique database of more than 18,000 consumer surveys; with this information consumer preferences on digital and physical formats are modelled and predicted through logistic regressions. Our method provides estimations for the digital business model challenge in each country; the variable is interpreted as an inverse measure of the digital dark matter. The country with the lowest business model challenge is US, where major companies developing digital technologies are located. Digital dark matter is positively correlated with Global Competitiveness Index from the World Competitiveness Forum. The success of a product-service combination requires good understanding of market demand. Governments embarking on soft innovation policies might incentivise and encourage the development of service orientated business models based on digital technologies. Theoretically we expand the concept of digital dark matter to the PSS literature. Empirically, we propose a novel method to measure digital dark matter, which is robust as it is positively linked to competitiveness.

1. Introduction
Aggregate productivity is the key determinant of the level of prosperity and value generation a territory can sustain over time (Porter, 2004). In that respect links of the digital economy and competitiveness are still unclear. While digitalization of productive resources has raised firm productivity, the rate of employment has decreased (Brynjolfsson & McAfee, 2011). Social science lacks the appropriate concepts and methodological tools for measuring directly what we only see indirectly

today (Greenstein, 2011). In that respect Greenstein and Nagle (2014) make a metaphor using astrophysics tem “dark matter” which defines the hidden parts of the universe. They argue that the benefits of digitalization of resources have hidden benefits or drawbacks for the economy in the form of spillovers. They coin the term “digital dark matter” to refer to this non-pecuniary impact of digitalization. They offer more precise figures of the real impact of open innovation for SMEs in USA and conclude that the use of the open access web server Apache potentially accounts for an economic mismeasurement in the range of $2 billion to $12 billion. The hidden benefits of open innovation were first described when studying the commercialization of Xerox PARC inventions by spinoff companies (Chesbrough & Rosenbloom, 2002). They conclude that new business models can appear for manufacturers which unlock latent value from their technology, forming a connection between technical potential and realization of economic value. The potential exists in the revenue gap between current revenue and the economic value that could be realised is currently dark matter. The success of new business models reflects the extent to which firms understand what their customer wants, how the value proposition is delivered, how the customer is locked in 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 (Mills, Platts, & Bourne, 2003; Vargo & Lusch, 2004, 2008). A firm may provide a number of different product-service offerings using their portfolio of resources, creating Product-Service Systems (PSS) (Neely, 2008). 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 models (Barnett et al. 2013; Macdonald et al., 2011; Thenent et al., 2014). This transition can generate hidden benefits or losses to the economy and consequently the aim of this article is to empirically assess the existence of digital dark matter within the implementation of PSS.

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, 2013). Studies are limited due to a scarcity of reliable consumer databases; which allow analysis of service-orientated business models (Sampson, 2012). 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 data from IFPI and data from 18,000 customer surveys provided by a major music-licensing firm (Bustinza et al., 2013). Information related to consumers permit the estimation of demand functions based on logistic regressions. The demand functions are estimated for two groups – tangible product and intangible-digital service as very rarely will a consumer purchase the same content in different formats (Koukova et al., 2012). The 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 – in each country. This analysis allows the estimation of the business model challenge for each country. That is, the gap between what the industry offers and what

the consumer desires is inversely linked to digital dark matter within PSS. The measure of business model challenge can then be correlated with Global Competitiveness Index to establish (Sala-i-Martin et al., 2012).

In sum, the main goal of this paper is to respond empirically to the following research questions:

- Are current digital business models fully satisfying consumer needs?
- Do we have digital dark matter within PSS and can we quantify it?
- What is the linkage between digital dark matter within PSS and national competitiveness?

The order of the article is as follows. Next section builds upon theoretical framework of 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.

2. Theoretical underpinning and model development

2.1 Business models, PSS, and consumer needs

Vandermerwe and Rada (1989) 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. The Resource based view suggests that resource bundles may be combined to create value propositions (Mills et al. 2003, 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., 2007). Servitization has been defined as creating product-based services while PSS is considered a specific product-service offering (Tukker, 2013); therefore discussions of PSS may be considered as placing more focus on integrated solutions.

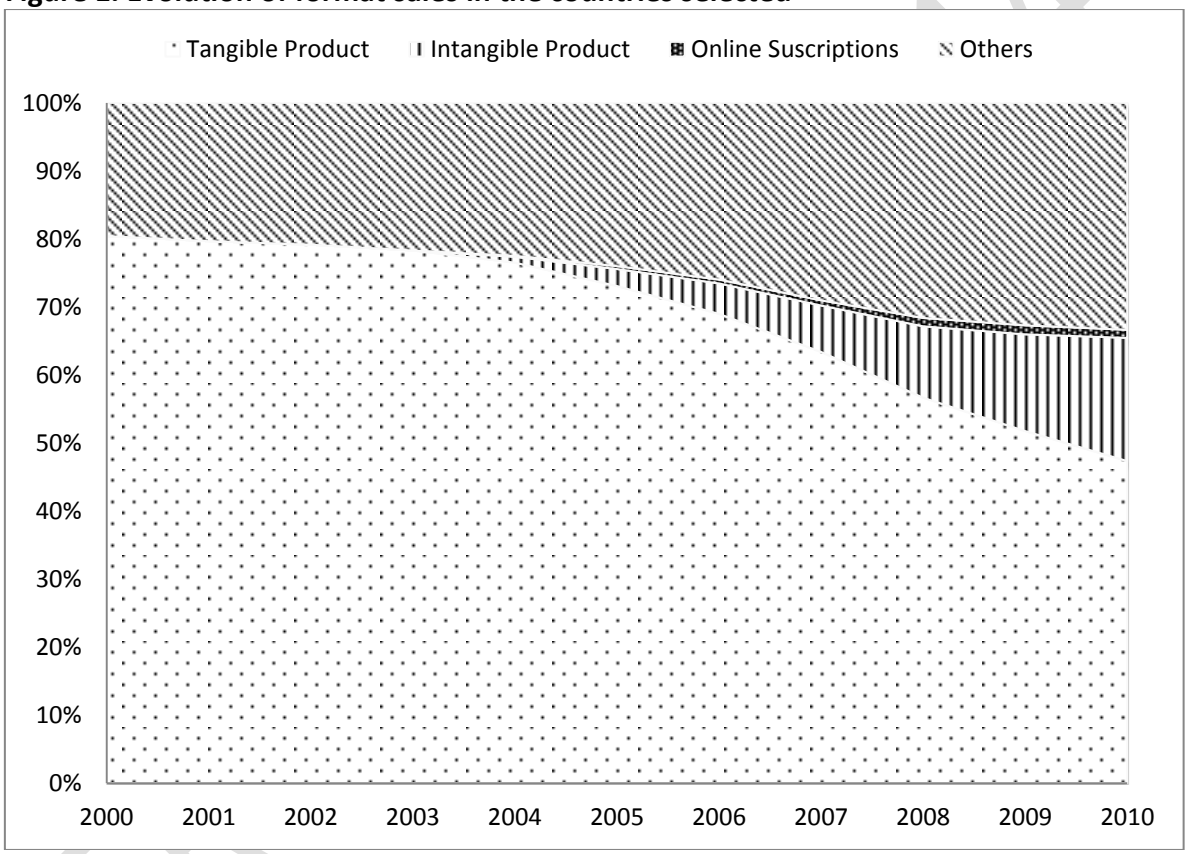
Baines et al. (2007) defined PSS as a unified mix of products and services that deliver value in use. This is consistent with the paradigm shift for manufacturing firms to compete through value-in-use and differentiation instead of cost (Porter et al., 2003). Based on the generic strategies for competitive advantage established by Porter (1979) the concepts of PSS and servitization are linked to firm differentiation 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) stated 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, 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, as 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). IBM digital product and service combinations now provide the main source of revenues, but capability was developed over two decades. PSS revenue grew from a marginal

contribution in the early 90s, to 58% of the revenues in 2001 and 90% in 2011. In contrast the coexistence of product and service may be cannibalistic, 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) proposed that the PSS offer of the music industry can be 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 as 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 realise value-in-use for customers (Vargo & 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 & Van Looy 2013). But is this also happening in cannibalistic PSS? This question is directly linked to the first research question to this article.

RQ1: Does bundles of Product-Service in cannibalistic PSS satisfy consumer needs?

2.2 The measurement of digital dark matter within 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 & 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. Through an approximation of the Luenberger (1992) indicator, the Euclidean distance between points A or B and the 45 degree line give a figure of business model challenge.

The indicator assumes that both inputs (horizontal axis in Figure 2) and outputs (vertical axis in Figure 2) can be quantified as the distance of the point defined by the Normalized consumer needs for intangible format (P_{IN}) and Normalized Intangible supply (S_{IN}) from the line P_{IN}=S_{IN} in the 2-dimensionsional axis (P_{IN},S_{IN}). According to Euclidean geometry the distance between a point (P_{IN0},S_{IN0}) and the 45 degree line is:

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

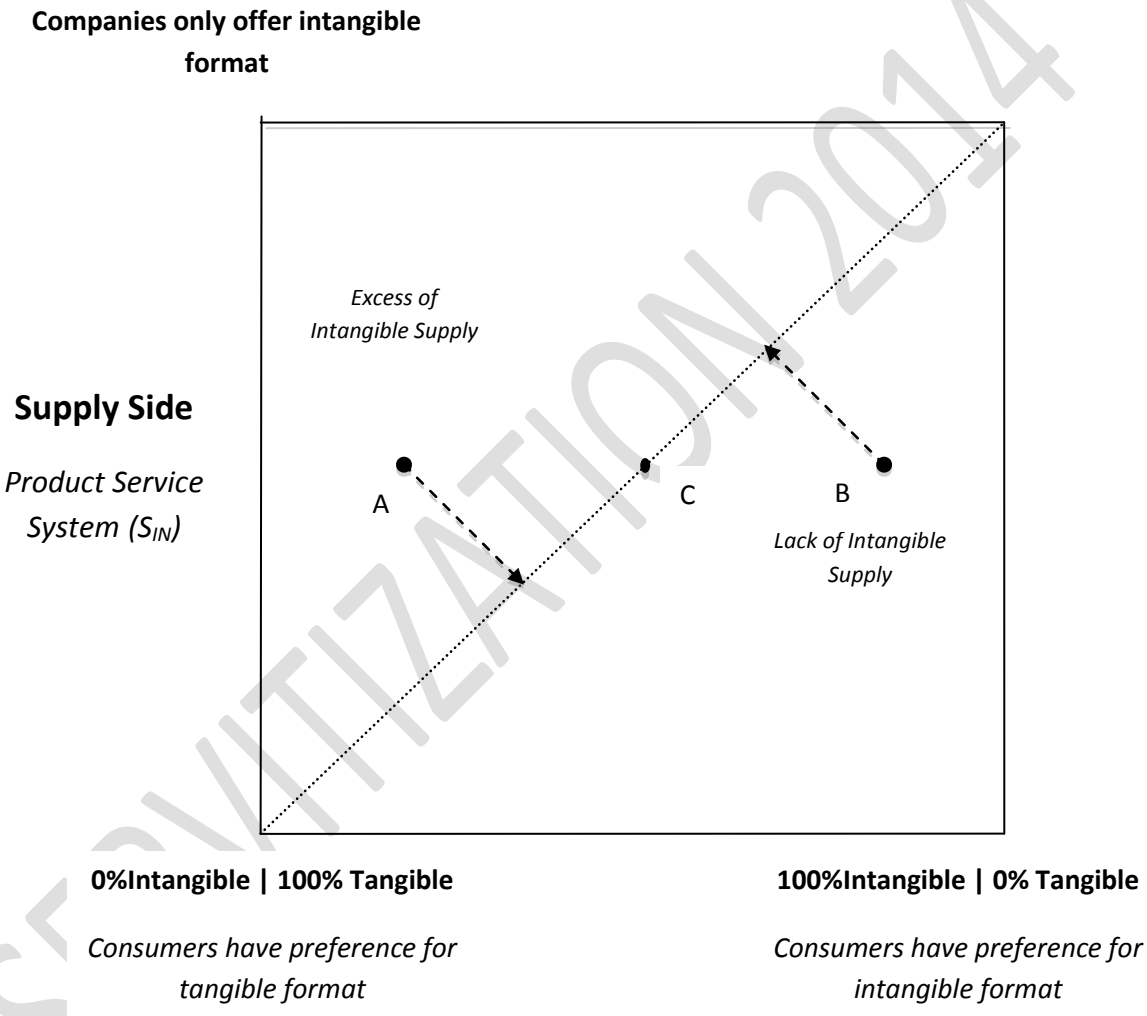
Therefore in this case we calculate the Business Model Challenge for each country using the formula:

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

But, how can we obtained 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 1 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, $S_{IN0} = R_I/(R_I + R_T)$.

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.

The empirical estimation of the demand side is not directly observable and by 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, ε_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 β 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 is relevant to know in which markets digital dark matter is more relevant, and whether it is an excess or lack of intangible formats. This brings to the second research question of this article.

RQ2: What is the business model challenge faced in markets where the PSS is not in equilibrium with consumer demand? Is there an excess or lack of service offering?

2.3 Digital dark matter and national competitiveness

Competitiveness is a concept that goes beyond the pecuniary 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 (Hall & Jones, 1999; Lewis, 2004).

Institutions like the World Bank with the Doing Business indexes and IMD World Competitiveness measure national competitiveness and other provide additional relevant institutional metrics for legal systems and state of a nation's infrastructure. However, the most comprehensive and accepted measure is the one developed by the World Economic Forum, which has published a report every year since 2004 and offers the Global Competitiveness Index which integrates the macroeconomic and the micro/business aspects of competitiveness into a single index. The Global Competitiveness Index is based on the 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.

Business dynamics requires the implementation of new business models to capture value, understanding the consumer (Vargo & Lusch, 2008). Digital technologies are facilitators for interacting with consumers and gathering relevant data to reposition new business models based on innovation and business sophistication. It is therefore proposed that digital dark matter, or benefits of digital technology not included or captured in pecuniary transactions (Greenstein, 2011; Greenstein & Nagle, 2014), are positively linked to national Competitiveness. This construct leads to the following empirical hypothesis.

Hypothesis 1: Digital dark matter and national competitiveness are positively correlated.

3. The PSS of the music industry

3.1 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., 2013; Myrthianos et al., 2014). Music industry was the first creative industry to suffer the threat of piracy which is being largely discussed as one of the main factors for explaining this decrease in revenues (see Parry et al., 2014 for a comprehensive summary of the literature). As it is explicit in Figure 1 the industry adapted to piracy with the implementation of digital business models, especially with downloads in 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. This includes other creative industries like cinema, videogames and books.

3.2 The data

Unique music industry dataset comprising information for 10 countries in 2010 was collected. 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 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). 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. (2013).

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 and even in 2012, though growing rapidly, represent 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 on tangible (Y_T) and intangible (Y_I) format we run discrete choice analysis. The binary dependent variables are *Buy tangible* that takes value 1 if the consumer claims to buy music in physical format and 0 otherwise. Similarly, *Buy intangible* takes 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 1 gives information for the average and dispersion of the variables and details of how they have been constructed. Finally, as a measure of national competitiveness we take the value of the Global Competitiveness Index for the year 2010 (Sala-i-Martin et al., 2012).

Table 1. 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	Consumer's answer to the question: *What is your working status/ occupation?*	18842	0.37 (0.48)
Income Part-Time		18842	0.21(0.41)
Out of Job Market		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.**

4. Results

The first stage in the empirical design is to analyse consumer preference through logistic regressions. Table 2 reports the results of two logistic regressions. Column 1 analyses the propensity to purchase in tangible format against not purchasing and the explanatory variables explain approximately 21% of the variance of the dependent variable. Column 2 analyses the propensity to purchase in intangible format, a model with an explanatory capacity of approximately 16%.

Table 2. The propensity to purchase in tangible and intangible form through logistic regression

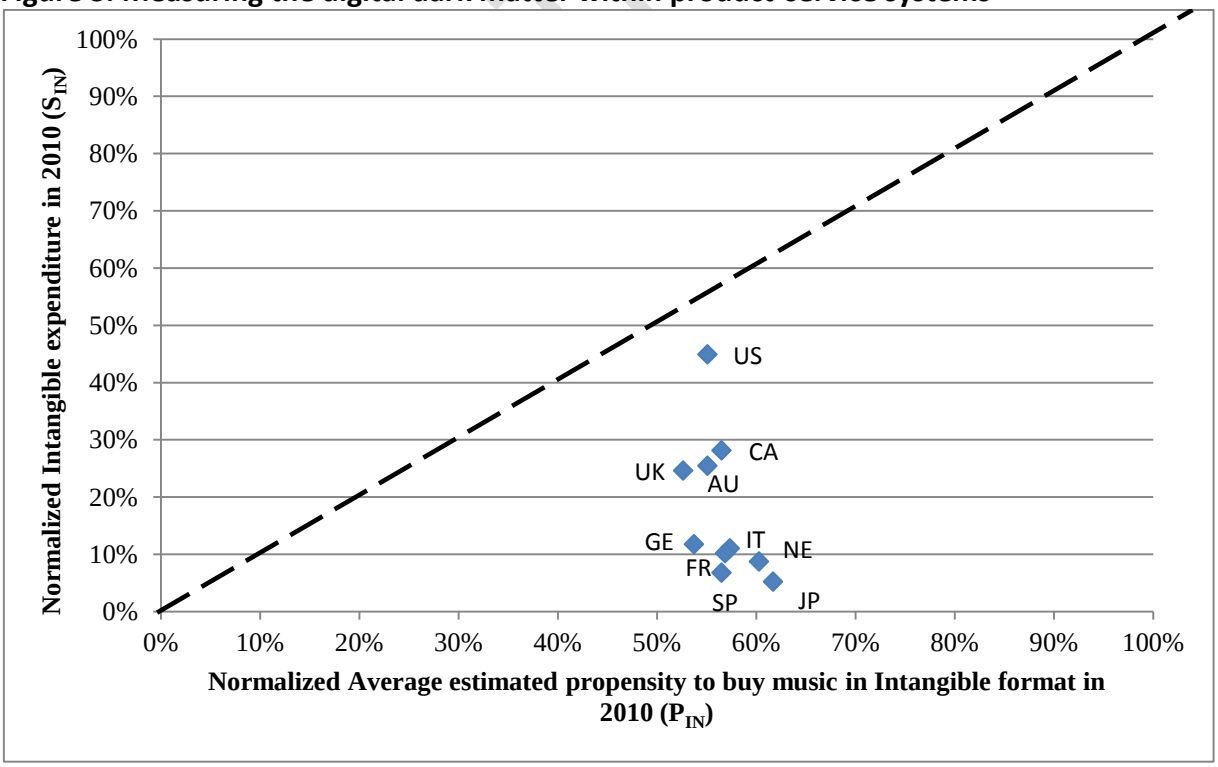
	Independent Variables	Tangible Buyer vs. Non Buyer	Intangible Buyer vs. Non Buyer
Variables related to Value-In-Use reported in Figure 2	Passion for Technology	0.751***	0.520***
		(0.046)	(0.039)
	File Sharers	-0.849***	-0.928***
		(0.049)	(0.041)
	Willingness to Pay	1.197***	0.942***
		(0.044)	(0.037)
	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)
Taste for Music	Passion for Music	1.034***	0.487***
		(0.070)	(0.050)
	Ln(Hours per week)	0.299***	0.155***
		(0.028)	(0.024)
Personal Characteristics	Gender	-0.004	0.088**
		(0.044)	(0.037)
	Ln(Age)	0.330***	0.110**
		(0.056)	(0.047)
Country Specific Characteristics	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

Standard Errors in Parenthesis. Level of statistical significance: *, ** and * denote statistically significance of 1%, 5% and 10% respectively. Reference groups are unemployed**

Consistent with most of previous literature using survey data (Parry et al., 2014) 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 & Watt, 2006). Ceteris paribus, file sharers have 19.8% (20.9%) lower probability of purchasing intangible (tangible) formats than non-file sharers. These results are statistically significant at 1%. 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% more likely to purchase music in intangible format than females. This result is significant at 1%.

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 including UK, US or Australia. 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 the PSS maximizes consumer surplus, or in terms of Figure 2 whether there is a match between supply and demand in cannibalistic PSS. As can be seen in Figure 3 consumer surplus is not maximised in any of the markets analysed. The consumers' propensity to purchase is unsatisfied as the observations are not on the 45 degree line. The finding answers the second research question which asks whether it is an excess or lack of intangible format offering, markets A and B in Figure 2 respectively.

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.

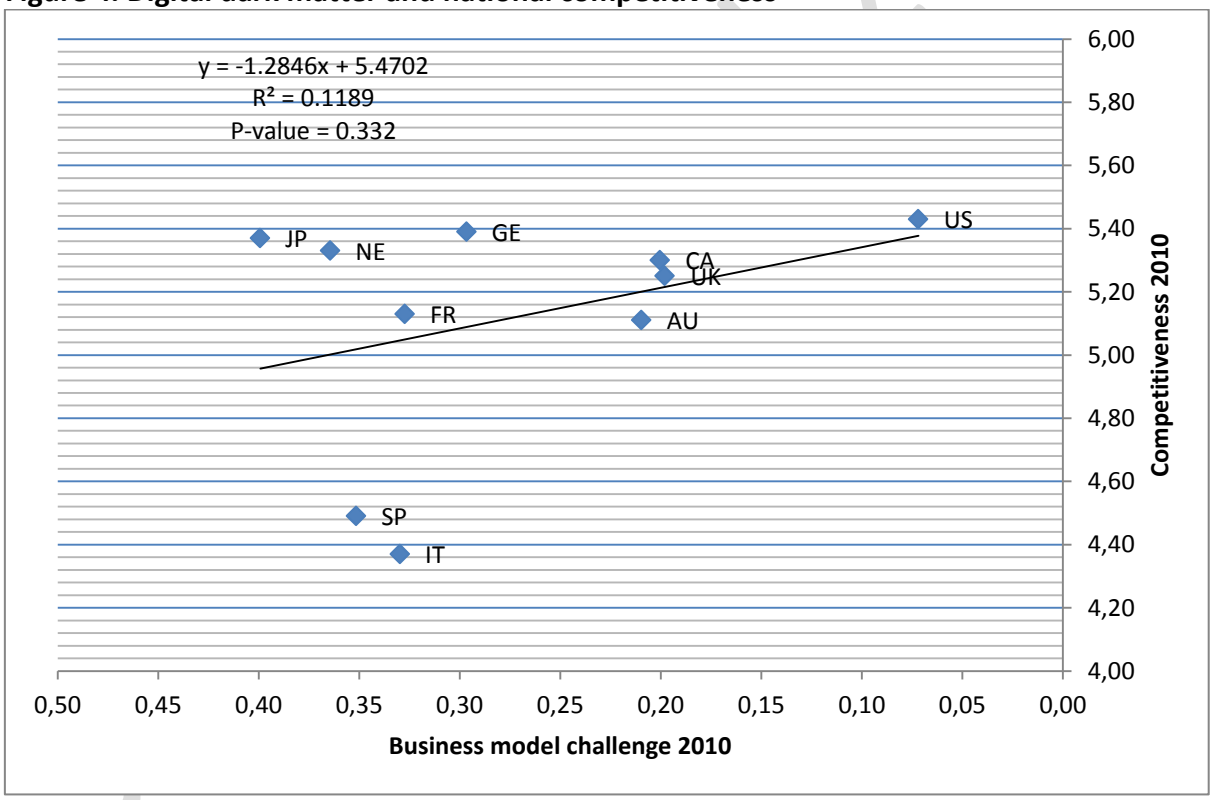
According to the representation in Figure 3 all countries analysed lack intangible format offerings, suggesting that the industry needs to redefine their PSS, enhancing

the digital offering. But, which are the countries with the largest business model challenge? Or in our framework, gain the least benefit from the digital dark matter in PSS as consumer requirement do not match business strategies?

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 a 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 Figure 3 it can be seen that those countries with English as a first language and an English Legal origin [UK, Canada, Australia and UK] (Djankov et al. 2002) appear to more closely meet their consumer needs.

The measure of business model challenge is inversely linked with the digital dark matter. The country with the smallest business model challenge by far is US. The current business model satisfies consumer needs in the transition towards PSS. This understanding of the consumers is perfectly consistent with the fact that the main international companies leading software and digital technologies development (i.e. Facebook, Google, Microsoft, IBM, Apple) are located in US.

Figure 4. Digital dark matter and national competitiveness



Source: Self-elaborated. Notice that the business model challenge is expressed in reverse order to reflect better the construct of digital dark matter. It shows negative correlation between our measure of business model challenge and national competitiveness measured by the Global Competitiveness Index (Sala-i-Marin et al., 2012); and hence it supports the empirical hypothesis that digital dark matter is positively linked to national competitiveness.

5. Discussion and conclusions

The transition towards service business models is not cost free (Suarez et al., 2013) but can potentially enhance firm profitability and innovation (Visnjic & Van Looy 2013).

Cases such as IBM reflect those benefits (Ahamed et al., 2013). However, previous literature have 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 this paper provides a new empirical methodology to understand the gap between business models value propositions in PSS and competitiveness. 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., 2014) facing similar transitions towards a cannibalistic combination of physical and digital formats (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 good 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 & Lusch, 2008).

Our measure of business model challenge is negatively correlated with national competiveness, as measured with the Global Competitiveness Index (Sala-i-Martin et al., 2012). 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. Some initiatives have been developed in that direction (see European Commission, 2011) but this is still in its inception stages.

This result gives more relevance to the construct of digital dark matter (Greenstein, 2011; Greenstein & Nagle, 2014). Digitalization of the economy has not only increase aggregated productivity (Brynjolfsson & McAfee, 2011), which means an enhancement of competitiveness (Porter, 2004), it also produce hidden benefits to the society not included in pecuniary transactions. Our evidence suggest that those hidden benefits are not only coming from the open innovation developments (Greenstein & Nagle, 2014), they also can be found in relation to a better comprehension by managers and consumers of the epistemological shift in value produced in PSS (Barnett et al., 2013; Macdonald et al., 2011; Thenent et al., 2014).

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. This 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. Besides, the evidence provided is silent on the relation between digitalization and competitiveness in developing countries. Overall, future research must analyse how PSS transforms and evolves over time and with changing contexts and consumer demand. In particular future studies should 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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