Catalogue no. 11F0027M — No. 084
ISSN 1703-0404
ISBN 978-1-100-21623-2

Research Paper

Economic Analysis (EA) Research Paper Series

Urban Productivity: Who Benefits from Agglomeration Economies?

by W. Mark Brown, Economic Analysis Division,
Statistics Canada, Ottawa, Canada
David L. Rigby, Departments of Geography and Statistics,
University of California Los Angeles

Economic Analysis Division

Statistics Canada Statistique Canada

Canada

How to obtain more information

For information about this product or the wide range of services and data available from Statistics Canada, visit our website, www.statcan.gc.ca.

You can also contact us by

email at infostats@statcan.gc.ca,

telephone, from Monday to Friday, 8:30 a.m. to 4:30 p.m., at the following toll-free numbers:

• Statistical Information Service	1-800-263-1136
• National telecommunications device for the hearing impaired	1-800-363-7629
• Fax line	1-877-287-4369

Depository Services Program

• Inquiries line	1-800-635-7943
• Fax line	1-800-565-7757

To access this product

This product, Catalogue no. 11F0027M, is available free in electronic format. To obtain a single issue, visit our website, www.statcan.gc.ca, and browse by “Key resource” > “Publications.”

Standards of service to the public

Statistics Canada is committed to serving its clients in a prompt, reliable and courteous manner. To this end, Statistics Canada has developed standards of service that its employees observe. To obtain a copy of these service standards, please contact Statistics Canada toll-free at 1-800-263-1136. The service standards are also published on www.statcan.gc.ca under “About us” > “The agency” > “Providing services to Canadians.”

Published by authority of the Minister responsible for Statistics Canada

Cette publication est aussi disponible en français.

Note of appreciation

Canada owes the success of its statistical system to a long-standing partnership between Statistics Canada, the citizens of Canada, its businesses, governments and other institutions. Accurate and timely statistical information could not be produced without their continued co-operation and goodwill.

Standard symbols

The following symbols are used in Statistics Canada publications:

.	not available for any reference period
..	not available for a specific reference period
...	not applicable
0	true zero or a value rounded to zero
0^s	value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded
^{p}	preliminary
^{r}	revised
x	suppressed to meet the confidentiality requirements of the *Statistics Act*
^{E}	use with caution
F	too unreliable to be published
*	significantly different from reference category (p < 0.05)

Urban Productivity: Who Benefits from Agglomeration Economies?

by

W. Mark Brown, Economic Analysis Division, Statistics Canada, Ottawa, Canada
David L. Rigby, Departments of Geography and Statistics, University of California Los Angeles

11F0027M No. 084
ISSN 1703-0404
ISBN 978-1-100-21623-2

Authors' names are listed alphabetically.

Economic Analysis Research Paper Series

The Economic Analysis Research Paper Series provides for the circulation of research conducted by the staff of National Accounts and Analytical Studies, visiting Fellows, and academic associates. The Economic Analysis Research Paper Series is meant to stimulate discussion on a range of topics, including the impact of the New Economy, productivity issues, firm profitability, technology usage, the effect of financing on firm growth, depreciation functions, the use of satellite accounts, savings rates, leasing, firm dynamics, hedonic estimations, diversification patterns, investment patterns, differences in the performance of small and large firms and of domestic and multinational firms, and purchasing power parity estimates. Readers of the series are encouraged to contact the authors with their comments and suggestions.

The primary distribution medium for the papers is the Internet. These papers can be accessed for free at www.statcan.gc.ca.

All papers in the Economic Analysis Research Paper Series go through institutional and peer review, in order to ensure that they conform to Statistics Canada's mandate as a government statistical agency and adhere to generally accepted standards of good professional practice.

The papers in the series often include results derived from multivariate analysis or other statistical techniques. It should be recognized that the results of these analyses are subject to uncertainty in the reported estimates.

The level of uncertainty will depend on several factors: the nature of the functional form used in the multivariate analysis; the type of econometric technique employed; the appropriateness of the statistical assumptions embedded in the model or technique; the comprehensiveness of the variables included in the analysis; and the accuracy of the data that are utilized. The peer group review process is meant to ensure that the papers in the series have followed accepted standards, in order to minimize problems in each of these areas.

Publications Review Committee
Analysis Branch, Statistics Canada
18th Floor, R.H. Coats Building
Ottawa, Ontario K1A 0T6

Acknowledgements

This work was partially funded by a Canadian Studies Research Grant. The authors would like to acknowledge the research assistance of Des Beckstead and Bob Gibson of the Economic Analysis Division of Statistics Canada. They also thank John Baldwin, as well as participants in the conference "Industrial Dynamics and Economic Geography," held at Utrecht University in September 2010, who commented on earlier drafts of this paper.

Table of contents

Abstract

There is abundant evidence that many firms cluster together in space and that there is an association between clustering and productivity. This paper moves beyond identifying the broad effects of clustering and explores how different types of firms benefit from agglomeration. It advances research on agglomeration by showing, first, that not all firms gain to the same degree from co-location and, second, that businesses with different internal capabilities capture different forms of geographical externalities. The empirical analysis focuses on Canadian manufacturing establishments operating over the period from 1989 to 1999. It finds young, small, domestic, and single-plant businesses, which typically cannot draw upon the internal resources available to older, larger, foreign-controlled, and multi-plant firms, benefit more from clustering in most but not all respects. These smaller and younger firms experience stronger productivity gains stemming from the localized pooling of workers with skills that match their needs and from knowledge spillovers, but weaker productivity gains from the presence of upstream input suppliers.

Executive summary

How do firms organize their activities and compete in the market economy? Individual producers have to make a series of complex and interrelated choices regarding what to produce, how much to produce, what technology to employ, how to organize their operations, and where to locate. When the structure of production within industries and across economies is examined, it is difficult not to be struck by the presence of considerable heterogeneity. The existence of heterogeneity acknowledges that firm-specific assets—management skills, organization, behavioral routines, size, knowledge, technology, and even location—are highly variable. Over much of the last two decades, evidence has been accumulated regarding the extent of firm heterogeneity and how the characteristics of individual business establishments shape their own performance and, in aggregate, the dynamics of industries and regions. In line with this work, a basic distinction can be drawn between those businesses that have the internal capacity to generate competitive advantage and those that seek advantage through co-location with others.

There is abundant evidence that many firms cluster together in space and that there is an association between clustering and productivity. This paper moves beyond identifying the broad effects of clustering and explores how different types of firms benefit from agglomeration. It advances research on agglomeration by showing, first, that not all firms gain from co-location and, second, that businesses with different internal capabilities capture different forms of geographical externalities.

For contrasting groups of firms, panel models are employed that regress firm-level labour productivity on firm-specific and place-specific characteristics. The place-specific characteristics represent varying types of agglomeration economies. In part, these economies may stem from (1) labour market pooling (local specialization in labour skills), (2) density of upstream suppliers (the development of localized buyer-supplier networks) and (3) knowledge spillovers (knowledge that spill across firms working in the same industry in the same location). The impacts of these externalities are compared across small and large plants, establishments that are part of multi-unit and foreign firms, and those that comprise single-plant firms. Also distinguished is how different economies of agglomeration benefit younger plants versus older plants, and how place-specific attributes influence the performance of plants born to incumbent firms vis-à-vis those born to new firms. The empirical analysis focuses on Canadian manufacturing establishments operating over the period from 1989 to 1999.

Dense concentrations of economic activity are generally seen as giving rise to increasing returns that may be shared by business units that cluster in space. Theories of the firm and of strategic management argue that competitive advantage originates in the development and exploitation of firm-specific assets or capabilities that may be internal or external to the firm. Older, larger, foreign-controlled, and multi-plant firms are anticipated to have greater internal resources upon which they might build advantage. Young, small, domestic, and single-plant businesses cannot draw upon these same resources and are more likely to develop strategies for survival that rest on place-based economies generated in particular locations. The analysis presented here is an attempt to identify the sources of these external resources and to examine whether they benefit all businesses or only some. It finds the following:

1. *Labour market pooling:* The analysis shows that virtually all plants reap productivity benefits from being located in places where the occupational distribution of workers matches the demand for labour by occupation. However, these benefits tend to be larger for small and young businesses, which is consistent with these firms relying more on local labour markets to find workers with the skills that match their needs. Larger and older firms, while still relying on local pools of labour, may have developed the internal resources to find and attract workers from farther away.

2. *Knowledge spillovers:* Knowledge spillovers, measured by own-industry plant counts within a radius of 5 kilometres, also generate productivity gains for plants, regardless of size or whether they are part of a single or multi-plant firm or are foreign owned. Younger establishments, however, which are expected to have less well developed capabilities to generate knowledge, rely more on local knowledge pools.

3. *Density of upstream suppliers:* The local density of upstream suppliers does not benefit the firms that are expected to have few internal resources. Rather, older firms, regardless of size or complexity, derive the largest benefit from having upstream suppliers nearby. This is consistent with the argument that older firms are better able to exploit the advantages of local supplier networks, because their production processes are more standardized and, therefore, portions of which are more amenable to being outsourced to specialized suppliers.

1 Introduction

How do firms organize their activities and compete in the market economy? Individual producers have to make a series of complex and interrelated choices regarding what to produce, how much to produce, what technology to employ, how to organize their operations, and where to locate. When the structure of production within industries and across economies is examined, it is difficult not to be struck by the presence of considerable heterogeneity. At least since the work of Penrose (1959) and Cyert and March (1963), such variety has been employed to understand firm performance and strategy (see Melitz [2003] for a recent formal treatment). The existence of heterogeneity acknowledges that firm-specific assets—management skills, organization, behavioral routines, size, knowledge, technology, and even location—are highly variable and that the value of such assets may change rapidly in competitive markets. This resource-based vision of performance is more explicitly developed by Wernerfelt (1984) and Barney (1991), in contrast to the opportunities and threats model promoted by Porter (1985). A resource-based model of firm performance is generalized by Prahalad and Hamel (1990) in their discussion of firm competence and capabilities. Kogut and Zander (1992) emphasize the critical role of knowledge within this framework, which is given an explicitly dynamic twist by Teece and Pisano (1994). Nelson and Winter (1982) ground their evolutionary model of economic growth on similar views of heterogeneity among competing agents in uncertain markets.

Over much of the last two decades, research has produced empirical evidence of the extent of firm heterogeneity and how the characteristics of individual business establishments shape their own performance and, in aggregate, the dynamics of industries and regions (Baily et al. 1992; Saxenian 1994; Baldwin 1995; Storper 1997; Rigby and Essletzbichler 2006; Boschma and Frenken 2011). Most of this research focuses on readily observable dimensions of business variability such as age, size, technology, location, organizational structure, and ownership status. While these variables by no means capture the full range of firm characteristics that shape performance, they serve to highlight the importance of variety, and they hint at the range of competitive strategies possible. Also clear from much of the work above is that firms search for efficiency in many different ways. A basic distinction can be drawn between those businesses that have the internal capacity to generate competitive advantage and those that seek advantage through co-location with others.

There is abundant evidence that many firms cluster together in space. In part, this may be explained by "first nature geography" and by the desire of firms in natural resource processing sectors to locate close to their raw material sources. Ellison and Glaeser (1999) estimate that at least 20% of firm co-location in the U.S. is driven by resource availability. Businesses outside the resource sector also tend to agglomerate, presumably because of the benefits they derive from close spatial association with one another. Indeed, Ellison and Glaeser (1997) report evidence of clustering across 446 of 459 4-digit Standard Industrial Classification (SIC) industries. While most reports of the agglomeration of economic activity tend to be rather crude, rigorous tests of the spatial clustering of establishments using distance-based methods are provided by Feser and Sweeney (2000), Marcon and Puech (2003) and Duranton and Overman (2005, 2008).

Two frameworks that help explain agglomeration are provided by Marshall (1920) and Jacobs (1969). For Marshall (1920), long interested in the development of industry-towns, local specialization in labour skills, buyer-supplier networks and knowledge spillovers generate and sustain place-specific competitive advantages within industrial sectors. Jacobs (1969), in contrast, is a champion of diversity, imagining the city as a dense assemblage of different knowledge pools that provide fertile ground out of which flows innovation and growth. More formal treatments of aggregate increasing returns, generated by the gains from a wider variety of intermediate inputs, from labour specialization, and by labour pooling, are provided by Abdel-Rahman and Fujita (1990), by Becker and Henderson (2000), and by Krugman (1991), respectively. Duranton and Puga (2001) develop a model of an urban system comprising both diverse and specialized urban centres. They link process innovation in new firms to the diversity of existing production arrangements within "nursery cities", while specialized urban centres offer mature firms with fixed techniques cost reductions through sharing intermediate suppliers. Duranton and Puga (2004) provide a detailed overview of these arguments.

Early empirical research sought evidence of the impact of agglomeration through the influence of industry scale and population size, the urban proportion of state population, or employment density on productivity levels or productivity growth (Sveikauskas 1975; Carlino 1978; Moomaw 1981; Beeson 1987; Moomaw and Williams 1991; Ciccone and Hall 1996). More sophisticated efforts to separate the influence of industry specialization and diversity, in dynamic form Marshall-Arrow-Romer (MAR) and Jacobs externalities, are offered by Glaeser et al. (1992) and by Henderson et al. (1995). Glaeser et al. (1992) examine employment growth for a sample of large industries in U.S. cities between 1956 and 1987. They report that local competition and industrial diversity accelerate growth, while regional industrial specialization has no significant effect. In line with Jacobs (1969), they hypothesize that knowledge spillovers flow between industries rather than within them. Henderson et al. (1995) report results from analysis of urban employment growth in five mature, capital-goods sectors and in three high-technology sectors between 1970 and 1987. MAR externalities exert a positive and significant influence on employment growth in the mature industries, while MAR and Jacobs externalities drive employment growth in new, high-technology industries. These results are broadly consistent with Henderson (2003). An extensive literature that tries to disentangle the relative importance of localization and urbanization economies has followed. Beaudry and Schiffauerova (2009) provide a comprehensive review.

Both Glaeser et al. (1992) and Henderson et al. (1995) showed that the life-cycle of products/industries is critical in determining whether (and what kinds of) agglomeration externalities enhance economic fortunes within urban industrial groupings. In this respect, they provide evidence consistent with the "nursery cities" model of Duranton and Puga (2001). McCann and Folta (2011) pushed this argument further, questioning whether all firms benefit equally from spatial clustering. They developed a knowledge-based view of the firm, after Kogut and Zander (1992), and hypothesized that the learning ability of firms and their organizational flexibility will moderate the influence of agglomeration externalities. Evidence from a sample of U.S. biotechnology firms confirmed that younger firms and firms with larger knowledge stocks gain most from cluster membership. Alcacer (2006) and Knoben et al. (2010) advanced related arguments about firm characteristics and agglomeration, while Potter and Watts (2011) and Neffke et al. (2011, 2012) developed agglomeration within an explicitly evolutionary framework, demonstrating how the life-cycle of industries regulates the form, and even the existence, of the benefits from co-location.

Running alongside the theoretical search for the micro-foundations of agglomeration, newer empirical papers seek not only to differentiate localization and urbanization economies but also to distinguish the precise mechanisms through which returns to agglomeration are generated. Dumais et al. (1997), Rigby and Essletzbichler (2002), Rosenthal and Strange (2001, 2003), and Baldwin et al. (2008, 2010) all key on Marshall (1920), seeking evidence of the relative benefits of labour pooling, buyer/supplier networks, and knowledge spillovers across different industries and regions.

This paper responds to the recent calls of McCann and Folta (2008, 2011) to explore how different types of firms benefit from agglomeration. It advances the research on agglomeration by showing, first, that not all firms gain from co-location and, second, that businesses with different internal capabilities capture different forms of geographical externalities. For contrasting groups of firms, panel models are employed that regress firm-level labour productivity on firm-specific and place-specific characteristics. Using a panel specification controls for plant-level unobserved heterogeneity that might exert a confounding influence in many of the cross-sectional studies reported above. In this regard, the results put forward in this paper are potentially more robust than those recently offered by Knoben et al. (2010). The analysis also differs from that of

McCann and Folta (2011) in that it explores how different mechanisms of agglomeration exert asymmetric effects across plants/firms with varying characteristics. The place-specific characteristics represent varying types of agglomeration economies after Marshall (1920) and Jacobs (1969). The differing impacts of those externalities are explored for small plants versus large plants, as well as between establishments that are part of multi-unit or foreign firms, and those establishments that comprise single-plant firms. The paper also examines how different economies of agglomeration benefit younger plants versus older plants, and how place-specific attributes influence the performance of plants born to incumbent firms vis-à-vis those born to new firms. The empirical analysis focuses on Canadian manufacturing establishments operating over the period from 1989 to 1999.

The rest of this paper is divided into three parts. Section 2 discusses data sources, the variables employed, and the modeling strategy adopted. The results of the analysis are presented in Section 3, beginning with a brief overview of past results generated from cross-sectional and panel models. These findings provide a benchmark that is then used to examine how subsets of plants with different characteristics are impacted by the different types of agglomeration economies that are identified. Section 4 concludes with a summary of findings and directions for future work.

2 Data, methods, and background findings

The variables used in the econometric models fall into two groups: characteristics of individual business units or plants; and characteristics of particular locations. The text box lists the variables in our models and provides brief descriptions. The plant-level information is developed from the Canadian Annual Survey of Manufactures (ASM) for 1989 and for 1999. Panel techniques require observations on individual establishments for at least two years.

Description of variables

Plant characteristics

Labour productivity: Value added divided by the number of production workers in the plant
Ratio of profit to value added: Value added minus wages, divided by value added
Production workers: Number of production workers in the plant
Ratio of non-production workers to production workers: Number of non-production workers divided by number of production workers in the plant

Place characteristics

Labour mix: Defined in Section 2 of the paper
Local density of upstream suppliers: Defined in Section 2 of the paper
Plants within 5 kilometers: Number of plants within 5 kilometres in the same two-digit industry defined by the Standard Industrial Classification (SIC)
Population: Population of the census metropolitan area (CMA) or census agglomeration (CA) where the plant is located

Place-specific data are derived from the ASM, from the 1991 and 2001 Census of Population, and from Canadian input-output accounts. All data were geocoded to a constant 2001 census geography for census metropolitan areas (CMAs) and census agglomerations (CAs)—hereafter, metropolitan areas. In 2001, there were 141 metropolitan areas in Canada, ranging in size from Kitimat, B.C., with a population of about 10,000, to the Toronto CMA, with a population of about 4.6 million. The 141 regions encompassed approximately 80% of the Canadian population in 2001 and roughly the same percentage of Canadian manufacturing establishments in 1999.

2.1 Plant- and firm-specific characteristics

The dependent variable in the analysis is labour productivity, measured as value added divided by the number of production workers. For each plant, value added and production workers are measured at their mean across three years. For 1989, these are the two adjacent years. Owing to the fact that 1999 is the last year on the longitudinal file, the mean level of value added and production workers is taken for 1999 and the previous two years. Value added is measured in constant dollar terms using an industry-level deflator. Three-year means are utilized for all plant-level characteristics in order to reduce the year-over-year variability inherent to micro-data. Plants often encounter shocks that may obscure the relationship between plant-level inputs and output (e.g., as a result of labour hoarding). Using three-year means helps to reduce the effect of this variability on our estimates.

Labour productivity is expected to depend on several plant-level characteristics. These include plant size, capital intensity, and the ratio of non-production workers to production workers. It is expected that labour productivity will be higher in plants that are larger in size because they are able to take advantage of various forms of scale economies (e.g., those that result from longer production runs). Plant size is measured by the number of production workers. The productivity of production workers is also expected to rise as the amount of machinery and equipment with which they work increases. Mechanization is best captured through the capital-to-labour ratio. Unfortunately, capital stock data are unavailable at the plant level, and so a proxy variable is used to represent the capital-to-labour ratio. Production workers tend to generate higher levels of output when more non-production workers are contributing to the production process. For instance, more input from management and engineering functions can help to improve the organization of the production process. Hence, labour productivity is expected to be positively associated with the ratio of non-production workers to production workers.

The model takes into account two types of firm characteristics. The first characteristic is whether the plant is part of a multi-establishment firm. This is a binary variable where the reference group is single-plant firms. Our expectation is that multi-plant firms will be more productive than single-plant firms. Multi-establishment status brings the benefit of firm-wide economies to the plant. For instance, multi-establishment firms may be better able to collect and analyze information that can improve management practices and thus raise productivity. The second characteristic is whether the plant is foreign-controlled. Foreign-controlled plants are expected to have higher levels of productivity because they have access to a broader range of experiences and technologies (Baldwin and Gu 2005). Foreign control is also a binary categorical variable where the reference group is domestically-controlled plants.

2.2 Place-specific characteristics

The agglomeration variables developed in the productivity model, the local density of buyer-supplier networks, labour pooling, and knowledge spillovers can all be traced back to Marshall (1920). The variables employed to measure these Marshallian economies, along with indicators used to capture other types of agglomeration economies, are outlined below.

An area's labour pool supports the needs of a particular industry when the occupational distribution of an area corresponds to the distribution required by that industry. The labour mix for an industry within a metropolitan area is defined after Dumais et al. (1997) as:

$$LABMIX_i^u = \sum_o \left(L_{io} - \sum_{j \neq i} \frac{E_j^u}{E^u - E_i^u} L_{jo} \right)^2,$$

where o represents an occupation, i and j represent index industries, and u refers to the metropolitan area. L measures the proportion of workers in a particular industry and occupation, while E measures the number of workers in a single industry or in all industries within a metropolitan area. This index is a sum of squared deviations that measures the degree to which the occupational distribution of employment in an industry is matched by the occupational distribution of the workforce in the metropolitan area as a whole, excluding the specified industry. The occupational distribution of industry workers is calculated at the national level and covers some 47 occupations at the two-digit level based on the 1991 Standard Occupational Classification, which is used for the 1991 and 2001 censuses. It is expected that a better match between the occupational distribution (demand) in an industry and the occupational distribution of the entire workforce of a metropolitan area (supply) will boost productivity. Improved matches reduce the value of the squared term. Thus, a negative coefficient on this variable in the following regressions is expected.

To calculate the benefits of the local density of buyer-supplier networks, national input-output data and indicators of the local concentration of production within specific sectors of the economy are used. These networks might convey additional benefits in the form of inter-industry spillovers embodied in material flows between industrial sectors. A high correlation between estimates of the geographic concentration of upstream producers and downstream customers led us to focus on upstream activity only. To measure local variation in the density of upstream connections for each four-digit industry and for each census metropolitan area in Canada, an upstream supplier-weighted location quotient is identified:

$$USXLQ_j^u = \sum_{i,i\neq j} w_{ij}^n \left(\frac{TVS_i^u / \sum_i TVS_i^u}{TVS_i^n / \sum_i TVS_i^n} \right).$$

The term in the parentheses is a location quotient for each industry i in metropolitan area u. The location quotients are calculated using the total value of shipments (TVS) of each industry and measure the degree to which a particular city is specialized in an industry. A value less than 1 would indicate that an industry is under-represented, while a value greater than 1 would indicate that an industry is over-represented. The terms w_{ij} represents the weight of industry i as a supplier of industry j—that is, the proportion of all manufactured input purchases by industry j supplied by industry i. Supplier weights are estimated from inter-industry transactions and are derived from the Canadian national input-output tables. The subscripts i and j refer to each of the 236 four-digit SIC manufacturing industries; u refers to a specific metropolitan area; and n refers to the country as a whole. Note that the influence of the own-industry in these measures is removed by dropping the principal diagonal from the input-output direct coefficients matrix. Metropolitan areas whose economies are specialized in industries that are significant suppliers to industry j will have a relatively high $USXLQ$, and this is expected to have a positive effect on labour productivity in plants in industry j within those areas.

Note that, because the labour mix and buyer-supplier network measures are defined at the metropolitan level, the values for these variables for a given industry are constant for all plants in that industry and metropolitan area. As noted above, this necessitates adjustment of the standard errors in our model, for, as Moulton (1990) demonstrates, they can be biased when aggregate variables all merged across micro-units of observation. In all the regressions below, standard errors are clustered by metropolitan area.

The third agglomeration effect, in addition to labour market pooling and buyer-supplier networks, arises from knowledge spillovers generated by the close proximity of producers in the same industry in the same urban area—intra-industry spillovers. Measuring knowledge spillovers is notoriously difficult, even impossible as Krugman (1991) claims, for they do not leave a paper trail. Jaffe et al. (1993) disagree, arguing that patent citations can track knowledge flows. Nevertheless, the linking of patent information to the plant-level data that are used increasingly to study agglomeration is surprisingly underdeveloped. Rigby and Essletzbichler (2002) show that flows of knowledge embodied in intermediate goods enhance the productivity of agglomerated plants. However, this sheds little light on the role of disembodied information flows. Some time was spent examining the influence of local own- and cross-industry patents, in industries of use and make, on plant labour productivity, but because the results were broadly insignificant this avenue was not pursued further. Our measures all used simple counts of patents within metropolitan areas and industries linked to the patent classification rather than citations. Raw patent counts for 1999, earlier years, or groups of years were not significantly related to productivity.

As a result, and following Henderson (2003) and Rosenthal and Strange (2003), counts/densities of plants in specific geographical areas are employed as a proxy for intra-industry knowledge spillovers. The latitude and longitude of individual plants are used to define concentric circles of varying distances around each one, within which the number of plants in the same two-digit (SIC) industry is counted. Our past research (Baldwin et al. 2010) has indicated that the productivity of an individual plant is influenced by the number of own-industry plant neighbours located within 5 kilometres. Plant counts within concentric circles that are more than 5 kilometres from a specific plant have no general influence on productivity. It is unclear why 5 kilometres represents a significant distance threshold, though it is in conformity with other research that shows knowledge spillovers are highly localized (Rosenthal and Strange 2003).

Metropolitan population size is added to our model as a proxy for urbanization economies that are not captured elsewhere in our model. The benefits of urban size are many. Large urban economies bring with them greater industrial and occupational diversity that facilitate the transfer of innovations across industries (Jacobs 1969) and that are thought to help incubate new firms (Duranton and Puga 2001). Large population centres also create the demand for infrastructure that can enhance the productivity of all industries.

2.3 Model

The relationships between value added, plant size, and capital intensity noted above can be formally derived from a production function using Cobb-Douglas technology where value added (VA) is expressed as:

$$VA = AK^{\alpha} L_{pw}^{\beta} L_{npw}^{\sigma}, \qquad (1)$$

where K is a measure of capital input, L_{pw} is the number of production workers employed by the plant, and L_{npw} is the number of non-production workers. With a little algebraic manipulation, equation (1) may be rewritten such that labour productivity (LP) is a function of capital and labour inputs:

$$LP = \frac{VA}{L_{pw}} = A\left(\frac{K}{L_{pw}}\right)^{\alpha} \left(\frac{L_{npw}}{L_{pw}}\right)^{\sigma} L_{pw}^{\beta+\alpha+\sigma-1}. \qquad (2)$$

The ASM does not provide plant-level estimates of capital and therefore a proxy $(\hat{K})$ is needed. $\hat{K}$ is estimated from the following expression for profit (π):

$$\pi = VA - wages = r\hat{K}, \qquad (3)$$

where r is the rate of return on capital. The profit-to-labour ratio, $r\hat{K} / L_{pw}$, can be substituted into equation (2), and, assuming the rate of return is equalized across plants, labour productivity is given by:

$$LP = Ar^{\alpha} \left(\frac{\hat{K}}{L_{pw}} \right)^{\alpha} \left(\frac{L_{npw}}{L_{pw}} \right)^{\sigma} L_{pw}^{\beta+\alpha+\sigma-1}. \quad (4)$$

Given this formulation, variation in profits across industries and provinces can be accounted for by industry and province fixed effects.

One of the practical issues with equation (4) is that our proxy of the capital to labour ratio and our measure of productivity are very highly correlated because both contain value added in their numerator and labour in their denominator. To address this problem, a slightly different model is estimated. Multiplying (1) by $VA^{\alpha} / VA^{\alpha}$ obtains

$$VA = Ar^{\alpha} \left(\frac{\hat{K}}{VA} \right)^{\alpha} VA^{\alpha} L_{pw}^{\beta} L_{npw}^{\sigma}, \quad (5)$$

which implies

$$VA = A^{\frac{1}{1-\alpha}} r^{\frac{\alpha}{1-\alpha}} \left(\frac{\hat{K}}{VA} \right)^{\frac{\alpha}{1-\alpha}} L_{pw}^{\frac{\beta}{1-\alpha}} L_{npw}^{\frac{\sigma}{1-\alpha}}. \quad (6)$$

Labour productivity can then be defined as

$$LP = \tilde{A}\tilde{r} \left(\frac{\hat{K}}{VA} \right)^{\frac{\alpha}{1-\alpha}} \left(\frac{L_{npw}}{L_{pw}} \right)^{\frac{\sigma}{1-\alpha}} L_{pw}^{\frac{\beta+\alpha+\sigma-1}{1-\alpha}}, \quad (7)$$

where $\tilde{A} = A^{1/(1-\alpha)}$ and $\tilde{r} = r^{\alpha/(1-\alpha)}$. Equation (7) can be used to solve for the values of α, β, and σ. Hence, despite the fact that the effect of the capital-to-labour ratio on productivity is not examined directly, an estimate is recoverable.

In order to estimate equation (7), a multiplicative error term, ε, is included and it is transformed logarithmically:

$$\ln LP_{lmq} = \ln \tilde{A} + \ln \tilde{r} + \delta_1 \ln \frac{\hat{K}_l}{VA_l} + \delta_2 \ln \frac{L_{npw,l}}{L_{pw,l}} + \delta_3 \ln L_{pw,l} + \ln \varepsilon_l, \quad (8)$$

where $\delta_1 = \frac{\alpha}{1-\alpha}$, $\delta_2 = \frac{\sigma}{1-\alpha}$, and $\delta_3 = \frac{\beta+\alpha+\sigma-1}{1-\alpha}$. Note also that l indexes plants, m indexes firms, and q indexes geographic locations.

Throughout the analysis the assumption is made that the other characteristics of the firm and the characteristics of the location of the firm are transmitted through the multifactor productivity term $\tilde{A}$. Hence,

$$\ln \tilde{A} = a + \varphi' \mathbf{lnX}_m + \theta' \mathbf{lnG}_q + \gamma_l + \eta_m + \lambda_q, \quad (9)$$

where $\mathbf{X}$ is a vector of characteristics related to the firm that controls plant l and $\mathbf{G}$ is a vector of characteristics associated with location q. These locational characteristics either are related to the metropolitan area (u) associated with q or are calculated according to a set distance from q, where q can be thought of as a point in space. Unobserved fixed effects associated with plant l, its related firm m, and location q are represented in equation (9) by γ_l, η_m, and λ_q, respectively.

The primary econometric issue associated with estimation of equation (8) is the potential correlation of the error term with one or more independent variables. This correlation may stem from the presence of unobserved fixed effects and/or endogeneity (reverse causality). To remedy the possibility of omitted-variable bias, equation (9) is substituted into equation (8) and the first difference is taken across periods:

$$\begin{aligned}\ln \Delta LP_{lmq} = \Delta a + \delta_1 \Delta \ln \frac{\hat{K}_l}{VA_l} + \delta_2 \Delta \ln \frac{L_{npw,l}}{L_{pw,l}} + \delta_3 \Delta \ln L_{pw,l} \\ + \varphi' \Delta \mathbf{lnX}_m + \theta' \Delta \mathbf{lnG}_q + \Delta \ln \varepsilon_l\end{aligned} \quad (10)$$

In so doing, the plant-, firm-, and location-level fixed effects that might be correlated with other independent variables are eliminated. For simplicity, it is assumed that the rate of return on capital is constant within plants across our two time periods, and so this term is dropped in equation (10). Elsewhere (see Baldwin et al. 2010), instrumental variables techniques are used to examine potential problems of endogeneity resulting from simultaneity bias. The results appear to be robust to such concerns.

2.4 Sample characteristics

Descriptive statistics for all place-specific variables and for plant variables that are continuous are reported in Table 1. The values in Table 1 are shown for the two years over which the observations are drawn, 1989 and 1999. These values are not logged. The mean, median, and standard deviation for all variables, and the number of observations are reported . There were 11,323 plants present in 1989 that were in business in 1999. The mean labour productivity of plants present in 1989 and 1999 increased from \$82,775 to \$87,298. Other plant-level characteristics remained relatively stable over the period. The profit to value added ratio remained essentially constant. Average and median plant sizes increased marginally, while non-production to production worker ratios fell modestly. Correlation coefficients for all pairs of continuous variables are reported in Baldwin et al. (2008).

Table 1

Descriptive statistics, panel of plants present in 1989 and 1999

	1989			1999		
	mean	median	standard deviation	mean	median	standard deviation
Plant characteristics						
Labour productivity (dollars)	82,775	57,910	113,862	87,298	55,644	112,083
Ratio of profit to value added	0.58	0.58	0.16	0.58	0.58	0.18
Production workers (number)	53	15	230	59	21	198
Ratio of non-production workers to production workers	0.46	0.37	0.52	0.42	0.33	0.53
Place characteristics						
Labour mix (index)	5.1	4.3	2.4	5.5	4.8	2.5
Local density upstream suppliers (index)	6.0	1.2	24.5	6.9	1.2	29.0
Plants within 5 kilometres (number)	41	17	74	31	13	54
Population (number)	159,220	37,932	463,249	178,011	39,992	535,224

	1989	1999
	number of observations	
Plant characteristics	11,323	11,323
Place characteristics		
Labour mix	3,204	3,204
Local density upstream suppliers	3,204	3,204
Plants within 5 kilometres	11,323	11,323
Population	138	138

Source: Statistics Canada, Annual Survey of Manufactures, 1989 and 1999.

Plant characteristics are measured across individual manufacturing establishments. The sample was limited in several ways. By construction, plants in rural areas are excluded from the study. Rural Canada covers an extremely large land area with relatively few plants. Hence, it is unlikely that significant agglomerations of manufacturing plants are missed. Furthermore, difficulties in constructing place-specific data for rural areas also suggest that adding observations from such regions would be largely impractical. Only plants with a three-year average level of employment above zero are included in the study, as labour productivity with zero employment is undefined. The sample is also restricted to plants with positive value added and positive returns to capital. For the latter, this implies that value added minus wages is greater than zero. As a practical matter, these restrictions are imposed because logarithmically transformed variables with a value of zero or less are mathematically undefined. They are also imposed because plants with negative value added or negative returns to capital are likely undergoing significant economic shocks. Again, this may blur the relationship between inputs and output. Also excluded are plants that change location and industry. While plants that switch industries may not be of great interest for the purpose of this study, those that change location certainly are. These plants exerted a good deal of noise in our general results, particularly on the impact of our different measures of agglomeration. Unfortunately, however, plants that changed location over the 1989 to 1999 period moved in many directions and their numbers were not large enough to identify distinct effects associated with such changes.

As a result of the longitudinal nature of the analysis, the most significant restriction to the set of plants is that they must have remained in business at least 10 years. In 1999, this restriction, plus all of the others noted above, reduced the number of plants in the sample from about 29,000 to 11,300. The loss of so many observations raises questions about sampling bias. However, the results reported below are very similar to those published earlier (Baldwin et al. 2008) on a much larger cross-section of plants from 1999. Furthermore, our concern in this paper is with differences in the effects of agglomeration across plants/firms with varied characteristics. The fact that all plants/firms examined are "survivors" suggests that they share a common bias. Also, the results are not separated by industry in the analysis that follows. It is entirely possible that results for individual industries might look somewhat different from the general finding presented. Unfortunately, there are not enough observations on individual industries over the study period to estimate panel models for different sectors of the economy.

Shifting to geographical or place-specific variables for each establishment, counts of the number of plants in the same two-digit (SIC) industry within 5 kilometres were generated. All establishments, not just those that form part of our sample, are included in these counts. Population values are reported for the 141 metropolitan areas that comprise the geographical units of analysis. The labour mix and upstream location quotient are calculated at the three-to-four-digit level of the Canadian SIC for each metropolitan area, yielding 3,204 observations.

3 Plant characteristics and the benefits of agglomeration

3.1 All plants

Model 2 in Table 2 is based on estimating equation (10) across the entire balanced panel of 11,323 plants. This model was estimated using ordinary least squares after differencing between years. All standard errors are robust and are clustered by metropolitan area, thereby adjusting for the potential correlation of errors between manufacturing establishments found in the same region (Moulton 1990). For purposes of comparison, and to show that most of the results are robust to a variety of econometric specifications, models 1 and 3 are also reported in Table 2. Model 1 is a cross-sectional model for the year 1999. Model 3 shows that the signs and significance of the coefficients in the panel model are consistent since instrumental variables techniques are employed here to address potential concerns with endogeneity. It is important to note that the coefficient for population, the measure of urbanization economies, changes from positive to negative, moving from a single cross-section to a longitudinal panel. This is a finding that is addressed later in the discussion of results.

Table 2
General model results

	Single cross-section, 1999[1]		Fixed-effects panel, 1989 and 1999[2]		Fixed-effects panel, 1989 and 1999 (2SLS)[3]	
	Model 1		Model 2		Model 3	
	coefficient	p-value	coefficient	p-value	coefficient	p-value
Plant characteristics						
Ratio of profit to value added	0.813	<0.001	0.750	<0.001	0.730	<0.001
Production workers	-0.031	<0.001	-0.109	<0.001	-0.120	<0.001
Ratio of non-production workers to production workers	0.274	<0.001	0.384	<0.001	0.400	<0.001
Multi-plant status (reference is single plant)	0.190	<0.001	0.086	0.002	0.060	0.041
Foreign-plant status (reference is domestic)	0.103	<0.001	0.094	<0.001	0.070	0.001
Place characteristics						
Labour mix	-0.838	<0.001	-0.508	<0.001	-1.190	<0.001
Local density upstream suppliers	0.014	<0.001	0.100	<0.001	0.380	0.049
Plants within 5 kilometres	0.013	<0.001	0.021	<0.001	0.100	0.032
Plants within 200 kilomètres	...	...	...	...	-0.240	0.055
Population	0.079	<0.001	-0.149	<0.001	-0.200	0.055
Constant	12.190	<0.001	0.044	<0.001	-0.014	0.656

	Model 1	Model 2	Model 3
Number of observations	20,424	11,323	10,615
R-squared	0.661	0.466	0.360
Root mean squared error	0.290	0.430	0.470

1. Reports results from a single cross-section of plants in 1999.
2. Report results from panel models estimated over the two years 1989 and 1999. Results are from a fixed-effects regression model.
3. Report results from panel models estimated over the two years 1989 and 1999. Results are from a fixed-effects regression model incorporating instrumental variables to control for potential endogeneity. The term *2SLS* stands for "two-stage least squares."

Note: In all regressions, standard errors are corrected for heteroscedasticity and potential correlation of errors across plants within the same census metropolitan area or census agglomeration.

Source: Statistics Canada, Annual Survey of Manufactures, 1989 and 1999.

The model estimates in Table 2 are broadly consistent with theoretical expectations. All plant and firm characteristics exert a significant influence on productivity in the anticipated direction. Labour productivity tends to be significantly higher in plants where the profit to value added ratio, the proxy for the capital to labour ratio, is high. Increases in the ratio of non-production to production workers inside plants also raises productivity, with an elasticity about half that of the profit to value added ratio. The negative sign on plant size reflects the value of the exponent in equation (7). For the fixed effects panel results, $\delta_3 = (\beta + \alpha + \sigma - 1)/(1 - \alpha) = -0.109$. Solving for β implies, trivially, that value added increases with the number of production workers (β = 0.425), but, since $\beta + \alpha + \sigma - 1 = -0.062$, plants experience moderate decreasing returns to scale.

The cross-section results in Table 2 indicate that establishments of multi-plant firms and foreign-controlled plants are more productive. Within a first-difference framework, the nature of the multi-plant and foreign-plant status variables requires some explanation. The effect of multi-plant status is captured through the effect of switches between single-plant and multi-plant status. The same holds true for foreign-plant status. As multi-plant and foreign-plant status are measured at the end of the period, a switch from single- to multi-plant status, or from domestic- to foreign-plant status, will result in a positive value (+1), while the reverse will result in a negative value (-1). The coefficient on both variables will reflect the weighted average of these bi-directional switches across plants. Turning to the results, the positive and significant coefficients for multi-plant status and foreign-plant status suggest that establishments that become part of a multi-plant or foreign-controlled enterprise tend to have higher productivity than domestic single-plant firms.

The influence of agglomeration economies on plant productivity is also indicated in Table 2, both for our cross-sectional sample and for all plants that comprise our balanced panel. The labour-mix variable exerts the largest impact of all agglomeration factors on productivity. Thus, plants located in urban areas where the supply of labour more closely matches the occupational demands of the plant's industry enjoy higher productivity than plants located in urban areas where there is a greater disconnect between the demand for labour within specific occupations and the available supply. The local density of upstream suppliers raises plant productivity, but its elasticity is only about one-fifth that of labour mix. Knowledge spillovers are also shown to improve plant performance, with our proxy for spillovers (the number of plants in the same two-digit [SIC] industry within 5 kilometres of a specific plant) significantly raising productivity, albeit by a relatively small amount. This spillover effect was insignificant for establishment counts at distances greater than 5 kilometres, confirming the results of Rosenthal and Strange (2003), who report a strong distance gradient with respect to intra-industry spillovers.

3.2 Domestic firms versus foreign firms

Of primary concern is how these agglomeration factors operate across subsets of plants identified on the basis of plant/firm characteristics that are commonly regarded as indicators of internally available resources/competencies. For all the tables that follow, results are reported from a fixed-effect panel model. The baseline results, for all plants in the panel, are those of model 2 reported in Table 2. In light of the caveats noted above, the models are estimated across the population of Canadian manufacturing plants that were in operation in 1989 and 1999. Thus, on the one hand, differences in regression coefficients reported for different subsets of the population can be regarded as meaningful. On the other hand, the examined plants may be interpreted as a sample drawn from some broader population. This latter interpretation demands that the significance of differences in regression coefficients be tested across the samples that are compared. This is done by regressing a base sample on the independent variables of equation (10), and then interacting a second sample of plants with each of those variables and establishing, via t-tests, whether the partial-regression coefficients in the second sample differ significantly from those of the base sample. The body of every table reports p-values for each partial-regression coefficient that establish the significance of variables within each model.

Table 3 separates the baseline sample into domestic and foreign-controlled firms. Most plants, some 73% of the original balanced panel, are domestic, single-plant firms. Plant size, the ratio of non-production to production workers and the profit-value added ratio, our proxy for capital intensity, are all significant, with the same sign, for domestic and foreign firms. The coefficients on these plant characteristics are slightly larger for foreign-controlled establishments, though only in the case of the profit-to-value added ratio is the difference in coefficients significant between the two sets of plants. A change to multi-plant status raises the productivity of domestic establishments, while it has no significant impact on foreign firms. This is suspected to be the case because foreign-controlled plants are *de facto* part of a multi-unit firm. Takeover by a foreign firm raises plant productivity, while foreign-controlled plants that switch to domestic control see no significant change in labour productivity. Differences in partial-regression coefficients for multi-plant and foreign-plant status are statistically significant between domestic and foreign manufacturing establishments.

Table 3
Domestic versus foreign plants

	Domestic plants		Foreign plants		Domestic less foreign plant coefficient	
	coefficient	p-value	coefficient	p-value	difference	p-value
Change in plant characteristics						
Ratio of profit to value added	0.718	<0.001	0.960	<0.001	-0.242	0.052
Production workers	-0.107	<0.001	-0.119	<0.001	0.012	0.715
Ratio of non-production workers to production	0.385	<0.001	0.447	<0.001	-0.062	0.592
Multi-plant status	0.115	<0.001	0.036	0.237	0.079	0.020
Foreign-plant status	-0.027	0.449	0.110	<0.001	-0.137	0.005
Change in place characteristics						
Labour mix	-0.497	<0.001	-0.491	<0.001	-0.006	0.956
Local density upstream suppliers	0.076	<0.001	0.203	<0.001	-0.127	0.013
Plants within 5 kilometres	0.021	<0.001	0.022	0.094	-0.001	0.945
Population	-0.169	0.015	0.033	0.819	-0.202	0.171
Constant	0.037	0.002	0.061	0.017	-0.024	...

	Domestic plants	Foreign plants	Domestic less foreign
Number of observations	9,704	1,619	...
R-squared	0.477	0.431	...
Root mean squared error	0.410	0.520	...

Note: The determination of foreign-plant status is made in 1999. Over the period from 1989 to 1999, foreign-plant status can change. Hence, foreign-plant status also appears as an independent variable.
Source: Statistics Canada, Annual Survey of Manufactures, 1989 and 1999.

Plants controlled by domestic and foreign firms gain from all three kinds of Marshallian economies. Differences in agglomeration coefficients between domestic and foreign-controlled plants are significant only in the case of the local density of upstream suppliers, where foreign-controlled plants gain more from such spatial association. This finding is revisited later in the discussion. Productivity in domestic plants falls as urban population size increases, though the the finding that the size of the urban population impacts the efficiency of domestic and foreign firms differently is not statistically significant. It should also be cautioned that some of the results in Table 3 might be driven by the sectoral and locational bias of foreign-controlled plants in relation to domestic plants. Foreign-controlled plants are over-represented in resource-based, scale-based, and science-based industries in Canada.

3.3 Domestic single-plant firms versus domestic multi-plant firms

Table 4 takes the 9,704 domestic plants from Table 3 and splits them into two groups: those that represent independent firms; and those that are part of a multi-establishment firm. Approximately 85% of Canadian domestic manufacturing plants are independent firms. The expectation is that these plants will make more extensive use of agglomeration possibilities than plants of multi-unit firms, which should be able to draw upon a more extensive set of firm-specific resources. Plant characteristics influence productivity in single-plant and multi-unit firms in similar ways, with increases in plant size, the profit-value added ratio and the ratio of non-production to production workers all leading to gains in productivity. The productivity of domestic establishments that are part of a multi-unit firm, as opposed to being single-unit firms, increases significantly faster with respect to the profit-value added ratio, and significantly slower with respect to the ratio of non-production to production workers.

Table 4

Domestic, single-plant versus multi-plant firms

	Single-plant firms		Multi-plant firms		Single-plant less multi-plant coefficient	
	coefficient	p-value	coefficient	p-value	difference	p-value
Change in plant characteristics						
Ratio of profit to value added	0.678	<0.001	1.040	<0.001	-0.362	<0.010
Production workers	-0.102	<0.001	-0.121	0.001	0.019	0.523
Ratio of non-production workers to production workers	0.424	<0.001	0.272	<0.001	0.152	0.041
Multi-plant status	0.120	0.011	0.095	<0.001	0.025	0.647
Foreign-plant status	-0.043	0.607	-0.008	0.861	-0.035	0.721
Change in place characteristics						
Labour mix	-0.510	<0.001	-0.384	<0.001	-0.126	0.003
Local density upstream suppliers	0.059	0.017	0.129	<0.001	-0.070	0.077
Plants within 5 kilometres	0.019	0.002	0.028	0.104	-0.009	0.657
Population	-0.157	0.057	-0.047	0.834	-0.110	0.660
Constant	0.031	0.043	0.036	0.136	-0.005	...

	Single-plant firms	Multi-plant firms	Single-plant less multi-plant coefficient
Number of observations	8,276	1,428	...
R-squared	0.477	0.501	...
Root mean squared error	0.406	0.415	...

Note: The determination of foreign-plant status and multi-plant status is made in 1999. Over the period from 1989 to 1999, foreign-plant status and multi-plant status can change. Hence, foreign-plant status and multi-plant status also appear as independent variables.

Source: Statistics Canada, Annual Survey of Manufactures, 1989 and 1999.

Table 4 shows that single-plant firms experience significant productivity benefits from all three localization economies and that they are negatively affected by urbanization economies. Examination of Marshall's agglomeration measures for the plants of multi-unit firms shows the positive benefits of labour market pooling and the local density of the supplier network. Multi-unit plants do not appear to gain from close spatial association with other establishments in the same broad industry. Statistical tests reveal that only in the case of the labour mix and the upstream supplier network are the regression coefficients between the two plant-type samples significantly different. Thus, single-plant firms tend to gain more from an advantageous labour market mix, while plants of multi-unit firms gain more from a dense local supplier network.

3.4 Domestic single-plant firms: small versus large

Table 5 splits the sample of domestic single-plant firms into two groups based on plant size. The first of these groups, the small-firm group, comprises 5,825 manufacturing establishments, each with fewer than 21 production workers, on average, between 1988 and 1990. The second group, consisting of relatively large businesses, comprises 2,451 establishments, each of which employs 21 or more production workers at the start of our study period. Again, individual plant characteristics affect productivity in similar ways across both groups. Large plants gain significantly more than small plants from higher levels of capital.

Table 5

Domestic single-plant firms by size

	Small single-plant firms		Large single-plant firms		Small less large single-plant firm coefficient	
	coefficient	p-value	coefficient	p-value	difference	p-value
Change in plant characteristics						
Ratio of profit to value added	0.604	<0.001	0.861	<0.001	-0.257	0.001
Production workers	-0.100	<0.001	-0.074	<0.001	-0.026	0.157
Ratio of non-production workers to production workers	0.464	<0.001	0.358	<0.001	0.106	0.150
Multi-plant status	0.146	0.032	0.141	0.004	0.005	0.994
Foreign-plant status	0.150	0.226	-0.102	0.246	0.252	0.074
Change in place characteristics						
Labour mix	-0.525	<0.001	-0.367	<0.001	-0.158	<0.001
Local density upstream suppliers	0.044	0.328	0.074	0.064	-0.030	0.342
Plants within 5 kilometres	0.021	0.004	0.021	0.074	0.000	0.982
Population	-0.251	0.005	0.039	0.777	-0.290	0.123
Constant	0.017	0.314	0.060	0.003	-0.043	...
	Small single-plant firms		Large single-plant firms		Small less large single-plant firm coefficient	
Number of observations	5,825		2,451		...	
R-squared	0.473		0.470		...	
Root mean squared error	0.406		0.389		...	

Note: Small plants are defined as employing fewer than 21 production workers. Large plants are defined as employing 21 or more production workers.
Source: Statistics Canada, Annual Survey of Manufactures, 1989 and 1999.

Small and large plants benefit from Marshallian localization economies, but in somewhat different ways. Though only the coefficient on the labour-mix variable can be shown to be significantly different across the two samples, the data in Table 5 suggest broad differences in the relative benefits of agglomeration. Small manufacturing establishments do not appear to benefit from the local density of upstream suppliers as much as larger plants, even though we cannot claim that the differences in coefficients are significant. Small and large, domestic, single-plant firms enjoy productivity benefits from their association with local clusters of own-industry plants.

Small plants face significant reductions in productivity associated with increasing urban size. The influence of urban size on large-plant productivity is ambiguous and measured with relatively little precision so that the coefficients on the urban-size effect cannot be said to be different between small and large plants.

3.5 Domestic single-plant firms by age

Table 6 presents the impacts of plant characteristics and agglomeration economies by age of manufacturing establishments. The plants identified in the panel were born prior to 1989. Eight hundred and twenty-two plants born before 1960 cannot be aged precisely and so are not included in the results presented. The oldest plants in the sample, domestic single-plant firms born in the 1960s, experience significantly larger productivity gains from a higher profit-to-value-added ratio and from larger size, than do younger plants, though all plants benefit from these characteristics. All plants are more productive when the non-production to production worker ratio is higher, though the oldest plants gain significantly less. The effects of changing ownership status and multi-plant status are more variable across plants of different age.

Table 6

Domestic single-plant firms by decade of birth

	1960s		1970s		1980s		1970s less 1960s coefficient		1980s less 1970s coefficient		1980s less 1960s coefficient	
	coefficient	p-value	coefficient	p-value	coefficient	p-value	difference	p-value	difference	p-value	difference	p-value
Change in plant characteristics												
Ratio of profit to value added	0.804	<0.001	0.702	<0.001	0.661	<0.001	-0.102	0.239	-0.041	0.402	-0.143	0.029
Production workers	-0.176	<0.001	-0.110	<0.001	-0.101	<0.001	0.066	0.018	0.009	0.553	0.075	<0.001
Ratio of non-production workers to production workers	0.292	0.018	0.532	<0.001	0.418	<0.001	0.240	0.064	-0.114	0.192	0.126	0.097
Multi-plant status	0.021	0.802	0.044	0.315	0.227	0.003	0.023	0.798	0.183	0.015	0.206	0.065
Foreign-plant status	-0.110	0.457	0.119	0.402	-0.335	0.217	0.229	0.038	-0.454	0.224	-0.225	0.554
Change in place characteristics												
Labour mix	-0.450	<0.001	-0.472	<0.001	-0.556	<0.001	-0.022	0.661	-0.084	0.054	-0.106	0.009
Local density upstream suppliers	0.113	0.022	0.099	0.002	0.035	0.300	-0.014	0.808	-0.064	0.161	-0.078	0.190
Plants within 5 kilometres	-0.032	0.059	0.003	0.778	0.026	0.018	0.035	0.127	0.023	0.111	0.058	0.007
Population	-0.141	0.300	-0.298	0.083	-0.211	0.026	-0.157	0.399	0.087	0.596	-0.070	0.632
Constant	-0.020	0.369	0.033	0.221	0.061	0.001	0.053	...	0.028	...	0.081	...

	1960s	1970s	1980s	1970s less 1960s	1980s less 1970s	1980s less 1960s
Number of observations	850	1,547	4,950	...	...	...
R-squared	0.504	0.539	0.466	...	...	...
Root mean squared error	0.376	0.370	0.424	...	...	...

Source: Statistics Canada, Annual Survey of Manufactures, 1989 and 1999.

With respect to the agglomeration effects, the youngest plants, those born in the 1980s, are anticipated to rely most heavily on external resources. Entrants born in the 1980s benefit significantly more from an appropriate labour mix than do older plants. Consistent with our expectations, knowledge spillovers also raise the productivity of the newest plants significantly more than the productivity of the oldest plants. The own-industry count of plants within 5 kilometres has no statistical influence on the productivity of plants born in the 1970s and has a negative impact on the productivity of older plants, those born in the 1960s. The productivity of new plant entrants is not significantly related to the local supplier network, while the density of that network raises the productivity of plants born prior to the 1980s. This finding is consistent with the results presented above, although the differences in the regression coefficient on the upstream network are not statistically significant across the plant-age groups. What might explain this pattern? One possibility is that new, single-plant domestic firms initially produce a large proportion of their inputs in-house, but that, as they learn over time and as their production processes become more standardized, different stages of production become more amenable to outsourcing. Finally, younger plants (those born in the 1970s and 1980s) appear more negatively impacted by urban size, though the coefficients on this variable are not significantly different across the three plant-age samples.

3.6 Domestic single-plant firms: incumbents versus greenfield entrants by age

The manufacturing establishments examined in Table 6 were all domestic single-plant firms in 1999, at the end of the panel. Some of these firms were born as new, or greenfield, entrants to the economy, and some were born as the plants of established, or incumbent, firms. Plants from the latter group might be able to draw on a different internal resource mix than greenfield entrants. This possibility is analyzed next.

Table 7 displays the results from estimating our model of the productivity benefits of agglomeration over domestic single-plant firms. In the first two columns of the table, plants born to incumbent firms (becoming independent single-plant firms by 1999) are distinguished from those plants born as new firms (most remaining independent single-plant firms through 1999). The right half of the table divides the latter group into those plants born in the 1970s and those born in the 1980s.

Table 7
Domestic plants, new firm entrants versus plants born to incumbents, and by decade of birth

	Born to incumbents		Greenfield entrants		Greenfield less incumbent coefficient		Greenfield entrants by decade of birth				1980s less 1970s coefficient	
							1970s		1980s			
	coefficient	p-value	coefficient	p-value	difference	p-value	coefficient	p-value	coefficient	p-value	difference	p-value
Change in plant characteristics												
Ratio of profit to value added	0.762	<0.001	0.646	<0.001	-0.116	0.014	0.660	<0.001	0.642	<0.001	-0.018	0.663
Production workers	-0.112	<0.001	-0.101	<0.001	0.011	0.314	-0.089	<0.001	-0.105	<0.001	-0.016	0.371
Ratio of non-production workers to production workers	0.373	<0.001	0.443	<0.001	0.070	0.265	0.567	<0.001	0.419	<0.001	-0.148	0.215
Multi-plant status	0.107	0.017	-0.013	0.882	-0.120	0.170	0.046	0.336	-0.015	0.886	-0.061	0.796
Foreign-plant status	-0.067	0.461	-0.245	<0.001	-0.178	0.062	-0.006	0.757	-0.517	<0.001	-0.511	0.000
Change in place characteristics												
Labour mix	-0.453	<0.001	-0.543	<0.001	-0.090	0.019	-0.467	<0.001	-0.559	<0.001	-0.092	0.083
Local density upstream suppliers	0.091	0.002	0.042	0.142	-0.049	0.123	0.095	0.044	0.036	0.267	-0.059	0.300
Plants within 5 kilometres	0.015	0.343	0.020	0.050	0.005	0.857	-0.012	0.338	0.025	0.037	0.037	0.038
Population	-0.036	0.737	-0.232	0.017	-0.196	0.072	-0.211	0.309	-0.238	0.020	-0.027	0.727
Constant	-0.007	0.650	0.050	0.010	0.057	…	0.011	0.729	0.058	0.004	0.047	…

	Born to incumbents	Greenfield entrants	Greenfield less incumbent coefficient	Greenfield entrants by decade of birth: 1970s	Greenfield entrants by decade of birth: 1980s	1980s less 1970s coefficient
Number of observations	2,572	5,704	…	986	4,718	…
R-squared	0.480	0.480	…	0.539	0.470	…
Root mean squared error	0.398	0.408	…	0.373	0.414	…

Source: Statistics Canada, Annual Survey of Manufactures, 1989 and 1999.

Focusing on the influence of agglomeration, plants born to incumbents and those born as new firms enjoy a boost in productivity from an advantageous labour mix. For greenfield entrants, this efficiency boost is significantly larger. Plants born to incumbents gain from the local density of upstream suppliers and experience no benefits from co-location. Conversely, greenfield entrants do not benefit from the local density of the upstream supply network, but they do benefit from co-location with own-industry plants. However, for both of these processes of agglomeration, the differences in coefficients between plants born to incumbents and those that are greenfield entrants are not significant.

At least in part, these results suggest that the origins of new plants impact their organization and structure as well as the potential benefits of agglomeration. Results in Table 7 also reveal that urban size negatively impacts greenfield entrants, though it has no influence on the productivity of plants born to incumbents. This finding is significant across the two groups.

When the greenfield entrants are separated by decade of birth, the following is observed: the youngest plants gain slightly more from the right kind of labour mix; they gain nothing from the local upstream supply network; and they benefit from co-location with plants in the same industry within a radius of 5 kilometres. Older greenfield entrants gain little from co-location with plants in the same industry, but they have learned to exploit the upstream supply network. Comparing the agglomeration coefficients between these two samples of establishments indicates that the influence of labour mix and co-location are significantly different.

Finally, the discussion turns to the effect of urbanization economies measured through changes in the population of the urban areas in which plants are located. Manufacturing establishments that are assumed to have fewer internal resources, that is, small, young, and domestic plants that are not part of multi-establishment firms are all negatively impacted (in terms of productivity) by urban size. Why there should be negative urbanization economies for these "more vulnerable" plants is open to question. Congestion effects would be expected to impact all plants. On the other hand, it is well known that wages tend to be higher in urban areas than in non-urban areas and higher in larger urban centres than in smaller ones. If smaller, younger, domestic, and single-plant firms have lower productivity than their rivals, these firms will experience difficulties attracting labour in urban areas because they cannot provide competitive wages. There is also a dynamic explanation for the urbanization effects. The option value of entry is higher in larger urban areas because of expected growth opportunities for less skilled/experienced entrepreneurs. They are able to survive, even when their productivity growth is lagging, because of expanding local markets. It is important to keep in mind that, because the data are differenced, the effects of urbanization economies are captured through the change in urban population. Therefore, while the change in population is being used as an estimator of the effect of urbanization economies on productivity, it is simultaneously a measure of local economic growth.

4 Conclusion

Dense concentrations of economic activity are generally seen as giving rise to increasing returns that may be shared by business units that cluster in space. Theories of the firm and of strategic management argue that competitive advantage originates in the development and exploitation of firm-specific assets or capabilities that may be internal or external to the firm. Older, larger, foreign-controlled, and multi-plant firms are anticipated to have greater internal resources upon which they might build advantage. Young, small, domestic, and single-plant businesses cannot draw upon these same resources and are more likely to develop strategies for survival that rest on place-based economies generated in particular locations. The analysis presented here is an attempt to identify the sources of these external resources and to examine whether they benefit all businesses or only some.

The analysis shows that virtually all plants reap productivity benefits from being located in places where the occupational distribution of workers matches the demand for labour by occupation. However, these benefits tend to be larger for small and young businesses. Knowledge spillovers, measured by own-industry plant counts within a radius of 5 kilometres also generate broad-based productivity gains. These gains, however, were stronger for younger as compared to older plants. The local density of upstream suppliers does not benefit the firms that we suppose have few internal resources. Rather, older firms, regardless of size or complexity, derive the largest benefit from having upstream suppliers nearby. This is consistent with the argument that older firms, whose production processes have been standardized, are better able to exploit the advantages of local supplier/buyer networks. It is suspected that younger plants have less information about internal versus external production possibilities and/or have not yet learned how to configure their production possibilities in an optimal fashion.

Our initial exploration of agglomeration within the Canadian economy, in the context of a cross-sectional model, reported a positive influence of urban size on plant productivity. That general finding was reversed when the analysis shifted to a fixed effect format in order to combat unobserved heterogeneity. The results from this paper cast further light on the relationship between urban size and manufacturing plant performance. Urban size has a significant negative impact on productivity in plants that are small, relatively young, domestically-controlled, and that comprise single-establishment firms. For larger plants, older plants, those that are foreign-controlled, and for plants that comprise part of multi-establishment firms, urban size has no significant effect on productivity.

Recent analysis, making use of micro-data, has been able to identify the gains from co-location. This paper illustrates that not all manufacturing plants benefit from localization and urbanization economies, and identifies the types of businesses that are able to exploit different forms of external economies. However, much remains to be done in order to understand precisely how and where the benefits of agglomeration are produced and how they are distributed across firms and regions. Of particular interest is the evolutionary dynamics of agglomerations. How do clusters of firms and other economic agents grow? What are the ties that bind economic actors to particular locations, and how do these change over time and space? How do the characteristics of clusters and the characteristics of the economic agents they embody co-evolve? Are the dynamics of firm entry, exit, and growth different inside and outside the agglomeration? And how does the geographical mobility of economic agents into and out of clusters shape their fortune? These questions speak to the geography of economic performance, to the ways that knowledge and other key resources are generated and captured in place, if only temporarily, and to the processes that control the movement of these resources.

References

Abdel-Rahman, H., and M. Fujita. 1990. "Product variety, Marshallian externalities, and city sizes." *Journal of Regional Science*. Vol. 30. No. 2. p. 165−183.

Alcacer, J. 2006. "Location Choices Across the Value Chain: How Activity and Capability Influence Collocation." *Management Science*. Vol. 52. No. 10. p. 1457−1471.

Baily, M.N., C. Hulten, and D. Campbell. 1992. "Productivity Dynamics in Manufacturing Plants." *Brookings Papers on Economic Activity: Microeconomics*. Washington, D.C. The Brookings Institution. Vol. 1992. p. 187−267.

Baldwin, J. 1995. *The Dynamics of Industrial Competition: A North American Perspective*. Cambridge, U.K., and West Nyack, New York. Cambridge University Press.

Baldwin, J., D. Beckstead, W.M. Brown, and D.L. Rigby. 2008. "Agglomeration and the Geography of Localization Economies in Canada." *Regional Studies*. Vol. 42. No. 1. p. 117−132.

Baldwin, J.R., W.M. Brown, and D.L. Rigby. 2010. "Agglomeration Economies: Microdata Panel Estimates from Canadian Manufacturing." *Journal of Regional Science*. Vol. 50. No. 5. p. 915−934.

Baldwin, J.R., and W. Gu. 2005. *Global Links: Multinationals, Foreign Ownership and Productivity Growth in Canadian Manufacturing*. Statistics Canada Catalogue no. 11-622-M. Ottawa, Ontario. The Canadian Economy in Transition Series. No. 9.

Barney, J.B. 1991. "Firm resources and sustained competitive advantage." *Journal of Management*. Vol. 17. No. 1. p. 99−120.

Beaudry, C., and A. Schiffauerova. 2009. "Who’s right, Marshall or Jacobs? The localization versus urbanization debate." *Research Policy*. Vol. 38. No. 2. p. 318−337.

Becker, R., and V. Henderson. 2000. "Intra-industry specialization and urban development." *Economics of Cities: Theoretical Perspectives*. J.-M. Huriot and J.-F. Thisse (eds.). Cambridge, U.K., New York, and Melbourne. Cambridge University Press.

Beeson, P. 1987. "Total factor productivity growth and agglomeration economies in manufacturing: 1959-73." *Journal of Regional Science*. Vol. 27. No. 2. p. 183−199.

Boschma, R., and K. Frenken. 2011. "The emerging empirics of evolutionary economic geography." *Journal of Economic Geography*. Vol. 11. No. 2. p. 295−307.

Carlino, G.A. 1978. *Economies of Scale in Manufacturing Location: Theory and Measurement*. Studies in Applied Regional Science, Vol. 12. Leiden, The Netherlands. Martinus Nijhoff Publishers.

Ciccone, A., and R.E. Hall. 1996. "Productivity and the Density of Economic Activity." *The American Economic Review*. Vol. 86. No. 1. p. 54−70.

Cyert, R.M., and J.G. March. 1963. *A Behavioral Theory of the Firm*. Englewood Cliffs, New Jersey. Prentice-Hall.

Dumais, G., G. Ellison, and E.L. Glaeser. 1997. *Geographic Concentration as a Dynamic Process*. Cambridge, Massachusetts. National Bureau of Economic Research. NBER Working Paper Series. Working paper no. 6270.

Duranton, G., and H.G. Overman. 2005. "Testing for Localization Using Micro-Geographic Data." *Review of Economic Studies*. Vol. 72. No. 4. p. 1077−1106.

Duranton, G., and H.G. Overman. 2008. "Exploring the detailed location patterns of U.K. manufacturing industries using microgeographic data." *Journal of Regional Science*. Vol. 48. No. 1. p. 213−243.

Duranton, G., and D. Puga. 2001. "Nursery Cities: Urban Diversity, Process Innovation, and the Life Cycle of Products." *The American Economic Review*. Vol. 91. No. 5. p. 1454−1477.

Duranton, G., and D. Puga. 2004. "Micro-foundations of Urban Agglomeration Economies." *Handbook of Regional and Urban Economics*. Vol. 4: Cities and Geography. J.V. Henderson and J.-F. Thisse (eds.). Amsterdam. Elsevier. p. 2063−2117

Ellison, G., and E. Glaeser. 1997. "Geographic Concentration in U.S. Manufacturing Industries: A Dartboard Approach." *The Journal of Political Economy*. Vol. 105. No. 5. p. 889−927.

Ellison, G., and E. Glaeser. 1999. "The Geographic Concentration of Industry: Does Natural Advantage Explain Agglomeration?" *The American Economic Review*. Vol. 89. No. 2. p. 311−316.

Feser, E.J., and S.H. Sweeney. 2000. "A Test for the Coincident Economic and Spatial Clustering of Business Enterprises." *Journal of Geographical Systems*. Vol. 2. No. 4. p. 349-373.

Glaeser, E.L., H.D. Kallal, J.A. Scheinkman, and A. Shleifer. 1992. "Growth in Cities." The Journal of Political Economy. Vol. 100. No. 6. p. 1126−1152.

Henderson, J.V. 2003. "Marshall's scale economies." *Journal of Urban Economics*. Vol. 53. No. 1. p. 1−28.

Henderson, V., A. Kuncoro, and M. Turner. 1995. "Industrial development in cities." *The Journal of Political Economy*. Vol. 103. No. 5. p. 1067−1090.

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

Jaffe, A.B., M. Trajtenberg, and R. Henderson. 1993. "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations." *The Quarterly Journal of Economics*. Vol. 108. No. 3. p. 577–598.

Knoben, J., O. Raspe, A.T. Arikan, and F. van Oort. 2010. *Location matters – But what kind of location matters to what kind of firms?* Paper presented at the DIME Conference. Utrecht, The Netherlands. Utrecht School of Economics, University of Utrecht. September 2010.

Kogut, B., and U. Zander. 1992. "Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology." *Organization Science*. Vol. 3. No. 3. p. 383−397.

Krugman, P. 1991. "Increasing Returns and Economic Geography." *The Journal of Political Economy*. Vol. 99. No. 3. p. 483–499.

Marcon, E., and F. Puech. 2003. "Evaluating the geographic concentration of industries using distance-based methods." *Journal of Economic Geography*. Vol. 3. No. 4. p. 409−428.

Marshall, A. 1920. *Principles of Economics* (8th ed.). London, U.K. Macmillan and Co.

McCann, B.T., and T.B. Folta. 2008. "Location Matters: Where We Have Been and Where We Might Go in Agglomeration Research." *Journal of Management.* Vol. 34. No. 3. p. 532−565.

McCann, B.T., and T.B. Folta. 2011. "Performance differentials within geographic clusters." *Journal of Business Venturing*. Vol. 26. No. 1. p. 104−123.

Melitz, M.J. 2003. "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity." *Econometrica*. Vol. 71. No. 6. p. 1695−1725.

Moomaw, R.L. 1981. "Productivity and city-size: A critique of the evidence." *The Quarterly Journal of Economics*. Vol. 96. No. 4. p. 675−688

Moomaw, R.L., and M. Williams. 1991. "Total Factor Productivity Growth in Manufacturing: Further Evidence from the States." *Journal of Regional Science*. Vol. 31. No. 1. p. 17−34.

Moulton, B. 1990. "An Illustration of the Pitfall in Estimating the Effects of Aggregate Variables on Micro Units." *The Review of Economics and Statistics*. Vol. 72. No. 2. p. 334−338.

Neffke, F., M. Henning, and R. Boschma. 2012. "The Impact of Aging and Technological Relatedness on Agglomeration Externalities: A Survival Analysis." *Journal of Economic Geography*. Vol. 12. No. 2. p. 485−517.

Neffke, F., M. Henning, R. Boschma, K.J. Lundquist, and L.O. Olander. 2011. "The Dynamics of Agglomeration Externalities along the Life Cycle of Industries." *Regional Studies*. Vol. 45. No. 1. p. 49−65.

Nelson, R.R., and S.G. Winter. 1982. *An Evolutionary Theory of Economic Change*. Cambridge, Massachusetts. Harvard University Press.

Penrose, E. 1959. *The Theory of the Growth of the Firm*. New York. John Wiley and Sons.

Porter, M.E. 1985. Competitive Advantage: Creating and Sustaining Superior Performance. New York. Free Press.

Potter, A., and H.D. Watts. 2011. "Evolutionary agglomeration theory: Increasing returns, diminishing returns and the industry life cycle." *Journal of Economic Geography*. Vol. 11. No. 3. p. 417−455.

Prahalad, C.K., and G. Hamel. 1990. "The Core Competence of the Corporation." *Harvard Business Review*. Vol. 68. No. 3. p. 79−91.

Rigby, D.L., and J. Essletzbichler. 2002. "Agglomeration economies and productivity differences in U.S. cities." *Journal of Economic Geography.* Vol. 2. No. 4. p. 407−432.

Rigby, D.L., and J. Essletzbichler. 2006. "Technological variety, technological change and a geography of production techniques." *Journal of Economic Geography*. Vol. 6. No. 1. p. 47−70.

Rosenthal, S.S., and W.C. Strange. 2001. "The Determinants of Agglomeration." *Journal of Urban Economics*. Vol. 50. No. 2. p. 191−229.

Rosenthal, S., and W. Strange. 2003. "Geography, Industrial Organization, and Agglomeration." *The Review of Economics and Statistics*. Vol. 85. No. 2. p. 377−393.

Saxenian, A. 1994. *Regional* Advantage: Culture and Competition in Silicon Valley and Route 128. Cambridge, Massachusetts. Harvard University Press.

Storper, M. 1997. *The Regional World: Territorial Development in a Global Economy*. New York. The Guilford Press.

Sveikauskas, L.A. 1975. "The Productivity of Cities." *The Quarterly Journal of Economics*. Vol. 89. No. 3. p. 393−413.

Teece, D., and G. Pisano. 1994. "The Dynamic Capabilities of Firms: An Introduction." *Industrial and Corporate Change*. Vol. 3. No. 3. p. 537−556.

Wernerfelt, B. 1984. "A resource-based view of the firm." *Strategic Management Journal*. Vol. 5. No. 2. p. 171−180.