Regional systems of entrepreneurship: the nexus of human capital, knowledge and new firm formation

Author(s): Haifeng Qian, Zoltan J. Acs and Roger R. Stough

Source: *Journal of Economic Geography* , Vol. 13, No. 4 (July 2013), pp. 559–587

Published by: Oxford University Press

Stable URL: https://www.jstor.org/stable/10.2307/26155413

REFERENCES
Linked references are available on JSTOR for this article:
https://www.jstor.org/stable/10.2307/26155413?seq=1&cid=pdf-
reference#references_tab_contents
You may need to log in to JSTOR to access the linked references.

Regional systems of entrepreneurship: the nexus of human capital, knowledge and new firm formation

Haifeng Qian*,†, Zoltan J. Acs** and Roger R. Stough**

*Maxine Goodman Levin College of Urban Affairs, Cleveland State University, 2121 Euclid Avenue, Cleveland, OH 44115, USA
**School of Public Policy, George Mason University, 3351 Fairfax Drive, Arlington, VA 22201, USA
†Corresponding author: Haifeng Qian, 2121 Euclid Avenue, UR 315, Cleveland, OH 44115, USA.
email <h.qian@csuohio.edu>

Abstract

This article focuses on entrepreneurship in economic geography and aims at a systematic investigation of regional variation in knowledge-based entrepreneurial activity. We develop and test a three-phase structural model for *regional systems of entrepreneurship* after introducing a systems approach to entrepreneurship. The model is built upon the absorptive capacity theory of knowledge spillover entrepreneurship that identifies new knowledge as one source of entrepreneurial opportunities and human capital as the major source of entrepreneurial absorptive capacity. Based on data of US metropolitan areas, we find that entrepreneurial absorptive capacity is a critical driving force for knowledge-based entrepreneurial activity. We also find that high technology and cultural diversity contribute to the vibrancy of regional systems of entrepreneurship.

1. Introduction

The role of entrepreneurship in economic development has become an active area of research. One approach to understanding entrepreneurship is through the lens of small/ new businesses. Economists traditionally focused on large incumbent firms, which according to Schumpeter (1942) carry out radical innovations and drive economic and social development. However, small firms and new firms play an increasingly important role in economic growth and particularly in job creation (Storey, 1984). Small firms have also proved more innovative than large firms in some sectors (Acs and Audretsch, 1987, 1988; Acs et al., 1994). New firms underpin economic dynamics. For instance, new firms accounted for all positive net job growth in the United States during 1992–2005 (Haltiwanger et al., 2010). Since the 1990s, many new firms were established as efforts to commercialize new technologies, thus creating an environment friendly to innovation, further highlighting the role of new firm formation in economic development.

The regional perspective of entrepreneurship interests economic geographers, policy makers and economic practitioners who have recognized entrepreneurship as a driving

force for regional growth (Lee et al., 2004; Acs and Armington, 2006; Delgado et al., 2010; Glaeser et al., 2010b). Regional variation in entrepreneurial activity or new firm formation has been documented in a large body of research [e.g. the 1994 special issue of *Regional Studies*; for a summary see Malecki (1997)]. Geography creates spatially varying regional environments that shape regional variation in entrepreneurial activity. Practically, the issue indeed is how to facilitate entrepreneurial activity at the regional level. Exploring geographically bounded factors that influence entrepreneurship may shed light on regional entrepreneurship policy.

Regional variation in entrepreneurship or new firm formation has traditionally been explained by population growth or in-migration, and the proportion of employment in small firms (Reynolds et al., 1994). Population growth signals growing market demand which may spur entrepreneurial activity, a mechanism to correct market errors (Kirzner, 1997). Concentration of small firms indicates both structural flexibility that characterizes many high-growth regions and a culture that welcomes new and small businesses. Start-ups are also affected by the tax rate and competitiveness of the local financial market (Bartik, 1989). These two factors may have impacts on financial/ accounting performance of firms.

The literature of economic geography has so far insufficiently associated entrepreneurship with knowledge, despite the massive transition to knowledge economies that has occurred in the developed world. Early research in this direction has been carried out by Acs et al. (2009) and Audretsch (1995) who develop a knowledge spillover theory of entrepreneurship. This theory has roots in the work of Arrow (1962), Grilliches (1979), Jaffe (1989) and Romer (1990). It identifies new knowledge as a source of entrepreneurial opportunities and suggests the regional level of human capital as a predictor of localized entrepreneurial activity. But overall, theoretical and empirical investigations of the relationship between knowledge and entrepreneurship have been insufficient.

This article aims to explain regional variation in knowledge-based entrepreneurial activity (i.e. entrepreneurship in the knowledge economy context). Entrepreneurship or entrepreneurial activity in this research means the discovery of market opportunities and appropriation of their associated market values via creating new firms. We consider entrepreneurial activity as a systematic process, addressing the concern of Shane (2003) over the lack of a holistic approach to entrepreneurship. Our discussion starts by introducing a systems approach to entrepreneurship. The concept of *regional systems of entrepreneurship* highlights important regional factors that may interactively influence the creation, discovery and exploitation of entrepreneurial opportunities. Within this conceptual framework, we propose a three-phase structural model for knowledge-based regional entrepreneurship systems, in which human capital attraction and knowledge production pave the way for the boom of new firm formation. The model is built on the absorptive capacity theory of knowledge spillover entrepreneurship that reveals new knowledge as one source of entrepreneurial opportunities and human capital as the major source of entrepreneurial absorptive capacity. We tested the three-phase model based on data of US metropolitan areas using path analysis/structural equation modeling (SEM).

The article is organized as follows. The next section introduces a systems approach to entrepreneurship. Section 3 reviews the literature on the relationships between knowledge, entrepreneurship and geography, which lays the theoretical foundation for a three-phase model of knowledge-based regional systems of entrepreneurship

proposed in Section 4. This model is empirically tested in Section 5. The last section summarizes the research and discusses policy implications.

2. Defining regional systems of entrepreneurship

Entrepreneurship manifests itself in a complex process and entrepreneurship research is multidisciplinary in nature. When investigating entrepreneurial behavior of scientists, Audretsch and Kayalar-Erdem (2005) identify a large set of determinants at the individual level, the firm level, the regional level, as well as the institutional/policy level, accentuating the complexity nature of entrepreneurship. As Shane (2003) notes, however, entrepreneurship research tends to study only one part of the entrepreneurial process, and an interdisciplinary approach has been missing. Audretsch and Kayalar-Erdem (2005) similarly suggest that a holistic approach to entrepreneurship is needed.

A holistic approach to innovation has been proliferating for the past two decades. Early studies focus on national settings that influence innovative activity (Lundvall, 1992; Nelson, 1993; Edquist, 1997). Edquist (1997) defines national systems of innovation as 'all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovations'. Braczyk et al. (1998) and Cooke et al. (1997) propose the concept of regional innovation systems, and examine how governances, institutionalized learning, and culture may impact innovation at the regional level. Studies on innovation systems address the importance of environmental and institutional factors in the innovation process.

Although entrepreneurship (in the Schumpeterian notion) is closely associated with innovation (Schumpeter, 1934), the literature of innovations systems sheds limited light on a holistic approach to entrepreneurship. To begin with, students of innovation systems have put little emphasis on individual traits, personalities and behavior in the innovation process, which carry much weight in understanding the entrepreneurial process. As Edquist (2005) has summarized, an innovation system consists of two main components: organizations and institutions. This is consistent with the notion of 'players' and the 'rules of game' addressed by North (1990). Research attention, therefore, has been paid to the role of firms in innovation (large firms with R&D capacity in particular) and institutional environments in which innovative activity occurs. Within this framework, entrepreneurial activity as individual behavior of entrepreneurs has been understated. Moreover, the systems approach to innovation fails to address new firm formation as an important reflection of entrepreneurial activity, while its primary focus has been on incumbent firms. Although the entrepreneurial process does not necessarily involve the creation of new organizations (Shane, 2003), many entrepreneurship scholars consider the creation of new firms as a conduit of pursuing entrepreneurial opportunities (e.g. Malecki, 1994; Audretsch, 1995; Acs and Armington, 2006). Cooke (2001) discusses entrepreneurs and venture capital in the context of regional innovation systems. However, entrepreneurship is loosely linked with the five core concepts he has identified for regional innovation systems, namely regions, innovation, network, learning and interaction.

The insufficient investigations of entrepreneurs and new firms in the literature of innovation systems further call for developing a systems approach to entrepreneurship. We make an effort toward this direction, define *systems of entrepreneurship* as *those*

economic, social, institutional and all other important factors that interactively influence the creation, discovery and exploitation of entrepreneurial opportunities. The explicit inclusion of factors' interactiveness addresses complexity and non-linearity of entrepreneurship systems. In some influential entrepreneurship research (e.g. Audretsch, 1995; Shane, 2003), the creation of entrepreneurial opportunities is not considered as part of the entrepreneurial process. These opportunities are generally assumed as exogenous. However, while it is not uncommon that entrepreneurs exploit market opportunities embodied in new knowledge, the production of commercially useful new knowledge becomes a process of creating entrepreneurial opportunities. We, therefore, consider the creation of entrepreneurial opportunities as an indispensable part of building an entrepreneurial economy.

The *function* of systems of entrepreneurship is to pursue entrepreneurial activity manifested in a serial process of creating, discovering and exploiting entrepreneurial opportunities, compared with the learning process as the primary function of innovation systems (Edquist, 2005). The performance of entrepreneurship systems depends on interactions among three major *components*: individuals, organizations and institutions. In addition to organizations (e.g. firms, research institutions and government agencies) and institutions (e.g. protection of property rights) that have been stressed by followers of innovation systems, individuals (e.g. inventors and entrepreneurs) are of particular importance in systems of entrepreneurship. Not all entrepreneurs are affiliated with firms or other organizations when they discover and/or exploit market opportunities. The separation of individuals from organizations thus becomes necessary in characterizing systems of entrepreneurship.

Any system should have a definable *boundary*. When the boundary is defined by geography, *regional systems of entrepreneurship* can be identified. A region can be a county, a city, a state, a group of any type (e.g. a metropolitan area or a mega region) or any definable geographic area that has a function of facilitating entrepreneurial activity. The focus of this research is on entrepreneurship in the knowledge economy context, and efforts are made to model knowledge-based regional systems of entrepreneurship. In others words, it seeks geographically bounded factors that interactively influence the creation, discovery and exploitation of knowledge-based entrepreneurial opportunities.

3. Literature: knowledge, entrepreneurship and geography

3.1. Knowledge and entrepreneurship

Economists have been long studying the economic values of knowledge, technology and learning. Marshall (1920) considers knowledge spillover as one of the driving forces of industrial clustering. Solow (1957) in the neoclassical framework addresses the importance of exogenous technological change for economic growth. Arrow (1962) identifies the characteristics of knowledge that differentiate it from traditional input factors (i.e. labor, land and capital) and discusses productivity growth through learning by doing. Despite these influential early studies, the economics of knowledge did not draw broad attention from economists before the 1980s.

This situation has been changed thanks to the seminal work on knowledge production and on endogenous growth theory. Knowledge production function (Grilliches, 1979; Jaffe, 1986, 1989) identifies both private and university R&D activities as sources of private innovations, suggesting the existence of knowledge

spillover from universities to the private sector. Endogenous growth theory developed by Romer (1990), differing from Solow's neoclassical growth model, considers technological change as an endogenous process. Firms' purposeful R&D activity in this framework becomes possible due to the existence of the patent system that makes new knowledge partially excludable. Knowledge spillovers or human capital externalities (Lucas, 1988) further lead to technological change at the social level.

While both the knowledge production function approach and endogenous growth theory recognize the importance of knowledge spillover for innovation and economic development, they have failed to explain the mechanism of knowledge spillover (Acs et al., 2009). They have also missed the differentiation between new knowledge and economically useful knowledge first raised by Arrow (1962). As Braunerhjelm et al. (2010) and Michelacci (2002) have argued, R&D or knowledge production may not lead to innovations and economic growth if new knowledge cannot be commercialized. To address these missing but important points, Audretsch (1995) and Acs et al. (2009) developed a knowledge spillover theory of entrepreneurship. The theory identifies new knowledge as one source of entrepreneurial opportunities and considers entrepreneurship as a conduit of transmitting knowledge spillover. It is consistent with the 'analytical knowledge base' that addresses innovative activity via commercializing new knowledge (Asheim et al., 2007). As a typical case exemplifying the theory, a researcher in a large firm may choose to leave and start a new firm to commercialize her/his research fruit, if the decision makers in the incumbent decide not to bring this new invention into the market end when they perceive its potential market value differently from the inventor. The existence of these different perceptions is not surprising, since knowledge, distinct from traditional input factors, is characterized with high degree of uncertainty, high extent of asymmetries and high transaction costs [Arrow, 1962; addressed by Audretsch and Lehmann (2005)]. When entrepreneurial activity occurs this way, knowledge spills over from the large incumbent firm to the newly created firm and thus entrepreneurial activity by the researcher becomes a conduit of transmitting knowledge spillover. Similarly, spillovers can also occur from universities or research institutions to new firms. When entrepreneurship serves as the conduit of transmitting knowledge spillover, it is identified as knowledge spillover entrepreneurship.

The knowledge spillover theory of entrepreneurship builds a link between knowledge and entrepreneurship. It clearly suggests that new knowledge represents one source of entrepreneurial opportunities, and thus a higher level of knowledge stock may leads to a higher level of entrepreneurship (Audretsch and Keilbach, 2006; Acs et al., 2009). Qian and Acs (2011) point out several weaknesses of the knowledge spillover theory of entrepreneurship: the mix-up of knowledge and new knowledge, the sole focus on scientific entrepreneurs and the lack of interpersonal knowledge spillover. They advance the theory by proposing an absorptive capacity theory of knowledge spillover entrepreneurship. According to their theory, the extent to which entrepreneurship represents a mechanism of transmitting knowledge spillover depends not only on the speed of knowledge production, but also on entrepreneurial absorptive capacity which they defined as 'the ability of an entrepreneur to understand new knowledge, recognize its value and commercialize it by creating a firm'. Based on this theory, entrepreneurs are not necessarily scientists or inventors in large incumbent firms or universities, and can be outsiders who seek for market opportunities. Qian and Acs identify two types of knowledge that underpin entrepreneurial absorptive capacity: scientific knowledge and business knowledge. They also contend that human capital is critical to both knowledge
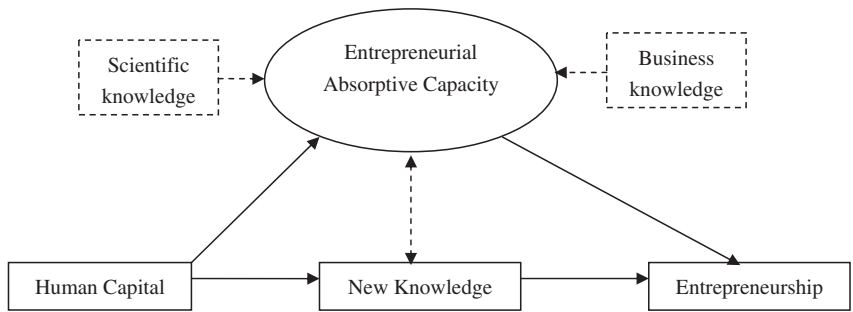
Figure 1. The absorptive capacity theory of knowledge spillover entrepreneurship. *Source:* Qian and Acs (2011).

creation and to building entrepreneurial absorptive capacity. The absorptive capacity theory of knowledge spillover entrepreneurship is described in Figure 1. Although the theory itself is about individual entrepreneurs, it also provides insights on building an entrepreneurial economy at the regional level.

On the empirical side, the effect of human capital on entrepreneurial activity has been extensively studied. At the regional level, Acs and Armington (2006) and Lee et al. (2004) reveal that the share of college graduates is positively associated with new firm formation rates in USA especially in its service sector. Audretsch and Lehmann (2005) demonstrate a positive relationship between university students and knowledge-based startups in Germany. At the firm level, Davidsson and Honig (2003) find a positive association between human capital and the successful completion of the start-up process. Similarly, entrepreneurs' human capital is positively associated with the survival of new entrants (Bates, 1990; Cooper et al., 1994), the growth of new technology firms (Colombo and Grilli, 2005) and the initial firm size of start-ups (Colombo et al., 2004).

3.2. The role of geography in knowledge spillover entrepreneurship

3.2.1. The geography of knowledge spillover

The relationship between knowledge and entrepreneurship is by no means independent of regions or geography, not only because both knowledge production and entrepreneurial activity have a geographic dimension (Feldman, 1994; Acs and Armington, 2006), but because knowledge spillovers are geographically bounded (Jaffe et al., 1993; Anselin et al., 1997; Acs et al., 2002a; Peri, 2005). Theories reviewed in last section (Audretsch, 1995; Acs et al., 2009; Qian and Acs, 2011) have identified entrepreneurial activity as a channel of transmitting knowledge spillovers. As a result, the literature on the geography of knowledge spillover may shed light on regional variation in knowledge-based entrepreneurial activity.

There are three main streams of research investigating knowledge spillover at the regional level. The first stream focuses on the geographic pattern of knowledge spillover, and in most cases concludes that the spillover effects are localized (Jaffe et al., 1993; Anselin et al., 1997; Almeida and Kogut, 1999; Acs et al., 2002a; Peri, 2005; Sonn and Storper, 2008). In addition, localized knowledge spillover generally occurs in

cities, while cities play an important role in fostering learning (Jacobs, 1969; Glaeser, 1998).

The second stream, following new economic geography (Krugman, 1991), supports a positive effect of agglomeration on geographically bounded knowledge spillover. Krugman (1991) argues that manufacturers' concern over economies of scale and transport costs under certain circumstances will lead the industry to concentrate in the region where the initial demand for their products is relatively high. Geographic concentrations of production, as Audretsch and Feldman (1996) have pointed out, facilitate knowledge spillover particularly in knowledge-intensive industries. Accordingly, knowledge-intensive industries are more clustered than traditional industries. The positive effect of agglomeration on technology or knowledge spillover is also found by Koo (2005).

The third stream, to some extent related to the second one, examines the role of industrial structure in knowledge spillover. Glaeser et al. (1992) summarize two technological externality theories that interpret what type of industrial structure is more conductive to knowledge spillover. One known as the Marshall–Arrow–Romer (MAR) externalities follows the idea of Marshall (1920) that the concentration of an industry in a city benefits producers through knowledge spillovers among firms within that industry. This is consistent with the empirical study of Acs et al. (2002b) and Henderson (2003). Contrary to the MAR theory, Jacobs (1969) and Quigley (1998) suggest that knowledge spillovers between industries are important for innovation and the growth of cities. In their view, diversity of geographically proximate industries in cities contributes more to knowledge spillover than specialization in one or a few industries. Empirical studies performed by Glaeser et al. (1992) and Feldman and Audretsch (1999) support Jacobs's emphasis on diversity. Duranton and Puga (2001) propose the coexistence of diversified and specialized cities, arguing that innovations generally occur in diversified cities but firms/establishments may relocate to specialized cities once the production process becomes standardized. So far no consensus has been reached on whether diversity or specialization can better facilitate knowledge spillover.

3.2.2. The geography of human capital

The absorptive capacity theory of knowledge spillover entrepreneurship (Qian and Acs, 2011) addresses the central role of human capital in fostering entrepreneurial activity. It is not only a major determinant of knowledge production through which knowledge-based entrepreneurial opportunities are created, but also a major determinant of entrepreneurial absorptive capacity that is critical to the success of entrepreneurial actions. That being said, understanding the geographic pattern of human capital contributes to a comprehensive investigation of the geography of entrepreneurship in the knowledge context.

Economists, geographers and regional scientists have examined and discovered the important role of some geographically mediated factors in determining the location of human capital.[1] As discussed by Florida et al. (2008), three factors are of particular importance. To begin with, regions that provide more amenities associated with the quality of life tend to have advantages in attracting talent (Florida, 2002c;

---

1   For a review, see Florida et al. (2008).

Kotkin, 2000; Glaeser et al., 2001). Florida (2002a) finds a positive relationship between cultural amenities in terms of bohemians and human capital. Shapiro (2006) concludes that 'roughly 60% of the effect of college graduates on employment growth is due to productivity; the rest comes from the relationship between concentrations of skill and growth in the quality of life' (p. 324). Moreover, social diversity, tolerance or openness has been identified as another factor that may affect human capital or talent. For instance, Saxenian (1999) finds cultural diversity among scientists, engineers and entrepreneurs in Silicon Valley. Florida (2002b; Mellander and Florida, 2006; Florida et al., 2008) argues that social diversity signals lower barriers to entry of outside talent with different backgrounds. As a result, regions with higher levels of social diversity may be more attractive to talent. In addition, the presence of universities appears to be critical to human capital stock (Berry and Glaeser, 2005; Florida et al., 2008; Qian, 2010). Universities not only produce human capital but also serve as the locus where researchers and professors can teach and conduct research.

4. A three-phase model of knowledge-based regional systems of entrepreneurship

4.1. The model

This section builds a model for knowledge-based regional systems of entrepreneurship, which directly stresses the objective of this research. Such a model is expected to meet four goals. First, it should identify those major factors that influence knowledge-based entrepreneurial activity. Second, the model should present a clear mechanism on how the system works to fulfill the function of pursuing knowledge-based entrepreneurial activity. In systems of entrepreneurship, factors that influence entrepreneurial activity may interact with each other. The model, therefore, should capture interconnectedness among variables. Third, the model should provide policy implications for regional or urban planners on how to build a vibrant regional entrepreneurship system. And last, the model should allow for empirical tests.

Based on the absorptive capacity theory of knowledge spillover entrepreneurship and the literature on the geography of human capital and on the geography of knowledge spillover, a three-phase structural model of knowledge-based regional systems of entrepreneurship is proposed in Figure 2. The core relationships in this model (in Phases II and III) are those suggested by the absorptive capacity theory of knowledge spillover entrepreneurship (consistent with Figure 1). Entrepreneurial absorptive capacity is not directly shown in Figure 2 but is indirectly suggested by the direct effect of human capital on entrepreneurship after isolating its indirect effect on entrepreneurship via knowledge creation.[2] By doing this it is assumed that there are only two conduits through which human capital can contribute to entrepreneurship. On the one hand, human capital produces new knowledge and thus creates entrepreneurial opportunities; on the other hand, human capital builds entrepreneurial absorptive capacity which is indispensable for successful entrepreneurial practices. Such an indirect way to measure entrepreneurial absorptive capacity is employed due to the difficulty in measuring it directly. Relatively speaking, it is easier to find a measurable proxy for new

---

2 While entrepreneurial absorptive capacity is measured indirectly, the distinction between its two components—scientific knowledge and business knowledge—is not reflected in Figure 2.
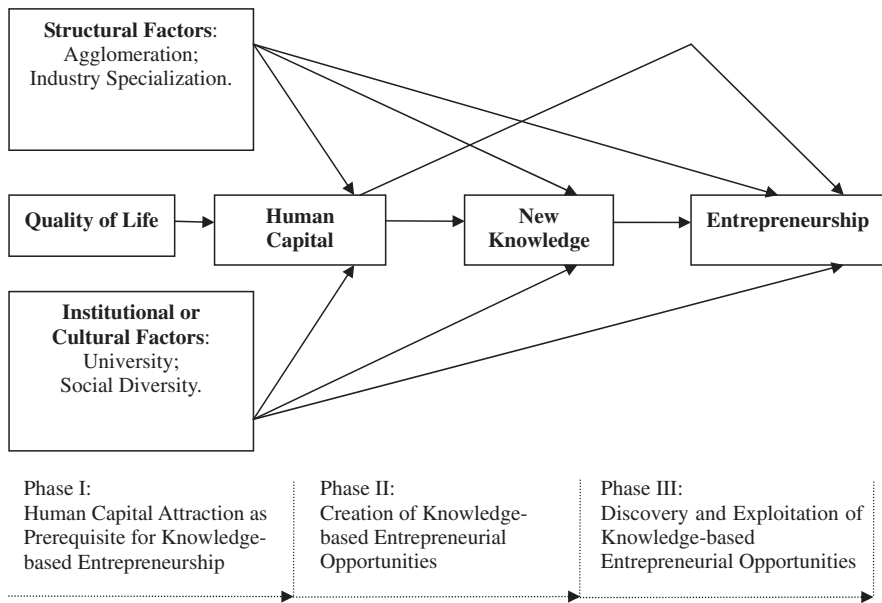
Figure 2. A schematic description of the three-phase model of knowledge-based regional systems of entrepreneurship.

knowledge than for absorptive capacity. The widely used R&D measure for absorptive capacity (e.g. Cohen and Levinthal, 1990; Zahra and George, 2002) does not apply to the case of entrepreneurship since new firm formation in most cases does not even involve R&D activity.

Besides those core relationships suggested by the absorptive capacity theory of knowledge spillover entrepreneurship, the model introduces five exogenous variables which may affect not only the location of human capital but also the geographically mediated process of knowledge spillover entrepreneurship. These exogenous variables include agglomeration, industry specialization, the quality of life, the university and social diversity. The relationships among these exogenous variables, human capital, new knowledge and entrepreneurship feature three phases of knowledge-based entrepreneurial activity: human capital attraction as the prerequisite, knowledge production to create knowledge-based entrepreneurial opportunities, and entrepreneurial actions to appropriate the market value of new knowledge. Next we will elaborate on these three phases.

4.2. Phase I

The first phase of the model focuses on the geography of human capital, in other words, those geographically mediated factors that are associated with the location of human capital. The first set of explanatory variables revolves around demographic and economic structures. Following the idea of Glaeser (1999), young and well-educated people tend to move to those cities where they may benefit from interpersonal learning. As a consequence, demographic and economic structures that facilitate interactive learning can better attract human capital. In this sense, agglomeration is likely to be a

factor positively associated with human capital, in that it indicates easy access to other people and frequent face-to-face communications through which knowledge can spill over both between economic agents and between firms. Phase I also takes into account another factor related to the economic structure of a region, industry specialization, which addresses the debate between the MAR notion and the Jacobs notion of knowledge spillover. While human capital may move to the places that encourage learning and knowledge spillover, industrial structure as a potential determinant of knowledge spillover may influence the location of human capital. The second set of factors addresses the role of the quality of life in attracting human capital. And the third set of factors is institutional or cultural. Of particular importance is the role of universities in producing and attracting well-educated human capital. The latter two sets have been discussed in the literature section.

4.3. Phase II

The second phase highlights geographically bounded factors that affect knowledge production, addressing the central role of human capital in generating new knowledge. The knowledge production function places primary emphasis on R&D, which in this model is manifested in human capital that undertakes R&D activity.

Phase II also stresses both direct and indirect effects on knowledge production imposed by those factors that influence human capital. The two structural factors, agglomeration and industry specialization, while associated with learning and knowledge spillover, are expected to influence new knowledge directly as well as indirectly through human capital. The quality of life addressing individual life styles is unlikely to exert direct effects on new knowledge. Those institutional and cultural factors identified in the first phase may directly influence knowledge creation as well. The university is apparently the locus where many new technologies are generated, acting as a magnet that draws together various resources for knowledge production. Social diversity may directly influence the knowledge creation process in that a diversified provision of people with different knowledge and cultural backgrounds encourages new combinations of existing knowledge which lead to the births of new knowledge. This is consistent with the argument made by Crescenzi et al. (2007) that migration flows especially in terms of human capital mobility contribute to new knowledge creation by increasing the diversities of knowledge, skills and cultures.

4.4. Phase III

The last phase directly addresses the function of knowledge-based regional systems of entrepreneurship and presents geographically bounded factors that influence entrepreneurship. Consistent with the absorptive capacity theory of knowledge spillover entrepreneurship, new knowledge and human capital play central roles in facilitating entrepreneurial activity in knowledge-based systems of entrepreneurship. New knowledge that is potentially valuable in the market creates entrepreneurial opportunities. Entrepreneurial discovery and exploitation are both highly reliant on knowledge and skills embodied in entrepreneurs (i.e. entrepreneurial absorptive capacity), which are in essence associated with human capital defined by Schultz (1961).

Some of those exogenous factors presenting indirect effects on entrepreneurship through human capital, new knowledge or both may directly influence entrepreneurial

activity. Agglomeration and industry specialization may impose direct impacts on new firm formation, echoing entrepreneurship effects of clusters addressed by Delgado et al. (2010) and Porter (1998). Agglomeration alone is critical to information stocks and flows that according to Sweeney (1987) are important elements of entrepreneurial culture. Similarly, industry specialization may also play a role in fostering localized knowledge spillover (MAR externalities), for which entrepreneurship has been identified as one of its mechanisms. The role of the university in a knowledge-based regional system of entrepreneurship is far beyond its supply of well-educated human capital and new inventions. It can influence local entrepreneurial spirit through those business trainings or courses it offers (Katz, 2003; Kuratko, 2005) and provide additional entrepreneurial opportunities not embodied in new inventions but in tacit knowledge that it delivers to the local community. A lot of business incubators, which facilitate new firm formation, are hosted by universities (Qian et al., 2011). Smilor et al. (2007) also note the role of research universities in encouraging faculty/students start-ups through their award and recognition programs. A direct effect of the university on entrepreneurship is thus hypothesized. Social or cultural diversity may also affect entrepreneurship directly. A diversified provision of individuals or potential entrepreneurs enlarges the span of differentiation in perceiving the market value of new inventions, thereby increasing the possibilities of entrepreneurial discoveries. Empirical evidence of this relationship has been found by Audretsch et al. (2010).

5. Empirical evidence from US metropolitan areas

5.1. Model specification

This section provides empirical evidence for the three-phase structural model. The model shown in Figure 2 has suggested three phases of economic activity in a knowledge-based regional system of entrepreneurship: human capital attraction, knowledge creation and entrepreneurial discovery and exploitation. Consistent with these three phases, three equations should be estimated, with human capital, new knowledge and entrepreneurship separately as the dependent variable. These equations are specified as:

$$\text{Human capital} = \alpha_1 \text{ Agglomeration} + \alpha_2 \text{ Industry spec} + \alpha_3 \text{ Life quality} + \alpha_4 \text{ University} + \alpha_5 \text{ Tolerance} + \varepsilon_1 \tag{1}$$

$$\text{New knowledge} = \beta_1 \text{ Agglomeration} + \beta_2 \text{ Industry spec} + \beta_3 \text{ University} + \beta_4 \text{ Tolerance} + \beta_5 \text{ Human capital} + \varepsilon_2 \tag{2}$$

$$\text{Entrepreneurship} = \gamma_1 \text{ Agglomeration} + \gamma_2 \text{ Industry spec} + \gamma_3 \text{ University} + \gamma_4 \text{ Tolerance} + \gamma_5 \text{ Human capital} + \gamma_6 \text{ New knowledge} + \varepsilon_3 \tag{3}$$

According to these equations, human capital, new knowledge and entrepreneurship are endogenous variables. They are determined by five exogenous variables: agglomeration, industry specialization, the quality of life, the university and tolerance or social diversity.

Table 1. Measurement of variables

Variable	Measure	Data sources
Entrepreneurship	General model: number of new firms (single-unit establishment births) per 1000 labor force High technology model: number of new firms in high technology industries per 1000 labor force Core high technology model: Number of new firms in core high technology industries per 1000 labor force	Business Information Tracking System (BITS); Bureau of Labor Statistics
New knowledge[a]	Number of patents per 1000 population	US Patent and Trademark Office; Census
Human capital[a]	Percentage of adults (age 25+) holding a bachelor's degree	Census
Agglomeration	Population per square mile	Census
Industry specialization[a]	Tech-pole Index	Milken Institute
Quality of life[a]	Number of consumer service industries (five-digit NAICS code)	Census
University[a]	Number of faculty per 1000 population	Integrated Postsecondary Data Set; Census
Tolerance[a]	Combined Gay Index and Bohemian Index	Census

[a]Kevin Stolarick generously provided cleaned data for these variables.

5.2. Measures and data

We use US metropolitan statistical areas (MSAs) as the geographic unit for analysis. MSAs are used for two reasons. First, over 90% of US business establishments concentrate in metropolitan areas (Plummer and Headd, 2008). Second, while knowledge spillovers are geographically bounded, cities or metropolitan areas play an important role in fostering knowledge spillover with the geographic proximity it provides for a large size of population. While our model of entrepreneurship is built on knowledge and knowledge spillover, cities or MSAs become exceptionally important for knowledge-based entrepreneurial activity.

Measurable proxies are introduced for all exogenous and endogenous variables. Table 1 summarizes measures of variables and their data sources. The remaining part of this section elaborates on these measures and their corresponding data.

5.2.1. Entrepreneurship

Entrepreneurship is the dependent variable of Equation (3) and the core item this research tries to explain. Following other empirical studies (Lee et al., 2004; Acs and Armington, 2006), entrepreneurship is measured through the new firm formation rate calculated by dividing the number of total firm births in an MSA by its total labor force. To capture the effect of knowledge on entrepreneurial activity, three models that measure new firm formation rates at three levels are separately used. The first one, called *the general model*, uses the new formation rate for all industries as a measure for entrepreneurship. The second model, called *the high technology model*, adopts the new firm formation rate for high technology industries as the measure for entrepreneurship.

In other words, this model seeks determinants of high technology entrepreneurship in the knowledge-based regional systems of entrepreneurship. We use the high technology industries defined by Hecker (2005) in terms of the share of technology-oriented occupations in four-digit NAICS code industries. One industry is identified as a high technology industry if its share of technology-oriented occupations is at least twice of the average of all industries [a full list of high technology industries can be found in Hecker (2005)]. While this share is more than five times of the all-industry average, the industry is named as a Level-1 industry. The third model, called *the core high technology model*, measures entrepreneurship only in those Level-1 industries.[3]

It is hypothesized that human capital and knowledge play an increasingly important role in entrepreneurial activity when shifting the focus from general industries to high technology industries and then to core high technology industries. On the one hand, entrepreneurial opportunities are more likely to come from new knowledge in high technology or core high technology industries than in general industries; on the other hand, the successful exploitation of knowledge-based entrepreneurial opportunities requires greater entrepreneurial absorptive capacity in high technology or core high technology industries than in general industries. As a result, both the direct and indirect effects of human capital on entrepreneurship are expected to be larger when industries are more technology-based.

5.2.2. New knowledge

It is difficult to measure knowledge and new knowledge. The literature (e.g. Polanyi, 1966) has identified two types of knowledge: codified knowledge and tacit knowledge. While it is almost impossible to quantify tacit knowledge, publications and patents are widely employed as measures for codified knowledge. This empirical analysis adopts the number of newly granted patents per capita as a measure for new knowledge, because patents can better represent commercially useful knowledge than publications. Although not every invention is patented, the number of patents relative to population is a reasonable measure for regional innovative activity and has been widely used in empirical studies on the geography of innovation (e.g. Jaffe, 1989; Acs et al., 2002a).

5.2.3. Human capital

Human capital, defined as knowledge and skills embodied in people (Schultz, 1961), is traditionally measured in terms of educational attainment. A typical measure is the percentage of adults (age 25+) with a bachelor's degree or above (Florida, 2002b; Lee et al., 2004; Acs and Armington, 2006), which is also used here.

---

3 Level-1 industries identified by Hecker (2005) include computer systems design and related services (NAICS code: 5415), software publishers (5112), architectural, engineering, and related services (5413), scientific research and development services (5417), internet service providers and web search portals (5181), computer and peripheral equipment manufacturing (3341), internet publishing and broadcasting (5161), navigational, measuring, electromedical, and control instruments manufacturing (3345), data processing, hosting, and related services (5182), aerospace product and parts manufacturing (3364), communications equipment manufacturing (3342), semiconductor and other electronic component manufacturing (3344), pharmaceutical and medicine manufacturing (3252), and other telecommunications (5179).

5.2.4. Agglomeration

Agglomeration or clustering of firms and people provides the physical proximity which facilitates the flow of knowledge and ideas among people. We use population density as a proxy for agglomeration. Although population density is not an ideal measure since it cannot capture the variation of densities with the metro,[4] it however has been considered as 'customary' in the literature (Crescenzi et al., 2007, 685). A higher population density indicates easier access to other people and thus signifies more potential opportunities for face-to-face communications through which knowledge especially in its tacit form can spill over. Population density is calculated as the population per square mile.

5.2.5. Industry specialization

Given the knowledge-economy context of this research, industry specialization measures specialization in high technology. Tech Pole Index developed by the Milken Institute is used as a proxy for industry specialization. It measures technology specialization of MSAs based on the location quotient of high-tech real output multiplying the percent of national high-tech real output (DeVol, 1999). The industry specialization variable (i.e. technology specialization) is expected to be positively associated with human capital,[5] new knowledge and entrepreneurship.

5.2.6. Quality of life

The quality of life has many dimensions, such as natural amenities, cultural richness and service amenities. Natural amenities may be less important in the context of cities. Consumer service amenities have been widely used to represent the quality of life in cities (Glaeser et al., 2001; Florida et al., 2008). Following this approach, the diversity of consumer service firms measured by the number of service industries (five-digit NAICS code) presented in an MSA is used to indicate the quality of life of this MSA.[6]

5.2.7. University

Universities may contribute to localized innovation and entrepreneurship by providing human capital, generating new knowledge which may contain entrepreneurial opportunities, and engaging in community services especially in business knowledge training. The faculty in universities plays a leading role in all these aspects and accordingly the size of the faculty may determine the extent to which universities facilitate regional innovative and entrepreneurial activity. The university variable is therefore measured by the number of faculty per capita.

---

4 We would like to thank one of the reviewers for raising this point.
5 Different from the assumption made by Florida et al. (2008), a causal relationship from high technology to human capital is assumed in this study. This is consistent with the "people are following jobs" finding of Partridge and Richman (2003). We however are aware of the inconclusive debate between "people follow jobs" and "jobs follow people" in regional and urban economics. In the context of human capital, a recent study by Chen and Rosenthal (2008) has found young, highly educated people move for high quality business environments. In the context of entrepreneurship, Harrison et al. (2004) report that entrepreneurs are attracted to technology clusters. Both studies support our assumption in the knowledge economy context.
6 A full list of service industries will be sent by the author upon request.

Table 2. Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Entrepreneurship	305[a]	4.280	1.275	2.412	10.843
High-tech entrepreneurship	305	0.292	0.184	0.022	1.328
Core high-tech entrepreneurship	305	0.148	0.105	0	0.798055
New knowledge	305	0.260	0.381	0.005	3.576
Human capital	305	23.329	7.312	11.048	52.383
Agglomeration	305	409.959	949.748	5.412	13,042.940
Tech specialization	302	0.493	2.015	0.000	29.956
Quality of life	305	220.272	23.844	41	253
University	305	2.138	2.140	0	14.445
Tolerance	305	0.858	0.280	0.437	2.866

[a]The 1999 US Office of Management and Budget (OMB) MSA definition identified 331 MSAs/PMSAs. We lost some observations that were not defined by county boundaries when we obtained the MSA-level data via aggregating the county-level data.

5.2.8. Social diversity/tolerance

Several measures for social diversity, tolerance or openness have appeared in the literature. Florida (2002c) suggests that the concentration of gays and lesbians can best reflect the level of tolerance in a city. Florida et al. (2008) also note that a greater presence of bohemian population may signal lower barriers to entry of talent. Following Florida et al. (2008), the average of the Gay Index and the Bohemian Index is used as a measure for tolerance. The Gay Index is constructed as the percentage of households in each MSA with a householder reporting a homosexual unmarried partner. The Bohemian Index is determined by the fraction of bohemians (including writers, designers, musicians, actors and directors, painters and sculptors, photographers and dancers) relative to total population.

The year of 2000 is used as the primary time for this cross-sectional analysis. All the five exogenous variables—including agglomeration, industry specialization, the quality of life, the university and tolerance—and the mediating variable human capital are measured with the 2000 data. Patent data for the variable of new knowledge are for the year of 2001, and new firm formation data are for the year of 2002.[7] The time lags between these two endogenous variables and other variables are employed to partially address the potential problem of endogeneity. Descriptive statistics of all variables are shown in Table 2. A correlation matrix of variables in their logarithm form is shown in Table 3. When running regressions later, the logarithm form of all variables is again used to reduce their variances, which may further reduce the effects of heteroscedasticity on parameter estimation.

5.3. Method

This article employs a SEM approach to path analysis to test the model, similar to the work of Florida et al. (2008) in the context of explaining regional development and

---

7   All population and labor force data are for 2000.

Table 3. Correlation matrix

Variables	Entrepreneurship	High-tech entrepreneurship	Core high-tech entrepreneurship	New knowledge	Human capital	Agglomeration	Tech specialization	Quality of life	University	Tolerance
Entrepreneurship	1.000									
High-tech entrepreneurship	0.694***	1.000								
Core high-tech entrepreneurship	0.590***	0.912***	1.000							
New knowledge	0.047	0.472***	0.515***	1.000						
Human capital	0.328***	0.681***	0.727***	0.556***	1.000					
Agglomeration	0.077	0.359***	0.373***	0.318***	0.330***	1.000				
Tech specialization	0.270***	0.583***	0.593***	0.507***	0.557***	0.521***	1.000			
Quality of life	0.213***	0.366***	0.347***	0.214***	0.295***	0.377***	0.475***	1.000		
University	−0.195***	−0.009	0.082	0.142**	0.427***	−0.049	0.030	−0.047	1.000	
Tolerance	0.390***	0.666***	0.672***	0.496***	0.722***	0.505***	0.598***	0.429***	0.159***	1.000

**Significant at 0.05 level; ***significant at 0.01 level.

Florida and Mellander (2010) in the context of investigating metropolitan housing values. It allows for multiple dependent variables and can produce a diagram presenting the relationships between independent, intermediary and dependent variables. In this process, path analysis/SEM allows for separating the direct effect of one explanatory variable from its indirect effects on the dependent variable via its effects on intermediary variables. Compared with regression analysis with a single dependent variable, path analysis not only presents the relationship between two variables but also suggests how (or through what) they are related to each other. These advantages make it possible to demonstrate how regional systems of entrepreneurship work to facilitate entrepreneurial activity. It, however, should be pointed out that the SEM method sheds no light on causalities. The causal directions in Figure 2 are assumed based on theories. Parameters are simultaneously estimated using maximum likelihood method.

5.4. Results

We now focus on the results of path analysis/SEM. The path diagrams with estimated path coefficients (i.e. standardized regression coefficients), regression coefficients and R^2 for each equation, and direct and indirect effects of exogenous variables will all be presented separately for the general model, the high technology model and the core high technology model. Following suggestions from McDonald and Ho (2002), three goodness-of-fit indices are reported for the SEM model: chi-square, CFI and RMSEA. For an acceptable SEM model, as Garson (2009) has summarized, p-value for chi-square should be no smaller than 0.05; CFI should be at least 0.90 and RMSEA should be no larger than 0.06.

5.4.1. The general model

The path diagram with path coefficients (also called β-coefficients or standardized regression coefficients) for the general model is presented in Figure 3. For the purpose of readability, insignificant relationships are labeled as dashed arrows and correlations between exogenous variables as well as error terms of endogenous variables are not shown in the path diagrams. The three goodness-of-fit indexes, including chi-square, CFI and RMSEA all satisfy the previously mentioned criteria and thus suggest the model is well structured. Regression weights before standardization are shown in Table 4.

We start our discussion with those parameter estimations associated with the absorptive capacity theory of knowledge spillover entrepreneurship, which are reflected by the direct and indirect effects of human capital on entrepreneurship. Consistent with new growth theory (Lucas, 1988; Romer, 1990), human capital has a positive relationship with new knowledge measured with patent output. It is highly significant and the path coefficient is as high as 0.40, meaning 1 SD change of human capital will change new knowledge by 0.40 SDs in the same direction (in the logarithm form).

Surprisingly, new knowledge and entrepreneurship are significantly but negatively related with each other. It suggests that additional knowledge output actually discourages rather than encourages entrepreneurial activity. This is inconsistent with the argument of the knowledge spillover theory of entrepreneurship that new knowledge is an important source of entrepreneurial opportunities (Acs et al., 2009). One explanation of this finding is that knowledge spillover entrepreneurship is not
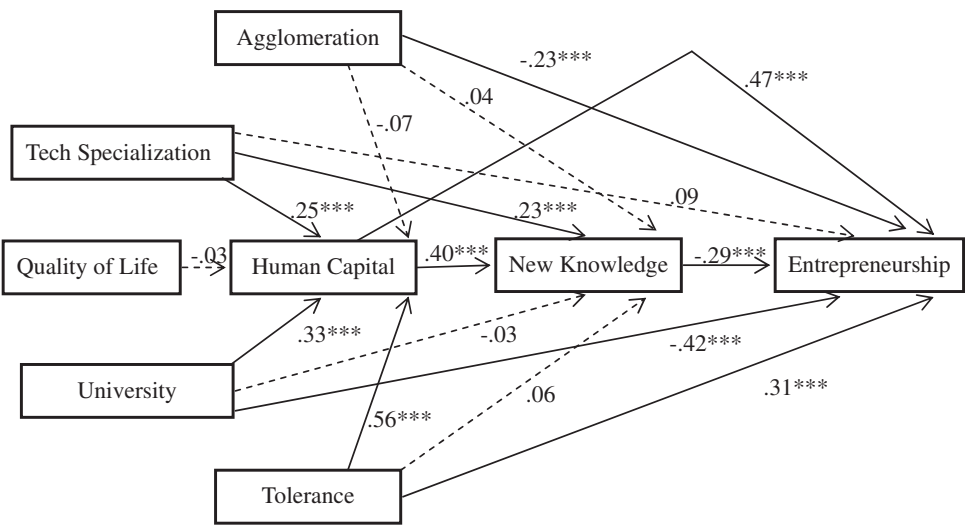
Figure 3. Path analysis/SEM results (general model). SEM goodness-of-fit indexes—χ^2: 2.5 (*p*-value: 0.287); CFI: 0.999; RMSEA: 0.029.

Table 4. Regression weights (general model)

Independent variable	Dependent variable		
	Human capital	New knowledge	Entrepreneurship
Agglomeration	−0.022 [0.013]	0.042 [0.057]	−0.064*** [0.016]
Tech specialization	0.031*** [0.006]	0.095*** [0.025]	0.009 [0.007]
Quality of life	−0.055 [0.085]		
University	0.129*** [0.013]	−0.033 [0.070]	−0.145*** [0.019]
Tolerance	0.590*** [0.047]	0.223 [0.258]	0.288*** [0.071]
Human capital		1.318*** [0.261]	0.422*** [0.075]
New knowledge			−0.079*** [0.016]
R^2	0.667	0.385	0.354
Obs.	305	305	305

***Significant at 0.01 level; SEs in square brackets; two-tail tests.

important for the overall entrepreneurial activity. Most start-ups likely represent the Kirznerian notion of entrepreneurship (Kirzner, 1997) that highlights the correction of market errors, rather than the Schumpeterian notion of entrepreneurship that addresses innovative activity. Similarly, the results may support 'necessity entrepreneurship' rather than 'opportunity entrepreneurship' defined in the Global Entrepreneurship Monitor (GEM) project. Necessity entrepreneurship represents entrepreneurial activity when no better option is available, while opportunity entrepreneurship refers to active engagement in starting a new business to explore a market opportunity (Acs, 2006). In addition, this negative relationship may reflect the 'industrial mismatch' between patenting and entrepreneurship. While the number of patents is disproportionally high

Table 5. Summary of standardized effects on entrepreneurship (general model)

Independent variable	Dependent variable: entrepreneurship		
	Direct effects	Indirect effects	Total effects
Agglomeration	−0.225	−0.036	−0.261
Tech specialization	0.085	0.022	0.108
Quality of life		−0.009	−0.009
University	−0.417	0.125	−0.292
Tolerance	0.308	0.183	0.491
Human capital	0.473	−0.116	0.357
New knowledge	−0.294		−0.294

in the manufacturing industry, Glaeser et al. (2010a) find that only manufacturing only accounts for 5% of US startups. Last, this negative relationship may also be supported by the competition model of knowledge spillover entrepreneurship proposed by L. A. Plummer and Z. J. Acs (unpublished data). According to this model, although new knowledge contains entrepreneurial opportunities, large incumbent firms have advantages in appropriating its market value over start-ups. As a result, a higher level of new knowledge production does not necessarily lead to more vibrant entrepreneurial activity.

After controlling the indirect effect of human capital on entrepreneurship (via new knowledge), the direct effect (i.e. the measure for entrepreneurial absorptive capacity) is positive and highly significant. The path coefficient for this direct effect is 0.47. This supports the absorptive capacity theory of knowledge spillover entrepreneurship and demonstrates the importance of entrepreneurial absorptive capacity in entrepreneurial discovery and exploitation. Human capital, therefore, does contribute to entrepreneurship but through the conduit of building entrepreneurial absorptive capacity rather than creating knowledge-based entrepreneurial opportunities.

Table 5 summarizes the direct, indirect and total effects of exogenous variables and intermediary variables on entrepreneurship. It shows that the positive direct effect of human capital (i.e. entrepreneurial absorptive capacity) outweighs its negative indirect effect (via the creation of new knowledge). As a result, the total effect of human capital on entrepreneurship remains positive. While the positive association between these two variables have been found in many studies even in the literature of the knowledge spillover theory of entrepreneurship (Acs and Armington, 2006; Acs et al., 2009), this study reveals HOW human capital influences entrepreneurship.

Now focus on the phase of human capital attraction which is the critical prerequisite for building knowledge-based regional systems of entrepreneurship. The empirical results shown in Figure 3 and Table 4 suggest several important determinants of regional human capital stock. To begin with, tolerance, openness or social diversity, with a path coefficient of 0.56, reveals its exclusively important role in attracting and retaining human capital. This further supports the argument of Florida (Florida, 2002c; Florida et al., 2008). Moreover, the role of the university in human capital attraction is also positive and very strong (with a path coefficient of 0.33), consistent with the findings of Berry and Glaeser (2005), Florida et al. (2008) and Qian (2010). Besides

these two non-market factors, technology specialization as a market factor presents a positive and significant relationship with human capital. It suggests that human capital goes to cities with available high-skill jobs. This echoes the traditional economic thinking of the demand-supply equilibrium in the high-skill job market. In addition, this study does not find a positive effect of consumer service diversity on human capital, against the conclusion of Glaeser et al. (2001) but to a certain extent supporting Storper and Scott's (2009) work that questions amenities-based urban growth theory.

As for the relationships between exogenous variables and the other two endogenous variables, agglomeration has a surprising negative relationship with entrepreneurship. This may occur due to measurement, since population density may be positively associated with labor force, whereas new firm formation per labor force is negatively associated with labor force. Technology specialization shows a positive effect on both new knowledge and entrepreneurship but only significant for the former. The university exhibits no positive relationships with new knowledge and entrepreneurship after controlling its indirect effects through human capital. This reveals the role of universities in the knowledge economy. Departing from Lee et al. (2004), a positive impact of tolerance on entrepreneurship is found in this study. This is not surprising, since tolerance or diversity brings diversified perceptions over potential market opportunities, and accordingly discovery and exploitation of entrepreneurial opportunities are more likely to occur.

From the policy perspective, it is important to examine the total effects of exogenous variables on entrepreneurship, which may imply policy tools to facilitate entrepreneurship. According to Table 5, both tolerance and technology specialization exhibit positive total effects on general entrepreneurial activity. In contrast, neither agglomeration nor the university shows positive total effects on entrepreneurship. Policy implications of these findings will be discussed in the final section.

5.4.2. The high technology model

The path analysis/SEM results for the high technology model are presented in Figure 4, Tables 6 and 7. They suggest factors that affect high technology new firm formation. And the model fit tests show that the structural model is acceptable.

As only the dependent variable is replaced compared with the general model, major changes of parameter estimations occur in the third phase. The most remarkable one lies in the path coefficient from new knowledge to entrepreneurship, which turns positive now however insignificant. This change may suggest that high technology entrepreneurship is more reliant on new knowledge as a source of entrepreneurial opportunities than general entrepreneurship, which to some extent supports the knowledge spillover theory of entrepreneurship. Even though, the insignificant relationship between new knowledge and entrepreneurship provides the evidence that new knowledge is not a significant source of entrepreneurial opportunities even for high technology entrepreneurship.

As expected, the direct effect of human capital on entrepreneurship after isolating its indirect effect through the creation of new knowledge becomes stronger in this model than in the general model. As an implication, high technology entrepreneurship requires higher levels of entrepreneurial absorptive capacity than general entrepreneurship. In high technology industries, scientific knowledge is generally needed to discover knowledge-based opportunities, and additional management skills may be required in
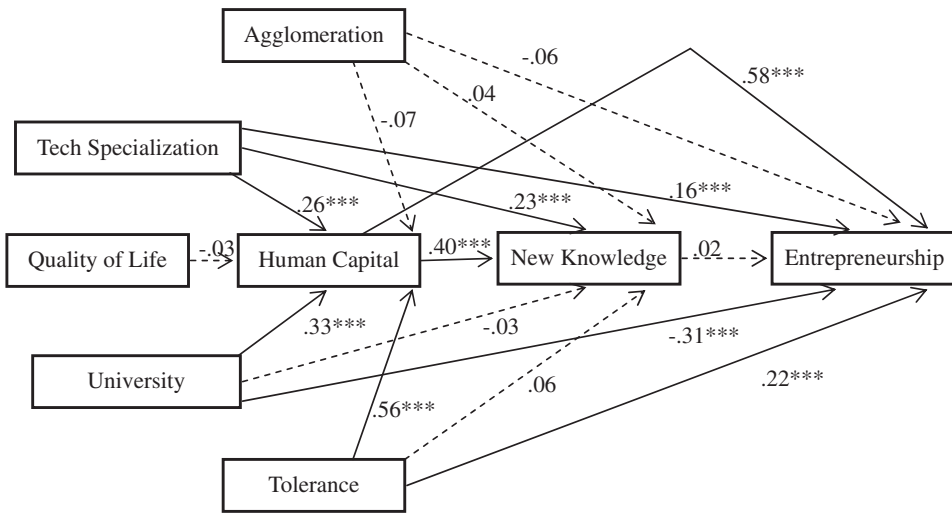
Figure 4. Path analysis/SEM results (high technology model). SEM goodness-of-fit indexes—χ^2: 3.613 (*p*-value: 0.164); CFI: 0.999; RMSEA: 0.052.

Table 6. Regression weights (high technology model)

Independent variable	Dependent variable		
	Human capital	New knowledge	Entrepreneurship
Agglomeration	−0.021 [0.013]	0.042 [0.057]	−0.037 [0.027]
Tech specialization	0.031*** [0.006]	0.095*** [0.025]	0.040*** [0.012]
Quality of life	−0.056 [0.085]		
University	0.129*** [0.013]	−0.037 [0.070]	−0.245*** [0.033]
Tolerance	0.589*** [0.047]	0.220 [0.258]	0.461*** [0.122]
Human capital		1.324*** [0.261]	1.181*** [0.128]
New knowledge			0.013 [0.027]
R^2	0.667	0.385	0.634
Obs.	305	305	305

***Significant at 0.01 level; SE in square brackets; two-tail tests.

order to successfully run start-ups in a more dynamic and risky business environment. This increased direct effect of human capital thus further supports the absorptive capacity theory of knowledge spillover entrepreneurship. As a consequence of the increased direct effect and reversed indirect effect, the total effect of human capital on entrepreneurship becomes much stronger (standardized effects in Tables 5 and 7: 0.59 versus 0.36).

As for direct effects of exogenous variables, although agglomeration still exerts a negative effect on entrepreneurship, the path coefficient increases to −0.06 and becomes insignificant. The positive effect of technology specialization turns significant. The university becomes less 'bad' for entrepreneurship with a higher value of path

Table 7. Summary of standardized effects on entrepreneurship (high technology model)

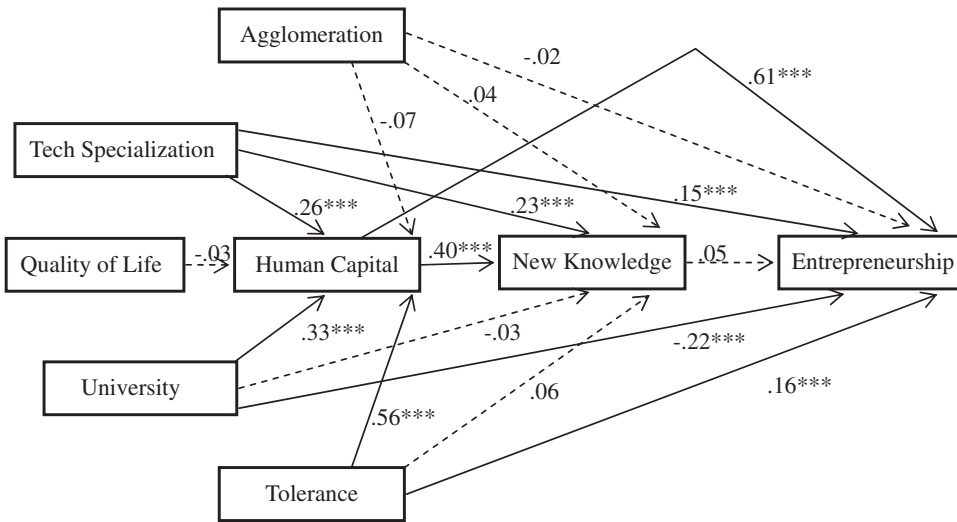| Independent variable	Dependent variable: entrepreneurship		
	Direct effects	Indirect effects	Total effects
Agglomeration	−0.058	−0.038	−0.096
Tech specialization	0.161	0.155	0.316
Quality of life		−0.015	−0.015
University	−0.308	0.194	−0.114
Tolerance	0.216	0.332	0.549
Human capital	0.580	0.008	0.588
New knowledge	0.021		0.021

Figure 5. Path analysis/SEM results (core high technology model). SEM goodness-of-fit indexes—χ^2: 2.565 (*p*-value: 0.277); CFI: 0.999; RMSEA: 0.03.

coefficient (despite the unchanged negative sign). And there is a decreasing role of tolerance or diversity in entrepreneurial activity when shifting from general entrepreneurship to high technology entrepreneurship. Comparing Tables 7 and 5, there is no sign change of standardized total effects except for new knowledge.

5.4.3. The core high technology model

The path analysis/SEM results for the core high technology model are similarly presented in Figure 5, Tables 8 and 9. The SEM goodness-of-fit indexes again supports that the structural model is acceptable.

Similar trends of path coefficient change are expected going from the high technology model to the core high technology model compared with going from the general model to the high technology model, while both moves are toward more knowledge-based

Table 8. Regression weights (core high technology model)

Independent variable	Dependent variable		
	Human capital	New knowledge	Entrepreneurship
Agglomeration	−0.021 [0.013]	0.042 [0.057]	−0.011 [0.031]
Tech specialization	0.031*** [0.006]	0.095*** [0.025]	0.041*** [0.014]
Quality of life	−0.058 [0.085]		
University	0.129*** [0.014]	−0.033 [0.070]	−0.199*** [0.037]
Tolerance	0.590*** [0.047]	0.223 [0.258]	0.380*** [0.138]
Human capital		1.319*** [0.260]	1.409*** [0.145]
New knowledge			0.037 [0.031]
R^2	0.667	0.385	0.639
Obs.	305	305	305

***Significant at 0.01 level; SE in square brackets; two-tail tests.

Table 9. Summary of standardized effects on entrepreneurship (core high technology model)

Independent variable	Dependent variable: entrepreneurship		
	Direct effects	Indirect effects	Total effects
Agglomeration	−0.015	−0.040	−0.054
Tech specialization	0.145	0.172	0.317
Quality of life		−0.017	−0.017
University	−0.219	0.206	−0.013
Tolerance	0.156	0.357	0.513
Human capital	0.607	0.021	0.628
New knowledge	0.053		0.053

entrepreneurial activity. This is supported by the empirical results. In particular, the positive effect of new knowledge on entrepreneurship becomes even stronger with the new path coefficient of 0.05. It, however, does not secure a significant relationship, meaning that new knowledge is neither a significant source of entrepreneurial opportunities in core high technology industries despite its growing importance compared with in high technology industries and in the overall regional economy. The direct effect of human capital on entrepreneurship also becomes stronger, presenting a path coefficient of 0.61 compared with 0.58 in the high technology model and 0.47 in the general model. It further proves that, the more the entrepreneurial activity is knowledge-based, the stronger entrepreneurial absorptive capacity is needed.

For exogenous variables, both agglomeration and the university appear to be less 'bad' for entrepreneurship compared with the previous two models. Again the effect of tolerance or diversity on entrepreneurship has declined. In terms of total standardized effects (Table 9), the core high technology model exhibits a similar pattern with the high technology model. One finding of interest is that the negative total effect of the university on entrepreneurship, while very strong in the general model, becomes negligible in the core high technology model.

Table 10. Comparison of path coefficients across three models

Independent variable	Dependent variable: entrepreneurship		
	General model	High technology model	Core high technology model
Agglomeration	−0.23***	−0.06	−0.02
Tech specialization	0.09	0.16***	0.15***
University	−0.42***	−0.31***	−0.22***
Tolerance	0.31***	0.22***	0.16***
Human capital	0.47***	0.58***	0.61***
New knowledge	−0.29***	0.02	0.05

***Significant at 0.01 level.

6. Discussions of results and policy implications

The purpose of this article is to investigate regional variation in entrepreneurial activity. It contributes to the literature by addressing (i) the knowledge economy context and (ii) a holistic approach to entrepreneurial activity. The article introduces a systems approach to entrepreneurship, and the research objective under this framework becomes efforts to model knowledge-based regional systems of entrepreneurship. A three-phase structural model is proposed based on the literature that examines the relationships between knowledge, entrepreneurship and geography, highlighting the absorptive capacity theory of knowledge spillover entrepreneurship. The model is subsequently tested using the data of US MSAs and the statistical method of path analysis/SEM. The empirical analysis reports three sets of regression results, with entrepreneurship, high technology entrepreneurship and core high technology entrepreneurship as the dependent variable respectively. Table 10 represents a comparison of these three sets of results in term of the direct effects of independent variables and intermediate variables on entrepreneurship.

There are three main findings in terms of the absorptive capacity theory of knowledge spillover entrepreneurship. To begin with, knowledge spillover entrepreneurship exists, since the more the industries under consideration are based on high technology, the more positive relationship between new knowledge and new firm formation can be found. However, knowledge spillover entrepreneurship carries little weight in overall entrepreneurial activity, while new knowledge presents a negative and significant association with new firm formation. In fact, even for high technology industries, new knowledge and entrepreneurship have no significant relationship although it is statistically positive. This result suggests cautiousness in accepting the knowledge spillover theory of entrepreneurship proposed by Acs et al. (2009). The third finding features the mechanism by which human capital affects entrepreneurial activity. Human capital is critical to entrepreneurship, but building entrepreneurial absorptive capacity rather than creating knowledge-based entrepreneurial opportunities primarily reflects its contribution.

For other relationships in the model, industry specialization in high technology, the university and tolerance have been found as significant predictors of regional stock of human capital, consistent with empirical findings in the literature. Due to a strong

negative direct effect, however, the university presents a negative overall effect on entrepreneurial activity, although this negative effect declines when industries of interest are more technology-intensive. The negative effect of the university on entrepreneurship may reflect the different cultures between the university and the private sector, and may also represents a substitution effect rather than a complementation effect in the sense that, when more human capital concentrates in universities (i.e. as faculty), there will be less human capital engaging in entrepreneurial actions. It may also reveal that university entrepreneurship programs in training, incubation and spin-offs play a minor role in facilitating entrepreneurship. Technology specialization exhibits a positive direct effect on entrepreneurship, which is especially higher for high technology industries, and is positively associated with entrepreneurship overall. Tolerance appears to be a significant determinant of both human capital and new firm formation, and is the exogenous factor that exerts the strongest total effect on entrepreneurship.

The theoretical framework and the empirical results of this research shed light on public policy making at the regional, local and especially urban levels to build an entrepreneurial economy. The major implication is to create a regional environment that is attractive to human capital, since human capital promotes entrepreneurial absorptive capacity which further facilitates entrepreneurial activity. Although our empirical tests have demonstrated a positive association between the university and human capital, supporting local universities does not necessarily lead to a higher level of entrepreneurial activity, since the direct effect of the university on entrepreneurship is negative after isolating its indirect effect via human capital. This, however, by no means suggests that policies should not aim at local universities, since there are many other benefits that universities may bring to the local community.

Our analysis shows that specializing in high technology not only contributes to human capital attraction and knowledge creation, but also promotes high technology entrepreneurship directly. Therefore, it implies that public policies should be made to encourage the development of high technology industries. This, however, might not be effective for many regions, at least from the cost-benefit perspective. As Audretsch and Feldman (1996) have found, knowledge-intensive industries tend to be more clustered. Regional variation in high technology accordingly can be described as a self-reinforcing process rather than a spatially equilibrating process. As a result, it is not easy for regions lagged in high technology to build a strong technology base.

Another key finding of the research lies in the strong association between tolerance and entrepreneurship. Tolerance or diversity is important for both general entrepreneurship and high technology entrepreneurship. Tolerance signals low barriers to entry of human capital, and a diversified provision of people with different backgrounds makes it more likely to discover and exploit potential profit opportunities. Public policies addressing non-discrimination, fairness and democracy are expected to encourage tolerance or diversity, and may further lead to a more entrepreneurial and innovative regional economy.

Acknowledgements

anonymous reviewers of *Journal of Economic Geography*; and participants in seminars held at Cleveland State University, George Mason University, Simon Fraser University and West Virginia University. Haifeng Qian acknowledges a dissertation fellowship from the Provost Office of George Mason University.

References

Acs, Z. J. (2006) How is entrepreneurship good for economic growth? *Innovations*, 1: 97–107.

Acs, Z. J., Anselin, L., Varga, A. (2002a) Patents and innovation counts as measures of regional production of new knowledge. *Research Policy*, 31: 1069–1085.

Acs, Z. J., Armington, C. (2006) *Entrepreneurship, Geography, and American Economic Growth*. New York: Cambridge University Press.

Acs, Z. J., Audretsch, D. B. (1987) Innovation, market structure, and firm size. *Review of Economics and Statistics*, 69: 567–574.

Acs, Z. J., Audretsch, D. B. (1988) Innovation in large and small firms: an empirical analysis. *American Economic Review*, 78: 678–690.

Acs, Z. J., Audretsch, D. B., Braunerhjelm, P., Carlsson, B. (2009) The knowledge spillover theory of entrepreneurship. *Small Business Economics*, 32: 15–30.

Acs, Z. J., Audretsch, D. B., Feldman, M. P. (1994) R&D spillovers and recipient firm size. *Review of Economics and Statistics*, 76: 336–340.

Acs, Z. J., Fitzroy, F. R., Smith, I. (2002b) High-technology employment and R&D in cities: heterogeneity vs specialization. *Annals of Regional Science*, 36: 373–386.

Almeida, P., Kogut, B. (1999) Localization of knowledge and the mobility of engineers in regional networks. *Management Science*, 45: 905–917.

Anselin, L., Varga, A., Acs, Z. (1997) Local geographic spillovers between university research and high technology innovations. *Journal of Urban Economics*, 42: 422–448.

Arrow, K. J. (1962) The economic implications of learning by doing. *Review of Economic Studies*, 29: 155–173.

Asheim, B., Coenen, L., Vang, J. (2007) Face-to-face, buzz, and knowledge bases: sociospatial implications for learning, innovation, and innovative policy. *Environment and Planning C*, 25: 655–670.

Audretsch, D. B. (1995) *Innovation and Industry Evolution*. Cambridge, MA: MIT Press.

Audretsch, D. B., Dohse, D., Niebuhr, A. (2010) Cultural diversity and entrepreneurship: a regional analysis for Germany. *Annals of Regional Science*, 45: 55–85.

Audretsch, D. B., Feldman, M. P. (1996) R&D spillovers and the geography of innovation and production. *American Economic Review*, 86: 630–640.

Audretsch, D. B., Kayalar-Erdem, D. (2005) Determinants of scientist entrepreneurship: an intergrative research agenda. In S. A. Alvarez, R. Agarwal, O. Sorenson (eds) *Handbook of Entrepreneurship Research*. New York: Springer.

Audretsch, D. B., Keilbach, M. C. (2006) Entrepreneurship, economic growth and restructuring. In M. Casson, B. Yeung, A. Basu, N. Wadeson (eds) *The Oxford Handbook of Entrepreneurship*. New York: Oxford University Press.

Audretsch, D. B., Lehmann, E. E. (2005) Does the knowledge spillover theory of entrepreneurship hold for regions? *Research Policy*, 34: 1191–1202.

Bartik, T. J. (1989) Small business start-ups in the United States: estimates of the effects of characteristics of states. *Southern Economic Journal*, 55: 1004–1018.

Bates, T. (1990) Entrepreneurial human capital inputs and small business longevity. *The Review of Economics and Statistics*, 72: 551–559.

Berry, C. R., Glaeser, E. L. (2005) The divergence of human capital levels across cities. *Papers in Regional Science*, 84: 407–444.

Braczyk, H.-J., Cooke, P., Heidenreich, M. (1998) *Regional Innovation Systems: The Role of Governances in a Globalized World*. London: UCL Press.

Braunerhjelm, P., Acs, Z. J., Audretsch, D. B., Carlsson, B. (2010) The missing link: knowledge diffusion and entrepreneurship in endogenous growth. *Small Business Economics*, 34: 105–125.

Chen, Y., Rosenthal, S. S. (2008) Local amenities and life-cycle migration: do people move for jobs or fun? *Journal of Urban Economics*, 64: 519–537.

Cohen, W. M., Levinthal, D. A. (1990) Absorptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly*, 35: 128–152.

Colombo, M. G., Delmastro, M., Grilli, L. (2004) Entrepreneurs' human capital and the start-up size of new technology-based firms. *International Journal of Industrial Organization*, 22: 1183–1211.

Colombo, M. G., Grilli, L. (2005) Founders' human capital and the growth of new technology-based firms: a competence-based view. *Research Policy*, 34: 795–816.

Cooke, P. (2001) Regional innovation systems, clusters, and the knowledge economy. *Industrial and Corporate Change*, 10: 945–974.

Cooke, P., Uranga, M. G., Etxebarria, G. (1997) Regional innovation systems: institutional and organizational dimensions. *Research Policy*, 26: 475–491.

Cooper, A. C., Gimeno-Gascon, F. J., Woo, C. Y. (1994) Initial human and financial capital as predictors of new venture performance. *Journal of Business Venturing*, 9: 371–395.

Crescenzi, R., Rodríguez-Pose, A., Storper, M. (2007) The territorial dynamics of innovation: a Europe–United States comparative analysis. *Journal of Economic Geography*, 7: 673–709.

Davidsson, P., Honig, B. (2003) The role of social and human capital among nascent entrepreneurs. *Journal of Business Venturing*, 18: 301–331.

Delgado, M., Porter, M. E., Stern, S. (2010) Clusters and entrepreneurship. *Journal of Economic Geography*, 10: 495–518.

DeVol, R. C. (1999) *America's High-Tech Economy*. Santa Monica, CA: Milken Institute.

Duranton, G., Puga, D. (2001) Nursery cities: urban diversity, process innovation, and the life cycle of products. *American Economic Review*, 91: 1454–1477.

Edquist, C. (ed.) (1997) *Systems of Innovation: Technologies, Institutions and Organizations*. London: Pinter.

Edquist, C. (2005) Systems of Innovation. In J. Fagerberg, D. C. Mowery, R. R. Nelson (eds) *The Oxford Handbook of Innovation*. New York: Oxford University Press.

Feldman, M. P. (1994) *The Geography of Innovation*. Boston, MA: Kluwer Academic Publishers.

Feldman, M. P., Audretsch, D. B. (1999) Innovation in cities: science-based diversity, specialization and localized competition. *European Economic Review*, 43: 409–429.

Florida, R. (2002a) Bohemia and economic geography. *Journal of Economic Geography*, 2: 55–71.

Florida, R. (2002b) The economic geography of talent. *Annals of the Association of American Geographers*, 92: 743–755.

Florida, R. (2002c) *The Rise of the Creative Class*. New York: Basic Books.

Florida, R., Mellander, C. (2010) There goes the metro: how and why bohemians, artists and gays affect regional housing values. *Journal of Economic Geography*, 10: 167–188.

Florida, R., Mellander, C., Stolarick, K. (2008) Inside the black box of regional development: human capital, the creative class and tolerance. *Journal of Economic Geography*, 8: 615–649.

Garson, D. (2009) *Structural equation modeling*. Available online at: http://faculty.chass.ncsu .edu/garson/PA765/structur.htm [Accessed 20 December 2009].

Glaeser, E. L. (1998) Are cities dying? *Journal of Economic Perspectives*, 12: 139–160.

Glaeser, E. L. (1999) Learning in cities. *Journal of Urban Economics*, 46: 254–277.

Glaeser, E. L., Kallal, H. D., Scheinkman, J. A., Shleifer, A. (1992) Growth in cities. *Journal of Political Economy*, 100: 1126–1152.

Glaeser, E. L., Kolko, J., Saiz, A. (2001) Consumer city. *Journal of Economic Geography*, 1: 27–50.

Glaeser, E. L., Kerr, W. R., Ponzetto, G. A. M. (2010a) Clusters of entrepreneurship. *Journal of Urban Economics*, 67: 150–168.

Glaeser, E. L., Rosenthal, S. S., Strange, W. C. (2010b) Urban economics and entrepreneurship. *Journal of Urban Economics*, 67: 1–14.

Grilliches, Z. (1979) Issues in assessing the contribution of research and development to productivity growth. *Bell Journal of Economics*, 10: 92–116.

Harrison, R. T., Cooper, S. Y., Mason, C. M. (2004) Entrepreneurial activity and the dynamics of technology-based cluster development: the case of Ottawa. *Urban Studies*, 41: 1045–1070.

Haltiwanger, J. C., Jarmin, R. S., Miranda, J. (2010) Who create jobs? Small vs. large vs. young. *NBER Working Paper, w16300*.

Hecker, D. E. (2005) High-technology employment: a NAICS-based update. *Monthly Labor Review, July*, 57–72.

Henderson, J. V. (2003) Marshall's scale economies. *Journal of Urban Economics*, 53: 1–28.

Jacobs, J. (1969) *The Economy of Cities*. New York: Random House.

Jaffe, A. B. (1986) Technological opportunity and spillovers of R&D: evidence from firms' patents, profits, and market value. *American Economic Review*, 76: 984–1001.

Jaffe, A. B. (1989) Real effects of academic research. *American Economic Review*, 79: 957–970.

Jaffe, A. B., Trajtenberg, M., Henderson, R. (1993) Geographic localization of knowledge spillovers as evidenced by patent citations. *The Quarterly Journal of Economics*, 108: 577–598.

Katz, J. A. (2003) The chronology and intellectual trajectory of American entrepreneurship education: 1876–1999. *Journal of Business Venturing*, 18: 283–300.

Kirzner, I. M. (1997) Entrepreneurial discovery and the competitive market process: an Austrian approach. *Journal of Economic Literatures*, 35: 60–85.

Koo, J. (2005) Agglomeration and spillovers in a simultaneous framework. *Annals of Regional Science*, 39: 35–47.

Kotkin, J. (2000) *The New Geography*. New York: Random House.

Krugman, P. (1991) Increasing returns and economic geography. *Journal of Political Economy*, 99: 483–499.

Kuratko, D. F. (2005) The emergence of entrepreneurship education. *Entrepreneurship Theory and Practice*, 29: 577–598.

Lee, S. Y., Florida, R., Acs, Z. J. (2004) Creativity and entrepreneurship: a regional analysis of new firm formation. *Regional Studies*, 38: 879–891.

Lucas, R. E., Jr. (1988) On the mechanism of economic growth. *Journal of Monetary Economics*, 22: 3–42.

Lundvall, B.-ý. (1992) *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. London: Pinter.

Malecki, E. J. (1994) Entrepreneurship in regional and local development. *International Regional Science Review*, 16: 119–153.

Malecki, E. J. (1997) Entrepreneurs, networks and economic development: a review of recent research. *Advances in Entrepreneurship, Firm Emergence and Growth*, 3: 57–118.

Marshall, A. (1920) *Principles of Economics*. London: Macmillan.

McDonald, R. P., Ho, M.-H. R. (2002) Principles and practice in reporting structural equation analyses. *Psychological Methods*, 7: 64–82.

Mellander, C., Florida, R. (2006) The creative class or human capital? *CESIS Electronic Working Paper Series*, 79.

Michelacci, C. (2002) Low returns in R&D due to the lack of entrepreneurial skills. *The Economic Journal*, 113: 207–225.

Nelson, R. R. (ed.) (1993) *National Innovation Systems: A Comparative Analysis*. New York: Oxford University Press.

North, D. C. (1990) *Institutions, Institutional Change and Economic Performance*. New York: Cambridge University Press.

Partridge, M. D., Rickman, D. S. (2003) The waxing and waning of regional economies: the chicken–egg question of jobs versus people. *Journal of Urban Economics*, 53: 76–97.

Peri, G. (2005) Determinants of knowledge flows and their effect on innovation. *Review of Economics and Statistics*, 87: 308–322.

Plummer, L. A., Headd, B. (2008) Rural and urban establishment births and deaths using the U.S. Census Bureau's Business Information Tracking Series. *SBA Office of Advocacy Small Business Research Summary*, *No. 316*. Available at: http://archive.sba.gov/advo/research/rs316tot.pdf.

Polanyi, M. (1966) *The Tacit Dimension*. New York: Doubleday.

Porter, M. E. (1998) Clusters and new economics of competition. *Harvard Business Review*, November–December: 77–90.

Qian, H. (2010) Talent, creativity and regional economic performance: the case of China. *The Annals of Regional Science*, 45: 133–156.

Qian, H., Acs, Z. J. (2011) An absorptive capacity theory of knowledge spillover entrepreneurship. *Small Business Economics*, doi: 10.1007/s11187-011-9368-x.

Qian, H., Haynes, K. E., Riggle, J. D. (2011) Incubation push or business pull? Investigating the geography of U.S. business incubators. *Economic Development Quarterly*, 25: 79–90.

Quigley, J. (1998) Urban diversity and economic growth. *Journal of Economic Perspectives*, 12: 127–138.

Reynolds, P. D., Storey, D. J., Westhead, P. (1994) Cross national comparisons of the variation in new firm formation rates. *Regional Studies*, 28: 443–456.

Romer, P. M. (1990) Endogenous technological change. *Journal of Political Economy*, 98: S71–S102.

Saxenian, A. (1999) *Silicon Valley's New Immigrant Entrepreneurs*. Berkeley, CA: Public Policy Institute of California.

Schultz, T. W. (1961) Investment in human capital. *American Economic Review*, 51: 1–17.

Schumpeter, J. A. (1934) *The Theory of Economic Development*. Oxford: Oxford University Press.

Schumpeter, J. A. (1942) *Capitalism, Socialism and Democracy*. New York: Harper & Row.

Shane, S. (2003) *A General Theory of Entrepreneurship*. Cheltenham, UK: Edward Elgar.

Shapiro, J. M. (2006) Smart cities: quality of life, productivity, and the growth effects of human capital. *Review of Economics and Statistics*, 88: 324–335.

Smilor, R., O'Donnell, N., Stein, G., Welborn, R. S., III (2007) The research university and the development of high-technology centers in the United States. *Economic Development Quarterly*, 21: 203–222.

Solow, R. M. (1957) Technical change and the aggregate production function. *The Review of Economics and Statistics*, 39: 312–320.

Sonn, J. W., Storper, M. (2008) The increasing importance of geographical proximity in knowledge production: an analysis of US patent citations, 1975–1997. *Environment and Planning A*, 40: 1020–1039.

Storey, D. J. (1984) Editorial. *Regional Studies*, 18: 187–188.

Storper, M., Scott, A. J. (2009) Rethinking human capital, creativity and urban growth. *Journal of Economic Geography*, 9: 147–167.

Sweeney, G. P. (1987) *Innovation, Entrepreneurs and Regional Development*. London: Frances Pinter.

Zahra, S. A., George, G. (2002) Absorptive capacity: a review, reconceptualization, and extension. *Academy of Management Review*, 27: 185–203.