2010

Opening up the 'Jacobs Spillovers' black box: local diversity, creativity and the processes underlying new combinations

article version: accepted manuscript

Desrochers, Pierre

Leppälä, Samuli

Desrochers, P., & Leppälä, S. (2010). Opening up the 'Jacobs Spillovers' black box: local diversity, creativity and the processes underlying new combinations. *Journal of Economic Geography*, 11(5), 843-863.

This is a pre-copyedited, author-produced version of an article accepted for publication in *Journal of Economic Geography* following peer review. The version of record, Desrochers, P., & Leppälä, S. (2010). Opening up the 'Jacobs Spillovers' black box: local diversity, creativity and the processes underlying new combinations. *Journal of Economic Geography*, 11(5), 843-863 is available online at: <https://doi.org/10.1093/jeg/lbq028>

HOW TO CITE TSPACE ITEMS

Always cite the published version, so the author(s) will receive recognition through services that track citation counts, e.g. Scopus. If you need to cite the page number of the TSpace version (original manuscript or accepted manuscript) because you cannot access the published version, then cite the TSpace version **in addition to** the published version using the permanent URI (handle) found on the record page.

Opening up the “Jacobs Spillovers” Black Box: Local diversity, creativity and the processes underlying new combinations.

Abstract

Despite numerous attempts to isolate the respective importance of intra- and inter-industrial localized knowledge spillovers, their underlying processes have remained hidden. This paper aims to provide a better theoretical understanding of the nature of inter-industrial or ‘Jacobs spillovers’ through a broad interdisciplinary literature review and additional evidence gained from a qualitative survey of Canadian inventors. The main stylized processes identified are: 1) adding to, switching or adapting specific know-how to other product lines; 2) observing something and incorporating it in another environment; and 3) formal or informal collaboration of individuals possessing different skills and backgrounds. Local economic diversity was found to facilitate these processes in several ways.

Keywords: knowledge spillovers, Jane Jacobs, local diversity, creativity.

JEL classifications: O18, O31, R11, L60.

1. Introduction

Following Glaeser et al.’s (1992) influential paper, several econometric studies have attempted to assess the relative importance and impact of localized knowledge spillovers¹ through the lenses of economists Alfred Marshall (1890), Kenneth Arrow (1962) and Paul Romer (1986) (known by the acronym MAR); management scholar Michael Porter (1990); and urban theorist Jane Jacobs (1969). While they differ on the issue of firm size and number (one large versus several smaller competing firms), MAR and Porter emphasize the relatively greater economic importance of intra-industrial knowledge spillovers that result from the frequent interaction of workers possessing similar or closely related skills, a stance which supports the regional specialization of economic activities as a more innovative setting. By contrast, Jacobs is said to argue that local economic diversity facilitates interactions between individuals possessing different

knowledge bases, resulting in more innovation and better economic performance. Various analysts have claimed statistical evidence on behalf of either or both types of spillovers using empirical tests based on unrelated inputs (greater or lesser regional diversity or specialization of larger or smaller firms) and outputs (such as Research & Development expenditures, patents, job creation, economic growth per capita and innovation counts) (Beaudry and Schiffauerova, 2009).

The MAR-Porter-Jacobs studies, however, have been criticized on at least two fundamental levels. The first is that knowledge spillovers account for whatever measure of growth or innovation is arrived at, a stance which neglects the obvious importance of factors such as urbanization economies, a sudden increase in the global demand for some locally-produced goods or services, and the fact that a growing economy is more likely to attract diverse types of businesses than a stagnant one (Brenner, 2007; Hansen, 2002; Henderson, 2007; Polèse, 2005). The second is that “virtually no contribution has explored the ways in which knowledge is actually transferred among people located in the same geographic area” and that knowledge spillovers are a convenient ‘black box’ providing researchers “with an escape route to avoid studying the specific mechanisms through which [geography and innovation] are linked” (Breschi and Lissoni, 2001, 994 and 976). In a recent review of sixty-seven such studies, Beaudry and Schiffauerova (2009: 320) not only observe that the “exact spillover mechanism is not yet fully understood and documented,” but also that there is “no direct proof of the existence of knowledge spillovers” and that “there probably never will be.” In a recent meta-analysis,

¹ Our discussion of knowledge spillovers does not assume that they are necessarily knowledge *externalities* for two reasons. First, not all important knowledge transmission mechanisms are externalities in the economic sense (Breschi and Lissoni, 2001). Second, in empirical research, as in our case studies, the

de Groot et al. (2009) found that while the positive effects of diversity seem stronger, it is also the case that different aspects of study designs influence outcomes. In addition, another meta-study by Melo et al. (2009) found that estimates for agglomeration economies, more broadly, may have little relevance beyond specific empirical contexts. Puga (2010) further argues that among the causes of agglomeration economies, learning in cities and its microeconomic foundations are the least understood (see also Rosenthal and Strange, 2004). Disaggregated and more detailed approaches could thus improve our understanding of the root causes of knowledge spillovers and observed differences between empirical studies.

The criticism levelled at the various methodologies and indicators used in the localized knowledge spillovers literature should not be considered surprising inasmuch as they do not radically differ from those used in previous and similarly unsatisfactory studies on the measurement of local diversity and of technology flows between industries.² Following Hansen (2002), we suggest that the only way forward in this debate is to document how innovative know-how is actually created, diffused, adapted and combined by *individuals* with different occupations, skills and backgrounds. Because much has already been written on localized intra-industrial knowledge spillovers in numerous qualitative studies of ‘industrial districts,’ ‘innovative milieux,’ ‘clusters,’ ‘regional systems of innovation’ and ‘learning regions’ (Rutten and Boekema, 2007), our focus is on Jacobs (or localized inter-industrial) spillovers.

criteria of knowledge externality (i.e., free and unpreventable benefits for third parties) are hard if not impossible to certify.

² Econometric studies on the latter topic have been conducted under various labels such as ‘inter-industry technology flows,’ ‘technological convergence,’ ‘techno-economic paradigms’ and ‘general purpose technologies.’ Attempts to measure local diversity were often motivated by ‘local economic base’ and ‘portfolio’ considerations. The main conceptual problems of these studies are examined in more detail in Desrochers (2001).

The remainder of the paper is structured as follows. Section 2 discusses the emergence and shortcomings of ‘Jacobs spillovers’ in the economics literature and identifies precedents of this perspective. We then review the economic and cognitive rationales underlying new combination of existing artifacts, materials and know-how. In section 4 we further document these patterns and discuss the importance of local economic diversity and the recent ‘related variety’ controversy through illustrative evidence collected in two qualitative surveys of Canadian individual inventors. Drawing on this material, our conclusion contains further thoughts on the current ‘creative class’ and ‘social proximity’ debates. As such, our contribution is limited to theory-building and does not attempt to isolate or measure the specific impact of Jacobs spillovers.

2. Local Economic Diversity and New Combinations

Jane Jacobs’ (1969: 3) own favorite book, *The Economy of Cities*, was the outcome of her “curiosity about why some cities grow and why others stagnate and decay.” Looking at cities as problems in organized complexity, she developed a dynamic theoretical framework that combined previously unrelated issues and insights gleaned from a wide array of sources and disciplines. Without getting into the details of her contribution, she proposed a new theory of agricultural origins and discussed, among other subjects, the sources of technically innovative behavior, the relocation of mature urban industries to rural areas, the importance of agglomeration economies for new business formation, the sources of financial capital for new ventures and the economic impact of political barriers to entry in various lines of work. Her overall conclusion was that high and sustained levels of innovative behavior and entrepreneurship inevitably result in the increased diversification and complexity of the local economic base over time and that a diversified

urban economy provides the best setting for entrepreneurial and innovative behavior. As she would argue in a later book: “The usefulness of cities is that they supply contexts... in which insights and adaptations can be successfully injected into everyday economic life” (Jacobs 1984: 193).

Lucas’ (1988) and Glaeser et al.’s (1992) characterization and emphasis of what came to be known as ‘Jacobs spillovers,’ however, is better understood as a rejoinder to then current debates on the *New Growth Theory* (NGT). In short, while NGT theorists’ highlighted the importance of human capital and knowledge spillovers, their effort amounted to developing “a theory of knowledge production that tries to do an end run around describing the creative act that produces the new ideas” (Weitzman, 1998: 332). The Jacobsian insight that Glaeser et al. (1992: 1131–1132) deemed most relevant in this context was that “the crucial externality in cities is cross-fertilization of ideas across different lines of work.” As Jacobs (1969: 59) indeed observed, “the greater the sheer numbers and varieties of divisions of labor already achieved in an economy, the greater the economy’s inherent capacity for adding still more kinds of goods and services. Also the possibilities increase for combining the existing divisions of labor in new ways.”

Most of Jacobs’ examples illustrating the importance of local economic diversity, however, are entrepreneurial in nature and typically involve the launching of a spin-off or start-up business that occupies a new niche by building on existing skills and diverse local suppliers and customers. For instance, a “chest and wardrobe manufacturer is starting, for a fee, to analyze what is wrong with one’s household or office storage arrangements; a playground designer is starting to make and sell equipment for playgrounds and nursery schools; a sculptor is starting a line of jewelry” (Jacobs 1969:

53–54). Consistent with the Glaeser et al. (1992) framework, however, the various (and typically imprecise) definitions of ‘Jacobs spillovers’ used in later econometric studies refer to cases of technology breakthroughs or transfers involving the application of skills and know-how used in one context to another existing business active in a different line of work. To our knowledge, the only such straightforward case provided by Jacobs (1969) herself involves the transfer of skills used in making and setting of sails to the creation and display of a huge street banner when a retired sailmaker was called upon by protesters. Another relevant issue in this context is that most analysts of localized knowledge spillovers have ignored Jacobs (1969: 61) comment that while industrial classification systems are useful for some type of analysis, “insofar as they are relevant at all to understanding how old work leads to new, they interfere with our understanding.”³

As we will later argue in more detail, the Jacobs spillovers argument is commonsensical in light of what is known about human creativity, at least inasmuch as innovations are always the results of new combinations of pre-existing know-how, skills, ideas, processes, materials and artifacts (Sternberg, 1999; Gassman and Zeschky, 2008). The pairing up of local specialization and creativity, however, seems odd and results perhaps from the mistaken application of the idea of specialization from the individual to the regional level (Leppälä and Desrochers, 2010). To sum up, creativity “generally involves crossing the boundaries of domains” while creative people typically “love to make connections with adjacent areas of knowledge” (Csikszentmihalyi, 1997: 9). Indeed, successful creative individuals tend to be “ever alert to what colleagues across the fence [i.e., in other disciplines] are doing” (idem: 88). In this context, creativity can be defined

³ The functional (as opposed to end use) classification of the patent system is less problematic in this respect, although patent data have other problems of their own (Desrochers, 2001).

as “any act, idea or product that changes an existing domain or that transforms an existing domain into a new one,” while a creative person is “someone whose thoughts or actions change a domain, or establish a new domain” (idem, 28).

Prominent economic analysts going back at least to Adam Smith have taken note of the combinatorial nature of innovation (Desrochers, 2001). For example, Usher (1929: 11) observed that invention “finds its distinctive feature in the constructive assimilation of preexisting elements into new syntheses, new patterns, or new configurations of behavior.” Ayres (1943: 113) wrote that “the history of every material is [...] one of novel combinations of existing devices and materials in such a fashion as to constitute a new device or a new material or both.” Machlup (1962: 156) distinguished between the ‘retardation school’ of technological change whose proponents believed that “the more that has been invented the less there is left to be invented” and the ‘acceleration school’ according to which “the more that is invented the easier it becomes to invent still more” because “every new invention furnishes a new idea for potential combination with vast numbers of existing ideas” and the “number of possible combination increases geometrically with the number of elements at hand.” This latter idea of ‘recombinant growth’ was more recently formalized by Weitzman (1998).

Perhaps not surprisingly in this light, a few writers anticipated the ‘Jacobs spillovers’ argument before Jacobs. For example, the social theorist Herbert Spencer (1889/1857: 52) viewed the “evolution of a homogeneous society into a heterogeneous one” as the inevitable result of innovative activities and an ever-increasing division of labor. For example, the development of bronze meant that in time some people specialized in its production, while others developed from it artifacts that were previously made of stones,

bones and other materials, while others found for it hitherto unknown uses. Millennia later, the advent of the steam engines drastically impacted different lines of work such as mining, transportation and manufacturing activities. Describing these cases along with the countless economic and social impacts brought by the railroad on the already diversified British economic base, Spencer (idem: 55) observed that these were but a few illustrations of a widespread pattern of outcome, i.e., that a developing society had been “rendered more heterogeneous in virtues of the many new occupations introduced, and the many old ones further specialized.” He further added that in settings characterized by a “fixed and multiplying community” which were already more heterogeneous, “the results are in a yet higher degree multiplied in number and kind.”

Conversely, the negative impact of a specialized local economy on the creative potential of its inhabitants was obvious to the geographer and economist Malcom Keir (1919: 47):

From the point of view of employees, [geographically-specialized] localization is bad because it also tends toward narrowing the minds of the townspeople. A young man brought up in Fall River [Massachusetts], say, has but little choice of occupation; he must become a weaver or a loom-fixer or some other artisan connected with cotton manufacture, because by upbringing, education and example he is forced into that path, and furthermore he goes to work at an early age. It may happen that many a square peg is rammed into a round hole in this way, or a life constricted which might under better conditions have expanded. There is something deadening to the human mind in uniformity; progress comes through variation, therefore in a town of one industry a young man loses the stimulus for self-advancement.

In his discussion of the “interdependence of knowledge of the various parts of the universe in which we human beings operate” such as, for instance, when “discoveries and inventions in the field of tensile strength of metals contribute to discoveries and inventions in the field of electric currents,” the economist Simon Kuznets (1960: 328–329) observed that “creative effort flourishes in a dense intellectual atmosphere, and it is hardly an accident that the locus of intellectual progress (including that of the arts) has

been preponderantly in the larger cities, not in the bucolic surroundings of the thinly settled countryside.” This was attributable to the “existence of adequately numerous groups in all fields of creative work” and the “possibility of more intensive intellectual contact, as well as of specialization, afforded by greater numbers.”

In summary, we suggest that the discussion of ‘Jacobs spillovers’ predates Jane Jacobs’ writings; that the argument that greater levels of local economic diversity will increase the probability of new combinations being created is uncontroversial; and that the processes underlying ‘Jacobs spillovers’ have remained an intellectual black box. We will now attempt to gain a better theoretical understanding of the latter issue by examining briefly the processes underlying new technological combinations.

3. On the Processes Conducive to Inter-industrial Knowledge Spillovers⁴

The fact that most innovations developed for some specific purposes end up having numerous other uses is as old as the varied uses of wood and bones in weapons, tools, jewelry and housing or the uses of fire in lighting, cooking, heating, as a weapon and to clear up land. Among well-known recent examples are Post-it Notes (developed from a weak glue without any initial useful application); tea bags (first used as packaging for loose tea samples); Teflon (mechanical lubricant), and microwaves (unexpected discharge from a radar system) (Berkun, 2007: 41). While the phenomenon is ubiquitous, its economic and creative rationale are rarely discussed in the MAR-Porter-Jacobs

⁴ Following the localized knowledge spillovers literature, our discussion is essentially limited to new technological combinations, but the same principles obviously apply to managerial and financial innovations.

literature.

Economic rationale and analysis of inter-industrial knowledge spillovers

A more concrete examination of actual inter-industrial knowledge spillovers and their economic rationale can be found in the work of economic historian Nathan Rosenberg. Looking at cases such as the application of sewing machines to the manufacture of boots and shoes, ready-to-wear clothing, awnings, tents, sails, pocketbooks, rubber goods, saddlery, harnesses and bookbinding, Rosenberg (1963: 419) illustrates that American industrialization “was characterized by the introduction of a relatively small number of broadly similar productive processes to a large number of industries” (422); metal-using industries “were continually being confronted with similar kinds of problems which required solution and which, once solved, took their place in short order in the production of other metal-using products employing similar processes” (425); and the machine-tool industry played a dual role in which “new skills and techniques were developed or perfected... in response to the demands of specific customers” and, once acquired, were then applied “to the entire machine-using sector of the economy” (426). As a result, industries achieved high rates of productivity growth by becoming “increasingly dependent... upon skills and resources external to, and perhaps totally unfamiliar to, themselves” (Rosenberg 1979: 43). In this context, talks about ‘interindustry’ flows have long been based on “an outmoded concept of an industry” (Rosenberg, 1979: 47).

Of course, from an economic perspective developing new applications for one’s existing expertise has always been a more sensible (if not always successful) proposition than developing a new product or expertise from scratch. The ways in which innovations in one line of work improves productivity growth and technological progress in another,

however, defy “easy summary or categorization,” some having evolved over considerable periods of time, others proceeding very quickly through the sales of new intermediary goods following some rapid advances in terms of new products or processes (Rosenberg, 1979: 44).

Later, Rosenberg (1998) looked at chemical engineering and the Corliss steam engine in light of the influential concept of ‘general purpose technologies’ (GPT) that are said to perform “some generic function that is vital to the functioning of a large number of using products or production systems” (Rosenberg and Trajtenberg, 2004: 65). Consistent with his lifelong insistence on the greater economic importance of incremental innovations, he nevertheless came to observe that “the question arises as to whether the Corliss steam engine ought to be regarded as a GPT in itself, or rather as a particular episode along the evolutionary path of the steam engine GPT” and added that, at any rate, “it is inherently very difficult to delimit what exactly constitutes a GPT in its own terms, and one cannot expect decisive answers” (idem: 68).

As is also obvious from this and other detailed case studies written within the GPT framework (Goldfarb, 2005; Thoma, 2008), the genesis of every GPT is a new combination and considerable amounts of time and innumerable unforeseen improvements were typically required to adapt them to new uses. Their ‘general purpose’ character was therefore hardly intrinsic or ontological, but rather only became so through countless actions of a more incremental kind. Furthermore, commercially successful technologies that remain confined to a single purpose over time are probably few and far between, or have perhaps even never existed in the first place. In this light, the GPT approach can perhaps be described as the latest incarnation of a perspective that

emphasizes the greater importance of radical breakthroughs as opposed to another view according to which technological change is much more incremental in nature while alleged radical departures are typically arbitrary selections on a broader continuum (Machlup, 1962). The engineer Michael Fores (1980: 69) thus wrote about the propensity of social scientists and historians to analyze technological change as a “stream of revolutions, crisis, insights, breakthroughs, discontinuities, and the rest, composed in a manner that looks needlessly hysterical to those who are more familiar with ordinary work places.” Building on the incremental view of technological change, we will now discuss briefly some basic cognitive processes and environmental factors underlying new combinations, a stance broad enough to encompass all current perspectives on Jacobs spillovers.

Cognitive processes and environmental factors in the creation of new combinations⁵

New technological combinations are ultimately the result of individuals finding a new use for their existing expertise or incorporating something new (to them) to their current activity (Desrochers, 2001). Cattani (2006: 287) describes the phenomenon as “the emergence of a new technology as a result of re-deploying existing knowledge into a new selection environment” and documents it for fiber optics. Of course, a creative individual’s experience is both suggestive and limiting. For example, Shane (2000) documents how, because of their previous know-how, eight sets of entrepreneurs saw different opportunities to exploit a single MIT invention. By contrast, the other side of

⁵ It seems fair to say that the study of creativity is still a somewhat marginal specialty in psychological research; that the study of technological creativity has generated little interest compared to artistic, scientific, children and managerial creativity; that most writings on the former subject have examined the work of historically important figures or significant recent commercial successes; and that despite this the relevant literature is too large to be reviewed in any detail in this section, hence our emphasis on widely accepted features of the process. For a recent article that covers many of these issues, see Gassman and Zeschky (2008).

the creative coin - incorporating something new to one's expertise - does not necessarily require direct prior experience in another line of work, as sometimes observation and subsequent learning can be sufficient. George Westinghouse thus developed his train brake by reading a description of the compressed air technology used in tunnel drilling (Skrabec, 2006). Bandura (1977) refers to this process as 'observational learning,' i.e., learning by observing, through deliberate search or luck, without tedious trial and error.

One essential ability to create new combinations is therefore the capacity to look beyond the normal application context of artifacts and ideas, a skill often highlighted in the 'pragmatic' literature intended to foster creativity in corporate settings.⁶ To give but one example:

One game... is called "What Is This?" Look at any object around you: a pen, a cup, this book. Ask yourself, what else can it be used for? Take, for starters, this book in your hand; it's a doorstop, a weapon, a plate to get your boss to be less of an idiot, a waste of \$25, and on it goes... The point is that anything can be used for things other than its intended purpose. We assume everything has one function, but that's wrong: you can use anything (although it might not work well, you can try). There's nothing stopping you from using this book as underwear to paper your walls. The game forces you to turn your filters off. Many great ideas come from the repurposing of one thing for something else. Laser beams were used to make CD players and supermarket checkout scanners. Even attempting to reuse something in a novel way, and failing, can lead to ideas no one else has thought of before (Berkun, 2007: 93).

Another facilitating factor is the opportunity for specialists to explore "areas [in which they are] not experts in" (Berkun, 2007: 89), including working "on several project at once, using different methods" as this keeps them from "getting bored or stymied" and "produces unexpected cross-fertilization of ideas" (Csikszentmihalyi, 1997: 272).

Intrinsic factors are obviously only one aspect of Jacobs spillovers, the other being the setting in which search procedures and developmental activities take place. In this respect, it has long been recognized that “talent is only as good as the environment it’s in” (Berkun, 2007: 96); that “creativity is more likely in places where new ideas require less effort to be perceived” (Csikszentmihalyi, 1997: 9); that the “importance of seeing people, hearing people, exchanging ideas, and getting to know another person’s work and mind” (idem: 66) is crucial; and that “certain [geographical nodes and] environments have a greater effervescence of ideas; therefore, they prompt the person who is already inclined to break away from conventions to experiment with novelty more readily than if he or she had stayed in a more conservative, repressive setting” (idem: 130).

Also directly relevant is the fact that, as John Stuart Mill (1848, Book III, Ch. XVII) observed, the interaction among persons with dissimilar modes of thought and action is one of the primary sources of progress. More systematic studies of this issue have been conducted in academic and corporate settings. For example, in twenty case studies of creative scientific research accomplishments in nanotechnology and human genetics, Heinze et al. (2009: 610) highlight the importance, among other factors, of “small group size, organizational contexts with sufficient access to a complementary variety of technical skills,” and “timely access to extramural skills and resources.” In some cases, breakthroughs had been accomplished because group leaders had “changed their research field, for example from chemistry to optics, or from semiconductor physics to biophysics,” and in others, such as in Rockefeller University which is organized “around laboratories rather than scientific disciplines and fields,” because research organizations

⁶ The term ‘pragmatic’ is used by scholars who take a more systematic and rigorous approach to the study of creativity to describe more intuitive approaches (Sternberg, 1999:5).

were environments in which “scientists communicate across disciplinary and thematic borders, and where research leaders provide strategies for integrating scientific diversity with rigorous standards of scientific excellence” (idem: 620).

We now turn to our own attempt to document, examine and analyze these insights and processes in the context of diversified local economies.

4. On the Processes Underlying Jacobs Spillovers: Evidence from Two Groups of Canadian Inventors

Using a methodology similar to some of the most influential research projects on human creativity (Csikszentmihalyi, 1997), we tried to examine the validity of the processes described in previous sections, along with the importance of local economic diversity for these processes, through semi-structured interviews conducted with over eighty French and English-Canadian individual inventors belonging to two inventor associations.⁷

⁷ Jewkes (1969: 72) define an individual inventor as choosing the field in which he works, as employing his own resources or acquiring them from others who exercise no control over his work, and as standing to gain or lose directly from his inventive success or failure. Unlike corporate inventors, an individual inventor typically works with limited resources and with colleagues subject to his guidance and leadership. To provide a brief description of our research project, two rounds of semi-structured interviews were conducted in Canada’s two most economically diverse regions to explore, among other things, eighty-five inventors’ lives, diverse work experiences and creative approaches. The first, conducted in collaboration with a Montreal-based French-Canadian inventors association (the now defunct *Le monde des inventions québécoises*) between 1997 and 1999, involved forty-five Southern Quebec inventors. These results were not published in the academic literature because of other professional obligations. The main deficiency of this study was that a majority of the interviewees were reluctant to engage in any form of long-distance business relationships with English-speaking individuals because of linguistic deficiencies. In order to address this issue, another round of interviews was conducted between 2006 and 2009 with a group of forty English-Canadian inventors in collaboration with the Toronto-based *Concept to Creation Cooperative*. Even though all the individuals interviewed in this latter phase were Canadian citizens or residents, the diversity of their backgrounds turned out to be quite remarkable, not only because of cultural differences between French and English-Canadians, but also because several Torontonians were born and educated in foreign countries. Because our objective was theory-building, the evidence presented in the remaining portions of this paper is the result of a constant iterative process between scholarship and other literature which helped sharpen lines of questioning and topics raised during interviews which suggested the exploration of previously unfamiliar sub-disciplines or lines of works. Because of this, we are confident that, despite undeniable limits or local peculiarities, the evidence presented in the remainder of this article

While we were obviously unable to come up with rigorous quantitative measures through our approach, we hope to demonstrate the relevance of theory-building in the context of the localized knowledge spillovers literature and that simply because something is immeasurable does not mean that it is necessarily unobservable, unintelligible or unimportant. As Einstein reportedly said: “Everything that can be counted does not necessarily count; everything that counts cannot necessarily be counted.”

The selection of individual inventors as units of analysis was based on four considerations. First, virtually all accounts describing the lives and professional trajectories of individual inventors reveal a high propensity to move between different lines of work (Brown, 1988; Jewkes et al., 1969). Second, individual inventors are typically not bound by confidentiality agreements and can therefore freely discuss technological innovations in a wide variety of contexts. Third, the majority of individuals working mostly alone usually limit themselves to projects or ideas that do not require complex technologies or significant capital investments, thereby providing researchers with a broad, but relatively easy to understand, array of cases. While this could be viewed as a liability or, at any rate less interesting than the few ‘high-tech’ sectors that are the focus of considerable social science research, ‘mundane’ inventions nonetheless represent a significant component of the industrial world (Hirsch-Kreinsen, 2008). Fourth, while some inventors limit themselves to one or a few inventions, most can be described as compulsive problem solvers who tackle a broad array of problems.

illustrates both the universality of human creative processes and the recurring problems faced by most individual inventors. Other details and limitations of our approach are covered in Desrochers (2000).

In the context of market activities, we define ‘innovation’ as ‘new products and processes that are actually used’ and that show(ed) potential marketability or other economic value.⁸ By using this definition, many individuals interviewed did develop over a hundred innovations during their lifetime, the near totality of which, of course, remained confined to their houses or places of employment. Their main economic impact is therefore overwhelmingly embodied in otherwise undocumented innovations created and used in factories or plants where they were employed (‘shop floor’ innovations) rather than in commercially (un)successful consumer or industrial products. While our perspective is incompatible with the traditional linear economic approach to ‘invention’ (the development of a new product or process), ‘innovation’ (the commercialization of an invention) and ‘diffusion’ (the adoption of innovations by other individuals and firms), we believe it sheds a different and complementary light to the existing literature.

Studying inventors can be problematic on two counts, especially when relying on the account of one individual: 1) most inventors tend to simplify and to idealize their stories; 2) there is often little agreement among collaborators as to where the emphasis of a story should be laid (Jewkes et al., 1969: 71–72). These problems could not be avoided. Regarding the former, it sometimes proved difficult to trace the origins of an inventor’s new idea, as the individual was often himself unaware of the basis of a creative insight or did not remember it at the time of the interview. In the end, however, we believe that the new knowledge gained from the use of potentially imperfect qualitative information is too valuable to ignore.

⁸ While some might disagree with this definition, most patents - key inputs in numerous innovation studies - do not even meet this criterion.

As could be expected from the literature discussed in the previous sections, we identified three broad, although not mutually exclusive, sets of circumstances through which individuals found new uses or applications for existing products and created new combinations of existing products, processes and materials: 1) by adding to, switching or adapting specific know-how to other lines of work; 2) by observing something in another line of work and incorporating it into one's own line of work; and 3) through formal and informal collaboration between individuals possessing different skills and working towards the creation of new products and processes. All of these, of course, first began with the identification of a problem, a point made most forcefully by Petroski (1992: 22) who argued that the "form of made things is always subject to change in response to their real or perceived shortcomings, their failures to function properly. This principle governs all invention, innovation, and ingenuity; it is what drives all inventors, innovators, and engineers." Indeed, "since nothing is perfect, and, indeed, since even our ideas of perfection are not static, everything is subject to change" (idem).

We will now provide a few illustrations of the processes we documented. Of course, the cases described in the remainder of this article were selected not only because of the broader patterns they illustrate, but also for the relative easiness with which they could be conveyed.

Adding to, switching or adapting specific know-how to other lines of work

Applying know-how gained in one setting to another often took place as a result of individuals moving between different lines of work. Representative cases of the latter phenomenon include an individual who had worked in various corporate contexts with electronics, digital devices, early IT and telephone technologies before striking out on his

own as a consultant to a broad customer base. One Quebec engineer had worked for firms involved in concrete preparation, textile manufacturing, nuclear-based electricity production, small business financing and garage door manufacturing. An industrial technician worked in the steel, chemical, aeronautical and armament industries before launching his own ceramic-making business.

This widespread pattern of employment across different lines of work seems attributable in part to the fact that technically creative individuals get bored very quickly with routine work. As one Quebec engineer who had worked in the cement-making, ore refining and manufacturing (cars, trucks, plastics) sectors put it: “As an engineer, I could never stay more than two or three years in the same business... After two or three years, I knew everything. I had done everything. I needed new challenges. I was soon looking elsewhere.” Other considerations include a lack of interest or the formal education (few individuals interviewed had completed university degrees) needed to transition into administrative work. Of course, finding a new job was also an imperative when a firm downsized, went out of business or when an employee was asked to relocate to a region he disliked. Whatever the cause, however, this widespread pattern of job mobility facilitates the spontaneous transfer of know-how across otherwise seemingly unrelated lines of work. As the last engineer mentioned put it:

“You always carry your experience and know-how with you from one line of work to the other... I would even go so far as to say that a lot of things are strikingly similar... I call that a food processor, a cake recipe. Whether you’re in mining, plastics, working for General Motors, everywhere you see pumps, compressors, tanks, pipes... in all lines of work... except when I was working for a truck box manufacturers, but even there you had a lot of systems to move parts that are similar to those you will see in other industries.”

One of the most interesting cases was that of a software engineer who worked as an IT consultant when we interviewed him. Years before, while working as an IT manager for a large supermarket chain, he came to understand that money in this line of work was not so much in the sale of food per se, but in the shelf space ‘real estate’ owned by retailers. He explained: “It doesn’t matter what product they put on the shelf. They charge premiums on the location on the shelf.” Later on, having now become a web designer, he applied this model to his new line of work and began charging different premiums for advertisements based on their location on the web page. “So you take along what other people are doing in different industries and put it into your industry” he observed, before adding: “You tend to take up information from one area and try to implement it on the other to make simple mimics. If one area works, you try to mimic the same process in another area to make it work for you.”

Another interesting case involved the transfer of some basic know-how from the newspaper printing business to asphalt production. A recurring problem in the latter line of work was the cleaning up of residual asphalt that would be found sticking inside tanks after long holidays such as Christmas or Easter. In a particular asphalt firm, people actually climbed in the tank to scrape the residual, a laborious and equipment-damaging process. After noticing this, an individual interviewed pointed out to his then new employer that, in the printing business where he was formerly employed, large tanks were cleaned by pouring hot water in them. Why couldn’t a similar approach be tried in the asphalt tank? This technique was tried and proved successful, in the process saving a significant amount of money.

Observing know-how and materials and incorporating them in a different setting

Several cases of ‘observational learning’ were raised during our interviews. For example, a chemical engineer once worked for a company with plants in remote locations at a time when his employer needed to reduce his manpower, but was reluctant to do so in isolated plants for fear that employees working alone would be left unattended for several hours if hurt. This individual knew of devices that alerted emergency response personnel when a button was pushed, but this approach would obviously be inadequate if a worker was knocked unconscious. The engineer contacted a company supplying this service and requested that motion detectors be incorporated in their system so that an emergency call would automatically be placed if no motion was detected after a predetermined amount of time. As a result of this new combination, the company was able to reduce costs without risking the safety of its employees. An additional feature was then added to the system to allow it to work as a burglar alarm when activated by the employee.

Another case involved a dental technician who, dissatisfied with existing materials, set out to develop a new type of acrylic for making dentures after observing mouth guards used in contact sports that were first warmed under hot water and then shaped in the mouths of athletes. After much trial and error, he finally developed a compound which proved superior to other existing materials out of which dentures could be created and could easily be molded with warm water while possessing controllable rigidity (from hard to soft).

We also documented how a shower brush was inspired by a car wash brush; a mouse pad arm rest was combined with an office chair after an individual had been inspired by some classroom furniture; a controllable sled was inspired in part by the movements of ice skates; a production shop for a new type of baby bag was inspired by the division of

labor in a restaurant kitchen; a device to conduct time studies drew on ideas from chess clocks, stop watches and computers, among others; and a pulp and paper mill machine was partly inspired by a meat grinder.

On the Importance of Local Economic Diversity for Jacobs spillovers

While we documented a large number of otherwise ‘invisible’ new combinations, assessing the specific impact of the large metropolitan areas in which they took place is not as straightforward as identifying the uniqueness of highly specialized industrial districts. Indeed, in most cases, these new combinations could probably have been developed in many other large urban agglomerations. This was certainly the case when individuals were inspired while traveling or watching television. Another problem is the wide discrepancy we observed in terms of the geographical (local versus regional) and time (rapid transfer or long development process) scales involved in various cases. In terms of geographical space, different individuals have obviously different perception of space, with inhabitants of rural areas (especially if they were born there) being much more inclined to travel long distances to interact with other individuals than urbanites (although in many cases repeated long distance commutes took their toll and resulted in the termination of projects). While most cases of Jacobs spillovers occurred at the metropolitan level, some involved collaborative efforts at what can only be described as the regional level (a couple hundred of kilometers). The amount of time required to develop new products or Jacobs spillovers also obviously depended on the level of technical difficulty involved and on contingent circumstances, such as the death of a collaborator, the bankruptcy of a firm, the enactment of new regulations affecting directly the product under development or other, more lucrative, opportunities.

Because this paper is limited to theory-building, we limit our discussion to the non-contingent factors that underlie Jacobs spillovers. This will be done in two ways. The first will be through a much more detailed description of a specific case in order to give a better sense of the complexity of the realities we documented. The second will be, once again, by identifying broad patterns that will be further illustrated through short descriptions of other cases.

Jacobs spillovers at the firm level: A case study

Our more detailed case is that of an experienced entrepreneur/inventor who spent his working life in Jacobs' adoptive hometown of Toronto, but who had by the time of our interview sold his business, been retired for eight years and was living in a (mainly) resort area located a three hour drive north of the Greater Toronto Metropolitan area.⁹ A chemical engineer by training, he first worked for the oil refining industry in the late 1940s, but soon struck out on his own as he felt that that this would give him more freedom to use his creative capabilities. His first business was in plastic molding, where he constantly developed new products such as bottle openers, sophisticated key holders, travel mugs and acrylic wine goblets. While describing the genesis and development of all these inventions is beyond our scope, it is interesting to note that the inspiration for that last item came as a result of his meeting some glass-makers in trade shows and of immediately seeing the advantages of using acrylic for some segments of this market. Acrylic was strong, safe and much more versatile than glass in terms of using colors, attachments and printed text or figures. After much trial and error which involved other creative individuals within and outside his firm, the product turned out to be a commercial success in the US market, but not in Europe.

This invention in time led the inventor/entrepreneur to increasingly switch his product line towards the glass ware industry where, after more research, he was able to build on technologies similar to those used in windshield production to create a compound that drastically improved the resistance of glass ware. While learning and experimenting, sometimes in collaboration with people involved in Southern Ontario's large auto parts industry (therefore involving collaboration at the regional as opposed to the metropolitan scale), he had observed the difficulties involved in decorating glass and learned about safety issues related to the use of lead in the process. To overcome these problems, he developed, again in collaboration with specialists possessing complementary expertise, a plastic coating for glass ware on which ink could be spray printed.

He further refined his ideas after seeing a demonstration of digital ink jet printing in a graphics show in Toronto. He looked for a specialist in this area and, at the time of our interview, was jointly developing the product with a digital inkjet printing company. According to him, digital printing will make the production faster and less costly than through traditional methods, while the resulting product will be durable, non-toxic and visually much more spectacular.

Interestingly, the inventor-entrepreneur was conducting these activities from his retirement home and was then collaborating with a firm located in the American Mid West. This arrangement, in our opinion, can mainly be understood in the context of its "retirement project" nature, at least inasmuch the inventor (and his wife) enjoyed his scenic surroundings and was under no short-term financial pressure. Indeed, the

⁹ This was, of course, under the best conditions as winter driving in this part of Canada is often arduous.

entrepreneur-inventor was adamant that his past business activities and operations could never have been located where he was then living and that being based in Canada's metropolis always provided him with, among other things, easy access to suppliers and specialized workers of all kinds who had themselves customers and experiences in a large array of industries. Of course, being based in the Greater Toronto Area also provided him with numerous opportunities to being exposed to countless lines of work.

From this and several other cases, we will now identify a few broad patterns that we deem especially relevant to better understand the importance of large and diverse urban agglomerations in facilitating inter-industrial knowledge spillovers.

Importance of agglomeration economies

Our first observation is that Jacobs spillovers are only one facet of the economic importance of large and diverse agglomerations. Indeed, in all our cases, the importance of traditional or 'static' urbanization economies was judged crucial by inventors, as benefiting from a proximate and diverse supply of components of all kinds obviously saved them much time and effort. Individuals who had lived in both a large urban agglomeration and a highly specialized (and typically smaller) one were especially adamant on this point. As Thomas Edison reportedly said, genius is 1% inspiration and 99% perspiration, meaning that an idea for a new marketable device is but the genesis of a lengthy process, much of which is entrepreneurial in nature, from which marketable products are eventually created. In the spirit of Edison, we suggest that agglomeration economies save inventors a lot of perspiration and that contributors to the localized knowledge spillovers literature should keep his dictum in mind in terms of the overall importance of inspiration.

Face-to-face Interactions

The greater facility of face-to-face interaction has long been emphasized in the literature on agglomeration economies. Not surprisingly, the fact that physical proximity greatly facilitated collaborations between individuals possessing different expertise in the development (if not necessarily commercial success) of new inventions was made abundantly clear to us. The reasons given in this respect ranged from traditional ones, such as establishing trust and jointly addressing innumerable hurdles in development phases, to one that is more specific to Jacobs spillovers, i.e., making sure that individuals with different expertise truly understood each other and that the final product reflected the vision of the project leader.¹⁰ Among other cases, an electrical engineer working for Quebec's largest public utility company spent his week-end perfecting the production processes of his uncle's window and door-making factory while a technical staff recruiter collaborated with his wife, a chemical engineer by training, to develop a wine-related technology.

To look at one case in more detail, the new type of denture acrylic mentioned earlier had, like most new materials, many different potential applications. Among other things, it is consistency controllable, thermo-elastic and has 'memory' (i.e., it returns to its original shape after cooling). According to the inventor, no other acrylic in the world did these three things simultaneously when it was developed. Furthermore, the product can be used as a quick and easy way of repairing and attaching things. The inventor had thought of more than 60 potential new applications, ranging from moldable handles and hearing aid devices to ski boot insoles and as replacement for plastic casts for broken limbs. At the

¹⁰ Of course, the importance of face-to-face interaction for people possessing similar expertise has long been a mainstay of the economic geography literature.

time of our interview, this last application was being explored in collaboration with medical researchers of a nearby academic institution.

Another interesting case is a bicycle rack for domestic use. The individual interviewed originally got the idea from a friend, who pointed out that no such thing existed yet. The reasons for this soon became obvious as the inventor began researching the topic. The rack needed to be light enough to be carried, heavy enough to hold the bicycles and prevent thefts, have a nice design, be maintenance-free, and suitable for at least four bicycles (two adult and two children's bicycles), be they racing or mountain bikes. Finally, its price should be affordable. A metallic structure would have met most of these requirements, but would have been too heavy to carry. Aluminum was a lighter option, but was too expensive. The inventor then thought of using plastic, but realized quickly that it would be too light. He contacted an industrial draughtsman with whom he had worked with in the past on a specially designed water container for long-distance running. His former collaborator suggested that the rack should be made by blowing rather than casting (i.e., filling a plastic mold) plastic. That way it would be empty inside, which would make it light enough to carry, but heavy enough to hold the bicycles in place after it was filled with water. This solution would finally prove the best one. Interestingly enough, although this solution could be seen *post facto* as a direct implementation of the main principle involved in their previous collaboration, the inventor still needed his previous collaborator to think of this approach.

Local Diversity as Offering More Creative Opportunities

Another recurring theme in many interviews was, not surprisingly, that a large urban agglomeration provides many unplanned learning opportunities by spontaneously

allowing creative individuals to observe processes and ways of doing things by people working in different contexts. They could, as discussed earlier, either borrow ideas and incorporate them in their own work or else contribute their expertise in a new line of work, thus resulting in countless ‘spontaneous’ (if undocumented) new combinations. The main channel in this respect, at least in terms of the actual development of innovations, seems to be job mobility between different lines of work, a process that is obviously facilitated by the fact that a large and diverse metropolitan area gives creative individuals the possibility to do so without having to relocate their family or lose their friends and social networks. Admittedly, the expertise and capacities possessed by an individual influence the number of possible job opportunities available to him. But while many companies are limited to a specific sector or a few end products, many industrial capacities are generic in nature and can be applied in many different contexts.

Local Networks

The importance of local networks for regional development has long been a mainstay of the economic geography and related literatures. Not surprisingly, the individuals we interviewed all belonged to various networks, some of which were obviously more specialized than others such as, for instance, the contacts that were developed by a plastic molder who had been active in this line of work for a long time and who had worked for several employers. Some networks, however, were especially conducive to Jacobs spillovers, chief among which were the inventors associations themselves. In short, since each individual member’s background is limited in various ways, belonging to an association whose members have diverse and complementary expertise typically proves valuable. While opening up to other individuals often proves difficult for inventors, as the limits of their know-how became apparent during the development phase of their

invention, they typically became more willing to discuss their ideas as they came to understand the trade-offs between secrecy and the sharing of insights and expertise with individuals whose own know-how was often complementary to theirs. Besides networking with other inventors in order to tap into different skill sets, intellectual stimulation and friendship, an important aspect of these associations is the support their members can provide to each other in terms of locating manufacturers for the supply or fabrication of specific parts, sources of capital and help with marketing and distribution, business and activities that are typically of a more generic nature.

5. Jacobs Spillovers and the Related Variety Controversy

One of the spillover effects of the MAR-Porter-Jacobs debate has been the development of the concept of ‘related variety’ (Frenken et al., 2007; Frenken and Boschma, 2007), a topic now controversial enough to warrant further attention and on which our work can shed additional light. As we see it, its most important aspect is its reliance and emphasis on the notion that sufficient ‘cognitive proximity’ (Noteboom, 2000) is required to actually facilitate innovative advances. In other words, large differences in expertise and jargon between individuals will prevent them from communicating effectively and will therefore hinder the creation of useful and commercially valuable new combinations. Our evidence suggests a number of rebuttals to this line of thought: 1) the significant internal diversity of large firms does not prevent individuals with very different backgrounds to collaborate towards a common goal; 2) individuals working for firms that are unrelated in terms of final products might nonetheless be using similar ‘generic’ technologies and thus benefit from learning from each others; 3) while ‘cognitive distance’ can indeed be a challenge, it can most easily be addressed through the frequent face-to-face interactions

of diverse individuals, which is obviously facilitated if they are all located in close geographical proximity.

The theoretical contribution of related variety and its proponents' less aggregated approach to study the effects of diversity is welcomed, but its reliance on industrial classifications remains debatable in our opinion. While one can plausibly argue that a pig farmer is unlikely to learn anything from a microchip company (Boschma and Iammarino, 2007), similar examples could doubtless be given using firms within the same two-digit level industrial classifications. Besides, while large-scale pig and microchip producers handle very different commodities, it doesn't seem implausible that some useful exchange of ideas might occur in terms of, say, controlling temperature or air quality in production facilities or workforce management. Besides, we did document Jacobs spillovers between sectors that seem equally implausible (such as production arrangement transfers between a restaurant and a baby accessory manufacturer).

We therefore suggest that it is probably more constructive to analyze creativity in terms of individual skills and know-how, a reality not well reflected in industrial classification schemes, and to consider the essence of innovation to be about making connections between previously unrelated things. While the ultimate goal of the relatedness approach is to separate the diversification benefits (unrelated variety) from Jacobs externalities (related variety), industrial classifications alone are probably not sufficient in this respect as they do not always reflect the correlation between the demand for outputs or the various ways in which ideas are used and transferred between industries (again, see the much earlier comments to that effect in Jacobs, 1969: 61). In fact, while this approach highlights the benefits of a more disaggregated method and gives an opportunity to study

these effects on different time scales (Saviotti and Frenken, 2008), it also shows that diversity is a complex and heterogeneous phenomenon (Bishop and Gripaos, 2009). As such, while it can yield a more comprehensive understanding of the phenomenon when coupled with studies on individual inventors and other experts, it might still assume away too much.

Reflective Conclusion

Shedding additional light on the intra and inter-industrial localized knowledge spillovers controversy requires methods that are complementary to the statistical approaches used in previous studies on the topic. In particular, proving and assessing the existence and importance of Jacobs spillovers requires a more fundamental understanding of the processes by which people actually come up with new combinations and the relative importance of local economic diversity on facilitating or promoting these processes. We attempted to provide a better theoretical understanding of this issue by identifying relevant insights from the creativity and other relevant literatures and by conducting semi-structured interviews with several Canadian individual inventors.

While determining the frequency of Jacobs spillovers and their relative importance to other factors could not be measured satisfactorily with our approach, we believe that it has given us the opportunity to identify the main types of stylized processes through which knowledge was actually transmitted between different lines of work: 1) adding to, switching or adapting specific know-how to other product lines; 2) observing something and incorporating it in a new environment; and 3) formal or informal collaboration between individuals possessing different skills and backgrounds. Local economic diversity was found to facilitate these processes in several ways, ranging from frequent

face-to-face interactions between people possessing different backgrounds and otherwise unlikely to understand each other to facilitating job mobility between different lines of work. We cannot claim on our evidence alone that these mechanisms are present in all technical lines of work, but because new combinations are at the roots of all creative processes we are confident that these basic patterns will be observed in all industrial sectors.

With these considerations in mind, we would now like to venture a few additional thoughts on two controversies that have sprung from the work of MAR-Porter-Jacobs literature. The first is that the notion of a ‘creative class’ (Florida, 2002) should at the very least be broadened to recognize the contribution of technically creative individuals who might not possess a university education and be working in unglamorous lines of work, but nonetheless contribute much to the economic vitality of their communities. As such there is a significant difference in terms of regarding ‘creativity’ as a ‘type’ (e.g., education or occupation) as opposed to an ability to create new things or ideas by recombining older ones (Weitzman, 1998), a distinction which should be kept in mind when these literatures are merged.

The second is Breschi and Lissoni’s (2009: 465) argument that it is not geographical distance as such that is crucial for knowledge flows, but that “the main reason why geography really matters is that mobility of technologists across organizations, either as employees or consultants, is bounded in space.” These authors have a point to the extent that two of our three Jacobs spillovers mechanisms, “adding to...” and multidisciplinary collaborations, are clearly dependent on social and personal ties. These ties are also typically more or less local, even if not necessarily so. In our opinion, however, social

proximity, while undoubtedly important, should not be unduly emphasized at the expense of geographical proximity since in the absence of such ties it is much more convenient for individuals looking for vaguely defined potential solutions - especially if they work alone or for small firms - to first contact nearby individuals that are beyond the confines of their “epistemic community” (Lissoni, 2001) and possess different and potentially complementary skills. In addition, one spillover mechanism, observing something elsewhere and incorporating it in someone’s own line of work, doesn’t seem reducible to social proximity, as there do not need to be any social ties present in order for this channel to work, while closer geographical proximity between different types of work do, in our opinion, provide better opportunities of observing something useful. Through observational learning, individual or corporate inventors can observe novel ideas being developed in particular circumstances and learn spontaneously without searching for new knowledge (Malmberg and Maskell, 2002).

In the end, no matter which spillovers are studied, their analysis should not be limited to why people innovate, but it should also explain *how* they go about it. We hope that the preliminary analysis presented in this paper has moved the understanding of this issue one step closer to that goal.

References

- Arrow, K. J. (1962) The Economic implications of Learning by Doing. *Review of Economic Studies*, 29: 155–173.
- Ayres, C. E. (1943) *The Theory of Economic Progress*. Chapel Hill: The University of North Carolina Press.
- Bandura, A. (1977) *Social Learning Theory*. New Jersey: Prentice-Hall.
- Beaudry, C. and Schiffauerova, A. (2009) Who’s Right, Marshall or Jacobs? The Localization Versus Urbanization Debate. *Research Policy*, 38: 318–337.

- Berkun, S. (2007) *The Myths of Innovation*. Sebastopol (CA): O'Reilly Media, Inc.
- Bishop, P., Gripaio, P. (2009) Spatial Externalities, Relatedness and Sector Employment Growth in Great Britain. *Regional Studies*, pp. 1–12, iFirst article.
- Boschma, R., Iammarino, S. (2008) *Related variety, trade variety and regional growth in Italy*. Papers in Evolutionary Economic Geography, No: 08.02. Utrecht University. Available online at: <http://econ.geo.uu.nl/peeg/peeg0802.pdf> [Accessed 8 April 2010].
- Brenner, T. (2007) Local Knowledge Resources and Knowledge Flows. *Industry and Innovation*, 14: 121–128.
- Breschi, S., Lissoni, F. (2001) Knowledge Spillovers and Local Innovation Systems: A Critical Survey. *Industrial and Corporate Change*, 10: 975–1005.
- Breschi, S., Lissoni, F. (2009) Mobility of skilled workers and co-invention networks: an anatomy of localized knowledge flows. *Journal of Economic Geography*, 9: 439–468.
- Brown, K. A. (1988) *Inventors at Work. Interviews with 16 Notable American Inventors*. Redmond (WA): Tempus Book of Microsoft Press.
- Cattani, G. (2006) Technological pre-adaptation, speciation, and emergence of new technologies: how Corning invented and developed fiber optics. *Industrial and Corporate Change*, 15: 285–318.
- Csikszentmihalyi, M. (1997) *Creativity. Flow and the Psychology of Discovery and Invention*. New York: Harper Perennial.
- de Groot, H. L. F., Poot, J., Smit, M. J. (2009) Agglomeration Externalities, Innovation and Regional Growth: Theoretical Perspectives and Meta-Analysis. In R. Capello and P. Nijkamp (eds.) *Handbook of Regional Growth and Development Theories*. Cheltenham: Edward Elgar, 256–281.
- Desrochers, P. (2000). [De l'influence d'une ville diversifiée sur la combinaison de techniques: Typologie et analyse de processus](#), Ph.D thesis, Department of Geography, Université de Montréal.
- Desrochers, P. (2001). Local Diversity, Technological Creativity and Technological Innovation. *Growth and Change*, 32: 369–394.
- Florida, R. (2002) *The Rise of the Creative Class*. New York: Perseus Book Group.
- Frenken, K., Boschma, R., (2007) A theoretical framework for evolutionary economic geography: Industrial dynamics and urban growth as a branching process. *Journal of Economic Geography*, 7: 635–649.
- Frenken, K., Oort, F. van, Verburg, T. (2007) Related Variety, Unrelated Variety and Regional Economic Growth. *Regional Studies*, 41: 685–697.

- Fores, M. (1980) Scientists on Technology: Magic and English-Language 'Industriespeak. In D. Sahal (ed.) *Research, Development, and Technological Innovation*. Lexington: Lexington Books, 239–250.
- Gassman, O., Zeschky, M. (2008). Opening Up the Solution Space: The Role of Analogical Thinking for Breakthrough Product Innovation. *Creativity & Innovation Management* 17 (2): 97–106.
- Glaeser, E. L., Kallal, H. D., Scheinkman, J. A., Shleifer, A. (1992) Growth in Cities. *The Journal of Political Economy*, 100: 1126–1152.
- Hansen, N. (2002) Dynamic externalities and spatial innovation diffusion: implications for peripheral regions. *International Journal of Technology, Policy and Management*, 2: 260–271.
- Heinze, T., Shapira, P., Rogers J. D., Senker, J.M. (2009) Organizational and institutional influences on creativity in scientific research. *Research Policy*, 38: 610–623.
- Henderson, J. V., (2007) Understanding knowledge spillovers. *Regional Science and Urban Economics*, 37: 497–508.
- Hirsch-Kreisen, H. (2008) "Low-Tech" Innovations. *Industry & Innovation*, 15: 19–43.
- Jacobs, J. (1969) *The Economy of Cities*. New York: Random House.
- Jacobs, J. (1984) *Cities and the Wealth of Nations*. New York: Random House.
- Jewkes, J., Sawers, D., Stillerman, R. (1969). *The Sources of Invention*. 2nd edition. London: MacMillan.
- Keir, M. (1919) The Localization of Industry. How it Starts; Why it Grows and Persists. *The Scientific Monthly*, 8: 32–48.
- Kuznets, S. (1960) Population Change and Aggregate Output. In National Bureau of Economic Research, *Demographic and Economic Change in Developed Countries*. Princeton University Press and National Bureau of Economic Research, 340–367. Available online at: <http://www.nber.org/chapters/c2392.pdf> [Accessed 11 September 2009].
- Leppälä, S., Desrochers, P. (2010) The division of labor need not imply regional specialization. *Journal of Economic Behavior and Organization*, 74: 137–147.
- Lissoni, F. (2001) Knowledge codification and the geography of innovation: the case of Brescia mechanical cluster. *Research Policy*, 30: 1479–1500.
- Lucas, R. E. (1988) On the Mechanics of Economic Development. *Journal of Monetary Economics*, 22: 3–42.

- Machlup, F. (1962) The Supply of Inventors and Inventions. In National Bureau of Economic Research, *The Rate and Direction of Inventive Activity: Economic and Social Factors*. Princeton: Princeton University Press, 143–167.
- Malmberg, A., Maskell, P., (2002) The elusive concept of localization economies: Towards a knowledge-based theory of spatial clustering. *Environment and Planning A*, 34: 429–449.
- Marshall, A. (1890) *Principles of Economics*. 8th edition. London: MacMillan. Available online at: <http://www.econlib.org/library/Marshall/marP.html> [Accessed 11 September 2009].
- Melo, P.C., Graham, D.J., Noland, R.B., (2009) A meta-analysis of estimates of urban agglomeration economies. *Regional Science and Urban Economics*, 39: 332–342.
- Mill, J.S. (1848) *Principles of Political Economy with some of their Applications to Social Philosophy*. 7th edition. London: Longmans, Green and Co. Available online at: <http://www.econlib.org/library/Mill/mlP.html> [Accessed 11 September 2009].
- Nooteboom, B. (2000) Learning by Interaction: Absorptive Capacity, Cognitive Distance and Governance. *Journal of Management and Governance*, 4: 69–92.
- Petroski, Henry (1992). *The Evolution of Useful Thing*. New York: Random House.
- Polèse, M. (2005) Cities and National Economic Growth: A Reappraisal. *Urban Studies*, 42: 1429–1451.
- Porter, M. E. (1990) *The Competitive Advantage of Nations*. London: MacMillan.
- Puga, D. (2010) The Maginitude and Causes of Agglomeration Economies. *Journal of Regional Science*, 50: 203–219.
- Romer, P. M. (1986) Increasing Returns and Long-Run Growth. *Journal of Political Economy*, 94: 1002–1037.
- Rosenberg, N. (1963) Technological Change in the Machine Tool Industry, 1840-1910. *Journal of Economic History*, 23: 414–443
- Rosenberg, N. (1979) Technological Interdependence in the American Economy. *Technology and Culture*, 20: 25–50.
- Rosenberg, N. (1998) Chemical Engineering as a General Purpose Technology. In E. Helpman (ed.) *General Purpose Technologies and Economic Growth*. Cambridge (MA): MIT Press, 167–192.

- Rosenberg, N. and Trajtenberg, M. (2004) A General-Purpose Technology at Work. The Corliss Steam-Engine in the Late Nineteenth-Century United States. *Journal of Economic History*, 64: 61–99.
- Rosenthal, S. S. and Strange, W. C. (2004) Evidence on the Nature and Sources of Agglomeration Economies. In Henderson, J. V. and Thisse, J.-F. (eds.), *Handbook of Regional and Urban Economics*, Vol. 4. Amsterdam: Elsevier, 2119–2171.
- Rutten, R. and Boekema, F. (eds) (2007) *The Learning Region. Foundations, State of the Art, Future*. Cheltenham (UK): Edward Elgar.
- Saviotti, P. P., Frenken, K. (2008) Export variety and the economic performance of countries. *Journal of Evolutionary Economics*, 18: 201–218.
- Shane, S. (2000) Prior Knowledge and the Discovery of Entrepreneurial Opportunities. *Organization Science*, 11: 448–469.
- Skrabec, Q. R. (2006) *George Westinghouse, Gentle Genius*. New York: Algora Publishing.
- Spencer, H. (1857) *Progress: Its Law and Cause*. Reprint in Herbert Spencer. 1889. Illustrations of Universal Progress; A Series of Discussion. New York: D. Appleton and Company, pp. 1–60. Available online at: <http://books.google.ca/books?id=9QIMAAAAIAAJ&printsec=frontcover&dq=spencer+illustrations+of+universal+progress> [Accessed 11 September 2009].
- Sternberg, R. J. (ed.) (1999) *Handbook of Creativity*. Cambridge: Cambridge University Press.
- Thoma, G. (2008) Striving for a Large Market. Evidence from a General Purpose Technology in Action. *Industrial and Corporate Change*, 18: 107–138.
- Usher, A. P. (1929) *A History of Mechanical Inventions*. Cambridge (MA): Harvard University Press.
- Weitzman, M. L. (1998) Recombinant Growth. *The Quarterly Journal of Economics*, 113: 331–360.