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Invention in the city: Increasing returns to patenting as a scaling function of metropolitan size

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Abstract

We investigate the relationship between patenting activity and the population size of metropolitan areas in the United States over the last two decades (1980–2001). We find a clear superlinear effect, whereby new patents are granted disproportionately in larger urban centers, thus showing increasing returns in inventing activity with respect to population size. We characterize this relation quantitatively as a power law with an exponent larger than unity. This phenomenon is commensurate with the presence of larger numbers of inventors in larger metropolitan areas, which we find follows a quantitatively similar superlinear relationship to population, while the productivity of individual inventors stays essentially constant across metropolitan areas. We also find that structural measures of the patent co-authorship network although weakly correlated to increasing rates of patenting, are not enough to explain them. Finally, we show that R&D establishments and employment in other creative professions also follow superlinear scaling relations to metropolitan population size, albeit possibly with different exponents.
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1. Introduction[2]

Inventors and innovators do not operate in isolation; the creation of new ideas is a process that very often involves the integration and recombination of existing knowledge originating from different individuals, locations, institutions and organizations (Lenski, 1979; Mokyr, 2002; Fleming, 2001). The size, density and compactness of urban centers foster interpersonal interactions, thus creating greater opportunities for enhanced information flows. As a result, historically cities have been the places where much innovation has occurred. The privileged role that cities have played in the development of science and technology, and more broadly, in the generation of inventions and

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innovations – intellectual and material, cultural and political, institutional and organizational – has been well documented by historians, urbanists, geographers, anthropologists and regional economists (Mumford, 1968; Pred, 1973; Jacobs, 1984; Hawley, 1986; Bairoch, 1988; Mokyr, 2002; Braudel, 1992; Hall, 1998; Feldman and Audretsch, 1999; Redman, 1999; Varga, 1999; Spufford, 2003; Algaze, 2005).

More recently the role of cities as centers for the integration of human capital and as incubators of invention was rediscovered by the "new" economic growth theory, which posits that knowledge spillovers among individuals and firms are the necessary underpinnings for growth (Romer, 1986, 1990; Lucas, 1988). As Glaeser (1996) points out, the idea that growth hinges on the flow and exchange of ideas leads naturally to the recognition of the social and economic role of urban centers in furthering intellectual cross-fertilization. Moreover, this process is self-reinforcing. The creation and concentration of knowledge in cities increases their attractive pull for educated, highly skilled, entrepreneurial and creative individuals who, by locating in urban centers, contribute in turn to the generation of further knowledge spillovers (Feldman and Florida, 1994; Glaeser, 1999; Florida, 2002, 2004). This seemingly spontaneous process, whereby knowledge produces growth and growth attracts knowledge, is the engine whereby urban centers sustain their continuous development through unfolding innovation.

It is therefore a compelling question to ascertain which features of urban societies foment, or hinder, invention and innovation. To step in this direction we need quantitative measures of innovation. Historical evidence notwithstanding, it is not easy to measure knowledge spillovers (a problem discussed by Krugman (1991)). This difficulty hampers progress towards the quantitative understanding of the relationship between urban characteristics and innovation. Some knowledge flows do nevertheless leave an evidentiary trail in the form of patented inventions (Acs and Audretsch, 1989; Malerba and Orsenigo, 1999; Jaffe et al., 2000; Jaffe and Trajtenberg, 2002).[3]

Patenting in the United States is and has always been largely an urban phenomenon, from the earliest stages of the nation's industrialization in the 19th century (Pred, 1966; Feller, 1971; Higgs, 1971; Sokoloff, 1988) and continuing during the first half of the 20th century (Ullman, 1958; Thompson, 1962). More recent studies have confirmed the importance of a metropolitan setting for the inventive process. Jaffe et al. (1993), in an examination of patent citations by new to previously issued patents, find that new patents are 5–10 times more likely to cite previous ones originating from the same metropolitan area. O'hUallachain (1999) confirmed that most of the patents issued in the United States are awarded to residents of metropolitan areas. Acs et al. (2002) also find that patenting in the United States is overwhelmingly concentrated in metropolitan counties, while Carlino et al. (2005) reaffirm that large metropolitan size and high metropolitan density favor patenting.

Based on this evidence we expect a close and positive relationship between city size and inventive activity.[4] Higher concentrations of individuals and firms in larger cities can be expected to sustain a larger repertoire of intellectual capabilities, thereby facilitating the creation and recombination of ideas. This environment in turn attracts creative individuals and firms to locate in cities thus sustaining a "virtuous" cycle of invention and innovation.[5] In the present discussion, we investigate the quantitative relationship between patenting activity and the size, measured in terms of population, of metropolitan areas in the United States over the last two decades. In particular, we will seek to identify whether this relationship is an instance of a general scaling relation. Issues of scaling are deeply involved in the study of systems whose macroscopic behavior emerges from general micro-level interactions among the system's constituent units (Chave and Levin, 2003). As discussed further on, a scaling relationship between metropolitan size and inventive activity is indicative of general organizational principles replicated across different metropolitan areas, of different sizes.

It is only a slight exaggeration to say that the most important attribute of a city is its size; it matters, because it is the most obvious and all encompassing manifes-

[3] We are well aware of the criticism that patents are not necessarily good indicators of generic innovative activity since not all new inventions are patented, and many economically important types of innovations (for example a musical theme, an architectural design, a children's story, an advertising campaign, a business model or computer software) cannot even be patented (Griliches, 1979, 1990; Pakes and Griliches, 1980). While these caveats make us cautious about the use of patent data and prudent in the interpretation of our results, we nevertheless see patents as the "footprints" of some (by no means all) inventive activity.

[4] We will use the term "inventor", in a rather restrictive way, to refer to those individuals who have been granted a patent for their invention. As in Kuznets (1962) we see "inventive activity" being concerned with technical inventions, involving the creation of new knowledge and the combination of existing knowledge.

[5] This expectation is a variant of the familiar argument that increases in urban scale generate greater positive externalities (Marshall, 1890; Jacobs, 1969).

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