The Effects of Agglomeration on Economic Activity: The Empirical Evidence on Mechanisms and Magnitudes

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Abstract

There is a rapidly developing empirical literature on the effects of agglomeration on economic activity. This paper surveys recent studies that provide econometric estimates of effects. Doubling economic density increases labour productivity by three or more per cent. Beneath this general picture, however, effects vary widely in a way that defies easy generalisation. A variety of factors are involved in producing effects, with labour market specialisation featuring as important in a number of studies. There appears to be an important positive interaction between human capital and agglomeration effects. However, the empirical literature surveyed does not shed much light on the precise nature of the mechanisms involved. Effects of own industry scale are substantial in some cases. But a majority of three or four-digit industries are not significantly agglomerated, and even fewer demonstrate significant positive agglomeration effects of own industry scale.

On the basis of this literature, New Zealand policy makers aiming to raise productivity should include a focus on the conditions that would allow its largest city to successfully grow in size. They should avoid attempts to select particular industries to increase their national scale in the hope of reaping agglomeration economies.

JEL Classification: O12; O31; R11; R12

Keywords: Agglomeration economies; cities; industry concentration; economic growth.
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1. Introduction

Why do people and firms locate in cities? Why do some cities seem to specialize in particular industries – but others contain a diverse range of industries? Part of the answer to these questions may be due to the productive advantages of people locating close together\(^1\) and the mechanisms by which these advantages operate. How important are such productive advantages, and are they likely to be relevant to economic development policy in New Zealand? If so, what sorts of policy instruments are relevant in exploiting these advantages?

The purpose of this paper is to review the empirical economics literature, to begin to draw out some answers to these questions. The primary focus is to identify the order of magnitude of so-called “agglomeration effects” on economic activity, and to sketch out the evidence for relevant mechanisms. The paper is intended to assist judgments on the likely effectiveness of a range of economic growth policies that have been motivated by a reading of the “new economic geography” and related literature.

\(^1\) Other factors include natural advantages (due, for instance, to topography or presence of raw materials), and the amenities that cities offer to consumers.
To provide some context, there are three main areas of policy in New Zealand, where agglomeration economies may be relevant. First, in 2002, as part of its Growth and Innovation Framework, the Government decided to focus particular policy attention on three industry sectors. While a range of considerations were at play\(^2\), an important contribution was the idea that increasing industry specialization (in some promising areas) would enhance growth prospects – through encouraging complementary investments in specialised capital and human capital, and, in other ways, achieving external economies of scale\(^3\). New Zealand’s small size and distance from major markets and sources of technology may pose particular difficulties for it achieving such economies of scale, making it less competitive in industries subject to them.

The policy rationale was not focussed specifically on geographic concentration in regions or cities – but the literature on agglomeration economies is relevant for two reasons. New Zealand is a small country – smaller in population, and even overall area, than many jurisdictions (such as states in the United States) that are sometimes used as the unit of analysis in the empirical agglomeration literature. Also, the selected industries are, in fact, mostly located in the largest cities in New Zealand, so increased specialization at the national level is arguably likely to have a dimension of increased geographic concentration.

Second, though on a small scale, New Zealand is implementing a policy to foster local industry clusters. This set of policies has a local or regional development dimension, but is also seen as a route to promoting economic growth at the national level. The policies are being integrated with other regional and industry assistance policies – perhaps making them more quantitatively significant than the quantum of direct resources devoted to them would suggest. While the concept of ‘industry cluster’ is unclear (see Section II) it has some intersection with the agglomeration literature.

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\(^2\) Gandar and Tullet (2003) provide a helpful summary of the range of rationales for and policies associated with government selection and engagement with industry sectors. Another important rationale was to strengthen industry sectors (such as ICT) that may have strong “horizontal” impacts across the economy.

\(^3\) These ideas are set out, for instance, in Skilling (2001).
Third, the Government is actively considering the role that cities, and in particular Auckland play or could play in achieving its economic growth objectives. A particular issue is the role that the provision of public infrastructure has in allowing denser and/or larger cities to function more productively. The existence or otherwise, of significant agglomeration economies, is clearly relevant to answering this question.

While the literature surveyed here is relevant to these policy questions, it will become apparent that careful judgment is required in applying findings from international studies to local policies. An earlier version of this paper identified a need for more empirical work in New Zealand that will describe the extent of geographic concentration of industry, the industries involved, the extent to which this might be explained by agglomeration economies, and the likely mechanisms involved. Two new empirical studies were initiated to begin to address these issues – Maré (2005) and Maré and Timmins (forthcoming). Their findings are incorporated into this version of the paper.

In terms of public infrastructure policy, the earlier version likewise noted a need to identify the marginal effects on productivity (and amenity value to consumers) of recent infrastructural projects. This issue has begun to be addressed in Timmins (2005) and Grimes (forthcoming).

The remainder of the paper is set out as follows. Section II outlines how the literature surveyed was selected, with a focus on quantitative empirical analyses that allow generalisable conclusions on the size and importance of agglomeration effects. Section III sets out some contextual material and trends that the theory and empirics of agglomeration effects must accommodate. Section IV outlines the mechanisms by which agglomeration effects are thought to work, and how they have been dealt with in empirical investigations. Generally, the empirical literature is limited in the extent to which it can shed light on the precise nature of the mechanisms at work. Section V discusses some methodological and empirical issues that need to be considered in interpreting the outcomes of empirical investigation of agglomeration effects. A wide variety of specifications, coverage, and measurement of variables poses difficulties in weighing the findings of
different studies. Accounting for the effects of unobserved characteristics on economic outcomes is a pervasive problem for discerning causal relationships. Section VI summarises empirical findings on the variety of factors involved in producing agglomeration effects, their scope and relative importance.

Section VII, the central part of the paper, sets out findings on the size of agglomeration effects on economic outcomes. There is clear evidence that density of economic activity has a moderate positive effect on productivity. However, these effects vary markedly across industries and the extent to which they are due to concentration of an industry in a particular location, or wider benefits of an urban agglomeration. A majority of three- or four-digit industries experience no statistically significant effects at all. Section VIII concludes by summarising the empirical evidence on agglomeration effects, and drawing out some policy implications.
2. Scope of Literature Surveyed

There is a very wide-ranging literature on cities, industrial concentration and the mechanisms by which they have effects on economic outcomes. This paper focuses on the empirical economics literature that is most likely to allow generalisable conclusions on the size and relative importance of these effects, and on the mechanisms by which they operate. Nevertheless, other literatures will be relevant to policy choices and understanding the factors that need to be considered in implementing policy.

There is a wide and burgeoning empirical literature that is relevant to the questions this paper attempts to answer, and I have necessarily been selective. I have given most attention to econometric studies that are more likely to yield robust, generalisable, quantitative estimates of the economic effects of city scale and density and the geographic concentration of industry. In general these cover studies from a variety of countries, but particularly the US, and use large data sets and more or less up-to-date and relatively sophisticated econometric techniques to discern the relationships of interest.

Hansen (2002) provides a preliminary and general review of some empirical findings on agglomeration effects. A search for relevant empirical studies began with those cited by Hansen. This was followed by a search for more recent work by the same authors, which was widened by reference to other works cited in this body of work. I have mostly restricted attention to English language studies completed since 1990.

A set of recent surveys published in Henderson and Thisse (2004) has greatly assisted. In particular I have followed Rosenthal and Strange (2004) in their treatment of the evidence on the scope of agglomeration spillovers, and the mechanisms by which they work. I have, however, paid more attention than them to the magnitude of effects and their relevance to aggregate economic activity.

There is a wide range of studies that use econometric analyses to study the particular mechanisms relevant to agglomeration effects. I make selective use of these in this paper. Understanding the nature of the mechanisms and
the factors that influence them is likely to be of importance for the design of policies intended to exploit agglomeration economies. Evidence on the mechanisms also reinforces the evidence on the size of effects that is my primary focus. In addition to Rosenthal and Strange (2004), I have also used surveys by Audretsch and Feldman (2004) on knowledge spillovers, Moretti (2004a) on human capital spillovers in cities, and Glaeser and Kohlase (2003) to round out the evidence on mechanisms. Occasionally I report findings in more recent studies not covered by these surveys.

Overall, the evidence from the econometric literature is far from unambiguous, and it is also subject to considerable limitations in scope. These are due partly to data limitations and partly to difficulties in specifying econometric models that adequately capture the effects being investigated.

My approach here has been to get a sense of the balance of probabilities and the orders of magnitude involved. This is partly a matter of finding a consistent, coherent and parsimonious explanation for a diverse range of findings. It is also a matter of understanding the inevitable limitations in the various empirical strategies employed, and factoring these into the weight to be applied to particular findings.

Other strands of literature not surveyed here are likely to contribute to a richer picture (although providing other interpretative difficulties for policy purposes). For instance, there are case studies of agglomeration effects in particular industries, sometimes employing econometric methods, and some of which might be relevant to the directions of New Zealand’s industry policy (biotechnology is a popular choice for study – for instance). There are case studies of the development of industry clusters (Saxenian, 1996; Bresnahan, Gambardella and Saxenian, 2001). There are studies of the effects of particular institutions in mediating knowledge spillovers. There is a diverse strand of literature (mostly based on case studies, and interpretation of ethnographic data) covering the role of business networks, culture and shared trust in building co-operation among inter-linked businesses and other

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4 Ultimately, judgments here will need to reflect possible upside and downside risks of feasible policies – but that is beyond the scope of this paper.
institutions on a regional, national and international scale (see, for instance, Maskell and Malmberg (1999); the survey by Rauch (2001); and, in a New Zealand context, Perry (2001)).

There is a growing literature on agglomeration and international trade (surveyed in Neary (2001)) and, on the empirical evidence, in Head and Mayer (2004)); and a relatively small literature on agglomeration and public infrastructure (surveyed in Eberts (1999)), with recent contributions from Haughwout (2001, 2002). There is also a literature that attempts to evaluate more directly the effects of government policies aimed to exploit agglomeration effects or clustering (e.g. Koh, Koh and Tschang (2005) on science parks).

Finally, as Rosenthal and Strange (2004) argue, an important issue for understanding and measuring agglomeration economies is their scope across industrial “distance”. Much of the literature surveyed in this paper is focused on distinguishing effects of “own industry” geographic concentration (with industry defined at varying degrees of aggregation) from those due to co-location with a geographic concentration of other industries. Some evidence (for instance, Feldman and Audretsch (1999)) suggests, however, that spillovers occur across industry boundaries in ways that may not easily be captured by this relatively crude characterisation.

Porter's (1990) work on industrial clusters takes a more nuanced approach to this issue. Most recently, he has been involved in an exercise defining significant industrial clusters across the United States, using employment patterns and other softer judgments as a basis (Porter 2003). These clusters generally cross conventional industry boundaries, and there are substantial overlaps among them. Some limited quantitative analyses are suggestive of spillovers within these clusters. However, there are questions about whether the definition of clusters in this way could be reliably replicated by other researchers. In any case, a search for evidence of spillovers using these definitions, and the techniques developed in the recent econometric literature, has not been carried out.
Thus, there is a wide range of other relevant literature. Much of this is
discursive and interpretative rather than relying on econometric analysis of
large data sets. The weakness of this literature is that it often fails to give
either a sense of scope and generalisability of the phenomena that it covers,
or its overall significance for aggregate economic activity. Nevertheless, it
can provide richer and more nuanced insights than is possible with the
relatively thin range of variables that are generally available in large scale
quantitative datasets. The potential contribution of other literatures should be
borne in mind, in considering the evidence reviewed in this paper.
3. Features of Agglomeration and Current Trends

Any understanding of agglomeration effects needs to be able to account for salient features of agglomeration and recent trends. Most industries are not significantly geographically concentrated, once the overall distribution of employment and industrial concentration is taken into account. Industrial agglomerations are mostly relatively stable over time. However, agglomeration is a dynamic process, and there is evidence for new firms tending to locate both in and away from existing geographical concentrations in their industry. In the past, many cities have tended to be relatively specialized in particular industries – but this pattern appears to be changing – at least in Europe and the U.S., where specialization by function has been growing in importance.

There has been a centuries-long trend to greater urbanization of the world’s population, but, at the same time, more recently cities have become less dense. This appears to be related to the rise of the automobile. Cities with high proportions of educated workers have been growing faster over the last twenty years, and once this is taken into account, larger cities have grown more slowly.

Innovations occur disproportionately in large cities. Agglomeration is associated with higher wages, rents and productivity.

Any account of agglomeration economies and their economic effects, should be able to explain the salient features of agglomeration and how they have changed over time. This section briefly sets out some relevant facts, as a context for the later discussion of the evidence. It relates mostly to the developed world, and to the United States in particular, where, perhaps, agglomeration has been most intensively studied.

First it is pertinent to note that, once the distribution of employment and the concentration of industries in particular firms is taken into account, a majority of industries (defined at the three-digit level) are not significantly agglomerated (Ellison and Glaeser (1997) for the U.S.; Devereux, Griffith and Simpson (forthcoming) for the U.K., Maré (2005) for New Zealand; and Maurel
and Sedillot (1999) for France\textsuperscript{5}. For those that are, 50 per cent of agglomeration may, perhaps, be accounted for by “natural advantages” (Ellison and Glaeser 1999)\textsuperscript{6}. Maré (2005) finds that New Zealand has a relatively high degree of geographic concentration of industry, and that it also has an unusually high proportion of very concentrated and very dispersed industries. This may reflect the very small size of New Zealand industries by international standards, and a related high level of industrial concentration (a tendency for the bulk of employment in an industry to be concentrated in a few firms).

Geographic agglomeration is a dynamic process, with firm births and deaths, expansions and contractions contributing to slowly changing patterns. The stability of geographic agglomeration\textsuperscript{7}, despite the dynamics, suggests that it is the result of an equilibrium phenomenon “whether due to increasing returns or cost differences” (Dumais, Ellison and Glaeser 2002).

Thus, agglomeration does not happen without limit. Once other factors contributing to growth are taken into account, larger cities tend to grow more slowly than others (Glaeser and Saiz 2003). Industry employment growth does not necessarily tend to occur where the industry is already highly concentrated (Henderson, Lee and Lee 2001; Combes 2000). If there are positive agglomeration effects promoting growth and concentration, there are also limits due to negative externalities of city size and industry concentration.

In general, in large economies there is a wide relative size distribution of cities that is stable over time. Within that distribution, individual cities are generally growing over time. While there is entry of new cities and both rapid growth and decline of cities at the bottom of the size distribution, at the top rankings

\textsuperscript{5} Ellison and Glaeser (1997) calibrate the economic significance of their index of geographic concentration using the literature on state new plant share-cost elasticities. Duranton and Overman (2002) develop a continuous measure of geographic concentration that allows them to calculate the statistical significance of estimates. For only 51 per cent of industries in their study is geographic concentration statistically significant, and among these the degree of concentration is very skewed.

\textsuperscript{6} A problem with this categorization is that the analysis treats labour as immobile – and low cost labour is therefore treated as a “natural advantage”.

\textsuperscript{7} The Ellison-Glaeser index of geographic agglomeration is strongly correlated over time (over 90 per cent even after 20 years). Kim's (1995) calculation of Hoover's coefficient of regional localization for two-digit industries shows a correlation of 0.64 between 1860 and 1987 values.
are “remarkably stable over time” (Henderson 2005). At the same time, re-allocation of sectoral employment across cities is much more rapid than re-allocation of employment alone (Duranton, 2005).

Consistent with this, some high-tech industries with rapidly changing technology (such as the computer industry in the U.S.) have been geographically quite mobile over recent decades (Beardsell and Henderson 1999; Henderson 1999). For New Zealand, Maré (2005) shows that there has been a slight but steady increase in geographic concentration between 1987 and 2003, mainly as a result of industries changing their degree of concentration rather than more concentrated industries growing faster.

Over recent decades, cities in the United States and Europe are becoming less specialized by industrial sector, and more functionally specialized in terms of a division between management and production. In particular, the largest cities have become more specialized in management, and smaller cities have become more specialized in production\(^8\) (Duranton and Puga 2005).

In the United States, the population is becoming steadily more urbanized. The percentage living in cities over 20,000 has increased from 38 per cent in 1890, through 73 per cent in 1970 to 75 per cent in 1990. But the share living in the ten largest metropolitan areas declined from 23 per cent to 21 per cent between 1970 and 1990 (Glaeser 1998). Around the world, cities are becoming more decentralized and this trend has continued steadily over the last two centuries (Anas (1998) referring to Clark (1967)). So, in the U.S. the percentage living in the one per cent densest counties is decreasing. It is likely that the introduction of mass public transportation (which encouraged suburbanization) and the automobile lie behind these long term trends (Glaeser and Kahn 2003).

\(^8\) A city of the size of Auckland in the United States will be in the range (500,000 to 1,499,000) where functional specialisation of employment in management is now evenly balanced against specialisation in production. In the next higher range (1,500,000 to 4,999,999) specialisation in management dominates.
Glaeser and Kohlase (2003) argue that it is face-to-face meetings that are likely most relevant to knowledge spillovers, that may be one source of agglomeration economies. They show that while the costs of transporting goods in the U.S. has been steadily falling over the long term, the costs of transporting people are going up – mainly due to the opportunity costs of people’s time rising with incomes, and congestion causing longer travel times.

They investigate the relative efficiency of cars compared to public transport in the U.S. Commuting times are, on average, longer by public transport than by car. They show that, in terms of the population that can be reached within 25 minutes, cities built around cars (such as Palo Alto) are “denser” than “walking” cities built around public transport. They acknowledge though that for some sorts of spillovers, - for instance those relevant to the creative arts – “walking cities” (such as New York) may dominate those based on cars.

Elsewhere, Gaspar and Glaeser (1998) survey a range of evidence that suggests that modern telecommunications complements, rather than substitutes for face-to-face contact. Thus the importance of proximity and low transport costs for facilitating spillovers may not be reduced by advances in telecommunications technology. In a similar vein, Sinai and Waldfogel (2001) find that the internet is both a complement to and a substitute for agglomeration – more local on-line content associated with agglomeration encourages more internet usage, but, given the level of on-line content, people are less likely to connect in larger markets. Overall they find that the internet does not promote or discourage agglomeration in larger markets. Charlot and Duranton (forthcoming), using a French survey of workplace communications, find that cities and modern telecommunications are complements. In particular, there is no propensity for face-to-face contacts external to the firm to increase with city size, but use of telecommunications does increase.

Human capital, as measured by education, is becoming more concentrated in cities over time – and is associated with higher productivity. Educated workers on average earn more in cities than elsewhere, but this effect is particularly concentrated on experienced workers (Glaeser and Maré 2001).
Nevertheless, young educated workers have become increasingly concentrated in cities (Peri 2002).

Cities with initially higher levels of human capital grew faster between 1990 and 2000 (Moretti 2004a) – but this effect is concentrated in cities not enjoying other growth advantages such as good weather and strong external migration (Glaeser and Saiz 2003). At the same time, cities with initially higher concentration of educated workers have subsequently attracted proportionately more such workers, at least since 1970 (Berry and Glaeser 2005). This seems to be accounted for by a greater demand for skilled workers in such cities.

In the U.S. about 96 per cent of new product innovations occur in metropolitan areas, and 45 per cent of these occur in four – New York, Los Angeles, Boston and San Francisco (Audretsch and Feldman 1996). As the rest of this paper documents, agglomeration is associated with higher wages, rents and productivity.
4. How Do Agglomeration Economies Work?

The theoretical literature distinguish three main mechanisms for agglomeration effects – sharing (for instance of inputs, or of indivisible facilities), matching (improving the frequency and quality of matches involved in transactions) and learning (improving the frequency and quality of transfer of learning). Depending on assumptions and features incorporated, theoretical models can produce differing implications for welfare and the efficiency of agglomeration. In other words, it is possible for there to be too much agglomeration for the maximisation of economic benefits. The current empirical literature sheds little light on the relevance of these models in practice. Instead it focuses on analysis of the factors involved in producing agglomeration effects, rather than the precise nature of the mechanisms.

Interest in agglomeration economies has grown over the last two decades at least partly because of links to the “endogenous growth” literature. Earlier “neo-classical” models of growth modelled it as resulting from factor accumulation, and the unexplained arrival of new technologies. Without new technologies, growth would reach a steady state driven by population growth, and be limited by diminishing returns to the accumulation of factors. However, empirically, it is observed that countries with already high levels of relevant factors of production continue to have productivity growth at rates often faster than less well endowed countries.

The “endogenous growth” literature sought to explain how economic activity might thus exhibit increasing returns to scale to factor accumulation, and why some countries might prosper while others stagnate. One possible explanation is in terms of economies of scale that are external to the individual firm or plant, and realised through geographic concentration of industry. A number of models posit the potential for path dependency and “multiple equilibria” in growth outcomes – so that “historical accidents” may lead to favourable outcomes in some locations, and unfavourable in others. Hansen (2002) provides a review of relevant theoretical models of increasing returns and agglomeration effects, viewed in the context of the endogenous
growth literature\textsuperscript{9}. As Hansen notes, the theoretical possibility of multiple equilibria raises the potential for government intervention aimed at steering an economy into more benign outcomes.

4.1. Models Of Agglomeration Economies

Before looking at the empirical evidence on agglomeration effects and the way in which they work, it is helpful to clarify conceptually the variety of mechanisms that might be operating. Duranton and Puga (2004) classify the micro-foundations of agglomeration economies into three groups. The first is based on the \textit{sharing} of indivisible inputs, sharing the gains from a wider variety of input suppliers that can be supported by a larger final-goods industry, and sharing risks. The second are gains from improved quality and higher probability of \textit{matching} and alleviation of hold-up problems. The third are based on \textit{learning} through the generation, diffusion and accumulation of knowledge.

In examining the conceptual base for these micro-foundations, Duranton and Puga draw out a number of pertinent points. First the empirical literature is not, in general, organised around this classification. Instead, as will become apparent in the next section, it is usually based roughly around the identity of the agents involved and the content of the relevant transactions – for instance through the labour market, intermediate and final good linkages or through knowledge spillovers. Duranton and Puga make the point, by way of example, that a matching model could encompass any of these three sorts of linkages.

\textsuperscript{9} Elaborate and sophisticated theoretical models, requiring numerical methods for solutions, have been developed to understand the relationship among agglomeration economies, transport costs, plant level economies of scale, firm location decisions, the growth and relative size of cities, patterns of trade and economic growth. Neary (2001) critically reviews the so-called “new economic geography” literature, in particular the work of Fujita, Krugman and Venables (1999). See also the survey in Head and Mayer (2004). In practice, these elaborate models are based on a relatively narrow range of the wider set of microfoundations that may explain agglomeration economies. Note also Glaeser and Kahlase's (2003) argument that by relying on transport costs of goods (which have been secularly declining in importance as a proportion of GDP) as an explanation, the standard models of the “new economic geography” are no longer apt. They propose that a model to explain agglomeration economies and the role of cities, should be based on the productivity advantages of interactions among people, the role of the automobile in facilitating that in modern cities, the relatively low cost of shipping output, the increasing importance of the production of services that require face-to-face contact, and the fact that some places simply offer higher amenity value (e.g. in climate) than others.
Generally, empirical models that explore these relationships in the broad are not able to explicate the precise nature of the mechanisms involved\(^{10}\).

This is perhaps inevitable because, as Duranton and Puga point out the different micro-foundations generate outcomes that are observationally equivalent in most respects.\(^{11}\) Thus, for policy purposes, the empirical literature reviewed here may often have to be supplemented by less generalisable but more informative evidence on particular mechanisms that may be at work.

A second point is that the precise nature of the micro-foundations matter because they interact with other elements of the urban environment that can only be recognised if they are explicitly stated. A related point is that different micro-foundations have different welfare and policy implications. Duranton and Puga demonstrate, for instance, that some models require assumptions about co-ordination (by developers or local government) in order for an equilibrium to be welfare maximising. Other models imply equilibria where cities may be either too big, or too small to maximise welfare, or where they may be too specialized in a particular industry.

This leads to an important general point. Establishing that agglomeration economies exist does not mean that more agglomeration at the margins will necessarily lead to better outcomes in terms of productivity or welfare. One lesson from these models, and, as we will see from the empirical evidence, is that it is possible to have too much agglomeration. Judgments on policy will require good empirical evidence on the marginal effects on economic and welfare outcomes of agglomeration in the range relevant to the policy focus.

**Empirical Evidence on Optimal Size**

Clearly, while cities have been continuing to grow in size around the world, and the world’s population is increasingly urbanised, agglomeration does not

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\(^{10}\) Datasets that have wide coverage and thus allow generalisable results are usually relatively “thin” in the variables they contain. This, together with limitations in available econometric methodologies, prevents precise exploration of the complex dynamic mechanisms covered in the theoretical literature.

\(^{11}\) Duranton and Puga argue that future theoretical work should attempt to derive more specific predictions that will enable empirical work to identify the precise microfoundations.
happen without limit. In particular the forces that drive agglomeration do not lead to accelerating growth of the largest agglomerations. These forces are balanced by the negative effects of increasing agglomeration. Other things equal, increasing agglomeration may lead to more congestion, higher rents, crime, poverty concentration, and pollution – factors that limit the productive advantages and profitability of firms locating in cities, and make them less desirable places to live in.

Henderson (1974) provides an early model that explains the size of cities in terms of technological economies of scale in production or consumption balanced by the diseconomies of congestion or commuting costs. Variation in size is explained because of city specific specialization in traded goods, which involves different degrees of scale economies. Over time, technological change and rising incomes make new solutions to these negative aspects of cities feasible, allowing further growth in size.

Conversely, policy settings might cause city growth to happen in ways not conducive to improved economic performance (Ades and Glaeser 1995). Hence, the existence of apparently dysfunctional large cities in developing countries should not be taken, by itself as evidence of the limits to productivity enhancing city growth in countries with more benign policies and institutions (cf. also Henderson and Wang 2005).

Henderson (2003b) investigates the question of optimal city concentration in terms of effects on economic growth in a sample of 70 countries over the period 1960-1995. He uses primacy – the percentage of the urban population in the largest city - as the principal explanatory variable, and employs a variety of specifications, allowing country fixed effects. He uses two periods of lagged explanatory variables as instruments to deal with the problem of correlation between output per worker and primacy. In his preferred results he finds that a one-standard-deviation (.15) increase in primacy from the best level, leads to a seven percentage point reduction in productivity growth over five years. Optimal primacy reduces as countries become more developed, and is lower for larger countries. For instance, for a medium sized country, optimal primacy declines from 0.4 at a low level of development to about 0.2
for a developed country. For a large country the corresponding figures are 0.2 and near zero\textsuperscript{12}.

4.2. Empirical Approaches To Understanding Mechanisms

In theory, the precise nature of the mechanisms by which agglomeration economies operate is important both for welfare and for policy design. However, the empirical literature has not yet succeeded (and likely will have difficulty in the future) in discriminating amongst alternative models (Duranton and Puga 2004). Rosenthal and Strange (2004) thus provide a simple classification of spillover mechanisms relevant to assessing the empirical literature, and that may explain the effects of agglomeration on productivity and productivity growth. I use this classification later, to discuss the evidence on mechanisms.

Agglomeration economies may operate through “thick" input markets. Concentration of producers using particular inputs allows increased specialization and greater economies of scale in the production of inputs.

Internal increasing returns will lead to the concentration of employment and thus the enlargement of the market in a particular location. Given transport costs, this in turn induces other firms to locate in the same place, with ongoing cumulative agglomeration effects – known as “home market” effects.

Geographic concentration of industry, and urban size, are also associated with “thicker” labour markets, producing labour market spillovers. Thick labour markets may allow greater specialization in human capital, by reducing the risks to workers of firm specific employment shocks. Similarly, it will be easier for firms to find new employees, should current employees quit. Matching between workers and firms may also be more efficient. On the other hand, large urban areas, with a diversity of industries may reduce the risk for workers of industry specific employment shocks. At the same time,

\textsuperscript{12} New Zealand is an outlier in terms of size, given its state of development, so the results of this study could not be applied with a great deal of confidence to gauge the optimal size of Auckland. Moreover, Henderson notes that a number of contextual factors affect the interpretation of the results for particular countries.
the movement amongst firms of workers in thick labour markets contributes to knowledge spillovers.

While not directly relevant to productivity, the empirical literature also investigates *consumption economies* in cities that are analogous to the production economies just discussed. Denser and larger cities facilitate a greater range of consumption choices, provide better matching of opportunities to individual tastes, and also allow, for given per capita expenditures, better provision of public goods, and other amenities.

More generally, agglomeration facilitates faster communication and transfer of information across firms, other institutions such as universities and individuals – producing *knowledge spillovers*. Knowledge is often embodied in individuals and is tacit, and agglomeration may speed the transfer of this by facilitating face-to-face contact and mobility of workers across jobs. There may, therefore, be *human capital spillovers* due to the concentration of skilled individuals in cities.

As mentioned above, much of the recent empirical literature attempts to measure the relative importance of two broad sorts of knowledge spillovers. The first type arises from industry specialisation in a particular location that allows thick and more specialised input and labour markets and also facilitates intra-industry spillovers of information about local input and output markets and technology\(^\text{13}\). The second type arises from urban industry diversity that facilitates cross-fertilisation of ideas across industries, raising the rate of innovation in particular industries\(^\text{14}\).

It is useful to remember that overall city scale or density is relevant to both of these types of spillovers. A larger or denser city (everything else equal) will allow either a greater geographic concentration of specific industries, or a greater diversity of geographically concentrated industries, or both.

\(^{13}\) In the literature these are often referred to as Marshall-Arrow-Romer (MAR) externalities – a reference to their early exposition by Alfred Marshall (Marshall 1920) and adoption into the endogenous growth literature through the work of Arrow (Arrow 1962) and Romer (Romer 1986).

\(^{14}\) These are referred to as Jacobs externalities after Jacobs’ (1969) account of urban economic growth processes.
The empirical literature also sometimes distinguishes between static and dynamic agglomeration externalities. The first refers to one-off contemporaneous effects of city scale or industry concentration on productivity levels. In practice, the second usually refers to effects that operate with lags. Underlying this distinction is the idea that some externalities affect only the level of per capita output by improving the efficiency of aggregate production; other externalities (particularly those that increase the rate of innovation and knowledge transfer) may influence the rate of growth of per capita output. It is the latter type that is relevant to the endogenous growth literature.

In practice, however, it is difficult, if not impossible to distinguish these effects empirically. This is an issue that also dogs the interpretation of cross-country growth regressions, with some researchers arguing that empirical work is not capable of distinguishing between the two effects.15

Even without these problems, the attempted distinction made in the empirical literature between static and dynamic externalities poses difficulties in interpretation. For instance, should a finding that current productivity is influenced by conditions pertaining 30 years previously be interpreted as a lagged but limited response to those conditions, or as evidence for effects on long term growth rates? In this paper, I regard evidence of lagged effects as simply that, and draw no conclusions about static versus dynamic externalities.

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15 For a discussion of the difficulties see Temple (1999). The distinction is reflected in theoretical models, with endogenous growth models predicting conditions that will influence long run growth rates in output per capita, while neo-classical models focus on factors that influence the (steady state) level of output per capita. Empirically some explanatory variables that influence the level of output adjust exogenously over time, and growth rates vary considerably and are only weakly correlated over time (Easterly 2001), making it difficult, even with high frequency panel data to distinguish effects. It is perhaps best to think of productivity growth trajectories as comprising sometimes extended but episodic bursts of growth, driven by innovation.
5. Methodological & Interpretative Issues

Despite the selection applied, the literature surveyed in this paper remains complex and diverse in its approach to understanding agglomeration economies. Relevant variables are measured in wide variety of ways, often imperfectly reflecting the theoretical concepts involved. Specification of regressions also differs greatly, sometimes reflecting differences in the nature and structure of the data available. Different outcome variables are used to measure effects on economic activity. This variety of approaches poses a considerable challenge to producing a summary view of the evidence on the size and importance of agglomeration effects and the mechanisms by which they operate.

A major issue in this literature is accounting for unobserved characteristics of cities, industries and individual workers that are systematically related both to economic outcomes and to the features of agglomeration under study. Such characteristics can lead to biased estimates of effects. Considerable caution needs to be used in applying results from particular countries to another. A range of factors, including differences in economic structure, institutional arrangements affecting factor mobility, the extent of congestion effects, and in economic and product cycles, should be taken into account.

Rosenthal and Strange (2004) discuss issues in estimating the size and scope of urban agglomeration economies, given the imperfect data sets available. In principle, aggregate effects could be estimated as the sum of a large number of individual externalities – arising from interactions between pairs of establishments that are at varying distances from each other. Distance can be conceived along three dimensions – obviously one is geographic, and the others are over time, and in terms of kinds of production activity. Agglomeration externalities can be conceived to attenuate as distance increases.

It follows from this, that agglomeration effects will vary across establishments. Rosenthal and Strange note that, in practice, the three dimensions of “distance” have rarely been considered simultaneously; that geographic
distance is often measured in terms of politically defined discrete areas within which all establishments are modelled as experiencing the same effects; and that industrial distance has generally been measured crudely as a binary variable – “own industry” and all others.

Moreover, the scope of agglomeration effects will vary according to the particular mechanisms involved. Studies that choose geographic units that capture some effects may fail to capture other effects.

Generally, the establishment level outcome of interest is productivity. A direct measure of this requires suitable measures of inputs (for example employment, land, capital and materials) – that are rarely comprehensively available in a consistent, accurate or coherent manner. Omission of some inputs that may vary systematically by city size (or industry concentration) will lead to biased estimates of effects\(^\text{16}\).

Even where suitable plant level data is available, estimates may be biased because successful entrepreneurs may seek out (and agglomerate) in the most productive locations. A strategy that is sometimes used to address this problem of “unobserved heterogeneity” is two-stage-least-squares (2SLS) estimation. In the first stage, “instrumental” variables are used to predict values for the explanatory variables that will appear in the second stage regression. Instruments must be correlated with these explanatory variables, but uncorrelated with the unexplained variation in plant productivity. The predicted values of the explanatory variables are, in effect, “stripped” of any effects due to the other variables in the second stage regression. The coefficients in the second stage can then more readily be interpreted as representing a causal effect.

In practice, it is frequently difficult to find suitable instruments that are sufficiently strongly correlated with the explanatory variables, and not

\(^{16}\) Basu and Fernald (1995) also criticise the use of value-added data to measure externalities in the presence of imperfect competition – showing (using data on 21 roughly two-digit manufacturing industries in the U.S.) that it can lead to spurious identification of externalities. The criticism does not appear to have been considered by researchers employing firm or city-industry level value-added data to directly estimate agglomeration effects on productivity.
correlated with the unexplained variation in the second-stage dependent variable.

If the data is available for various points over time (a panel), an alternative may be to estimate regressions in “first-differences”. This will remove the effect of any time unvarying unobserved heterogeneity. If establishment level data is being used, time specific metropolitan “dummies” may be used to capture the effect of unobserved time varying characteristics of cities. However, the use of panel data in differences can exacerbate measurement error. It can also cause problems with sample selectivity due to attrition – particularly if firm level data is used, given high rates of firm births and deaths over time.

The difficulties with finding suitable and convincing methods to deal with problems of endogeneity are highlighted by Moretti (2004a) in his review of the evidence on human capital spillovers in cities. He notes that estimates of the effects of average human capital levels on wages that attempt to account for endogeneity rarely agree. He says this is mostly due to differences in the particular empirical strategies adopted to account for unobserved heterogeneity. The same is almost certainly true of other approaches to gauging agglomeration effects on productivity.

5.1. Other Difficulties In Interpretation Of Econometric Results

The econometric literature employs a wide variety of measures of agglomeration, and care is required in interpreting the economic significance of coefficients on variables. Total employment is often used to capture city scale (and sometimes as a proxy for urban diversity). Share of own industry employment in total employment is used as a measure of city specialisation. Sometimes, however, own industry local employment levels (or plant numbers) are used to capture the effect of own industry scale. Diversity may be captured by a Herfindahl index of other industry shares of local employment. These variables may or may not be normalised in terms of the corresponding variables at the national level. Competition (which may also be thought of as a function of urban scale) is also measured differently in different studies. In
some, it is simply the own industry ratio of firms to workers (intending to capture the idea that it is the competition for ideas among competing firms that counts), while, in others a standard Herfindahl measure of local industry concentration is used.

A number of these measures are arithmetically related to each other. When total own industry employment is controlled, the number of own industry plants in a locality is also arithmetically related to average plant size.

With many different specifications of similar variables and regression equations that include different mixes of them, accounting for differences in results becomes a complex exercise. Differences in industry and geographic coverage may also account for differences in results. A very few studies cover a comprehensive set of industries, and an entire nation. Most, however, are highly selective – both in terms of industry and of geographic coverage. Such selection also creates difficulties in assessing the relevance for a nation’s overall economy of agglomeration effects.

Finally, there are issues in comparing findings and applying them across countries. There are obvious differences in the sectoral composition of economies and in urban scale. Models predict that differences in external transport costs may change the pattern of agglomeration, and hence the size of agglomeration externalities. Agglomeration dynamics depend on factor mobility, and cultural and institutional differences that influence this will thus cause differences in agglomeration patterns across countries. Past history may matter for current configurations, and differences across countries in the provision of public infrastructure and other public goods in urban areas will also be relevant to understanding agglomeration patterns.\textsuperscript{17}

Countries may also vary in the stage of adoption of a new general purpose technology. It appears that the United States has experienced rapid productivity and employment growth over the 1990s associated with the diffusion of IT use across a range of industries. Other countries have not yet, or have only very recently begun to experience the same effects. In previous

\textsuperscript{17}Combes (2000).
decades the computer industry in the U.S. experienced rapid shifts in geographic location and employment. Thus, for various reasons, estimates of agglomeration effects based on the United States in this period may not be typical of effects in other time periods or other countries.

6. Empirical evidence on Mechanisms

The literature finds evidence for a wide range of factors involved in producing agglomeration effects. These include shared inputs, common labour markets, “home market” effects, greater variety and specialization in consumption, and knowledge and human capital spillovers. Many effects are relatively localised in scope and rapidly attenuate with distance – though in at least one case (manufacturing in Japan) effects still persist at the national level. Shared labour markets seem to be of particular importance in a range of studies.

This section looks at evidence for the specific mechanisms by which agglomeration economies occur. The purpose is two-fold. First, evidence on mechanisms lends weight to the studies reviewed below that look at the strength of the relationship between agglomeration and economic activity. Second, understanding the nature and relative importance of different mechanisms may be relevant to policy design. The section mostly relies on surveys contained in Audretsch and Feldman (2004), Moretti (2004a) and Rosenthal and Strange (2004). It mostly follows the classification of mechanisms utilised by Rosenthal and Strange and briefly summarised above in Section IV.

6.1. Input Market Spillovers

Ellison and Glaeser (1997) look at the extent of coagglomeration among three-digit industries in the same two-digit industry. They find evidence of some coagglomeration (controlling for own industry agglomeration, industrial concentration and the distribution of total employment). The extent varies greatly across industries, and is only strong in three (resource based) industries of the 20 two-digit industries. They then investigate the importance for coagglomeration of suppliers and customers among four-digit industries within the same three-digit industry. In particular, they identify the 100 four-
digit industries which receive the largest share of the value of inputs per value of output from a single supplier industry, and the 100 four-digit industries that supply the largest share of the value of their output per value of input to a single customer industry. They then calculate for each pair an index of coagglomeration and an index indicating the extent to which inferred spillovers are industry specific or general to the industry group. They find that 77 of the first group and 68 of the second exhibit economically significant coagglomeration.

Holmes (1999) finds that “purchased input intensity” (the ratio of purchased inputs to sales) in a particular industry, varies systematically by geographic concentration in the U.S. – with more concentrated locations having significantly greater purchased input intensity than less concentrated locations. Across all industries, moving from a location with fewer than 499 own industry employees to one with over 10,000 results in a three per cent increase in purchased input intensity. For the ten most concentrated industries, the effect is twice as large. He shows that in the textile industry (where relevant data is available) the proportion of specialized inputs is higher in more concentrated locations.

While not investigating the effects of geographic concentration per se, Bartelsman, Caballero and Lyons (1994) show that over the longer run, an index of aggregate supplier activity is strongly related to industry productivity (in the shorter term, the level of customer activity has a stronger effect)\(^\text{18}\).

6.2. Labour Market Spillovers

Baumgartner (1988) provides evidence for increased specialization among physicians in large labour markets. Simon (1988) shows that unemployment is higher in more specialized cities and Diamond and Simon (1990) show that this is associated with a wage premium that is related to the cyclical variability in an industry’s employment. Costa and Kahn (2000) show that couples where

\(^{18}\) Note, however, Basu and Fernald's (1995) scepticism on these findings on short term effects, mostly because value-added data provides a poor basis for productivity measurement in the presence of imperfect competition. They demonstrate that when gross output is used, or the value-added data is corrected for omitted intermediate inputs, the externalities disappear.
both partners have at least a bachelor’s degree are much more likely to be located in large cities now than fifty years ago, and that roughly a third of this change seems to be because such cities facilitate dual careers\textsuperscript{19}. Similarly, Duranton and Jayet (2005) document French evidence that scarce occupations are over-represented in large cities. As noted below, Dumais, Ellison and Glaeser (1997) find that labour market spillovers (measured in terms of local occupational mix) appear to be a particularly important determinant of growth in industry plant numbers in a locality.

6.3. Home Market Effects

Davis and Weinstein (1999) for Japanese prefectures and Hanson (1998a, 1998b) for Mexico before and after the NAFTA find evidence for such effects at the regional level. Head and Mayer (2004) survey the evidence in the context of agglomeration and international trade. Behrens et al (2005) present a more recent multi-country model exhibiting home market effects which they find supported in trade data.

6.4. Consumption Effects

Large cities allow a greater variety of consumption opportunities, and better matching with individual preferences, as well as the provision of public goods not available in smaller centres. They also allow denser and more rapid social interactions. These effects parallel similar effects on the production side. Glaeser, Kolko and Saiz (2001) present evidence for such effects. First, there has been an increase in reverse commuting in the decade between 1980 and 1990 indicating that people are willing to pay for higher property prices in central cities simply for the amenities offered there. Cities with good climates and endowed with museums and theatres are growing faster. There is an increasing concentration of wealth in central locations.

As population rises, the proportion listening to the radio increases more than proportionately – suggesting that provision is more closely tailored to individual tastes (Waldfogel 2003). There are similar effects in internet usage\textsuperscript{19}.

\textsuperscript{19} The effect is identified through comparisons with other types of households, using “difference-in-difference” estimation methods.
(Sinai and Waldfogel 2001) and newspaper purchases (George and Waldfogel 2003).

There is a literature that attempts to disentangle production and consumption externalities by looking at relative effects on land prices and wages (Gabriel and Rosenthal 2003); or at differences in nominal and real wages (Tabuchi and Yoshida 2000). The idea here is that differences in nominal wages reflect productivity differences – otherwise firms will relocate to a city with lower nominal wages. Differences in real wages reflect amenities to workers – otherwise workers would migrate to a city with higher real wages. The studies find evidence for both production and consumption effects.

6.5. Knowledge Spillovers

Much of the literature reviewed below is focused on discerning whether knowledge spillovers are more likely to occur within industries or groups of industries with similar technologies; or across industries in the context of dense and diverse urban agglomerations. But, as Rosenthal and Strange (2004) note, this literature is not able to shed much light on specific mechanisms. Given that much or most of knowledge spillovers are likely to occur without market transactions and thus a data trail, systematic evidence for it may be difficult to accumulate.

One of the most compelling studies is Jaffe, Trajtenberg and Henderson (1993). They study the geographic location of patent citations in relation to the original patent, and a control sample of technologically and temporally matched patents. They find a clear pattern of localisation of citations at the city, state and national levels, compared to the controls. Citations are five to ten times as likely to come from the same city as the originating patents; (two to six times as likely when self-citations are excluded). They are three to four times as likely to come from the same state (roughly twice as likely, excluding self-cites).

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20 A related literature uses similar data to estimate the value to firms and households of public infrastructure (Haughwout 2002).
Audretsch and Feldman (1996) look at the concentration of product innovation in the United States in 1982, using data compiled from trade publications by the Small Business Administration. They find that product innovation is significantly more geographically concentrated than manufacturing and that industry Gini coefficients for each exhibit almost no correlation. Using the innovation Gini coefficient as the dependent variables, and controlling for concentration in manufacturing, they find that industries with higher R&D rates and higher share of skilled labour are more concentrated. They interpret their results as being evidence of the importance of tacit transmission of new economic knowledge. This may be, for instance, through the movement of skilled labour between jobs. Incidentally, they find that natural resources explain a considerable part of industry agglomeration (cf. Ellison and Glaeser 1999).

Adams and Jaffe (1996) study the productivity effects of R&D spillovers between firms. They compare the effects of R&D performed in a plant, outside a plant but within a parent firm, and in external plants in the same geographical area or industry. They find that the effect of parent firm R&D on plant-level productivity is diminished by both the geographical distance and the technological distance between the research lab and the plants. Interestingly, they find that the marginal effects of own industry R&D intensity is approximately 40 per cent as large as the marginal product of parent firm research intensity.

Audretsch and Feldman (2004) review the extensive literature on geographically confined knowledge spillovers. Acs, Audretsch and Feldman (1994) find that whereas innovation in large firms tends to depend on their own R&D effort, in small firms it depends more on R&D in universities. Innovation across all firms is influenced by aggregate R&D effort.

Feldman and Audretsch (1999) link the innovative output of product categories within a specific city to the extent to which the economic activity of

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22 They implement a number of estimation models, including a three-stage-least-squares approach with lagged exogenous variables to deal with possible bias because firm concentration and local resources may each influence the other simultaneously.
that city is concentrated in that industry, or diversified in terms of complementary industries sharing a common science base. They find that diversity across a common science base is more conducive to innovation than specialization. Audretsch and Feldman (2004) conclude from these two studies that underlying economic and institutional structures matter for generating knowledge spillovers as well as the endowment of knowledge inputs.

They go on to review a wide and diverse literature on specific mechanisms by which knowledge spillovers occur. These include technology transfer from research universities, or relational networks at various levels of analysis that may involve, for instance, recruitment of talent from outside the region, venture capital firms, and the presence of “star” scientists.

Audretsch and Feldman (2004) devote considerable attention to the role that the start-up and growth of new enterprises plays in transmitting knowledge spillovers in agglomerations. Feldman (2001) looks at the development of an internet and biotechnology cluster around Washington D.C. and finds that clusters form not because resources are initially located in a particular region, but rather through the work of entrepreneurs (most of whom were previously employed in the region). “Moreover, entrepreneurs are endogenous and organize resources and institutions to support their firms. As their businesses begin to thrive, resources such as money, networks, experts, and related services develop in, and are attracted to, the region. With this infrastructure in place, more entrepreneurial ventures locate and thrive in the region, which ultimately may create a thriving cluster where none previously existed.”

Population density, population growth, and skill and human capital levels of the labour force all have positive impacts on new start up rates, while average establishment size has a negative effect. However, the evidence on the relationship between start-up rates and productivity growth are mixed – with the most consistent evidence for a positive relationship coming from European studies. Acs and Armington (2003) look at the determinants of industry employment growth in local labour market areas covering the U.S. over the period 1989 to 1996 (a period of strong employment growth). They
use a large longitudinal data base covering all private sector employers, in six service sector industry groups. The early net employment growth of new start-ups accounts for a large percentage of this growth. Their results suggest that much of the effect of human capital on employment growth is mediated through new start-ups. This suggests a possibly important role for entrepreneurs in the transmission of human capital and knowledge spillovers.

Lovely, Rosenthal and Sharma (2005) use differencing methods to look at the spatial concentration of the headquarters of exporting firms in the United States. They use different measures of the difficulty of particular export markets (degree of integration into the world economy and poor credit ratings, for instance), and compare exporting and non-exporting firms in the same industry. They find that the headquarters of firms exporting to difficult countries are more spatially concentrated than the others. They interpret this as suggestive of the importance of knowledge spillovers, where information on particular markets is difficult to get.

6.6. Human Capital Spillovers in Cities

Moretti (2004a) surveys the empirical literature on human capital spillovers in cities. As noted above, there are difficult estimation issues that the literature needs to address, because of unobserved heterogeneity in cities and workers that may bias results. In sum, Moretti believes that it is too early to reach firm conclusions – different methods to address this issue produce somewhat different results.

Moretti (2004b) uses cross-sectional and longitudinal data to look at the effect on wages of the labour force share of college graduates. He uses instrumental variables, and individual-city fixed effects to deal with unobserved heterogeneity, and looks at effects for both skilled and unskilled workers to identify the effect of spillovers. A one percentage point increase in

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23 They find that these patterns do not hold for manufacturing. This highlights problems with generalising from studies of agglomeration effects that focus only on manufacturing.

24 Another important empirical challenge is to distinguish between spillovers and complementarities. An increase in the numbers of skilled workers may cause the wages of unskilled workers to rise, if they are complements to skilled workers. Duranton (forthcoming) also reviews the identification issues in estimating human capital externalities in cities.
the college share increases wages of high-school drop-outs and high-school graduates by 1.9 per cent and 1.6 per cent respectively, and of college graduates by 0.4 per cent. The last finding suggests spillovers, while the other results also reflect complementarities.

However, Ciccone and Peri (forthcoming) find no significant human capital externalities, unless they assume that highly educated and less educated workers are perfect substitutes. They estimate the effect of average schooling on average wages across cities, holding the relative size of each skill group constant, using a reweighting scheme. This is obtained by first estimating a city-year-education group specific conditional average wage, and then regressing these cell averages on average schooling, weighting the regression by the size of the group in a base year. The intention is to separate complementarity from spillovers by holding the skill distribution of the labour force in the city constant. They also use instrumental variables to account for the endogeneity of aggregate human capital.

Conley, Flyer and Tsiang (2003) use Malaysian data, and a pair specific measure of economic distance in terms of travel times, to estimate human capital externalities. Using instrumental variables, they find significant human capital spillovers operating within travelling times of 90 minutes. For instance, in one specification they find that a one-standard deviation increase in the secondary education percentage from 30 to 90 minutes travel distance raises wages by about five per cent. They find that land prices are positively correlated with human capital stocks.

Moretti (2004c) uses longitudinal data to estimate establishment-level production functions for all manufacturing industries in the U.S., controlling for establishment-specific permanent heterogeneity, as well as time-varying, industry-specific and state-specific heterogeneity. The study uses a matched firm-worker dataset, combining the Census of Manufacturers with the Census of Population. He finds evidence of “relevant” human capital spillovers in cities. However, because human capital stocks are growing only slowly over time, the contribution to economic growth is small. He estimates that human capital spillovers were responsible for an average of a 0.1 per cent increase in
output per year during the 1980s – mostly from high-tech plants. The size of the spillovers between plants depends on their level of interaction. It is also high for single-unit plants, but low for plants of corporations having many establishments in different cities. The productivity effects across cities of human capital spillovers are matched by wage differentials.

Rosenthal and Strange (2005) find that the wage premium caused by the geographic concentration of employment may be in considerable part due to human capital spillovers. Using U.S. Census data and instrumental variables, they estimate that, while an additional 100,000 workers within five miles raises individual wages by 1.5 per cent, transforming 50,000 “less than college educated” workers within five miles into “college-or-more educated” workers raises individual wages by ten per cent. Combes et al (2005) find that roughly half of the estimated effect of employment density on wages in previous studies\textsuperscript{25} is due to sorting of higher quality workers into denser urban areas on characteristics not observed in the data.

In an important paper, Glaeser and Maré (2001) look at how earnings premia for workers vary across cities by city size and with worker education and experience. They use a variety of cross-sectional and longitudinal datasets to investigate alternative hypotheses to explain the premia. They find that real wages for observationally equivalent workers do not vary much across locations in the U.S. Nominal wages vary – workers in large cities receive a nominal wage premium in the order of 30 per cent. The higher productivity implied by this might be due to spillovers; but it might also be due to unobserved worker characteristics that cause higher productivity. When, using an alternative dataset, controls are introduced for ability, job tenure and occupation, the premium drops only slightly. Glaeser and Maré reason that if unobservables have a similar effect, then a large proportion of the premium may be due to spillovers.

They then investigate the structure of the premium by migration and experience. They find that workers who migrate to cities do not receive the full premium at first. As experience accumulates, however, the premium rises.

\textsuperscript{25} Notably Ciccone and Hall (1996) and Ciccone (2002).
Workers who leave cities for other areas experience only a small drop in wages (though selection effects could be operating here). Taken together, these findings suggest that young educated workers migrate to, or remain in cities at least in part to take advantage of learning opportunities (perhaps through contact with other educated workers) that will make them more productive over time, and provide them with a steeper wage growth path.

Peri (2002) investigates similar ideas. He notes that the experience premia for college-educated workers are larger in urban areas and that this implies that younger educated workers receive a smaller premium than required by older workers. Between 1970 and 1990, younger workers have become more concentrated in urban areas, and the propensity for the college-educated to move across counties has increased dramatically – both in absolute terms, and relative to the high school-educated.

Peri develops a simple model to explain the location and migration decisions of highly educated workers. In the model, workers learn from each other when young, increasing their skills and productivity. Once they mature and their rate of learning decreases, some of them choose to move out of densely populated areas. The model shows that as production tasks become more complex, the scope for learning increases and the learning intensity from interactions increases. This leads to a change in the distribution of educated workers in dense areas. Peri loosely calibrates the model parameters against results reported by Glaeser and Maré (2001) and Topel (1991), and finds values that in his model mark the boundary between one equilibrium and another, thus potentially accounting for observed changes in location patterns.

6.7. Scope and Relative Importance of Spillover Mechanisms

Rosenthal and Strange (2004) report the rather sparse findings of the economics literature on the geographic scope of spillovers due to agglomeration. Most studies are limited by the prior selection of the geographic area of study. Ellison and Glaeser (1997) create an index of
industry geographical concentration, which they compare at three different levels of geography in the U.S. – county, state and region. They find that the pattern is consistent with within county spillovers being stronger than across county. Nevertheless, spillovers are still quite substantial at a broader range. Davis and Henderson (2005), looking at effects on expected births of company headquarters in the U.S., also find that within county spillovers of total employment are stronger than for larger geographic units.

Duranton and Overman (2002) develop a continuous measure of geographic concentration of industry. They find that geographic concentration in the U.K. takes place mostly at small scales below 50 kilometres.

It may be expected that the geographic scope of spillovers will vary by industry and by the nature of the spillover mechanism. Rosenthal and Strange (2001, 2003) investigate this idea. In the first paper, they look at the relationship between agglomeration and industry characteristics that might identify the sources of agglomeration economies. They find that reliance on factors sensitive to shipping costs is associated with agglomeration at the state level, while factors associated with knowledge spillovers are highly localised. Labour market factors are associated with agglomeration at all levels.

In the second paper, they look at where new plants in six industries locate in relation to own industry employment at different distances from one to 15 miles. The stronger own industry employment within one mile, the more likely a new plant is to locate there. The effect is much smaller at a five mile radius – though there is still a remaining effect at 15 miles.

Dekle and Eaton (1999) investigate the geographical range of agglomeration economies in manufacturing and financial services in Japan, using variation in rents to identify effects. They find that effects decay much faster with

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26 As noted above, the index controls for the overall geographic distribution of employment, and the extent to which employment in the industry is concentrated in a few firms.  
27 Computer software, apparel, food processing, printing and publishing, machinery and fabricated metals.
distance in financial services than in manufacturing. In manufacturing, in particular, there is a strong agglomeration effect at the national level.

Conley et al (2003) investigate human capital spillovers in Malaysia, and find that they operate at distances within 90 minutes travel time. Rosenthal and Strange (2005), using U.S. Census data, find that the effects of agglomeration and human capital spillovers on wages attenuate rapidly with distance – at more than five miles, but less than 25, they are 2.5 to three times smaller. At larger distances, effects persist - in some models beyond 50 miles. In an interesting micro-spatial study of the effect of existing advertising agency location on births in New York, Arzhagi and Henderson (2005) find that “scale externalities are very large but they dissipate very quickly with distance … and are gone by 750 meters. The effects seem to strongly suggest networking, or information ‘spillover’ effects.” Finally, in a micro-geographic study of the determinants of firm births and new employment in New York, Rosenthal and Strange (forthcoming) find that effects of own two-digit industry employment and total employment attenuate by an order of magnitude beyond one mile.

Rosenthal and Strange (2004) review the evidence on the relative importance of different spillover mechanisms. The main approach used in various studies is to look at the determinants of agglomeration – with the implication that these will provide clues as to the spillover mechanisms at work.

One of their main sources is Dumais et al (1997). The paper looks at the determinants of growth in plant numbers through births and closures in particular localities, taking account of general agglomeration effects, industry and location specific characteristics, and the presence of other related industries. They look for evidence of three agglomeration mechanisms – shared labour markets (measured in terms of the occupational mix used in the industry), shared inputs, and potential knowledge spillovers. The last is rather imperfectly proxied by indexes constructed in two ways – one through a “technology flow matrix” designed to calculate the degree to which innovative

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28 This is a reference to the NBER Working Paper version, rather than the 2002 article published in The Review of Economics and Statistics. The NBER paper contains substantial additional analyses not published in the article.
activity (R&D and patents) in one industry is likely to benefit another. The other is based on co-ownership of firms across industries – with the idea that this represents economies of scope and potential spillovers.

Overall, Dumais et al (1997) find evidence for all three mechanisms – but the strongest evidence by far is for the importance of shared labour markets. The presence of likely customers encourages new firm births, while the presence of likely suppliers encourages birth of new plants from existing firms. There is stronger evidence for knowledge spillovers being important – in particular as proxied by economies of scope. Theoretically, in equilibrium, the marginal effects of various sources of agglomeration economies should be zero. The authors therefore also regress the levels of employment on the proxies. All except the presence of input suppliers are significant.

Rosenthal and Strange (2001) use the Ellison-Glaeser index to investigate the determinants of agglomeration. They use data for four-digit manufacturing industries at the zip code, county and state levels in the fourth quarter of 2000. They use measures of prior innovation in the industry, the use of manufactured and service inputs, and labour specialization as proxies for hypothesised sources of agglomeration economies – knowledge spillovers, and thick input and labour markets respectively. They find the strongest evidence for the importance of labour market pooling, a factor that operates at all three geographic levels. Thick manufactured input markets influence agglomeration at the state level, while knowledge spillovers are important at the zip code level. Reliance on service inputs reduces agglomeration at the state level.

Hejazi, Strange and Tang (2005) model agglomeration as being motivated by firms desire to manage uncertainty about competitive conditions, about the availability of skills and about the expected success of innovation. Firms differ

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29 Rigby and Essletzbichler (2002) find positive effects on labour productivity of a measure of intensity of input and output linkages, a measure of the fit between local industry requirements and the local occupational mix, and a measure embodied technology flows. However, their results are not presented in a way that clarifies the relative size and importance of effects, and they vary considerable across industry. They used 1991 establishment level data from the U.S. Census Bureau, covering all manufacturing in 276 metropolitan areas.
in the degree of uncertainty they face, and this is reflected in their different propensities to locate in large urban areas per se, or in areas where other firms in their industry are already concentrated, where thicker markets will assist them to maximise expected profits from dealing with this uncertainty. They use Canadian survey evidence on firms’ perceptions of their competitive environments and the factors that are required to be successful. In their preferred specification, they find a tendency for firms that focus on competitive instability and on innovation, to locate in large urban areas; conversely, firms that stress the importance of hiring educated workers (but not experienced workers per se), or skilled workers from outside Canada tend to be located in places where other firms in their industry are already concentrated. Firms facing less competitive uncertainty tend to locate in more specialised localities.

Holmes (forthcoming) develops a model for the location of sales offices in the U.S. in terms of fixed costs and “frictional” cost for out-of-town sales (both of which favour larger cities), a cost-reducing “knowledge spillover” related to city size, and an idiosyncratic “match quality” for each firm-city pair. The model predicts that large firms with many sales offices will be relatively more concentrated in medium-sized cities. Smaller firms are more heavily concentrated in small cities than are large firms because they can do little to reduce their frictional costs. The data, and a model estimated using simulated method of moments, is consistent with this prediction. Overall, Holmes finds that the factors emphasized in the home-market effect literature, namely fixed costs and frictional costs, are important for the location of sales offices. Match quality also matters, but the evidence for knowledge spillovers influencing location is at best weak.

As Rosenthal and Strange (2004) note, many of these approaches constrain effects to be the same across industries – but there is much to suggest that effects may be quite heterogeneous. They refer to examples of industry
specific [case] studies\textsuperscript{31} – but of course the difficulty here is to generalize from them\textsuperscript{32}.

\textsuperscript{31} In particular they refer to Klepper’s study of the automobile industry in Detroit (Klepper 2002).

\textsuperscript{32} LaFountain (2005) models the relationship between agglomeration forces and land rents facing firms – the predicted relationship varies according to the mechanism operating – natural advantage, production externalities through localisation and urbanisation, and market access. Using relatively simple regression, he applies the model to U.S. manufacturing data in 1980 and 1990 and finds considerable heterogeneity across two- and three-digit industries, but with a large proportion of agglomeration explained by natural advantage. However, the model is unable to explain observed agglomeration in a number of industries, which casts doubt on its validity.
7. The Size of Agglomeration Effects

In ranges relevant to the U.S. and Europe, doubling the density of economic activity leads to an increase in productivity of three or more per cent. Productivity, employment growth and firm location effects appear to vary widely across industry. There is evidence for statistically significant effects for only a minority of industries at the four-digit level. Nevertheless, effects at this and more aggregated levels can be economically substantial, with particularly strong effects associated with existing industry specialization in some cases. Overall, there is very mixed evidence on whether these effects are due to city specialization in an industry, or, relatedly, geographic concentration of an industry, or whether they are due to industrial diversity. It is likely that effects vary by industry type, and by country-specific circumstances. Diversity seems to have an important positive effect on the location of new industries and on the location of new firms in technologically progressive industries. There appears to be an important positive interaction between agglomeration and the concentration of human capital.

The primary focus of this review is to get a sense of the order of magnitude and the industrial scope and variation of the economic effects of agglomeration. A number of studies estimate the size of agglomeration effects – using four main strategies (Rosenthal and Strange 2004). The first group looks at effects on labour productivity; the second on employment growth; the third at effects on wages and rents; and a fourth group looks at effects on new establishment location, or on the probability of an industry having a significant presence in a city.

7.1. Effects on Labour Productivity

Five studies reviewed look directly at agglomeration effects on labour productivity. Two studies – Ciccone and Hall (1996) and Ciccone (2002) - look at the global effects on productivity of employment density in the U.S. and Europe, respectively. The other three studies – Henderson et al (2001), Henderson (2003a) and Maré and Timmins (forthcoming) look at the effects of
local own-industry size and local industrial diversity in Korea, the U.S. and New Zealand respectively\textsuperscript{33}.

Ciccone and Hall (1996) use U.S. counties as their unit of analysis. They argue that earlier studies of labour productivity effects using value-added calculated from Census of Manufactures are “seriously flawed” because they omit purchased services or those obtained from corporate headquarters\textsuperscript{34}. The degree of vertical integration and thus the purchase or transfer of services varies systematically with city size, leading to biased estimates of agglomeration effects. Instead they use state level data on gross output, calculating an index of inputs adjusted for density at the county level. The index depends on increasing returns, and the scale parameter is estimated to best explain the pattern of value-added across states. They use instrumental variables reflecting historical patterns of agglomeration, to control for endogeneity of current agglomeration to productivity differences. They estimate that doubling employment density in a U.S. county increases average labour productivity by six per cent.

Ciccone (2002) carries out a similar analysis using local administrative region data from five European countries. Because, compared to the U.S., better quality data on value-added is available at this level his estimation procedure is more straightforward. He uses land area as an instrument for employment density, and estimates that doubling density produces a 4.5 per cent increase in labour productivity. He finds no evidence of significant variation in the size of agglomeration effects across countries.

\textsuperscript{33} A further study, Rigby and Essletzbichler (2002) estimates agglomeration effects on labour productivity in manufacturing in 276 U.S. metropolitan areas, using 1992 establishment level data from the U.S. Census bureau. While positive effects of dense input-output linkages, local occupational mix, and embodied technology flows are found, the results are not presented in a way that allows simple quantification of the size of effects. In addition the study does not address the problem with using value-added measures of labour productivity identified by Ciccone and Hall (1996), and does not control for unobserved city heterogeneity. \textsuperscript{34} Quigley (1998) reports estimates from the 1970s for the U.S. of the effects of city scale on productivity, based on production functions for selected industries. Shefer (1973) for instance concluded that doubling city size would increase productivity by 14 to 27 per cent. Other more sophisticated methodologies, for instance that used in Sveikauskas (1975) produced estimates of around six to eight per cent.
However, both these studies use aggregate data. An important recent study shows that sorting of workers on unobserved characteristics into areas of dense employment leads to biased estimates of agglomeration effects on wages when using such data. Combes et al (2005) use a very large dataset covering individual data on French workers in every four years between 1976 and 1996. They undertake a two stage estimation – first estimating employment area fixed effects (in the presence of industry fixed effects, within industry interactions, and basic worker characteristics), and then estimating the determinants of these area fixed effects, using long-lagged variables as instruments. They show that when using individual data in their preferred specification, a doubling of density leads to a three per cent increase in worker wages. When using aggregate data, the figure rises to over six per cent - consistent with Ciccone and Hall’s (1996) estimates for labour productivity.

Less compelling evidence on labour productivity effects is available from two further studies. Henderson et al (2001) use data from the Korean Census of Manufactures, and attempt to overcome Ciccone and Hall’s criticism by using a city-industry as the unit of analysis and netting out intermediate material inputs and measuring labour inputs by production workers. Essentially this ignores the contribution of sales, advertising, research and accounting inputs to productivity. The study covers 21 manufacturing industries in five groups over 74 metro areas at a time (1983 – 1993) when Korea was undergoing a massive shift of industry from Seoul and Pusan to provincial cities. They find that increasing local own-industry scale of employment ten-fold increases productivity by 15 per cent. For high-tech industries only, a one standard deviation decrease in industrial specialization in a city (again measured by a Herfindahl index) increases productivity by 60 per cent.

Henderson (2003a) uses the Census of Manufactures data criticised by Ciccone and Hall. In addition, because he uses panel methods to estimate plant level production functions, and discards observations that contain imputed data, the sample used for estimation is subject to extreme
selectivity. The study covers four high-tech and five large machinery three-digit industries across 742 U.S. counties. He finds that a ten-fold increase in the number of local plants in a high-tech industry increases labour productivity by over 20 per cent - but effects for machinery industries are small. There are five year lagged effects for single plant firms in high-tech industries. Urban scale has a large positive effect on productivity for machinery industries (with an elasticity of over 0.10), but has no effect for the high-tech industries. City industrial diversity (measured by a Herfindahl index) has no effect on productivity.

In a careful and comprehensive study using New Zealand business demography panel data covering 1987 to 2003, Maré and Timmins (forthcoming) estimate the effect of a full range of agglomeration and concentration variables on labour productivity, using firm, location and period fixed effects, and a variety of specifications to test robustness. The New Zealand value-added data used to measure labour productivity is derived from the administration of a comprehensive goods and services tax, and thus avoids a number of the problems with U.S. data identified by Ciccone and Hall (1996).

In the most stringent specification (which identifies effects purely from within firm changes over time) the observed decadal change in average LMA size contributed three per cent to productivity growth, or around $NZ 1,500 per worker. Local diversity of industry mix has a positive effect on productivity – thus the decadal decline in local diversity is estimated to have reduced average productivity by about one per cent or around $800 per worker. A decadal increase in own-industry agglomeration contributed only $200 to $300 per worker. In the most stringent specification only local diversity has a statistically significant effect.

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35 He uses individual-industry and plant fixed effects and lagged values of explanatory variables to control for endogeneity.

36 Beardsell and Henderson (1999) also find that own industry employment levels lagged up to four years have significant effects on current productivity in non-affiliated plants in the U.S. computer industry over the period 1977-1992. “Together, a firm operating in a city with consistently double own industry employment compared to another city has 17 per cent greater output than if it operated in the other city. For non-affiliates that is a great reason to cluster into big high-tech centers like San Jose or Austin.”
The study investigates both aggregate effects across the economy, and for industry segments grouped according to their co-locating agglomeration patterns. As expected, effects vary across these groups.

Taking these studies together, the evidence that agglomeration per se significantly increases labour productivity is strong. Nevertheless, the limited evidence suggests that the effects differ by industry type and country, sometimes operate with lags, and may be due both to own industry local scale and local industrial diversity.

### 7.2. Effects on Labour Productivity

Five studies reviewed look at effects of agglomeration on employment growth. All except one interpret the results in terms of productivity effects. Rosenthal and Strange (2004) note that, in the short run, the relationship between productivity changes and employment growth may not be so clear cut, because employers are constrained by prior choices (particularly of capital). They argue that the difficulty can be overcome by looking at employment changes over a sufficiently long time frame, so that all factors have time to adjust. Because employment growth affects the level and composition of employment (which are used to measure agglomeration effects), it is, nevertheless, desirable to use instrumental variables to disentangle the causal effect of these measures on employment growth.

Even taking these points on board, the arguments for this interpretation are dubious. First, as Ciccone and Hall (1996) note, small productivity externalities may lead to big shifts in employment – so, at the least, it will be difficult to infer the size of productivity effects from this evidence. Second, the interpretation requires an assumption that the productivity effects of agglomeration are homogeneous with respect to the factors of production\(^\text{37}\). In particular, this approach will not capture the effects of labour-saving technological innovations (that might arise as the result of agglomeration), or innovations that result only in further accumulation of physical capital (Glaeser, Kallal, Scheinkman and Shleifer 1992). The same authors also point out that

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\(^{37}\) Rosenthal and Strange (2004) citing Henderson (1986) as authority, assume that agglomeration economies are “Hicks neutral” with respect to the inputs in production.
their results on employment effects of city diversity may be explained by a simple model where new employment is attracted to places where inputs are cheaper.

Combes (2000) notes that employment growth may be influenced by congestion effects, by product life cycles, and by the economic cycle or by an interaction between the latter two. He notes too that country differences in factor mobility (caused perhaps by institutional factors) will make it difficult to generalise from one country to another.

Most tellingly, Henderson (1999) re-estimates his equations for productivity, with employment growth as the dependent variable. The coefficients on various measures of agglomeration differ both quantitatively and in terms of significance across the alternative specifications. An important conclusion that Henderson draws from this study is that the lagged effects of scale and diversity on employment growth found in other studies may not represent productive externalities at all, but rather other factors that influence plant location decisions.

Nevertheless, there may be a policy interest in agglomeration effects on employment growth irrespective of whether they represent true productivity effects.

Glaeser et al (1992) look at the determinants of employment growth over a thirty year period in the six largest two-digit industries in each of 170 U.S. cities. They find that specialization of a city in an industry (measured as the local share in employment normalised by the national share) has a small negative effect on employment growth. Reducing diversity (measured as the fraction of city employment in the five other large industries) by ten percentage points, reduces employment growth by 0.1 per cent.

Highlighting the possibility of alternative interpretations of estimated effects of agglomeration on employment growth, they note that "The result that

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38 In particular he shows, using fixed effects estimation that all other industry diversity has a positive effect on county-industry employment growth for high-tech industries – whereas there is no such effect on productivity. Note, this paper is an earlier version of Henderson (2003a).
employment in an industry grows higher in a diversified city might reflect the fact that such cities are less crowded and hence cheaper to locate in. Competition for space and labor might thus explain many of our findings."

Henderson, Kuncoro and Turner (1995) investigate employment growth in five two-digit “mature” capital goods industries in 224 SMSAs in the U.S. over a seventeen year period 1970 to 1987. They find that the 1970 own industry employment share is strongly related to the 1987 employment level. For machinery, for example, a one standard deviation (.03) increase in the 1970 employment share increases 1987 employment by 25 per cent. In contrast to the findings of Glaeser et al (1992), lack of diversity (measured by a Herfindahl index) has no consistent or significant effect. They find evidence of a home market effect – a one per cent increase in current all other manufacturing employment increases own industry employment by 0.3 – 1.0 per cent.

Henderson (1997) also studies five U.S. capital goods industries across 742 urban counties. Using annual data between 1977 and 1990, he employs fixed effects panel estimation, and instrumental variables, allowing for lagged effects. He finds that a one standard deviation increase in industry employment share five years previously leads to a four to five per cent increase in current employment. A one standard deviation permanent decrease in diversity reduces current employment by between two and 42 per cent – with the strongest effects for six to eight years previously. Again he finds home market effects – the elasticity of county-industry employment with respect to metropolitan scale is in the range of 0.7 to 2.4.

As noted above, Henderson (1999) supplements his estimates of agglomeration effects on labour productivity with estimates of their effects on employment. He finds that both own industry employment (or number of plants) and diversity have a significant positive effect on employment growth for high-tech industries (with an elasticity of 0.8). However only own local industry scale has an effect on employment growth for machinery industries.
Combes (2000) criticises the specification used in Henderson et al (1995) and Henderson (1997) because they include both own industry employment levels, and industry share of local employment in the specification. He argues that a change in own industry share of employment, while the own industry employment level is held constant, requires that total local employment is also changing. A positive coefficient on share might thus be capturing the fact that smaller cities grow faster. He shows elsewhere (Combes 2000) that when he replaces total local employment with own industry employment in the specification, he gets results that are more like those reported in Henderson et al (1995).

Combes (2000) covers the whole private sector French economy in the period 1984-2000, excluding firms with less than 20 employees. His geographical unit of analysis is an employment zone – there are 341 covering France. He reports global results for manufacturing and services separately, and for each of 94 industry sectors. Overall local industry employment density has a negative effect on employment growth in manufacturing, and no significant effect in services. Specialization (normalized local employment share) has a negative effect on employment growth in both manufacturing and (particularly so) services. Industrial diversity (measured by an Herfindahl index) has a positive effect for services, but negative for manufacturing.

The results for individual industries show a wide spread of effects on each of the agglomeration measures, with most industries experiencing no significant effects, and some on each measure significantly positive or negative effects. Overall, it is difficult to draw any generalisable conclusions about the effects of agglomeration on local industry employment growth – unless it is that most industries will not experience significant effects, and, of those that do, some will experience positive and some negative effects.

7.3. Effects on Wages and Rents

Seven studies reviewed look at agglomeration effects on wages, rents or wages and rents simultaneously. Wage data is widely available and on the assumption that workers are paid their marginal product, should reflect productivity differences. Nevertheless, care is required to control for unobserved worker characteristics that may explain wage differentials – and unobserved characteristics of cities that attract more productive workers. Rents are also used to identify effects, on the argument that if firms are willing to pay higher rents there must be some compensating productivity advantages in the location.

In theory, productivity differentials should be reflected in both wages and rents. As Rosenthal and Strange (2004) note: “The degree they are captured in one or the other depends on elasticities in the markets for land and labor and also on the presence of other local attributes like natural amenities. The absence of differentials in one of the two should not then, be taken as evidence for the absence of agglomeration economies.”

Glaeser et al (1992) repeat their analysis of the determinants of city-industry employment growth with city-industry wage growth as the dependent variable instead. They find that specialization has no effect on wage growth, but that increasing diversity raises wage growth. Because these effects are roughly the same as those they found for employment growth, they are more inclined to interpret the latter as true productivity effects.

40 Glaeser et al (1992) raise a number of problems with interpreting wage differences in terms of productivity differences. Productivity increases might accrue only partly to labour, there might be a selection effect as declining industries fire their less able and experienced workers first, technological innovations might favour employment of less skilled workers, and wages may reflect rent sharing – particularly in heavily unionised industries.

41 Haughwout (2002) presents a related two-sector model to capture the effect of urban public infrastructure on rents and wages. In this model, in equilibrium, higher wages cause higher costs for firms, but the aggregate effect of this is offset in the households’ expenditure function. The effects of public infrastructure are, therefore, fully capitalised in land prices. Equilibrium changes in wages reflect the extent to which the marginal change in infrastructure is benefitting firms in terms of productivity, or households in terms of enjoyment of city amenities. A similar analysis is relevant to understanding the effects of agglomeration on rents and wages.
Dekle and Eaton (1999) use data on wages, house rents and value-added\(^{42}\) for manufacturing and financial services for 46 Japanese prefectures over the 13 years 1976-1988. They pool data across years, and regress the share weighted sum of wages and rents on a measure of industry-prefecture economic activity, allowing for prefectural fixed effects. They incorporate a parameter that allows for decay of effects over distance. They calculate implied effects on output from their results. They find that the elasticity of output in manufacturing with respect to local and national economic activity is 0.010 and 0.260 respectively. The corresponding elasticities for financial services are 0.012 and 0.016.

Tabuchi and Yoshida (2000) also use Japanese data, to estimate the effects on nominal and real wages of city size (in terms of population). They develop a model in which differences in nominal wages reflect productivity differences (otherwise firms would relocate to lower wage cities) and differences in real wages reflect differences in amenities to households (otherwise households would relocate to cities where they can earn either higher wages, or enjoy greater amenities. They estimate city specific cost functions and indirect utility functions for households, using weather conditions, status as a prefectural capital, being an industrial city, and coastal location as instruments. They find that as city size doubles, nominal wages go up by ten per cent or less (reflecting productivity gains to firms), while the real wage goes down by seven to twelve per cent, reflecting net amenity benefits to households\(^{43}\).

Glaeser and Maré (2001) use a range of U.S. data sources to investigate wage differentials between large urban, other urban and non-urban areas. They find that the differentials (in the order of 25 – 30 per cent) appear to be mostly nominal rather than real, and that controls for education, experience and ability (where available) reduce them only modestly. When they use longitudinal data and fixed effects estimation, the differentials are reduced to

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\(^{42}\) They do not comment on the quality of their value-added data, and so it is not possible to judge whether it avoids the problems identified by Ciccone and Hall (1996) with similar U.S. data.

\(^{43}\) The reliability of these estimates will be affected by the validity of the instruments used. The results are not widely inconsistent, however, with estimates of productivity effects in Ciccone and Hall (1996) and Ciccone (2002).
about five to ten percent - but this effect is being identified by migrants between rural and urban areas. They show that migrants to urban areas do not immediately receive the full wage premium, and that, in any case, better educated and more experienced workers receive a higher premium. They also show that migrants from cities retain a significant part of the premium in their new location – though selection may influence this result. An inference from these findings is that the urban wage premium reflects real productivity differences that gradually accrue to educated workers (in particular) the longer they work in cities.\footnote{It might be possible to calculate an average effect on productivity implied by these findings, of differences in city size, given the composition of the city workforce by education.} This in turn suggests that one source of agglomeration externalities are the learning opportunities that are afforded in cities.

Wheaton and Lewis (2002) investigate the effects of occupational and industrial specialization (share of city employment or establishments in the industry or occupation) and concentration (share of national occupational or industry employment or establishments in the city) on wages. They control for demographic variables, and allow for city, occupation and industry fixed effects, and different age-earning profiles by sex and education. The data cover full-time private sector employees living in 220 U.S. cities. A doubling of occupational specialization raises wages by four per cent; a doubling of industry specialization raises wages by three per cent, with smaller effects for concentration in each case. The study was unable to identify the distribution of effects across disaggregated industry and occupational categories.

Rosenthal and Strange (2005) estimate the effects of agglomeration (numbers of full time workers in a defined geographic range) and of human capital spillovers (numbers of “college-or-more” or “less-than-college” educated workers in a defined geographic range) on hourly wages in the U.S. They use geologic variables as instruments for agglomeration to deal with endogeneity and to deal with error in the measurement of geographic range. They also control for standard demographic variables, and MSA/occupation fixed effects. They find that an additional 100,000 full time workers within five miles raises hourly wages by 1.5 per cent; transforming 50,000 “less-than-college"
educated workers within a five mile range into “college-or-more” educated workers raises wages by ten per cent.

Combes et al (2005) use a very large French dataset on individual workers in employment areas over the period 1976 to 1996. They use a two stage procedure – first estimating area fixed effects in the presence of industry fixed effects, observed worker characteristics, and industry-area characteristics. In the second stage they estimate the determinants of these area fixed effects using lags as instruments. Agglomeration measures include employment density, land area, industrial diversity, proximity to other areas of dense employment, and amenities. They find that doubling employment density increases wages by three per cent – a figure that is more than doubled when aggregate data is used. This highlights the importance of selection of workers into areas of dense employment on the basis of unobserved characteristics – leading to upwardly biased estimates of agglomeration effects when using aggregate data.

Overall, the evidence using wage and rent effects is broadly consistent with estimates of direct effects on productivity. In the U.S. and Japan, at least, an increase in city size or the scale of local economic activity, as well as industrial specialization and concentration appears to be associated with wage and rent increases that reflect underlying productivity differentials. However, the literature tells us little about how much the aggregate effect is due to industrial diversity or specialization, and how these effects might vary across industry sectors.

The results from Glaeser and Maré (2001) suggest an important interaction between agglomeration and skills – agglomeration effects may be stronger (on some dimensions at least) in cities with a well-educated population. This idea is reinforced by the fact that U.S. cities with higher proportions of educated workers grew faster both in employment and in wages over the period 1960 to 1990 (Glaeser, Scheinkman and Shleifer 1995). Glaeser and Saiz (2003) find that this effect is particularly concentrated in cities that do not have other growth advantages such as a good climate, or strong external migration. Results reported in Acs and Armington (2003) suggest that some
of this effect is likely to be mediated through the relationship between education levels and new start-ups.

7.4. Effects on Industry and Firm Location Decisions

A range of studies reviewed look directly, or in supplementary analyses, at agglomeration effects on industry and firm location decisions. As Rosenthal and Strange (2003) note: “the idea here is that entrepreneurs seek out profit-maximizing locations and are disproportionately drawn to the most productive regions.” While data requirements are less demanding than for direct study of productivity effects, many locations do not receive births in a given period, which may require the use of econometric methods that deal with censored data.

There are also issues of interpretation to consider. If industry concentration reflects the existence of positive externalities then new firms in the industry are likely to locate there. On the other hand, “congestion” effects may set in – and new firms may seek to locate elsewhere.

Industry life-cycle effects might also be relevant. For instance, Duranton and Puga (2001) develop a model of the life-cycle of products in which city diversity encourages innovation, but once the new industry has discovered its “ideal process”, it switches to mass production which is favoured by specialised cities. They study establishment relocation patterns across French employment areas in the period 1993-1996 and find that they fit their theoretical model – 72 per cent were relocations from an area with above-median diversity (measured by the inverse of a Herfindahl index of sectoral concentration of local employment) to an area of above-median specialization in the relevant sector (as measured by the Ellison-Glaeser geographic concentration index).

Henderson (2003a) finds that the high-tech industries he studies in the U.S. for the period 1963-1992 are relatively mobile geographically, and that firm births may be a source of positive spillovers – meaning that new locations are not “at such a distinct disadvantage in attracting plants compared to existing agglomerations.”
Devereux et al (forthcoming) speculate that similar forces may be at play in explaining why, in the UK, high-tech industries appear to be less agglomerated than other industries. They also note another issue of interpretation – if externalities are sufficiently high in an industry, firms may internalise them by merging so that high industrial concentration accounts for the geographic concentration.\(^{45}\)


Acs and Armington (2003) look at the rate of new firm formation in the services sector across all 394 Labor Market Areas in the U.S over the period 1996 to 1998. They model this as a function of initial education levels in the local population, and the ratio of establishments in the industrial sub-sector to the population (intensity). Controls include local population levels, and “all establishments” intensity. They find that a one standard deviation increase in sub-sector intensity increases the rate of new firm formation by 0.6 of a standard deviation. A one standard deviation increase in log population increases the firm birth rate by 0.2 of a standard deviation, while a one standard deviation increase in the “all establishments” intensity decreases the firm birth rate by 0.2 of a standard deviation.


\(^{45}\) Like Ellison and Glaeser (1997) they use an agglomeration measure that controls for industrial concentration.
almost all cases, the local own-industry number of firms per worker (a proxy for competition) and employment levels have a positive effect on both outcomes. Local industrial diversity (measured by a Herfindahl index) has a positive effect. The effect of total other-industry employment is also mostly positive but smaller by an order of magnitude. The local own-industry numbers employed in firms of less than 25 employees has a 90 per cent stronger effect on births, than numbers employed in larger firms; and a 60 per cent stronger effect on new-establishment employment.

Davis and Henderson (2005) find that, over a five year period, a ten per cent increase in the number of local business services increase expected births of company headquarters in U.S. counties by 3.6 per cent. There are similar effects for financial service inputs – though imprecisely estimated. They also find evidence from births that a few other own-industry headquarters in a county is extremely beneficial, but the effect rapidly diminishes with increasing numbers. There are small effects from total county employment.

Arzaghi and Henderson (2005) look at the determinants of advertising agency births and re-locations in census tracts in New York between 1992 and 1997. They find that births and re-locations are influenced both by rents, and by the existing stock of all firms in the census tract and advertising agencies within 250 metres to 750 metres distance. In one specification, a one per cent increase in all establishments in the census tract raises expected births by 0.5 per cent. A one standard deviation increase in advertising firms within 250 metres increases expected births by 20 per cent; a one standard deviation increase in advertising firms between 250 metres and 500 metres increases expected births by 46 per cent. Moreover, “high quality” firms, proxied by payroll size\(^{46}\), are more likely to locate and re-locate in high rent census tracts, with a concentration of existing high quality firms. This produces a geographic segmentation by quality of the industry.

Rosenthal and Strange (forthcoming) also study the determinants of firm births and employment in new firms in New York over 2001 to 2004, using

\(^{46}\) On the basis of theoretical priors about scale economies in matching, and the observation that larger firms are willing to pay higher rents to locate with each other.
Dun and Bradstreet Marketplace data matched to census tract data. In a set of simple tobit models with two-digit industry fixed effects, they find that own-industry employment within one mile has a significant effect, particularly for business services, while total employment has a smaller and sometimes insignificant and/or negative effect. The effect is strongest for business services – increasing own two-digit industry employment within one mile raises births by .2860 and employment by 2.20. The effects attenuate by an order of magnitude beyond one mile.

While their sectoral and geographic coverage is patchy, the evidence from these studies suggests that agglomeration often has an important effect on establishment start-ups, and employment levels in new establishments. These are likely, in turn, to reflect geographical productivity differences or potential productivity differences. In the U.S. service sector, at least, new start-ups are frequently associated with an innovation, and a large proportion of employment growth is associated with the first few years of successful new start-ups (Acs and Armington 2003).
8. Conclusion

8.1. Empirical Evidence on Agglomeration Effects

The literature provides evidence for a wide variety of factors involved in generating agglomeration economies – but not very clear evidence on the precise nature of the mechanisms involved. Input market and labour market spillovers, consumption economies, and knowledge and human capital spillovers are all documented. A number of studies suggest that labour market spillovers are relatively more important, and also relatively pervasive. It needs to be remembered though that labour market spillovers may operate through any one of the three mechanisms identified in the theoretical literature – shared inputs (allowing greater specialisation, for instance), better matching (in this case of workers to jobs), or learning. In turn, evidence for knowledge spillovers may be hard to come by if they are mediated through non-market transactions that do not leave a data trail.

It is likely that the extent to which particular factors are important in generating agglomeration economies will vary by a wide variety of city, industry and country characteristics. These could include technology, industry mix, skills in the population, industry or firm vintage, the place in relevant product cycles, the presence of amenities attractive to consumers, the extent that congestion has set in, and institutional arrangements that may differ across jurisdictions. It should not be surprising that the evidence fails to find clear and common patterns by three- or four-digit industry sector.

Two studies surveyed (Ciccone and Hall 1996, Ciccone 2002) reinforce an earlier generation of studies that suggest economically significant general labour productivity effects of agglomeration. In particular, they find that doubling density of economic activity will lead to an increase in aggregate regional productivity of four to six per cent – though a more recent study looking at wage effects (Combes et al 2005) suggests a more conservative figure of three per cent. While most studies deal with methodological issues in a way that still leaves room for scepticism, a number demonstrate industry level productivity effects that are large. Agglomeration also appears to have
significant effects on industry employment growth, and the location of new firms.

However, each of the two studies\(^{47}\) that cover a full range of industries present in a jurisdiction fail to find significant effects of agglomeration for a large majority of four-digit individual industries – whether due to industry concentration or local diversity. A further study\(^{48}\) finds it impossible to identify stable and significant effects at the three-digit industry or occupational level. Generally, effects of particular agglomeration measures can be both positive and negative for different industries in the same study – though often with a preponderance of one or the other. These findings are consistent with other evidence that a majority of industries are not significantly agglomerated, once the overall distribution of employment and concentration of production in particular firms is taken into account. And of those that are significantly agglomerated, much can be explained by factors other than agglomeration economies.

It is useful to remember that these studies cover countries that are many times larger than New Zealand, and with many more, and denser urban agglomerations. On the basis of this evidence, it is likely that few, if any three- or four-digit industries in New Zealand are of sufficient scale to be able to detect the presence of statistically significant agglomeration economies, if they exist. Moreover, as argued above, it would be unwise to draw conclusions for New Zealand from results for specific industries in other countries.

In any case, other studies are so selective in the industries covered, that it is near impossible to draw conclusions about general patterns of agglomeration effects, with any confidence. There is a perhaps unsurprising suggestion that high human capital and local industrial diversity may be important for the location of new, technologically progressive industries, and that the human capital effect may operate through entrepreneurial start-ups. On the other hand, a number of traditional manufacturing industries appear to demonstrate

\(^{48}\) Wheaton and Lewis (2002) for wages.
positive productivity effects of local industry scale. Some of these at least, such as car manufacture, or heavy machinery, are industries where New Zealand is unlikely ever to have the scale to be competitive.

More generally, the evidence suggests important interactions between agglomeration economies and human capital. Cities with high levels of education have grown faster in recent decades, and human capital has become more concentrated in cities. Human capital spillovers may account for a significant proportion of measured agglomeration economies (Rosenthal and Strange 2005). Human capital may also play an important role in periodic city regeneration after adverse shocks (Glaeser 2003, Glaeser and Saiz 2003). Young educated workers are attracted to cities (Peri 2002), where, after a period, they enjoy significant nominal wage premia (compared to their non-urban counterparts). In part, these premia appear to reflect productivity differentials (Glaeser and Maré 2001). Big cities are places where innovations occur at disproportionately high rates, and education may mediate the relationship between agglomeration and entrepreneurial start-ups in services in the U.S. (Acs and Armington 2003). Nevertheless the evidence of aggregate human capital spillovers in cities remains inconclusive (Moretti 2004a).

8.2. What Does this Mean for Policy?

This paper began by describing three policy areas that are developing at least in part on the assumption that agglomeration economies pertain. Cities appear to play an important role in economic growth. Facilitating larger and more efficient cities may be a route to raising output per capita. In New Zealand there is a particular focus on Auckland as the largest city.

The evidence surveyed in this paper supports this line of thought. The economic effects of urban density or scale covered in the surveyed literature are identified by differences among urban agglomerations that are probably dominated by those much larger than Auckland. It is very unlikely that Auckland has reached the point where further growth would not produce positive productivity effects. Thus, if Auckland doubled its population, other
things affecting productivity remaining the same, then it might be expected that its output per capita would rise by something in the order of three per cent, and New Zealand’s GDP per capita by 1.5 per cent. Of course the quality of the growth would matter, in terms of human capital, the age structure of the population, and the provision of infrastructure to counteract congestion.

There is an additional consideration, mostly not covered by the literature surveyed here – and that is Auckland’s broader role in the Australasian region. A city the size of Auckland in the U.S. would be relatively unspecialised by function, in terms of production versus higher management and associated services (Duranton and Puga 2005). It is likely, given New Zealand’s geographic isolation and overall size, that Auckland has a greater proportion of higher management and associated service functions than would be the case for a similar sized city in the U.S. Nevertheless, to the extent that the New Zealand economy is an integral part of Australasia, there will be a tendency to lose these functions to Sydney and Melbourne. Anecdotal evidence tends to confirm this tendency. Growth in Auckland’s population will tend to counteract it49.

What sorts of policy are likely to assist a city like Auckland to grow successfully? It is important to recognise that the size distribution of larger cities within countries is remarkably stable over time and across countries. This suggests powerful forces shaping the distribution that would make it unwise for governments to attempt to engineer a major shift in the distribution. Evidence suggests that very distortionary policies that are likely to be harmful for growth would be needed to divert resources from other regions to significantly change the balance (Ades and Glaeser 1995). Nevertheless, within the broad distribution it should be possible to devise policies to ensure that New Zealand’s largest city continues to play the role that only it can play in the Australasian regional economy.

49 The so-called “New economic geography” (for instance Fujita et al 1999) generates classes of models based on varying assumptions about transport costs and economies of scale, that lead to predictions about the distribution of economic activity across regions and across countries. However the empirical applicability of these models is still very much in question (Neary 2001, Head and Mayer 2004).
Appropriate provision of infrastructure can help reap the benefits of agglomeration (Eberts 1999, Haughwout 2001). The key here is to know when marginal infrastructural projects are likely to produce positive benefits. Similar methodologies to those used to investigate agglomeration effects are relevant. Successful infrastructural projects are likely to lead to changes in wages and land prices, and these can, in principle, be used to identify productivity effects (Haughwout 2002).

Other relevant policies include introducing congestion pricing in transport, reviewing planning regulations that may cause distortions in development, encouraging the provision of high quality education and training in the city, and facilitating the inflow and successful settlement of skilled immigrants.

Glaeser (1998) suggests three areas where local government choices can exacerbate urban problems – the inappropriate provision of “monumental” infrastructure; the use of quantity controls through zoning ordinances for instance that impose costs and distort development; and redistributive policies that cause the better off to vote with their feet. The first two are potentially problems in the New Zealand context.

The potential importance of successful migrant settlement is highlighted in a recent paper looking at the effects of linguistic diversity in U.S. cities on wages and employment of natives (Ottaviano and Peri 2005). Using an index of linguistic diversity, they find strong positive effects on both wages and employment over the period 1970 to 1990, which are robust to a variety of specifications and instruments, and suggest true productivity effects. The effects are strongest for skilled natives, and depend on the extent to which those with a non-native mother tongue speak English well.

Will building regional or national scale in an industry sector produce productivity and other economic benefits? There are clearly sectors where own industry scale appears to have positive effects on productivity and particularly employment growth, sometimes quite substantial. However, a large majority of industries do not exhibit such effects, at least in a detectable statistically significant way, and for some industries, in some regions, effects
are perversely negative. Few, if any three- or four-digit industries in New Zealand are likely to be of sufficient scale to be able to identify positive agglomeration effects, even if they exist\textsuperscript{50}. Thus, a sound empirical base is lacking for a policy that aims to increase industry scale in the hope of reaping agglomeration economies. Nevertheless, there are other more cogent reasons for governments to design policies focused on industry sectors\textsuperscript{51}.

The literature surveyed in this paper has little to say directly about policies focused on the development or maintenance of clusters – not least because the term “cluster” is slippery, and capable of wide variety of meanings (Martin and Sunley 2003). To the extent that cluster policy aims to reap benefits from building dense networks and linkages per se, then it incurs the same criticism set out in the previous paragraph. Unless clusters are very large, the evidence for substantial economic benefits is likely to be lacking. In the New Zealand context, cluster policy appears to be focused on very small groupings of firms.

Of course, cluster policy may have other more cogent objectives – such as promoting more productive linkages between firms and research institutions. Nevertheless, in practice, the policy appears to be intensive of policy and administrative resources relative to the size of clusters, and to be highly dependent on bureaucratic rather than industry-led initiatives (Perry 2004). The same resources might be better directed to policies that are inherently more likely to have greater measurable economic impacts.

Much of the literature surveyed in this paper is very recent, and reflects a rapidly developing area of empirical economic investigation. There is much about the precise nature of mechanisms and the size and distribution of agglomeration effects that remains uncertain. Nevertheless the evidence is

\textsuperscript{50} This claim has not been directly tested in the only relevant New Zealand study (Maré and Timmins, forthcoming). However, effects were only weakly statistically significant for much larger industry groupings. At this level, there is even a suggestion that taking into account local agglomeration forces, increasing industry scale at the national level has a negative effect on productivity.

\textsuperscript{51} Improving sector co-ordination between the public provision and industry in areas such as education and training; research, science and technology; regulation and infrastructure, and improving the design of generic policies by better understanding how they impact on particular sectors, are two justifications for such a policy.
sufficient to conclude that in aggregate, agglomeration does have a moderate effect on productivity outcomes. Beneath the aggregate effect, there is considerable variation by sector, country and time. This evidence conveys important messages for the design of economic policy. Promoting high quality growth of New Zealand’s largest city is likely to produce net economic benefits; but any policy that is designed to build national or regional scale in particular industries in order to get productivity benefits is unlikely to succeed.
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### Table 1: Labour productivity effects

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<th>Data &amp; coverage</th>
<th>Estimation methodology and explanatory variables</th>
<th>Key findings</th>
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<tbody>
<tr>
<td>Ciccone and Hall (1996)</td>
<td>1988 U.S. state level data on gross output and county level data on employment density and average education.</td>
<td>Cross-sectional non-linear IV using historic agglomeration patterns as instruments. An index of inputs for each state is adjusted for density of labour, and human capital at the county level. The elasticity of output with respect to employment density is estimated as a parameter in the density index. Using state level input data avoids systematic measurement problems at the county level.</td>
<td>Doubling employment density increases productivity by six per cent.</td>
</tr>
<tr>
<td>Henderson, Lee and Lee (2001)</td>
<td>1983 – 1993 data on five groups containing 21 manufacturing industries in 74</td>
<td>Panel data methods to control for city-industry fixed effects. Specification includes time dummies. Contemporaneous and lagged effects are modelled separately. <strong>Explanatory variables:</strong> Real value-added per production worker, capital stock, total own industry employment,</td>
<td>Increasing local own- industry scale by a factor of ten, increases productivity by 15 per cent. No evidence of lagged effects. For high-tech industries, a one</td>
</tr>
<tr>
<td>Source</td>
<td>Data Source and Methodology</td>
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</table>
| Metro areas in Korea. Metro-level value-added data by industry | **an Herfindahl like index of urban specialization** *(alternatively city population proxies for diversity)*
Note: input measures to calculate value-added may be systematically biased by urban scale. | standard deviation decrease specialization increases productivity by 60 per cent. |
| Ciccone (2002) | Eurostat regional data for the late 1980s on private, non-agricultural value-added and employment from five countries | Employment density elasticity is 4.5 per cent. No evidence of significant differences across countries |
| | A similar methodology to Ciccone and Hall (1996) is used. However, the effect of employment density is directly estimated with regional data and regional dummies, with more flexible controls for education levels. Alternative IV estimates use land area as an instrument for density. | |
| Henderson (2003) | Six periods of US LRD CM & ASM data, 1963-1992, for four high-tech | A ten-fold increase in number of local plants raises high-tech productivity by over 20 per cent. Only small effects for machinery plants. | Industry group panel estimates of plant level production functions with individual-industry and plant fixed effects, and time dummies. Alternative 2SLS and GMM estimation is also used, to address the issue of possible endogeneity of urban scale. |
and five large machinery three-digit industries covering up to 742 counties.

**Explanatory variables:** hours worked, materials input, capital stock, number of own industry-county plants (alternatively own-industry employment).

In separate regressions, the effect of urban scale (using various measures of total employment) & an Herfindahl like index of diversity are tested. 

Note: extreme sample selectivity; input measures may be systematically biased by urban scale

**Five year lagged effects** (elasticity = 0.7- 0.8) for high-tech industries, but none for other groups.

Urban scale has a strong positive effect for machinery (elasticity > 0.10), but not for other groups. No lagged effects.

Urban diversity has no significant effects.

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**Maré and Timmins (forthcoming)**

Statistics NZ BD and BAI providing longitudinal data on a majority of NZ businesses from 1987 to 2003

Panel estimation with controls for firm, location and period fixed effects. Explanatory variables cover a comprehensive range of agglomeration and concentration concepts – treating industries and locations symmetrically – geographic concentration of industry (using the Maurel-Sedillot index); industry non-competitiveness (Herfindahl), industry total employment; LMA non-diversity (LMA Maurel-Sedillot), LMA market thin-ness (LMA Herfindahl), LMA total employment;

In the most stringent specification (which identifies effects purely from within firm changes over time) the observed decadal change in average LMA size contributed three per cent to productivity growth, or around $NZ 1,500 per worker. Local diversity of industry mix has a positive effect on
and a measure of own-industry agglomeration (the log of the locational quotient). Controls cover an exporting indicator, whether the firm experienced a birth or a death, whether a seasonal firm, whether a firm spans industries, firm FTE employment, and firm age. Robustness is checked with a wide variety of specifications, and the effect of error in the measurement of employment in new and dying firms is bounded through alternative specifications using assumptions that over-estimate or under-estimate employment.

productivity – thus the decadal decline in local diversity is estimated to have reduced average productivity by about one per cent or around $800 per worker. A decadal increase in own-industry agglomeration contributed only $200 to $300 per worker. In the most stringent specification only local diversity had a statistically significant effect.
### Table 2: Employment growth effects

<table>
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<th>Data &amp; coverage</th>
<th>Estimation methodology and explanatory variables</th>
<th>Key findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glaeser, Kallal, Scheinkman and Shleifer (1992)</td>
<td>Data from CBP for the years 1956 and 1987, on employment, payroll and number of establishments by two-digit industries in 170 U.S. cities</td>
<td>OLS regressing employment growth in six largest industries in each city on explanatory variables: Ratio of industry employment share in city to national share (specialization), Ratio of average firm size in city-industry, to national industry average (competition) 1956 fraction of city employment in the five other large industries (inverse of diversity). Controls for 1956 city employment and wages, national industry employment growth, and region. Robustness tested through a variety of specifications.</td>
<td>An increase in specialization has a small negative effect on growth. Reducing average firm size to half the national average (a 2.5 s.d. change) increases growth by 59 per cent (or 2/3 of a s.d.). Reducing diversity by ten percentage points, reduces employment growth by 0.1 s.d. A one per cent increase in growth in four largest industries, leads to a 0.5 per cent increase in other industries in the city.</td>
</tr>
<tr>
<td>Henderson, Kuncoro</td>
<td>Data on five two-digit “mature” capital</td>
<td>For each industry, Tobit estimation of 1987 employment levels on explanatory variables: 1970 own industry employment, share of own industry</td>
<td>1987 employment level is strongly and significantly positively related to industry share of employment in</td>
</tr>
</tbody>
</table>
and Turner (1995) | goods U.S. manufacturing industries, in 224 SMSAs from the CM, CP, CBP, and the City and CCDB, in 1970 and 1987. | employment in total employment, and a Herfindahl-like index of lack of diversity. Controls for 1970 own industry employment, and 1987 wages, and market conditions (regional dummies, an access to market measure, and employment in all other manufacturing) Issues of endogeneity of current wages are explored separately. When addressed 1970 employment share has an even stronger positive effect on 1987 levels. | 1970 - e.g. for machinery, a one s.d. (.030) increase in 1970 share increases 1987 employment by 25 per cent. Lack of diversity has no consistent or significant effect. A one per cent increase in current all other manufacturing employment increases own industry employment by 0.3-1.0 per cent.

Henderson (1997) | Annual CBP & CCDB data for five capital goods industries across 742 U.S. urban counties, over the period 1977 to 1990. | GMM panel estimation of city-industry employment growth, with contemporaneous and lagged explanatory variables, differencing out fixed effects, and using lagged variables as instruments. Explanatory variables: Own industry employment, share of own industry employment in total employment, an Herfindahl like index of lack of diversity, with controls for metro area total employment, and average county wages in all other industries. A one s.d. increase in industry employment share five years previously, leads to a 4-5 per cent increase in current employment. A one s.d. permanent decrease in diversity reduces current employment by between two and 42 per cent, with strongest effects from six to eight yrs previously. Long run elasticities of county-
<table>
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<tr>
<th>Henderson (1999)</th>
<th>See table 1</th>
<th>Both base period own industry employment (or number of plants) and diversity have a significant positive effect (elasticity = 0.8) on employment growth for high-tech industries, but only own industry employment (or number of plants) has an effect for Machinery industries.</th>
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</thead>
<tbody>
<tr>
<td>See table 1</td>
<td>Supplementary analyses look at determinants of employment growth rather than productivity, using OLS and (preferred) fixed effects estimation. Explanatory variables: base period all other industry employment, all other industry diversity (measured by an Herfindahl like index), own industry employment (or number of plants) and time-industry dummies.</td>
<td>Both base period own industry employment (or number of plants) and diversity have a significant positive effect (elasticity = 0.8) on employment growth for high-tech industries, but only own industry employment (or number of plants) has an effect for Machinery industries.</td>
</tr>
<tr>
<td>Combes (2000)</td>
<td>Data on employment from 1984-1993 for 341 ZEs covering all of France, and all plants with over</td>
<td>In the preferred specification, explanatory variables are specialization, diversity (an inverse Herfindahl like index</td>
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<td></td>
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<td>In global regressions employment density has a negative effect on employment growth in manufacturing, but no significant effect for services. Specialization has a slight negative effect for manufacturing, and more so for</td>
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<tr>
<td></td>
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<td>In global regressions employment density has a negative effect on employment growth in manufacturing, but no significant effect for services. Specialization has a slight negative effect for manufacturing, and more so for</td>
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</table>
20 employees in four-digit industries aggregated into 42 service and 52 manufacturing sectors

covering sectoral concentration all other industries), competition (a Herfindahl index of local plant employment shares in the industry), and total employment density. Controls are average size of plants in the local sector (representing internal economies of scale), and regional dummies. All variables are normalized by dividing by the corresponding national value.

services. Diversity has a positive effect for services, but negative for manufacturing. Competition has a negative effect in manufacturing, and is not significant in services.

Individual sector regressions show a wide spread of effects, with most insignificant, but on each measure there are some sectors where elasticities are significantly positive, and some that are significantly negative.
# Table 3: Wage and rent effects

<table>
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<tr>
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<tbody>
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<td>Glaeser et al (1992)</td>
<td>Data from CBP for the years 1956 and 1987, on employment, payroll and number of establishments by two-digit industries in 170 U.S. cities</td>
<td>OLS regressing wage growth in six largest industries in each city on explanatory variables: Ratio of industry employment share in city to national share (specialization), Ratio of average firm size in city-industry, to national industry average (competition), 1956 fraction of city employment in the five other large industries (inverse of diversity). Controls for 1956 city employment and wages, national industry employment growth, and region.</td>
<td>Specialization has no effect on wage growth. Reducing average firm size reduces wage growth. Increasing diversity raises wage growth.</td>
</tr>
<tr>
<td>Dekle and Eaton (1999)</td>
<td>Data on wages, house rents and value-added for manufacturing and financial</td>
<td>Non-linear least squares regression of the share weighted sum of average wages and land rents on a term reflecting agglomeration economies from local and wider sources (with a parameter reflecting decay of effects over distance), prefectural and time dummies.</td>
<td>For manufacturing the elasticity of output with respect to local and national economic activity is 0.010 and 0.260 respectively; for finances the figures are 0.012 and 0.016. the</td>
</tr>
<tr>
<td><strong>Tabuchi and Yoshida (2000)</strong></td>
<td>Data for 1992 on population &amp; other variables in Japanese SMEAs with more than 100,000 population,</td>
<td>Simultaneous GMM like IV estimation of a city specific cost function for firms and indirect utility function for households, with prices, wages (proxied by income) and rents treated as endogenous. Exogenous variables include Nitric Oxide levels, average age of population, and distance to Tokyo. Instrumental variables reflect weather conditions, whether a prefectural capital or an industrial city, and coastal location.</td>
<td>As city size doubles the nominal wage goes up by ten per cent or less (reflecting productivity gains to firms), while the real wage goes down by seven per cent to 12 per cent, reflecting net amenity benefits to households.</td>
</tr>
<tr>
<td><strong>Glaeser and Maré (2001)</strong></td>
<td>A range of cross-sectional and longitudinal individual data</td>
<td>A range of OLS and panel fixed effects regressions of wages on explanatory variables, including: Population density of area of residence (categorical) – main effects are identified by comparing living in a city of over</td>
<td>The urban wage premium of about 20-30 per cent is mostly nominal rather than real. In OLS, living in a dense urban area</td>
</tr>
</tbody>
</table>
on wages of employed males in U.S. cities covering the 1980s and early 1990s – from the CP, PSID, CPS & NLSY

| Wheaton and Lewis (2002) | 1990 CP data covering private sector full-time manufacturing employed individuals living in 220 MSAs, OLS of log wages on demographic variables, and measures of occupational, industry and establishment specialization and concentration. Specialization is share of MSA employment (number of establishments) in the occupation or industry. Concentration is share of national employment (number of establishments) in the occupation, or industry in the MSA. | A doubling at the mean of the relevant variable is associated with the following wage increases: Occupation specialization: four per cent. | is associated with a wage premium in the order of 25 per cent. With fixed effects, this is reduced to about five to ten per cent. However, the premium is stronger with education and experience. Recent urban migrants do not receive the full wage premium immediately, and emigrants do not lose it entirely. |
combined with CBP data on employment and establishments by county for 1989. Data covers 424 occupations and 77 industries.

Preferred regression controls for MSA, occupation and industry fixed effects, seven demographic dummy variables, and allow a different quadratic age-earnings profile for each of eight sex-education groups.

Supplementary regressions check effects of clustering on standard errors (except for establishment concentration estimates remain statistically significant), and attempt to isolate disaggregated industry and occupational effects (unsuccessfully).

| Rosenthal and Strange (2005) | 2000 Census five per cent IPUMS covering the U.S. | 2SLS IV, using geologic features impacting on urban density as instruments to control for endogeneity and error in the measurement of geographic range, main explanatory variables - number of full time workers, or numbers of less than college and more than college educated workers in defined geographic range. Controls for worker education, presence of children, marital status, age, race, years of residency in U.S., MSA/occupation fixed effects. | Occupation concentration: 0.5 per cent.  
Industry specialization: three per cent.  
industry concentration: two per cent.  
An additional 100,000 workers within five miles raises individual wages by 1.5 per cent.  
Transforming 50,000 “less than college educated” workers within five miles into “college-or-more educated” workers raises individual wages by 10 per cent. |
| Combes et al (2005) | Data from DADS on wages, worker characteristics and industry in French ZEs covering all of France at four year intervals from 1976 to 1996, supplemented by data on ZE characteristics. | Two stages – the first estimating ZE fixed effects, and the second estimating the determinants of these. In the preferred specification lagged variables are used as instruments in the second stage.  

In the first stage, covariates are industry fixed effects (for 99 composite industries in scope), age, age squared, and area measures of log industry share of employment, industry share of workers in professionals, and number of establishments in the industry.  

In the second stage, covariates are area employment density, land area, diversity (log inverse of a Herfindahl of industry employment shares) market potential (an index of proximity to other dense urban areas), and amenities (architecture and geography). | A doubling of employment density produces a three per cent increase in wages. Land area has comparatively small effects, and the effects of diversity are negative. Market potential and some amenities have positive effects, while other amenities have negative effects – reflecting a lack of productive advantages. |
Table 4: Other effects – industry and firm location decisions

<table>
<thead>
<tr>
<th>Study</th>
<th>Data &amp; coverage</th>
<th>Estimation methodology and explanatory variables</th>
<th>Key findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Henderson et al (1995)</td>
<td>Data on three three-digit high-tech U.S. manufacturing industries, in 224 SMSAs from the CM, CP, CBP, and the CCDB, in 1970 and 1987.</td>
<td>Industry specific Probit estimation of determinants of presence of &quot;significant employment&quot; in an industry in a city in 1987, and, conditional on that, determinants of employment levels (as for analysis of mature capital goods manufacturing industries set out in Table 2). Explanatory variables: 1970 own industry employment, share of own industry employment in total employment, and a Herfindahl-like index of lack of diversity. Controls for 1970 own industry employment, and 1987 wages, and market conditions (regional dummies, an access to market measure, and employment in all other manufacturing)</td>
<td>Having employment in the predecessor industry in 1970 raises the probability of having significant employment in 1987. The greater the 1970 level, the greater the probability. Lack of diversity in 1970 has a large negative effect on the probability. However, the effect of lack of diversity is strong only for cities without the industry in 1970.</td>
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<tr>
<td>Acs and Armington</td>
<td>Three periods of data from</td>
<td>Dependent variable defined as new firms per thousand labour force in the LMA (for whole of services sector)</td>
<td>In global regression, a one s.d. increase in sub-sector intensity</td>
</tr>
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<td>(2003) Rosenthal and Strange</td>
<td>1996 &amp; 1997 data from the DBMP on employment, the LEEM database, on new establishment formation in the services sector between 1989 and 1998, covering all 394 LMAs in the U.S.</td>
<td>Tobit estimation of the number of new establishments/employment in new establishments within defined geographic range. Explanatory variables: (at zip code level): Herfindhal index</td>
<td>Own industry competition encourages new establishment births and employment in every industry but one.</td>
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<td>regression) or as new firms relative to the number of establishments already in existence in the LMA (when pooled subsector regressions are used). Explanatory variables: percentage of adults in LMA with College degree; percentage of non-college adults who are high-school dropouts; intensity of subsector in terms of establishments/population. Controls: Population growth, per capita income growth, log population, unemployment rate, average size of all establishments, intensity of establishments/population. Note collinearity between sub-sector and all establishment intensity means that in pooled sub-sector regressions, coefficients fall (but not greatly for sub-sector intensity, and log population).</td>
<td>produces a 0.6 s.d. increase in the rate of new firm formation. The effect is strongest in subsectors serving a non-local market. Log population has an effect size of 0.2 Intensity of all establishments has a negative effect size of 0.2</td>
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</table>
new establishments and new establishment employment in five two-digit U.S. manufacturing industries, by geographic location.

of local industry diversity; local firms per worker in other industries; local firms per worker in own industry (proxies for competition)

(at defined geographical range) – other industry employment; own industry employment.
Controls for metropolitan-area, and 50 state non-metropolitan location fixed effects
Supplementary estimation of effects of local industrial structure (in terms of numbers employed in small – less than 25, medium – 25-99 and large 100+ employees) on dependent variables.
Robustness of results to possible imprecise estimates of fixed effects checked through supplementary probit and OLS estimates.

A decrease in diversity of employment decreases births and new establishment employment.
In most cases, own industry employment is more important (by an order of magnitude) for births and new-establishment employment than other-industry employment.
In all industries but one, the own-industry number employed in small firms has the strongest effect on births (by a margin of 90 per cent) and new establishment employment (60 per cent).

| Davis and Henderson (2005) | SSEL data on county location of and employment in company HQs | Preferred specification IV GMM estimation of expected HQ births in a three sector model covering manufacturing, retail and services. Principal explanatory variables are indexes (separately) of diversity in business and financial services at the county level, and the log of the number of
| | | A ten per cent increase in the number of local business services providers increases the expected HQ births in a county by 3.6 per cent. There is a similar effect for financial |
in U.S. in five year periods from 1977 to 1997, similar data on business and financial services establishments, & on county employment own industry HQs in the county, with controls for HQ wages, wages in the input business and financial services and time dummies. Lagged values of covariates are used as instruments.

A variety of robustness checks are performed.

Arzaghi and Henderson (2005)

U.S. Census Bureau SSEL data on location of a stock of approximately 1000 advertising agencies and Poisson & IV estimation of determinants of advertising firm births within census tracts. Explanatory variables - total number of establishments, stock of single unit ad agencies within successive 250 metre rings, broadcasting employment within 500 metres. Instruments - distance to Rockefeller Center, 1970 log of total housing units, 1970 share of housing units in buildings with less than five units, stocks of ad agencies in each of the five rings in 1977, count of all establishments in each of the first four services, but it is imprecisely estimated. There is an HQ own industry scale elasticity of .17 for a service industry, but in non-linear specifications the effect diminishes rapidly. There are only weak positive effects of total county employment on births.

A one per cent increase in all establishments in the census tract raises expected births by 0.5 per cent. A one s.d. increase in ad firms within 250 metres raises expected births by 20 per cent; a one s.d. increase in ad firms from 250-500 metres raises expected births by 46 per cent. “High quality” firms,
| **164 births in New York between 1992-1997, Census tract rents, and profits for a subset of firms** | **rings in 1977, and 1992 establishments in own tract. A variety of robustness checks include instrumenting only rents, using profits for a subset of 30 firms as the dependent variable, and using a subset of births.** | **proxied by payroll size, are more likely to locate in high rent locations, with a concentration of high quality firms.** |
| Rosenthal and Strange (forthcoming) | **DBMP data on employment and births in establishments in NY CMSA over 2001-2004 matched to year 2000 Census tract geography.** | **Tobit estimation of the number of new establishments/employment in surviving new establishments within defined geographic range – one mile, one to five miles, five to ten miles. Separate models for broad industry groupings. Explanatory variables: Total employment, own two-digit industry employment, two-digit industry fixed effects.** | **For all industries adding 1000 workers in a firm’s own industry within one mile raises births by .0832, and new employment by 1.37. Strongest results for Business Services – adding 1000 own industry workers within one mile raises births by .2860 and new employment by 2.20. Effects of total employment small and sometimes negative. Effects attenuate by an order of magnitude beyond one mile.** |
**Abbreviations**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ASM</td>
<td>Annual Survey of Manufactures</td>
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<tr>
<td>BAI</td>
<td>Business Activity Indicator Series (New Zealand)</td>
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<td>BD</td>
<td>Business Demography Statistics (New Zealand)</td>
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<td>CBP</td>
<td>County Business Patterns</td>
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<td>CCDB</td>
<td>City and County Data Book</td>
</tr>
<tr>
<td>CM</td>
<td>Census of Manufactures</td>
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<td>CP</td>
<td>Census of population</td>
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<td>CPS</td>
<td>Current Population Survey</td>
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<td>DADS</td>
<td>Déclarations Annuelles des Données Sociales (France)</td>
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<td>DBMP</td>
<td>Dun and Bradstreet Marketplace Database</td>
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<td>GMM</td>
<td>Generalised Method of Moments</td>
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<td>IPUMS</td>
<td>Integrated Public Use Microdata Series</td>
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<td>IV</td>
<td>Instrumental Variables</td>
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<td>LEEM</td>
<td>Longitudinal Establishment and Enterprise Microdata (U.S.)</td>
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<td>LMA</td>
<td>Labour Market Area (U.S. &amp; New Zealand)</td>
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<tr>
<td>LRD</td>
<td>Longitudinal Research Database (U.S. Census Bureau)</td>
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<td>MSA</td>
<td>Metropolitan Statistical Area</td>
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<tr>
<td>NY CMSA</td>
<td>New York Consolidated Metropolitan Statistical Area</td>
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<td>OLS</td>
<td>Ordinary Least Squares</td>
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<td>PSID</td>
<td>Panel Study of Income Dynamics</td>
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<tr>
<td>SMEA</td>
<td>Standard Metropolitan Employment Area (Japan)</td>
</tr>
<tr>
<td>SMSA</td>
<td>Standard Metropolitan Statistical Area (U.S.)</td>
</tr>
<tr>
<td>SSEL</td>
<td>Standard Statistical Establishment List (U.S.)</td>
</tr>
<tr>
<td>ZE</td>
<td>Zones d’Emploi (France)</td>
</tr>
<tr>
<td>2SLS</td>
<td>Two stage least squares</td>
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