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Measuring creativity:
Learning from innovation measurement

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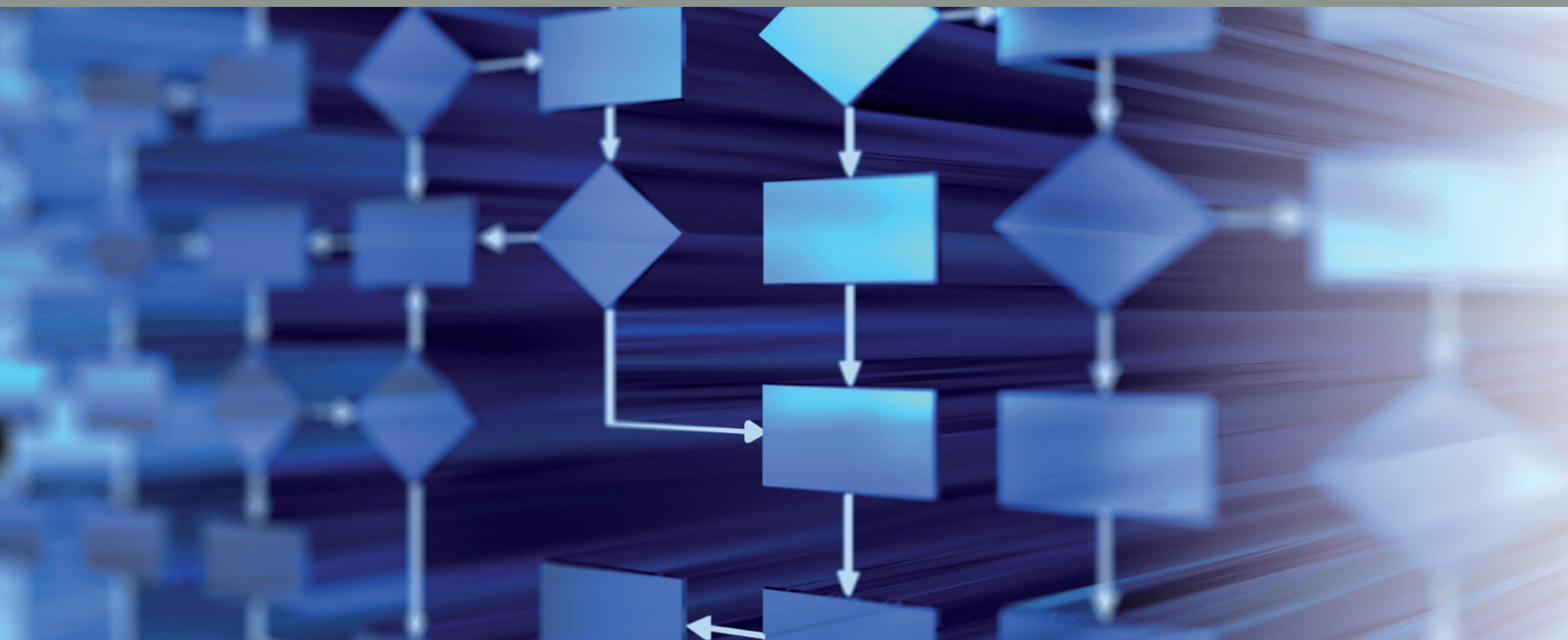

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# Measuring Creativity: Learning from Innovation Measurement

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### Abstract

Abstract: There is a growing interest in broadening the measurement scope of innovation and considering “creative” activities, meaning that the usual indicators of innovation satisfy neither scholars nor policy makers. Conceptually, there is not much difference between innovative and creative activity: but to what extent are current measures that capture innovation relevant for creativity? Can the new measures for creativity benefit from the experience accumulated through R&D and innovation? Our article provides insights and lessons learned from using measures of innovative activities for scholars who are interested in capturing creative activities. We underscore the difficulties faced when measuring innovation and draw some parallels of these difficulties with the efforts undertaken to measure creativity.

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### Disclaimer

## 1. Introduction

Since the contributions of Francis Bacon, observation and measurement have been central to scientific research. Research on knowledge production is no exception, and efforts were made early on to collect data measuring the scientific and technological capacities at the country level (Godin, 2012). For decision-makers, collecting data on the scientific and technological capacities at the country level has become a priority because innovation creates national competitive advantages. Over the past 50 years, important efforts have been undertaken to capture, categorize and standardize measures related to innovative activities. These ongoing efforts include the collection of research and development (R&D) and non-R&D activities, as well as technological and non-technological factors that may affect economic activity (see OECD, 2010; OECD, 2013 for an overview).

There is a growing interest in broadening the measurement scope of innovation and considering “creative” activities, meaning that the usual indicators of innovation satisfy neither scholars nor policy makers. Conceptually, there is not much difference between innovative and creative activity. After Schumpeter, innovative activities usually involve an inventive step where new knowledge or ideas are processed, whereas an innovation step addresses the use of or commercialization of an invention. Additionally, environments that stimulate creativity are likely to motivate innovation (see, for example, Amabile, 1996). Creativity based on imagination and originality can thus be considered as overlapping strongly or even included as part of inventive activities. The first issue is to know to what extent current measures that capture innovation are relevant for creativity.

However, some aspects of creativity may not be fully or even partially captured by innovation measurements, such as the “irrational” elements that are often associated with creativity. Similar to technological innovation activities, scientific and technological intelligence is not contingent on creative activities where sensibility or faith can be central. Furthermore, for some scholars, creativity can exist *per se* with aesthetic value, without any relation to a new process or product (Runco, 2014). The usual innovation measures may thus be inappropriate and new data must be collected. A second issue then becomes whether the new measures for creativity can benefit from the experience accumulated through R&D and innovation.

In this paper, we provide insights and lessons learned from using measures of innovative activities for scholars who are interested in capturing creative activities. We underscore the difficulties faced when measuring innovation and draw some parallels of these difficulties with the efforts undertaken to measure creativity.

Reviewing the enormous body of literature on the topic is not easy. Direct measures of innovation are being proposed by different surveys administered by academic bodies, government, international organizations, consulting firms and think tanks, and some indirect measures are available through financial statements, tax credit files and intellectual property rights registration data. For the sake of brevity, we focus on the measurements taken at the firm level and on a large scale and standardized national surveys defined in the Frascati manual (OECD, 1962) or Oslo Manual (OECD, 1992). We also consider artistic creativity as a role model of creative activity in challenging the usual measures. The lessons learned and the problems highlighted in this paper should be relevant for measurements performed by public research organizations at the employee level and for many types of creative activities.

This paper is structured as follows: First, we identify the factors that are considered inputs into innovation production and differentiate between R&D and non-R&D activities that a firm can undertake. We then delve into the various outputs of the innovation process and distinguish between direct measures used in innovation surveys and indirect measures proposed in alternative databases (Section 3).

## 2. Innovation inputs

One of the oldest and most common methods of measuring innovative activities is through capturing R&D data (OECD, 1963; UNESCO, 1968; Godin, 2009). The popularity and prevalence of R&D indicators stem from their ability to quantitatively capture efforts related to innovation directly. However, these data neither provide a complete picture of innovation, nor are the most reliable or easiest indicators to interpret.
This section discusses the different input measures of innovative activities, highlights their limitations, and shows how they can be relevant for measuring creative activities.

### *2.1 R&D inputs*

Research and experimental development (R&D) refers to “creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications” (OECD, 2002, p 30). R&D should thus capture a large share of creativity inputs. The scope of R&D activities is limited by definition problems and by the use of multiple categorizations. Additional lessons for creativity measurement can be derived from the efforts made to address R&D accumulation and organization.

*R&D definition and categorization*

First, R&D efforts must be intentional. Unintentional processes will not be considered R&D, and some intended heuristics is required in creative tasks (Amabile, 1983). Even if it is successful, a random process cannot be considered R&D. "Systematic" activities were historically interpreted as planned, organized and continuous cognitive activities (Uhlmann, 1977; Godin, 2004). However, evidence has shown that industrial R&D is often not necessarily planned, organized or even continuous because it often lacks a dedicated R&D department (Kleinknecht, 1989; Kleinknecht et al., 1991; Santarelli and Sterlacchini, 1990) or clear R&D budget (Gault and Von Hippel, 2009). Furthermore, firms may strategically declare that they do not conduct R&D (Hunter et al., 2012) or refuse to disclose their R&D activities (Koh and Reeb, 2015; Chen et al., 2015), which lead to the artificial observation of non-continuous R&D activity. Scholars have addressed this issue by focusing on R&D-performing firms employing at least one full time-equivalent (FTE) researcher, even if doing so causes scholars to overlook up to one-third of firms (Kleinknecht and Reijnen, 1991; Bönte and Keilbach, 2005).

The most recent Frascati manuals finally acknowledged the existence of "informal" and "occasional" R&D activities (OECD, 2002, p 17). However, the "systematic" trait remains and suggests that the measured R&D activities data are still biased toward organized, formal and continuous activities (Godin, 2004). Creative activities, such as ideation activities or artistic works done by individuals who prefer independence, are likely to be underestimated.

Second, R&D activity must possess an uncertain element. The Frascati Manual states that: "[t]he basic criterion for distinguishing R&D from related activities is the presence in R&D of an appreciable element of novelty and the resolution of [...] uncertainty" (OECD, 2002, p. 34). Such distinction in cognitive activities is necessary to differentiate experimental development from other types of development activities, such as marketing-related activities. However, the (auto-)evaluation of uncertainty is difficult, particularly when R&D measurement methods fail to follow up on the outcome of R&D projects, such as their failures[1]. The measurement of uncertainty in creative activities remains a challenge.

Third, the degree of novelty will depend on a benchmark: "someone familiar" (OECD, 2002) with the state of the art knowledge or an "appropriate observer" (Amabile, 1983). This benchmark can be achieved through standard or novel heuristics. However, knowledge is either assumed to be common to all of the knowledge producers or dispersed, leading to different conclusions on R&D. The former Mertonian view implies that the R&D definition is universal and applicable in every country despite their different contexts (as in OECD, 2012). The latter view implies that the novelty related to the declared R&D actually depends on a local benchmark. Once the benchmark is identified, the inventive step or degree for novelty must also meet the "non-obviousness" criterion. A particular case emerges for artistic activities based on aesthetic values and originality criteria, where a claimed inventive step may be subjective and not consensual.

[1] Data on R&D failures are only collected by sponsoring bodies (See Link and Wright, 2015).

Despite the problems cited, R&D remains the main measure of innovation inputs because the definition of R&D can be fine-tuned by users to their advantage (Bosworth et al., 1993; OECD, 2012). For example, in general, R&D in the social sciences, arts or humanities is ineligible for R&D tax credits in the UK (HMRC, 2014). Managers and accountants can consider some expenses as R&D expenditures, such as downstream activities that include pilot plants or marketing activities (see Hunter et al., 2012), to reinforce a positive signaling for shareholders (Chen et al., 2015). In the case where there is a non-incremental R&D tax credit, relabeling activities can be particularly rewarding. However, in purely incremental R&D tax credit schemes, firms may underestimate their initial R&D budgets to boost their marginal effort and obtain a higher tax credit (Hall and Van Reenen, 2001). Similar practices may emerge from the creativity tax credits that were recently implemented in the U.K. for example.

The usual definition of R&D sounds flexible enough to be compatible with different views of creativity, including artistic activity. However, the OECD manual restricted the scope of measured creative activities in two drastic ways: first, in R&D activities, uncertainty must be a “scientific and/or technological” uncertainty (OECD, 2002, p. 34), thus excluding artistic and non-scientific techniques, such as “traditional knowledge” (OECD, 2012). Second, R&D activity is considered when there is a utility. Three different categorizations linking R&D activities to improved industrial products or processes can be found: development activities (as well as applied research) must “be directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed related products or processes” (OECD, 2002, p 30). R&D surveys must classify R&D budgets according to the different lines of businesses targeted (see US Census, 2014), whereas a distinction between process R&D and product R&D can also be found (see Bogers and Lhuillery, 2011 on Swiss data).

However, the delineation by firms between fundamental research activities, applied research and experimental development activities is unstable and unexplainable, which renders it difficult to link R&D to improved firm performance (see Czarnitzki and Thorwarth, 2012). The attribution of R&D budgets to different lines of business increases the size of R&D questionnaires (See in UK or US questionnaires) and induces a severe downward bias of the declared variety of R&D activities. Furthermore, the business line categorization is irrelevant for new key technology fields and industries, such as software, biotech, nanotech, environmental protection, new materials, social sciences and humanities, and other classifications based on scientific and technology fields where socio-economic objectives were implemented (See OECD, 2002, pp 85-88; US Census, 2014). These measures are maintained in surveys despite their limited quality and their limited use by scholars or policy makers.

*R&D accumulation and organization*

Computing the volume and accumulation of R&D is important to approximating firms' real R&D efforts and capabilities (Griliches, 1979). However, these measures depend heavily on R&D price indices and depreciation rates. Inflation can indeed be specific to R&D inputs, e.g., a shortage of skilled researchers' local supply. One method for overcoming this haunting problem is neglecting individual effects and considering that different firms face the same inflation rates in an industry. Then, the R&D price index used is the standard GDP or a set of more detailed price indices applied to different R&D components, such as wages, materials or capital (NSF, 1972; Dougherty et al., 2007; OECD, 2002, annex 9).

R&D depreciation rates are also notoriously difficult to calculate, particularly because the rate is oftentimes endogenously determined by the firm, its competitors or universities (Griliches, 1979). Even when the shelf life of an invention can be observed – either through records kept on the maintenance period for patents (Pakes and Shankerman, 1988) or through the existence of a market for technological knowledge (Arora et al., 2004) – the actual rate of knowledge depreciation remains largely unknown. A recent UK R&D survey conducted in 2011 included a question on R&D service lives, and showed that R&D depreciation rates are smaller for high-tech industries and for fundamental research activities (Ker, 2013).

The amortization data in financial statements are easier to observe. In the new EU accounting frameworks, R&D expenses can be considered as an investment for the D-part when "technical and Commercial Feasibility of the asset for sale or use have been established" (IAS38). The declared values of capitalized R&D provide an interesting measure of industrial R&D capabilities. The disadvantage of using this source of information is that the declared values are biased because firms can strategically increase capitalization to raise their financial performance (Principe et al., 2008). A strategy can aim, for example, to inflate R&D transactions because R, and not only D, can then be capitalized. A second strategy is to play with the frequent changes in accountancy norms (Clem et al., 2004).

The capitalization of creative activities is thus a critical task that may be even more complex for artistic activities. What is the depreciation rate of artistic capital paid by creative firms? At odds with R&D activities, accountants consider that the depreciation rate for artistic goods is null, partially reflecting copyright protection terms, which span for several decades.

Few systematic efforts have been made to measure how R&D is accumulated in organizations.

The first attempts to measure R&D addressed allocation problems, with R&D measured at the plant level (Klette, 1996), project level (Henderson and Cockburn, 1996), divisional level (Argyres and Silverman, 2004) or business group level (Arora et al, 2014b). The identification of R&D allocation is complex for multinational enterprises (MNEs) – which account for approximately 80% of industrial R&D activity worldwide[2] – because standard R&D surveys usually adopt a national point of view (OECD, 2002). Some national R&D surveys tried to measure R&D conducted by worldwide affiliates (e.g., US Census bureau, 2014; OFS, 2014), whereas some international organizations launched specific surveys (UNCTAD, 2005; JRC-IPTS, 2014) to fill the gap.

The direct measure of cross-country R&D is a laudable solution but can be problematic; the aggregation of international R&D values depends on the scope of consolidation and currency rates (US Census, 2014; OECD, 2002, annex 9). R&D activities conducted by a national subsidiary of a MNE may be consolidated only if the MNE owns at least 50% of equities and the exchange rates are applied at the end of the accounting period (in EU IAS or US GAAP). The disclosed R&D levels also rely on accountancy optimization. The R&D levels declared by MNEs are often highly dependent on the different national tax systems (Heckemeyer et al, 2014) and related intra-group transfer pricing strategies (Barry, 2005).

The external organization of R&D activities has been studied in greater depth. The measurement of R&D activities conducted by firms in collaboration with other firms or universities was first captured by the financial flows resulting from R&D links or R&D public funding (OECD, 2002). These links can be used to approximate the level of R&D transactions performed in the markets for knowledge (Arora et al., 2001). However, the resulting information has barely been used by scholars. First, external R&D expenditures are not reported for non-R&D performing firms in R&D surveys, despite their importance (Cassiman and Veugelers, 2006; Rammer et al., 2009). Second, many R&D collaborations between firms do not induce financial flows. Finally, the external R&D expenditures measured do not identify the types of goods and services bought (licenses, R&D services, partnerships, etc.) or the types of industrial partners (e.g., suppliers).

For example, CIS surveys addressed this last deficiency by introducing qualitative questions on the type of innovation partners chosen, covering formal versus informal links, whereas the complementary questions on the sources of innovation broadened the measure to incoming spillovers, including scientific and technological knowledge and also possibly other influential types of knowledge, such as artistic knowledge (Belderbos et al, 2004). The CIS qualitative measures of external innovation cooperation and knowledge sourcing were so successful that they supplanted the historical and public data on R&D partners and partnerships (See Hagedoorn, et al., 2000 for an overview of these databases). Still, the standard innovation surveys are not perfect on external arrangements because they restricted the means deployed for knowledge sourcing to the role of fairs and scientific and patent publications (Eurostat, 2012), despite the fact that more interesting and comprehensive measures can be performed (See Arora et al., 2014).

[2] The location of R&D facilities is usually badly approximated by the addresses of inventors or applicants, as shown by Arora et al. (2014).

### 2.2 Non-R&D inputs

*Non-R&D costs and links*

Since the first innovation studies were conducted, efforts have been made to include non-R&D inputs that contribute to technological innovation (Rothwell et al., 1974; Mansfield, 1975). Recent innovation surveys confirmed the importance of non-R&D inputs, with R&D representing only one-third of innovation costs (Brouwer and Kleinknecht, 1997; Sterlacchini 1998) and providing measures of different non-R&D costs (Santamaria et al., 2009), such as machinery and equipment (Pellegrino, et al., 2011), licenses, software or external know-how (Czarnitzki and Kraft, 2005), specific training (Evangelista and Savona, 2003), design (Marsili and Salter, 2006) and marketing costs (Lhuillery, 2014). Innovation costs are cumbersome or strategic for firms, thus rendering firms unlikely to disclose them or to do so only for the R&D component. Consequently, many countries have put an end to quantifying non-R&D-related expenditures, requesting only qualitative information. The tool used to measure non-R&D-related expenditures thus became similar to qualitative questionnaires that use a functional view and measure the importance of marketing, manufacturing and managerial functions at the team (Bunderson and Sutcliffe, 2002) or firm level (Bogers and Lhuillery, 2011) using a Likert scale.

Teece (1986) underlined that distribution channels, services or complementary technologies are critical non-R&D assets enabling firms to exploit innovation. However, in general, it is difficult to know to what extent these assets are actually deployed for innovation purposes. Åstebro and Serrano (2015) used phone calls to certify the role of declared complementary assets and to overcome the issue. Despite its outstanding impact on scholars and policy makers, the systematic measure of complementary assets has still not been achieved or even proposed. Only scattered econometric results can be found on the level and role of these non-R&D assets.[3] The burgeoning literature on servitization and its difficulties in measuring and categorizing product-related services is a good introduction to the issue (See Eggert et al., 2011).

Despite their frequency and importance (Colombo et al., 2006) and their availability in large data sets (Schilling, 2009 for an overview), production and marketing alliances have also been overlooked in questionnaires focused on R&D alliances.[4] Recent studies on startups or SMEs with low endowments in some innovation capabilities proposed to measure new non-R&D partners involved in innovation: consultants, law firms, accounting firms, talent search firms, and financial service firms, including venture capitalists (e.g., Zhang and Li, 2010). A final interesting strand in the literature measures innovation networks, including non-R&D links (e.g., Powell et al., 2005). However, it is still difficult and costly to collect data on knowledge networks though questionnaires (Broekel and Boschma, 2012). An additional problem with declarative measures is that the respondents are usually not aware of the indirect links they have or they possess a biased representation of their innovation networks.[5]

[3] See Cohen (2010) for a survey.
[4] See the 2002 Swiss innovation survey, KOF-ETHZ.
[5] See Lhuillery and Pfister (2011) and references therein

*Intangible assets and smart activities*

Some scholars choose a more general path, considering the measurement of intangible assets (e.g., Corrado et al., 2009;  Maroccu et al, 2012).  A major avenue of research has been the disentanglement of R&D from non-R&D intangibles in financial statements (Marrocu et al, 2012) and specific surveys (e.g., Montresor et al., 2014).  In this literature, the level of non-R&D intangibles is assumed to be a decent approximation of non-R&D knowledge involved in innovation.  However, a substantial part of these non-R&D intangibles may be used for other purposes than knowledge production and can even hamper innovation (e.g., organizational capital, specific human capital or brands).

Recent studies in management and economics delineating and measuring “creative” classes, industries or cities have attempted to more broadly measure non-R&D activities likely to be performed by poets, novelists, artists, entertainers, actors, designers and architects (Florida, 2005).  At the firm level, the identification and quantification of the workers, firms and industries considered as non-creative is difficult (Rodgers, 2015) and should require, similar to R&D activities, a measure of full-time equivalent (FTE) employees working on creative tasks.  It should be mentioned that some non-R&D creativity costs are already delineated and measured in the tax credit schemes for culturally creative activities (e.g., video games, film, fashion) that were recently implemented in several OECD countries (e.g., Canada, France, the UK), and applicant data can be possibly matched with R&D and innovation data.  A less ambitious but workable solution was proposed by the CIS 2010 questionnaire introducing a set of items identifying the use of eight “creative skills” (Eurostat, 2010;  OECD, 2013).[6]

The measure of creativity at the individual level remains challenging because creativity can be tacit and difficult to observe.  Psychologists tried for decades to measure individuals’ creativity, skills and creative orientation through self-reports and checklists (See Plucker and Makel, 2010 for a survey).  More convincing for scholars in management and economics is perhaps the type of questionnaire used at the employee level to identify creative tasks (See Lorenz and Lundvall, 2011, on the Fourth European Working Conditions Survey).

[6] An analogous effort to define and measure “talented” individuals and positions in organizations has been proposed (Collings and Mellahi, 2009).

*Knowledge management practices*

Knowledge Management Practices (KMPs) are a final means to identify creative production (See Cohendet and Simon, in this volume). IPR tools, business intelligence practices, concurrent engineering, CAD methods, C/K methods, crowd-sourcing practices, and design thinking are some KMPs used by firms that can be identified and qualified through questionnaires focused on organization or innovation. Some are more oriented toward the management of technological innovation processes, whereas some other practices are more broadly dedicated to the early stages of creativity with the identification of different ideation methods (brainstorming, TRIZ or lateral thinking). Efforts were made to enlarge and standardize the measure of the KMPs (See OECD, 2003). Some questions were even introduced in European innovation surveys (CIS3) enabling the identification of many innovating firms with no R&D but with KMPs and their positive roles in innovation success (See Kremp and Mairesse, 2004; Cantner, 2011). However, these KMP questions were focused on knowledge sharing and knowledge integration practices. Some recent contributions have emphasized the importance of other KMPs, such as teaming or incentives (Amabile, 1996; Sauermann and Cohen, 2010). The 2010 CIS questionnaire thus introduced a set of six KMPs: brainstorming, work teams, job rotation, training, financial incentives and non-financial incentives (Eurostat, 2010). After the Yale survey (Levin et al., 1987), appropriation practices are the most surveyed KMPs by standard questionnaires (e.g., Eurostat, 2012).

## 3. Innovation outputs

### *3.1 Direct measures: innovation survey*

Part of the challenge of measuring creative outputs relates to the difficulty of agreeing on a definition. In general, existing definitions focus on those creative outputs related to new final and intermediary products produced by firms, new production processes employed to produce products, new ways for organizing firm resources and new means of commercializing products. Joseph Schumpeter was the first to tackle all of these elements together in a systematic manner (Schumpeter, 1939).

The first large scale attempts to directly measure innovation output can be traced to the 1980s, when a round of at least seven national innovation surveys were conducted (Arundel & Smith, 2013; Crespi & Peirano, 2007). These national initiatives paved the way for the first edition of the Oslo Manual in 1992 and the international effort to create a standardized innovation survey questionnaire (CIS). The Oslo-CIS template focused on the micro-perspective of the innovation process, mostly capturing innovation activity and outputs at the enterprise statistical unit level.

The first two editions of the proposed guidelines for measuring innovation – the Oslo Manual – considered innovations as new or significantly improved products or processes, which together are referred to as technological innovations (OECD, 1997). Back then, the manual mentioned organizational innovations and other creative outputs – such as artistic designs – but recommended not measuring them unless related to technological innovations[7].

[7] Many specific surveys were launched on organizational innovation (See Greenan and Lorenz, 2013).

However, several innovation surveys already provided evidence of firms declaring design and marketing innovations.[8] Since the third edition (OECD, 2005), the Oslo manual broadened the innovation scope to include organizational and marketing innovations. According to this new definition, marketing innovations can be related to the creative output of firms – such as product design or branding – which arguably can involve artistically new traits but not technical or technological new traits (Stoneman, 2010).
The first rounds of CIS-based surveys excluded service sectors from the sample, but later rounds included them. These surveys were based on the Oslo Manual guidelines and measured innovation output in the same way that they measured it in the manufacturing sector. In the discussion that follows, we refer to both the manufacturing and the service sectors.[9]

*Main direct innovation output indicators*

The main creative output indicator issued by innovation surveys is qualitative in nature and captures whether the respondent firms have achieved a product, process, or organizational or marketing innovation during a given period, often the past three years. As mentioned, one clear advantage of this indicator is attempting to capture firms becoming innovators – or continuing to be – regardless of how large the innovative leap is, how far from the innovative frontier firms are, and their ability to disentangle the different types of innovation (Simonetti et al., 1995). This is an extremely relevant trait of the vast majority of innovation surveys, which has spurred hundreds of articles about different dimensions correlating with innovation at the firm level (Arundel & Smith, 2013).

However, this strategy has proven to be hard to scale up to national indicators – such as counts or shares of innovative firms by country – due to the limited insights of their comparison (Arundel & Hollanders, 2005). We often observe economies being compared using aggregated R&D indicators but rarely using innovation indicators (Hollanders & Janz, 2013). A main problem is the critical lack of cardinality of the previous indicator. For instance, two firms innovating in their productive processes may reach different productivity gains, but both are considered equally innovative by such indicators. This situation demonstrates the limitations in capturing the degree of novelty of a given innovation (Duguet, 2006).

To overcome this limitation, three main alternatives exist: innovation counting, innovation novelty identification and innovation impact.

A set of studies – predating CIS surveys – proposed to count the number of innovations achieved by firms (Pavitt, Robson, & Townsend, 1987; Acs et al., 1988). Such a solution is limited because major and minor innovations carry the same weight in the count measure. Furthermore, innovations were still counted (by experts in Pavitt et al., 1987) beyond a subjective threshold.

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[8] For instance, Lhuillery (2001) documents that 27% and 22% of firms surveyed in the French CIS2 declared design and marketing innovations.
[9] For a discussion on the pertinence of CIS in capturing innovation in the service sector, see Drejer (2004).

Alternatively, CIS and other similar innovation surveys cope with this latter limitation by distinguishing firms attaining disruptive innovations – i.e., new to the world or market – from those reaching just new-to-the-firm innovations. Implicitly, such variations require respondents to have a perfect knowledge about the state of the technology, about either local or worldwide market structure, and to be willing to disclose it. Unfortunately, the asymmetry of information – both among heterogeneous respondents and between surveyors and respondents – has made such variation of limited value. Furthermore, the obtained leader/laggard distinction does not cover the usual concepts of radical and incremental innovation. Finally, an imitator can consider itself as a laggard or as a non-innovator.

A third and dominant innovation output indicator refers to its impact on the firm's economic performance. In particular, innovation surveys have requested the percentage of turnover related to product innovations, which is more quantitative in nature. Another main interest of this measure is that innovative sales also cover the non-R&D investments and all of the complementary assets involved in the innovation projects to achieve their success. In theory, this indicator can be easily transformed into a pecuniary form and, given the broad use in CIS-based surveys, also easily scaled-up to a macro level – e.g., country, region or even industry – for comparison purposes. However, a problem for aggregation is the difficult distinction between the zero values relating to product innovations that are market failures or still in an early stage compared with those related to non-product innovators. Moreover, this indicator suffers partially from the same limitations discussed above when splitting the innovation-related sales into those relating to new-to-the-world, new-to-the-market and new-to-the-firm product innovations. A final issue is the lack of similar inquiry for process innovation, given that the Swiss survey has requested that the percentage of costs be lowered by process innovation for the past 15 years (KOF, 2013).

*Indirect measures in innovation surveys*

Interestingly, innovation surveys have also collected information related to indirect measures of creative outputs, namely regarding patents, utility models, trademarks, industrial designs and copyrights. However, innovation surveys were typically confined to those outputs related to the product or process innovations of the firm. As such, innovation surveys as indirect measures of creative outputs is severely hampered. Not surprisingly, scholars have not used these indicators much as measures of creative output but mainly as control for appropriation capabilities of innovation. Some exceptions are the use of trademarks as proxies of innovation activities (e.g., Mendonça, Pereira, & Godinho, 2004).

The most notable exception to this trend concerns the use of patent counts issued from the first waves of CIS-based and other innovation surveys. In the past, innovations surveys captured the number of patents that were related to the product or process innovations of a firm. An interesting variation to this indicator has been to ask for the percentage of patent-protected sales (Mairesse & Mohnen, 2005). Scholars have used the patent count indicator as an indirect measure of technological innovation, particularly in industrialized economies. This idea is supported by Crepon et al (1998), who found a near unit elasticity of patent counts with respect to R&D capital intensity. Mairesse and Mohnen (2005) tested the similarities between several technological innovation outputs against three patent indicators from innovation surveys, finding limited differences in terms of R&D intensity and firm size elasticities.

However, the patent count indicator has lost terrain lately, disappearing from the most recent CIS-based surveys. Several limitations at least partially explain the declining trend in the use of patent counts from innovation surveys. First, and it will be discussed in further detail later, patents have limits as a measure of innovation. Second, patenting is an extremely skewed phenomenon to measure, even more so than performing R&D or innovating. This measurement difficulty is worse in developing economies, where the patent system is rarely used and much of the innovation by firms concerns the acquisition and use of preexisting technologies, which by definition are not patentable. Finally, the quantitative advantage of patent counts is in many cases deceptive because patent unit record data has shown that patents are often misrepresented in innovation surveys (Raffo & Lhuillery, 2008). This misrepresentation can likely be explained, at least partially, by: (i) the fact that patenting activities are often centralized at the firm's headquarters, rendering respondents at remote units unaware of the precise amount of patenting activity; (ii) patents have many dates – priority filing, subsequent filing, grant, expiration, etc. – which make it confusing to non-expert respondents to state how many patents were filed (or are active) in a certain period, and (iii) the same patent can be filed in many different jurisdictions, and innovation surveys have done little to account for patent applications corresponding to the same technologies, i.e., patent families. Martínez (2011) showed that approximately two-thirds of patent applications filed in the US, France and Germany are also filed elsewhere. Moreover, Martínez found that approximately one quarter of patent families have complex structures that can lead to bias in patent counting.

### *3.2 Indirect measures of innovation outputs*

*IP unit record data*

Basberg (1987), Pavitt (1985), and Griliches (1990) shared the conclusion that patent statistics are a relatively good proxy for measuring innovation, but are not without limitations. IP unit record data documents contain broader and more useful information on creative activities and output than patent statistics. Arguably, patents, trademarks, industrial designs, copyrights and any other form of IP reflect, to some extent, the inventive, innovative, artistic and other creative activity occurring within a firm.

Contrary to data issued from innovation surveys, IP data were not originally conceived to be used in innovation or other statistics. Each form of IP is simply a government-sanctioned exclusive right, granted for a set amount of time, which typically leaves a paper trail. For instance, to obtain patent protection, an applicant must disclose information about the invention to the public, and the invention must meet the patentability criteria of novelty, non-obviousness and industrial application. The requirement of disclosure and the examination of patentability led to the creation of patent documents databases, which eventually allowed scholars to compute patent statistics. IP statistics is thus a by-product of a legal system and, therefore, subject to legal and institutional idiosyncrasies across countries and, many times, among sectors.

By all accounts, patent bibliographical information is the most sourced IP unit record data. Patent counts, in particular, have been found to approximate technological innovative outputs fairly well at the national (e.g., Basberg, 1987; Kortum & Lerner, 1998), regional (e.g., Acs, Anselin, & Varga, 2002) and micro levels (e.g., Zvi Griliches & Lichtenberg, 1984). In principle, patent counts can quantify both process and product innovation, but in practice, making such a distinction can be difficult. Moreover, at least in some jurisdictions, such as the US, patents can cover non-technological innovations, such as business or financial methods and software (Allison & Tiller, 2003; Lerner, 2008). However, service sector firms are less prone to using patents (Edler et al., 2003).

Many jurisdictions – but not the US – allow for utility model protection, which is an IP instrument similar to patents but typically with a lower inventive threshold and shorter exclusive right protection. Scholars have found – particularly in the case of Asian economies – that utility models better reflect innovative activity than patents in the early stages of industrial development (Kim, Lee, Park, & Choo, 2012).

In following patents, it can be observed that trademark unit record data are likely the other IP unit record data more frequently sourced. Trademark counts approximate marketing innovation as closely related to brand and marketing strategies (Millot, 2009). Additionally, trademark counts can approximate product innovations (Mendonça et al., 2004). In this respect, some argue that trademarks are a better indicator of product launches than patents due to less selectivity and being closer to market entry (Hipp & Grupp, 2005). In some cases, trademarks can also point to other creative and more artistic outputs, such as sounds (jingles), text (slogans) or shapes (packaging) (Stoneman, 2010).

Historically, scholars and policymakers have made less use of unit record data than other forms of IP despite their valuable information. Industrial designs can, for example, indicate product and marketing innovations (Walsh, 1996). However, most industrialized economies observe more patent and trademark applications than industrial design applications, which may explain the lower amount of interest in using such an indicator (WIPO, 2014). In turn, copyrights can approximate several different creative outputs within the firm. For instance, some firms have sought copyright protection for their designs or package inserts. Nevertheless, the fact that copyright unit record data are fed on a voluntary basis has made them of limited value, particularly to monitor creative outputs within the firm.

*Advantages and limitations of IPR sources*

The richness of IP unit record data allows us to go beyond the simple IP counts provided in innovation surveys. First, there is the possibility of constructing IP stock measures for firms over time, which can provide metrics for the accumulation and path dependence of knowledge and creative capabilities, offering a more accurate indicator of technological and artistic capabilities (Park and Park, 2006). Firms holding IP rights must actively maintain them during their limited (e.g., patents) or unlimited (e.g., trademarks) time span. For instance, the decay of the number of patents in a patent portfolio can be an interesting indication of the depreciation of R&D assets (e.g., Bessen, 2008). Firms may as well seek protection for the same IP in different countries, reflecting the geographical distribution of their market of interest and existing competition. In addition, firms may hold the same IP right in different countries but not for the same duration, indicating when the marginal benefit from holding the IP no longer covers the marginal cost of holding it in each country. In spite of this, we have limited information regarding IP families beyond those that include patents and utility models.

Second, IP examination – particularly in the case of patents – imposes a threshold on the innovation novelty. On the one hand, thresholds avoid the comparability problems of innovations only being new-to-the firm. On the other hand, thresholds prevent the analysis of the subset of laggard innovators if they do not file for IP. In this respect, patent examination makes counts of granted patents a more reliable source than counts based on patent applications (Guellec & van Pottelsberghe de la Potterie, 2000), even if national differences in the required inventive step exist (Ordover, 1991). However, many IP collections do not trace refusals and withdrawals, which, in addition to the important and growing examination backlog in many countries, advocates instead for the use of IP filing information. In the case of patents, examination is not the only approach for handling the unobserved value of inventions. One typical way is to make use of forward citation information to measure the value of the invention (Harhoff et al., 2003). Another way is to consider the information about the patent family, such as international size (Harhoff et al., 2003) or the simultaneous filing at the USPTO, EPO and JPO (Dernis & Khan, 2004). Renewal, fast-track search requests, accelerated examination requests, filing routes, oppositions, litigations or the number of claims can also be considered as signals correlated with patent values (Van Zeebroeck & Van Pottelsberghe, 2011; Lanjouw & Schankerman, 2004).

Third, the use of IP unit record data allows empirical studies to dissociate the categorization of innovations from the one of innovators, which is particularly useful when comparing the innovator's industry with the innovation's technological field or type. For instance, a firm of a given industry may hold in its portfolio many patents or utility models that were classified in several different technological fields according to national or international classification of technologies – such as the IPC or the CPC. Similarly, one firm can hold industrial designs classified as different products – using the Locarno classification – or trademarks from different industries – using the Nice classification. The Nice classification even allows for the broad distinction between product and services trademarks, which is a valuable trait of the trademark data (Hipp & Grupp, 2005).

Fourth, in the case of patents, citations data can be used to track knowledge flows or spillovers.  Such data have been used to localize in space knowledge flows and particularly, the spillovers of public research work (Jaffe, Trajtenberg, & Henderson, 1993).  There is evidence that not all patent citations are appropriate indicators of knowledge flows because many patent citations are not introduced by the inventors (Alcácer, Gittelman, & Sampat, 2009) and reflect duplicative effort (Baruffaldi & Raffo, 2013).

Patents capture better invention than innovation (Griliches, Pakes, & Hall, 1988).  Inventions tend to be the result of R&D activities, but not all inventions are patented, either because the inventions do not meet the criteria of patentability or because the inventor prefers other legal means of protecting his intellectual property or other appropriation tools that can be less costly and more efficient (Giuri et al., 2007;  Cohen, Nelson, & Walsh, 2000).  The same remarks hold for other types of new knowledge, including artistic creations.  Many artistic creations by firms never seek protection as trademarks, industrial designs or copyrights. However, the work of many artists and firms who do seek protection for their creations is never used commercially.

## 4. Conclusions

The present review addressed how measurement is conducted by scholars and statisticians. We observed that either inputs or outputs have been expanded over time to escape from restricted scientific and technological considerations.  By highlighting the use and the problems and limitations, we provided some insights into the future development of indicators of creativity that are, despite some efforts, still far from being diffused and standardized in international surveys.  Multiple level questionnaires, big data and complementarity analysis should consolidate the current improvements.

The present overview paid limited attention to the measurement of critical social conventions and institutional environments.  Tools can measure the declared role of public research organizations or the use of intellectual property rights.  However, it remains difficult to measure these elements completely.  A solution of innovation surveys is to measure the obstacles likely to identify the different boundaries that surround firms.  The obstacles are usually biased because they are identified merely when innovation and creativity are experienced (D'Este et al., 2012).  A further problem is that the creative environment must also be considered at the personal level and not only at the firm level.  A promising solution for capturing the context of where individual creativity takes place would be to issue questionnaires to both employers and employees (Greenan and Lorenz, 2013).

Technology has changed and will further change the type and the way data are collected. Online surveys, e-administrative records, internet data and social media data provide new opportunities (Sauermann and Roarch, 2013; Geuna et al., 2015), even if confidentiality remains a serious problem. We have discussed how the digital collection of IP unit record data has increased the scope of possible creative outputs analysis. This has been the case for patent data in the last two decades and we are now observing a new and rising trend for recently available bulk trademark unit record data (Graham, et al., 2013). It is not hard to foresee that other equivalent unit record data in digital form – e.g., industrial designs or copyrights – will follow a similar a trend. The measurement of artistic activities should thus be eased. Technology also changes creativity and innovation processes. The scanty use of the distinction between labor costs, material costs and capital costs available from standard R&D surveys remind us of the unawareness of the role of instruments and material in R&D and creative activities (See Stephan, 2012; Lane et al., 2015). This is an overlooked avenue for R&D activities but also for artistic activities in firms that are, to a certain extent, computerized.

The measurement of innovation inputs and outputs has made important progress over the last 20 years. A last challenge will be to articulate these various measures and to measure the complementarity or substitutability among innovation inputs for the production of new knowledge (innovativeness) or the complementarity or substitutability of innovation outputs for firm performance (productivity). The multiplicity of the inputs and outputs now available is a critical problem. A solution is to use multiple equation models to examine the decisions regarding innovation inputs or innovation outputs where the positive correlation among residuals is a test for complementarity (Arora and Gambardella, 1990; Belderbos et al., 2004). An alternative solution is to test complementarity among innovation inputs, comparing their sole and joint impacts on innovation outputs (e.g., Cassiman and Veugelers, 2006) or the synergies between technological and non-technological innovation outputs on performance (Justin Doran, 2012; Ballot et al., 2015). A difficulty with the last supermodularity tests is that the number of explanatory sets that can be introduced into econometric equations rises exponentially (Carree et al., 2011). Thus, other methods should be kept in mind (See Ichniowski et al., 1997; Battisti & Stoneman, 2010).

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