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A simple index of innovation with complexity

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ABSTRACT

Patents are the main source of data on innovation. Since most of the innovative activity happens outside of the patenting system, and since patents –and innovations- have different quality, complexity, and impact on each market, unweighted sums of patents and proxies are an imperfect indicator of a country's innovative activity. I generate two very simple indices of innovation (one dependent on the size of a country, and another that normalizes country-size), based on weighting patents and exports by a complexity measure. Each index captures the technological complexity of innovations inside and outside the intellectual property rights system. I empirically analyze the rankings of these innovation indices, and contrast the results with technological development, GDP, and the existing mainstream innovation index.

Introduction

Along history, innovation metrics have evolved consistently from input measures of innovation, such as R&D expenditure, to output measures, such as patent counts, and then to composite indicators. The awareness of patents being a biased measure of innovation made composite indices and rankings popular, even though these indices rely heavily on patent counts that do not take into account the differences in inventive steps across patents. Moreover, most composite indices use a large number of proxies to account for different types of innovation, and how much innovation these proxies account for is, in many cases, doubtful.

Either as a simple counting indicator, or as part of a composite index, patents have become the standard measure for innovation in most disciplines. Indeed, patents are public and available information. There are, however, numerous concerns that patent counts may be a biased and imperfect measure of innovation. For example, simply adding patents without any measure of the quality of the invention (e.g. inventive step covered by a patent), inflates the measure of innovation for countries where most patents are just small inventive steps from previous inventions. Similarly, the unweighted sum of patents ignores the sophistication and complexity of each innovation, and just assumes that all patents have the same innovative content and impact.

Furthermore, most inventive activity happens outside of the patenting system (Moser, 2013). Keeping an innovation as a secret can be a dominant strategy over patenting when the cost of secrecy is lower than the potential loss of imitators "inventing around" once the innovation has been disclosed. There is empirical evidence suggesting that the complexity of the invention is an effective deterrent for imitators, as the cost of copying the new idea (e.g. reverse engineer) increases with complexity (Fernandez Donoso, 2014).

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How can we accurately measure innovation when most of it stays outside of the formal intellectual property rights system? How does one generate a measure of innovation that incorporates complexity or sophistication differences across inventions? This paper offers two simple, computable and comparable metrics to compare innovation across economies. These metrics have the virtue of reducing the bias of adding patents, without the need of looking for large sets of innovation proxies.

Using a very simple method, I generate a normalized index of innovation that incorporates differences in the complexity at the industry level for patents and exports. Though the index is improvable, the rankings of computing the index are consistent with intuitive results, such as the correlation with technological development.

This remainder of this paper is organized as follows. Next section discusses different measures of innovation used along history and their limitations. Section 3 explains the calculation of the indices. Section 4 shows the empirical results. Final section concludes.

2. Metrics of innovation

2.1. Overview of innovation metrics

The first generation of innovation measures, mostly based on input indicators, date from the late 1950s to mid 1960s (e.g. National Science Foundation surveys in the United States). Input measures (e.g. R&D expenditure, number of scientists, etc.) were typically used as proxies to innovation metrics. Countries compared their performance by comparing their R&D measures, ignoring the limitations of the definitions of these measures, and the endogenous role of governments in using these type of metrics to compare public policies to other countries (e.g. R&D in socialist economies and OECD in the 70s and 80s). Though the limitations of R&D measures are self-evident, their use has not been completely ruled out, as there are no available output measures of R&D in health or education sectors.

Many contributions intended to accurately measure those activities in R&D that do matter to innovation and technology change, and to develop international standards for R&D measurement. Among them, the Frascati Manual (2002) theoretically breaks up activities that should be excluded from R&D measurement by splitting them between novelty and routine. If a given activity "follows an established routine pattern," it should be excluded from R&D, while if it "departs from routine and breaks new ground, it should be qualified as R&D."

While this distinction between novelty and routine activities helps to construct an accurate measure of R&D, it does not provide a clear definition of innovation, or of how to measure it at the firm, industry, and country level. The reason for this lies in the fact that not all innovative activities are developed in laboratories or plants with full-time qualified research staff. Measures of R&D are a good statistic to infer professional R&D activity, but they fail to account for important inventions made by private inventors or entrepreneurs. Moreover, if this type of "informal" R&D was somehow negatively correlated with the technological complexity of the industry, then R&D measures would underestimate the amount of innovation input for many industries, and particularly for poor and middle-income countries, as their technological development is lower (Fieler, 2011).

The second generation measures (1970s–1980s) focused on innovation outputs, such as patent applications, publications, or licensing. Patenting a new product variety, input, or process requires paying a fixed cost, in exchange for the inventor to earn a legal monopoly right over its invention. If the monopoly profits over the time of the patent exceed the fixed cost of the patent, one would expect that all profitable innovations ought to be patented.

Consequently, the fact that since 1900 the share of individual patents have declined, while corporate patents have increased their share (Freeman & Soete, 2009), means that most innovative activity happens within the boundaries of specialized R&D laboratories and departments of firms, government, and academia. If the patenting story holds, something does not add. According to the 2008 U.S. Census R&D and Innovation Survey (NRDIS), for 85% of surveyed firms, trademarks are not important. Moreover, for 96% of surveyed firms utility patents are not important, and for 95% of them design patents are not important for business. Only by splitting the sample and selecting those firms that engage in formal R&D activity, these numbers decrease (though 67% consider design patents as not important, and 85% thinks of them as not or somewhat important).

In fact, patents have shown to be an imperfect proxy for innovation. First, not all innovations are patentable, as States have exclusions for some innovations. Second, the enforcement of the patent is private, which means that if the patent is imitated without the owner's consent, the owner must take action at nonzero cost, i.e. legal costs and uncertain outcome. If the outcome probabilities depend on the legal costs (e.g. more qualified and expensive lawyers), it is straightforward that smaller firms will patent less than large corporations will. Third, firms may engage in strategic patenting if the size of a patent portfolio increases bargaining power in patent disputes (Noel & Schankerman, 2013), or if it affects the ability of other firms to develop a similar patentable innovation (Stiglitz, 2014). Third, if there is a fixed cost of imitation, i.e. product complexity (Fernandez Donoso, 2014) or the timing of shorter product cycles (Bilir, 2013), there is no incentive to patent an innovation, since the cost of imitation for a potential rival exceeds the profits of imitating. Finally, only "successful" innovations are patentable, meaning that all trial and error are omitted from the measure.

These limitations of patent counts as an output statistic were at the origin of the development of innovation output indicators. Some of these indicators were based on innovation surveys, within the framework of the Oslo Manual (2002). The manual defines innovation as follows: "An innovation is the implementation of a new or significantly improved product