Agglomeration Externalities and Growth in Urban Industries

- empirical evidence from Sweden, 1896-1910

Abstract

What are the effects of regional specialization, industrial diversity, and local competition on industrial growth? Utilizing a novel dataset on the Swedish manufacturing industry, 1896-1910, an OLS model is estimated that captures the relationship between dynamic agglomeration externalities, i.e. knowledge spillovers, and employment growth in industries located in cities. The main results are that on a high level of industrial aggregation, specialization is associated with lower successive employment growth in urban industries, while diversity and competition encourages employment growth. On a lower level of aggregation, specialization *and* diversity decreases employment growth in urban industries, while the effects of competition remain positive. A plausible interpretation is that while inter-industrial externalities were important between broadly defined industries, disaggregated industries benefited from proximity to other dissimilar *dominant* industries. Thus, there is little support for the notion of Marshall (1890), Arrow (1962), and Romer (1986), that intra-industrial externalities are an important determinant of growth, while there is support, although somewhat inconclusive, for the notion of Jacobs (1969) that diversity and competition encourages industrial growth.

Keywords: Industrialization, externalities, endogenous growth theory, MAR, Jacobs, OLS

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1 Introduction

A striking feature of the spatial distribution of economic activity is a high degree of concentration[1]. Essentially it is a phenomenon of Mandelbrotian nature - i.e. it is observable irrespective of the level of scale; agglomeration is evident at the national, regional, as well as the urban level. An intuitive explanation of this concentration is that strategic cost advantages produced by factor endowments, economies of scale, and transportation costs determine the localization of industries (for early inquiries into the causes of industrial agglomeration see von Thünen 1826 and Marshall 1890). While these factors to a large extent can explain the location and long run average productivity level of an industry (see for example Kim 1995; Róses 2003), they cannot explain spatial differences in long run growth trajectories, across that same industry. According to endogenous growth theory, one explanation of differentials in long run growth rates is the existence of externalities, associated with the accumulation of knowledge (Romer 1986; Lucas 1988; Arrow 1962). As geographic proximity and density ought to encourage knowledge spillovers, the relationship between agglomeration and knowledge externalities is a compelling research area. As cities ensure repeated and frequent interactions between economic agents, they foster an environment in which knowledge spillovers should be a particularly important phenomenon. Some authors (the most influential contribution is Marshall 1890) have emphasized that knowledge externalities are most prevalent in regionally specialized industries, while others (most prominently, Jacobs 1969) have stressed the importance of industrial, or urban, diversity as a factor that fosters industrial growth. The main objective of this thesis is to examine the relationship between knowledge externalities and the growth rates of urban industries, in the context of the Swedish industrialization process.

The late 19th and early 20th century was a period of rapid economic transformation in Western Europe, characterized by accelerating industrial growth, migration, and urbanization. The trajectory of Sweden's development is especially interesting, as the country - initially backward - experienced rapid economic growth during the latter half of the 19th century, forging ahead and outgrowing both the early European industrializers and the U.S. during the decades around the turn of the 20th century[2]. The *First Industrial Revolution* gained ground in Sweden around the middle of the 19th century with industrial growth primarily concentrated in the wood, iron and steel industries[3]. The spatial distribution of economic activity in the early 19th century were to a large extent determined by the location of natural resources, as production generally were highly resource dependent, both in terms of energy supply - primarily water and wood - and as inputs in production. Industrial production was thus naturally regionally dispersed, as industries located near factors that were intensive in their production, similar to the patterns in other industrializing countries (see for example Bairoch 1988; Crafts and Mulatu 2006). At the end of the 19th century, the underlying constitution of the Swedish economy was exposed to a pervasive, transformational pressure as the center of gravity shifted from the earlier growth industries toward growth concentrated around sophisticated mechanical engineering and electrical motors. The more traditional and heavily natural-resource dependent industries gradually lost ground. To some extent, this was a story of catching up. But innovative firms such as Ericsson, ASEA, Separator, and SKF (which were all founded during this period) forged ahead – taking several Swedish industries to the technological

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[1] For example, in 2005, 87 percent of the Swedish population worked in cities, which in turn occupied roughly 1 percent of the country's area (SCB 2005).
[2] Between 1890 and 1910 Sweden's GDP per capita grew at 2.4 percent annually; whereas the GDP per capita in the U.S., Great Britain, and continental Europe grew annually at 2.0, 0.9, and 1.4 percent respectively, during the same period (Schön 2000, p.223).
[3] The rest of this section builds, where not otherwise stated, exclusively on Schön (2000).

frontier. In addition to the structural change in the composition of industrial production, declining transport costs, resulting from the expansion of the railroads from 1850s and onwards, loosened the localizational constraints on industries[4]. Further, innovations in the field of generation and transmittance of electricity shifted the fundamental advantage of industrial localization in the countryside in favor of localization in urban areas[5]. As the constraints on industrial location were loosened, one would expect the period to be characterized by reallocation of economic activity across regions. Enflo et al. (2010) indeed argues that the period 1855-1910 was an especially turbulent period in the Swedish regional system, as the early stages of industrialization was characterized by spatial redistribution of production.

Although Sweden was - in a European comparison - a relatively rural country at the inception of industrialization (Bairoch 1988), the number of cities[6] increased from three in 1800, to five in 1850, to twenty-six in 1910. While these cities accounted for roughly 4 percent of the population in 1800, they accounted for roughly 20 percent of the population in 1910 (SCB 2005). Regarding the manufacturing industry, the absolute importance of cities[7] is even more striking; in 1896, roughly 41 percent of all workers in the manufacturing industry worked in cities, contributing roughly 48 percent of the gross value of output in that sector (Statistics Sweden BISOS-D, 1896). The increasingly intensive process of urbanization was an evident feature of economic development, primarily during the latter half of the 19th century. Between 1890 and 1910 the average annualized urban population growth accelerated to 2.2 percent, while the rural population only increased 0.4 percent annually; between 1880 and 1900 the fifteen fastest growing cities accounted for more than half of the total population growth. The second largest city in 1910, Malmo, with a population of 85 000 had, become the second most important industrial center, both in textiles and iron and steel. In the early 19th century, the city was only the tenth largest, with a population of around 4 000. Similarly, the three cities in which the manufacture of matches developed during the 19th century, accounted for a population of 6 000 in 1800 and 46 000 in 1910. Only two of these cities had existed in 1800. (Bairoch 1988, p.263f) The urban growth was important since it provided significant demand *and* supply side effects. On the demand side, the primary effect were that urbanization created new markets for industrial products, partly because of the higher urban wages, but also as it increased the scope for product standardization - i.e. mass production. Urbanization also facilitated an increasing integration of regional as well as international markets, leading to declining transaction costs while further advancing the division of labor. A secondary effect on the demand side was the increased demand for labor within the construction sector, as the cities themselves expanded. But presumably most important; on the supply side, urbanization resulted in a concentration of knowledge and infrastructure, as entrepreneurs, financiers, and skilled and specialized labor were drawn to the urban areas. While it is hard to disentangle the causal effects between industrialization and urbanization, the rise of cities, during the *Second Industrial Revolution,* arguably constituted a precondition for the successful transformation of the Swedish economy at the dawn of the 20th century.

Although cities in the 19th century were marred by negative externalities such as pollution, and suffered from congestion, through density they provided an important prerequisite for the effective diffusion of knowledge and innovations. Even though the process of urbanization entails centripetal as well as centrifugal forces, if these positive externalities did not outweigh the negative

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[4] Kim (2006, p.471) similarly argues, regarding the U.S., that "…between 1860 and 1914, changes in technology and the rapid decline in transportation cost with the introduction of the railroads, unleashed Marshallian agglomeration economies which led industries to locate in cities."

[5] Hunter (1985) and Rosenberg and Tratjtenberg (2004) explain the relocation of factories to urban areas, with the introduction of the steam engine in the U.S. along the same lines.

[6] The definition is an urban area with a population that exceeds ten thousand (SCB 2005).

[7] This is based on Statistics Sweden BISOS-D, 1896, where a city is defined as an urban area that exceeds a population of two hundred.

externalities in the long run, it becomes hard to understand the almost unabated urban growth that have been an evident feature of economic development throughout the 20th century. To lend the words of Glaeser et al. (1992, p.1127): "…without an opportunity to learn from others and thus improve one's own productivity, there would be little reason for people to pay high rents just to work in a city". To summarize, the period 1890-1930 saw the breakthrough of industrialism in Sweden; the early decades of this period are thus naturally compelling in an economic historical perspective since they provided the dynamics that substantiated a century of almost unabated economic growth. As the period was characterized by intensive urbanization and urban growth, the city becomes a natural point of departure in the further analysis.

While the relationship between agglomeration externalities - stemming from specialization, diversity, and competition - and industrial growth has been prominently featured in the empirical literature (for an overview see Rosenthal and Strange 2002); the studies have solely been based on modern data[8]. Due to lack of readily available firm- or industry-level data, little empirical research has been conducted regarding the 19th century, in the context of industrialization. This thesis differs along two dimensions in relation to the earlier literature. First, the empirical relationship between dynamic agglomeration externalities and growth has, to the best of the author's knowledge, not explicitly been treated in the context of industrialization before. Second, earlier studies have primarily estimated the relationship on *one* level of industrial aggregation; in this thesis *two* levels of industrial aggregation are utilized, to examine whether the influence of externalities differ at different levels of aggregation (as concluded by De Groot et al. 2007). Thus, utilizing a novel dataset on the Swedish manufacturing industry 1896-1910, growth in urban industries will be regressed on the degree of industrial specialization, diversity, and competition controlling for a range of other factors, by estimation of an log-linearized ordinary least squares model. It is explicitly asked whether the degree of industrial specialization, diversity, and competition were important determinants of growth in Swedish urban industries between 1896-1910. Further, by estimating the model at two levels of industrial aggregation, eventual differences in the influence of externalities at different levels of aggregation can be highlighted. Hopefully this thesis can contribute to a better understanding of the underlying dynamics of industrial growth in the context of industrialization, while simultaneously expanding on the understanding of the factors underlying urban growth in the late 19th century. In addition it serves as an empirical examination of the theories of Marshall (1890), Arrow (1962), Romer (1986), and Jacobs (1969).

The main results can briefly be summarized as follows: On a high level of industrial aggregation, specialization is associated with lower successive employment growth in urban industries, while diversity and competition encourages employment growth. Using a lower level of aggregation, specialization *and* diversity decreases employment growth in urban industries, while the effects of competition remain positive. A plausible interpretation is that firms benefited from proximity to *dissimilar* large industries, which can be interpreted as a diversity effect, even though this would imply that the city as a whole became more specialized. Thus, there is little support for the notion that intra-industrial externalities was an important determinant of growth, while there is, although somewhat inconclusive, support for the notion that diversity and competition encouraged growth in Swedish urban industries between 1896-1910.

The rest of the thesis is organized as follows. In section two the theoretical framework is developed, and the existing literature is briefly reviewed. Further, a theoretical model that will guide

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[8] Kim (2006) examines the relationship between urban agglomeration externalites and industrial location in cities, but does not explicitly link it to a growth framework.

the empirical specification is derived. In section three, the data is described and two samples are constructed. Section four deals with the specification of the relevant variables and estimation of the econometric model. In section five the results are discussed, and some concluding remarks are made.

2 Theoretical Framework

In section 2.1 the existing literature is briefly reviewed, in section 2.2 the main theories of dynamic agglomeration externalities are described and summarized. The concluding section deals with the derivation of a theoretical model that will serve as a point of departure when formalizing the empirical model in section 4.1.

2.1 Literature Review

In the literature on the spatial dimension of economic activity one can distinguish primarily two approaches; one explains why economic activity tends to concentrate in space and the other relates agglomeration externalities to localized or regional growth.

In the first strand of the literature, Duranton and Puga (2004) provide a summary of the micro-foundations of the models of city formation. They categorize the models into three categories: matching, sharing, and learning; broadly coinciding with Marshall's (1890) seminal insights regarding industrial localization. Industrial agglomerations arise (and cities thus implicitly forms) as agglomeration decreases labor matching costs, decreases transportation (and transaction) costs with regard to input and output markets while also decreasing the cost of providing public goods, and because it additionally increases the potential for knowledge spillovers. Similarly, Krugman (1991) in his influential paper demonstrates how spatial concentration occurs under different levels of transport costs and internal scale economies. In theory, industries thus would tend to concentrate geographically as agglomeration provides potential productivity gains. Regarding the U.S., Ciccone and Hall (1996) indeed found a positive relationship between the density of regional employment, and labor productivity; their results were corroborated by Braunerhjelm and Borgman (2004a) utilizing data for Sweden. While these theories can explain the formation of cities, and spatial distribution of employment across industries, differences in long run city growth can hardly be explained without explicitly incorporating some type of dynamic externality (Glaeser et al. 1992, p.1129f). Endogenous growth theories have stressed the role of knowledge[9], and especially knowledge externalities, as the engine of economic growth (Romer 1986; 1990; Lucas 1988). Knowledge is treated as an input in the production function, which has increasing marginal productivity. Thus, differences in the growth rate of knowledge can explain divergences in regional long run growth trajectories; since significant knowledge spillovers are associated with the production of knowledge, regional divergences in growth rates are probable.

The second strand in the literature on the spatial dimension of economic activity examines the relationship between externalities and growth (for an overview, see Rosenthal and Strange 2002). The seminal contribution of Glaeser et al. (1992) explicitly links the endogenous growth framework to that of dynamic agglomeration externalities. They regress employment and wage growth on variables that proxy three potential sources of externalities: specialization, diversity, and competition. Utilizing data on the six largest industries in 170 US cities between 1956-1987, they found that industrial diversity and local competition, but not specialization, encouraged employment growth in industries. De Groot et al. (2007) provide a meta-analysis of over thirty articles, containing almost four hundred empirical estimations, that have applied variations of the methodology utilized in Glaeser et al. (1992). While the observed outcomes are dependent on methodological choices, they conclude that diversity and competition encourages industrial growth, while the evidence of the effects of specialization is less clear-cut. Although the results are

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[9] Knowledge and technology is used interchangeably in this context.

somewhat inconclusive, to summarize the available literature, there is ample evidence that externalities foster both agglomeration and growth (Keilbach 1998).

2.2 Theories of Dynamic Agglomeration Externalities

An agglomeration externality can broadly be defined as the costs or benefits that that a firm derives from geographical proximity to other economic actors, without proper monetary compensation. A distinction can be made between two types of externalities that arises from agglomeration: localization and urbanization externalities. The former consists of externalities arising from the spatial concentration of an industry, while the latter consists of externalities arising from the urban environment itself. The externalities considered in this thesis are dynamic (localization) externalities, or knowledge spillovers, i.e. they affect the long run growth rates of industries, and thus implicitly cities. There are two main theories regarding externalities arising from localization, that differ along two important dimensions: MAR[10] and Jacobs externalities[11]; where the former emphasizes industrial specialization and a low degree of local competition, and the latter industrial diversity and a high degree of competition as important factors that induce industrial and urban growth.

MAR externalities arise from geographical proximity of *similar* firms. Marshall (1890) emphasized that that externalities accrue from mainly three sources; labor market pooling, proximity to input and output markets, and knowledge spillovers. In a specialized industry firms can sustain a specialized and skilled labor force, with low matching costs between firms and employees. As similar firms have a high probability of shared suppliers and customers, specialization within an industry decreases the volatility of both demand and supply, while additionally lowering transport and inventory costs for the aggregate industry. While these externalities essentially are static, in that they can explain the level of productivity at a certain point of time, they cannot explain productivity growth in the long run (Rosenthal and Strange 2002). In the MAR framework of intra-industrial specialization three transmission mechanisms exists, for long run growth-enhancing dynamic MAR externalities. First, labor market pooling increases the potential for knowledge diffusion within the industry, as employees internalize firm-specific knowledge, which is transferred through employees migrating between firms. Second, innovations and knowledge are diffused across similar firms through imitation and reverse engineering. Third, knowledge diffuses through increased and repeated interaction between spatially proximate actors within the industry. All these effects ought to be especially important in cities as they ensure a high frequency of interaction. But as intra-industrial specialization increases, so does local competition. In the MAR framework, a firm will decrease the investment share in innovative activities if it cannot internalize a sufficient share of the externalities arising from their innovations. A higher degree of local competition would thus lower the innovation rate, and the optimal market structure would be a local monopoly, where the innovative firm is able to internalize all externalities (Romer 1990)[12].

Jacobs (1969) argues, in contrast to MAR, that the spatial proximity of *different* industries is the most important factor that facilitates innovation and growth, of an industry. Problems arising in one production process often have their solutions in the processes, or innovations, of other industries, and inter-industrial knowledge spillovers are thus of particular importance. The cross-fertilization of ideas between different industries can give rise to new products, or entirely new industries. One example of highly successful cross-fertilization is the case of the construction of the first (flying)

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[10] An abbrevation for Marshall (1890), Arrow (1962), and Romer (1986).

[11] Porter (1990) externalities are a third type, sometimes explicitly mentioned in the literature. Since Porter's framework overlaps MAR and Jacobs to a large extent, in that he argues that the proximity of similar industries stimulates innovation, knowledge diffusion, and growth (similar to MAR), while he (Porter 1998) argues that a highly competitive local environment increases the degree of innovation (similar to Jacobs). Although the underlying dynamics differ slightly between Porter and MAR/Jacobs, since the theorized outcome is essentially the same, the former will henceforth be grouped with the latter.

[12] The notion that local monopoly induces innovation is evident already in the work of Schumpeter (1942).

aircraft in which the Wright brothers utilized inputs from the bicycle, the combustion engine, and dragon flying (Braunerhjelm and Borgman 2004b). With regard to local competition, Jacobs argue that monopoly is harmful, not only because of non-competitive price setting, but also more importantly since it forestalls experimentation with alternate production processes, services, and technological development.

While the theoretical views are not mutually exclusive, they differ in their placement of the center of gravity. Both theories predict that cities should grow faster than rural areas, because of the larger externalities present in cities, as interactions are more intensive between economic actors. Further, both theories are compelling in that they explain not only city formation, but also more importantly, city growth rates. In Table 1 the theories are summarized with regard to their view on specialization, diversity, and competition. A positive (negative) sign should be interpreted as if the theory predicts that the factor increases (decreases) long run growth through positive (negative) externalities.

Table 1 Summary of the Theories of Dynamic Agglomeration Externalities

	MAR	Jacobs
	Effect on Industrial and Urban Long Run Growth	
Specialization	+	-
Diversity	-	+
Competition	-	+

2.3 Deriving a Theoretical Model

Following Glaeser et. al. (1992) a theoretical model is derived[13] to clarify the theoretical discussion above, and to guide the empirical specification in section 4.1. Assume that the output of a single firm *f* in industry *i*, at time *t*, can be described as a one-factor production function, such as (1):

$$y_{f,t} = A_t f(L_t) \tag{1}$$

Where *A* is the overall level of technology and *L* is the available stock of labor, both at time *t*. *A* at time *t* is assumed to consist of two components as given by (2) - the national level *n* of technology, exogenously given to all firms, and a local component *l*, exogenous to the single firm but endogenous to the firms operating in a specific region, both at time *t*. The technology of a firm located in a specific region thus depends both on the national level of technology, but also the local technology exclusively available to the firms in that region.

$$A_t = A_{n,t} + A_{l,t} \tag{2}$$

If the labor market is assumed to be homogenous and integrated, the firm faces the following profit maximization problem, where *w* is the wage rate in the industry at time *t*:

$$max\, A_t f(L_t) - w_t L_t \tag{3}$$

The firm sets the wage rate equal to the marginal product of labor, according to the first order condition:

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[13] Essentially it is the same model as the one derived in Glaeser et al. (1992), with some clarifying expansions on the microeconomic foundations for non-economics oriented readers.

$$MP_{L_t} = \frac{\partial y_{i,f,t}}{\partial L_t} = A_t f'(L_t) = w_t \tag{4}$$

Rearranging and rewriting (4) as growth rates yields:

$$log\left(\frac{A_{t+t}}{A_t}\right) = log\left(\frac{w_{t+1}}{w_t}\right) - log\left[\frac{f'(L_{t+1})}{f'(L_t)}\right] \tag{5}$$

Similarly, rewriting (2) as growth rates yields:

$$log\left(\frac{A_{t+1}}{A_t}\right) = log\left(\frac{A_{n,t+1}}{A_{n,t}}\right) + log\left(\frac{A_{l,t+1}}{A_{l,t}}\right) \tag{6}$$

Drawing upon the discussion of the theoretical framework of MAR and Jacobs above (as summarized in Table 1), the local component of technology can be described as a function g of geographic specialization, industrial diversity, local competition, and a set of initial conditions:

$$log\left(\frac{A_{l,t+1}}{A_{l,t}}\right) = g\left(\begin{matrix} geographic\ specialization, industrial\ diversity, \\ local\ competition, initial\ conditions \end{matrix}\right) + \varepsilon_{t+1} \tag{7}$$

Assume that the share of labor in the production function is $1 - \alpha$[14], where α is a constant that satisfies $0 < \alpha < 1$, combining (5), (6), and (7) yields:

$$\alpha\ log\left(\frac{L_{t+1}}{L_t}\right) = -log\left(\frac{w_{t+1}}{w_t}\right) + log\left(\frac{A_{n,t+1}}{A_{n,t}}\right) + g + \varepsilon_{t+1} \tag{8}$$

Where g is the function specified in (7). It is assumed that the labor market is fully integrated. Wage growth thus is constant across the industry. Thus the employment growth in an industry essentially depends on technological growth; where the local component is determined by the degree of specialization, diversity, competition, and other initial conditions. Equation (8) will be the point of departure when specifying the econometric model in section 4.

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[14] As: $f(L_t) = L_t^{1-\alpha}$.

3 Data

In section 3.1 the data is described. In section 3.2 the construction of the aggregated and disaggregated sample respectively is described.

3.1 Description of the Data

The main dataset is constructed from a forthcoming database on the Swedish manufacturing industry 1890-2000[15]. It consists of official records from the *Contributions to the Official Statistics of Sweden: Factories and Manufactures* and the *Official Statics of Sweden: Industry[16]*, which contain information on the number of firms, workers, and gross value of output, for each industry, at the city-level. Data is available in five-year intervals over the entire time period, and annually for the period 1896-1910.

Firms are classified according to their main lines of production. Though, if a single firm is involved in production spanning several industries, it is represented once in each industrial class. For example, if a firm is involved both in the spinning and weaving of cotton, it is counted once in the *cotton weaving mills*- and once in the *cotton spinning mills*-industry. This could introduce a positive bias toward industries where a large number of firms had secondary lines of production. Workers, is the average number of workers during the time that the factory have been active, in a given year. In effect the number of employees in seasonally dependent industries thus should be overestimated. This introduces a bias toward industries that employ seasonal labor, since the output per labor unit is underestimated. The gross value of output is measured at final sales prices. Output that is primarily destined as inputs in other industries is counted at final sales prices as well, which in effect means that some double counting exists.

Two levels of industrial aggregation are readily available in the data. At the highest level of aggregation, industries are classified according to the aggregated taxonomy employed by the *Official Statistics of Sweden: Industry 1930*, where the manufacturing industry is classified into nine broad industrial groups (see Table 2). In addition, each industry is also classified according to the original industrial classification system employed when collecting the data. This industrial classification system is considerably more disaggregated than the aggregate classifications in the *Official Statistics of Sweden: Industry 1930* (see Table 3). Both levels of aggregation will be utilized in the empirical analysis.

In Table 2 the aggregated industries, employment, and the gross value of output per worker is presented. In 1896 the Swedish industrial structure were dominated by metal, engineering, mining, and wood industries, which accounted for roughly 44 percent of all employment in the manufacturing industry. All industries experienced rapid growth between 1896 and 1910, with an average growth of roughly 134 percent.

3.2 Construction of the dataset

The main dataset is constructed from cross-sectional data on the manufacturing industry in 1896 and 1910. The choice of time period is mainly motivated by the fact that it broadly coincides with a dynamic period of industrialization and urban growth in Sweden. On a more pragmatic note, the disaggregated industrial classifications are relatively consistent over the period, which is essential as the empirical model is to be estimated on the highest as well as the lowest level of aggregation.

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[15] Constructed within a research project led by Kerstin Enflo, at the Department of Economic History and Martin Henning at the Department of Human Geography, both at Lund University.
[16] The Swedish acronyms - BISOS-D and SOS – are used as references throughout the rest of the thesis.

Because of the inherent problem in appropriate deflation of the gross value of output, the only variables utilized are workers and the number of firms. Thus, a cross-sectional dataset is constructed from the data on the number of firms and workers in the manufacturing industry in 1896 and 1910.

Since the data is spatial, an appropriate regional unit of analysis must be chosen. Traditionally, regional units are either defined based on the homogeneity principle (i.e. similarity with regard to certain characteristics across regions) or the functional integration principle (i.e. variations of a core-periphery model). As noted by Kim (1995), the regional unit of analysis depends on the theoretical framework one adopts. As the theoretical framework is that of localization externalities, the

Table 2 Employment and Output in Aggregated Industries, Sweden, 1896

Industry	Number of Factories	Number of Workers	Share of Total Workers (%)	Employment Growth 1896-1910 (%)	Gross Value of Output per Worker
Metal, Engineering, and Mining Industries	1284	40009	19.8	61.3	31.2
Quarrying and Manufacturing of Stone, Clay and Glass Products	1034	29386	14.5	61.8	28.4
Wood Industries	1449	49090	24.3	35.1	33.9
Manufacture of Pulp, Paper, Paper Products & Printing and Allied Industries	365	10882	5.4	75.8	29.8
Food Manufacturing Industries	2668	25136	12.4	33.8	9.4
Manufacture of Textiles	785	30896	15.3	39.5	39.4
Leather, Hair, and Rubber Industries	664	5874	2.9	113.3	8.8
Manufacture of Chemicals and Chemical Products	516	10794	5.3	29.7	20.9
Electricity, Gas, and Water Services	31	164	0.1	753.0	5.3
Total	8796	202231	Average	133.7	23.0

Source: Statistics Sweden BISOS-D, 1896, 1910. Author's calculations. Gross value of output per worker is measured in thousands 1896 SEK.

regional unit of analysis should be defined such that externalities are likely within the regional unit, but less so across units, to minimize the influence of spatial autocorrelation. The chosen regional unit of analysis is cities, as they are defined in the data. Cities are an especially interesting unit of analysis, as they ensure a high degree of interaction between economic agents it is an environment in which externalities should be a particularly important phenomenon. Spatial autocorrelation ought to be a minor issue, as Swedish cities were relatively dispersed throughout the country.

In their meta-analysis, De Groot et al. (2007, p.19) found indications that the level of aggregation affects the observed outcomes, as different agglomeration forces are operational at different levels of aggregation. Because it is hard to theorize ex ante which types of externalities could be important

at different levels of aggregation, the model will be estimated both for aggregated and disaggregated urban industries[17], to control for different transmission mechanisms. Therefore, two samples will be constructed; one consisting of aggregated urban industries, and one consisting of disaggregated urban industries. In the following section, the construction of each sample is described in detail.

Aggregated Sample

The aggregated sample is constructed utilizing cross-sectional data on the number of workers and number of firms in each aggregated urban industry respectively, in 1896 and 1910. It contains all 99 cities[18], which had employment in one, or several, aggregated industries in 1896. By construction, all urban industries that were missing data on employment in either 1896 or 1910 were excluded from the sample. The urban industries are categorized according to the aggregated industrial classification presented in Table 2 (*Manufacture of Textiles, Wood industries,* and so forth). The sample consists of 499 aggregated urban industries, spanning from the very small (one employee in the food manufacturing industry in Vimmerby) to the very large (over eight thousand employees in the metal, engineering, and mining industry in Stockholm). These 499 urban industries accounted for roughly 42 percent of the employment in the manufacturing industry in 1896.

In Table 3 the six largest aggregated urban industries in the sample are presented. Stockholm dominates as expected, with three out of the six largest urban industries in the sample. Although these are large, presumably mature industries, which had an average employment growth of roughly 31 percent between 1896-1910, only the metal, engineering, and mining industries in Eskilstuna grew faster than the national average.

Table 3 Six Largest Urban Industries in the Aggregated Sample

City	Industry	Employment 1896	
Stockholm	Metal, Engineering, and Mining Industries	8313	24.0
Norrkoping	Manufacture of Textiles	5514	3.4
Stockholm	Food Manufacturing Industries	4147	22.2
Gothenburg	Manufacture of Textiles	3459	-0.3
Eskilstuna	Metal, Engineering, and Mining Industries	2602	74.6
Stockholm	Manufacture of Pulp, Paper, Paper Products & Printing and Allied Industries	2530	62.7

Source: Statistics Sweden BISOS-D, 1896, 1910. Author's calculations.

Disaggregated Sample

In addition to the highly aggregated sample, an additional sample is created using the more disaggregated industrial classification originally employed when collecting the data. It was created as follows[19]: The ten largest cities, with regard to employment in the manufacturing industry, at the beginning of the period (1896) were selected (see Table 5). Using employment as the selection-criteria is consistent with the theoretical framework – if externalities are a source of long run growth they should be evident in the largest cities. The six largest industries in each respective city were then selected. The disaggregated sample thus contains sixty urban industries that are consistent over the entire time period. These sixty urban industries accounted for roughly 17 percent of the employment in the manufacturing industry in 1896.

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[17] An urban industry is simply defined as an industry that is located in a city.
[18] Nine cities that had employed in the manufacturing industry in 1896 lacked employment in 1910, and were thus excluded from the sample.
[19] The construction of the disaggregated sample largely follows the methodology of Glaeser et al. (1992)

In Table 4 the most common industries in the disaggregated sample are presented. Throughout the disaggregated sample the mechanical workshops dominate, as they are represented in seven out of ten cities. Of the six most common, and by construction large, disaggregated industries only one saw decreasing employment, which corroborates the notion that the period was characterized of broad industrial expansion. Book printing, mechanical workshops, and foundries all saw rapid growth, with an average employment growth between 1896-1910 of 54 percent.

In Table 5 the ten largest cities with their six respective largest disaggregated urban industries in 1896 are presented, along with employment data for each city respectively. It largely corroborates the prevailing understanding of the industrial distribution in Sweden at this time (see Schön, 2000). In Boras and Norrkoping the industrial sector was dominated by the textile industry, while Eskilstuna were dominated by the metal and engineering industries. Cities such as Gavle, Malmo, and Stockholm were considerably diversified. All cities but one (Halmstad) saw large increasing employment in the manufacturing industry between 1896-1910, with an average growth of 41 percent during the period.

Table 4 Most Common Urban Industries in the Disaggregated Sample

Industry	Frequency in sample	Employment Growth 1896-1910 (%)
Mechanical Workshops	7	36.8
Book Printing	6	47.6
Brewing of Malt Beverages	6	9.2
Manufacture of Iron and Steel Goods, and Foundries	5	77.7
Tobacco Factories	4	20.4
Cotton Weaving Factories	4	-2.6
Wool Weaving Factories	4	-10.3

Source: Statistics Sweden BISOS-D, 1896, 1910. Author's calculations.

A Note on Wages

Data on regional agricultural wages in 1896 were obtained from the Lund University Macroeconomic and Demographic Database that in turn are based on the data available in Jörberg (1972). The day wage data is based on market scales, that were (monthly) representations of market prices used to translate tax payments paid in kind into monetary values. Wage data were unavailable for one county (Blekinge), for which an approximation of the wage-level using the un-weighted average of the wage levels in adjacent counties was used.

Table 5 Selected Cities and Urban Industries, in the Disaggregated Sample

City	Number of Workers in the City 1896	Employment Growth in the City 1896-1910 (%)	Six Largest Disaggregated Industries
Boras	2436	93.7	Cotton Weaving Mills Wool Spinning Mills Wool Weaving Mills Bleacheries, and Dye and Appretation Works Tricot and Sock Factories Mechanical Workshops
Eskilstuna	2961	77.8	Manufacture of Iron and Steel Goods, and Foundries Mechanical Workshops Manufacture of Non Specified Metal Products Brewing of Malt Beverages Galvanization and Etching Factories Book Printing Works
Gavle	2451	43.7	Cotton Weaving Mills Mechanical Workshops Manufacture of Iron and Steel Goods, and Foundries Wool Weaving Mills Sawing and Planing Mills Brewing of Malt Beverages
Gothenburg	8363	63.6	Sewing Factories Brewing of Malt Beverages Cotton Weaving Factories Tobacco Factories Cotton Spinning Mills Book Printing Works
Halmstad	1825	-36.5	Stone Masonries and Grinderies Book Printing Works Brewing of Malt Beverages Tanneries Carpentry and Furniture Factories Mineral Water and Soft Drink Factories
Helsingborg	2204	46.6	Mechanical Workshops Glove Factories Flour and Grain Mills Tobacco Factories Shoe Factories Book Printing Works
Jonkoping	3123	37.2	Manufacture of Matches Carpentry and Furniture Factories Mechanical Workshops Manufacture of Iron and Steel Goods, and Foundries Manufacture of Non Specified Metal Products Book Printing Works
Malmo	6928	49.0	Wool Weaving Mills Tobacco Factories Mechanical Workshops Cotton Spinning Mills Manufacture of Iron and Steel Goods, and Foundries Chocolate Factories
Norrkoping	7637	12.3	Wool Weaving Mills Cotton Weaving Mills Lithographical, Chemical, and Graphical Est. Carpentry and Furniture Factories Tricot and Sock Factories Brewing of Malt Beverages
Stockholm	21413	34.6	Mechanical Workshops Book Printing Works Brewing of Malt Beverages Shipyards, Docks, and Construction of Boats Tobacco Factories Manufacture of Iron and Steel Goods, and Foundries
Tot.	59341	Avg. 42.2	

Source: Statistics Sweden BISOS-D, 1896, 1910. Author's calculations.

4 Empirical framework

In section 4.1 the dependent variable and all regressors are defined. The econometric model is specified, and estimated for the aggregated and disaggregated sample respectively in section 4.2 and 4.3. The results of the estimations are discussed, and concluding remarks are made in section 5.

4.1 Definitions of variables

Equation (8) from section 2.3 is restated, as it will loosely be the point of departure when formalizing the empirical model:

$$\alpha \, log\left(\frac{L_{t+1}}{L_t}\right) = - \, log\left(\frac{w_{t+1}}{w_t}\right) + log\left(\frac{A_{n,t+1}}{A_{n,t}}\right) + g + \varepsilon_{t+1} \tag{8}$$

As wage growth is assumed to be a constant across the industry since it is assumed that workers participate in an integrated national labor market, labor growth in industry i is thus determined by the national level of technology, and a function g capturing the local technology. The latter is specified as a function of specialization, diversity, competition, and a set of initial conditions in industry i.

Employment Growth

Urban industry growth can primarily be measured in two ways, either as the productivity growth or as the employment growth in an urban industry. The former requires data on value added and effective labor hours in each urban industry, which is not readily available. Thus, following Glaeser et al. (1992), urban industry growth will be measured as employment growth in that industry. The log of urban industry employment growth (EG) will be calculated for each urban industry for the time period 1896-1910, as:

$$EG_{i,j} = log\left[\frac{e_{i,j,1910}}{e_{i,j,1896}}\right]$$

Where EG is employment growth, and e is employment, in industry i in city j. The temporal dimension of employment growth – fixed factors, such as the level of capital previously installed, which affects how firms value marginal workers – could introduce biases. But since it is aggregates of urban industry employment that is measured, over a long time frame, these biases ought to be minimized since the number of fixed factors should be few (see Rosenthal and Strange 2002).

Specialization

To address the theories of MAR, a measure of industrial specialization must be introduced. The Location Quotient (LQ) is a traditional measure of the degree of regional specialization (see for example Kim 1995)[20]. The LQ is defined as:

$$LQ_{i,j} = \frac{e_{i,j}/\sum_j e_{i,j}}{\sum_r e_{i,r} / \sum_r \sum_i e_{i,r}}$$

Where e is the share of employment in industry i in city j. Thus, the numerator measures the share of employment in industry i in city j with respect to the total employment in city j, and the denominator measures the share of total employment in industry i with respect to the total employment in all industries in all regions r in the country. LQ measures the regional deviation

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[20] Henderson (2003) argues that a better measure of the potential MAR externalities are the number of firms in a region. But since growth depends positively on specialization but negatively on the level of local competition according to MAR, it is hard to disentangle which effect – specialization or competition – the variable captures. Since both specialization and competition is to be estimated in the same regression, LQ seems to be a sensible measure of specialization.

from an even distribution of employment throughout the country, in a given industry. A value above unity should be interpreted as specialization in industry i, as the share of that industry's employment in city j is higher than the share of industry i in national employment. According to MAR, urban industry growth should be an increasing function of LQ.

Diversity

To address the theory of Jacobs, a measure of industrial diversity must be defined. Following Glaeser et al. (1992) industrial diversity is measured as the share of employment in the five largest industries outside the urban industry[21]. To attain a more intuitive interpretation of the coefficient estimate, the variable will be defined as the inverse of the measure used in Glaeser et al. (1992), as:

$$DIV_{i,j} = \frac{1}{\text{Share of employment in the five largest industries outside the urban industry } i}$$

Where DIV is diversity *outside* industry i in city j. As this measure is not very informative in the aggregated sample, since it consists of only nine industrial classes, and the average city only had employment in five aggregated urban industries, industrial diversity in the aggregated sample will be measured with a common entropy index. An entropy index[22] measures the evenness in the distribution of employment across a given set of industries, and is calculated as:

$$E_j = g(s_i, \dots, s_n) = \sum_{i=1}^{n} -s_i \log[s_i]$$

Where: $\sum_{i=1}^{n} s_i = 1$

Where E is diversity in city j, which is a function of the employment share s in each industry i. The lower bound of E is zero, if employment is concentrated in one industry, and the upper bound is given by $\log(n)$[23], if employment is evenly distributed across all industries. Note that while the measure of diversity (DIV) in the disaggregated sample essentially is a proxy for diversity *outside* the urban industry, the measure employed in the aggregated sample (E) thus measures diversity in the *city*. According to Jacobs, urban industry growth should be an increasing function of both DIV and E.

Competition

The degree of local competition in urban industry i, in city j is following Glaeser et al. (1992) calculated as:

$$COMP_{i,j} = \frac{F_{i,j}/e_{i,j}}{F_{i,N}/e_{i,N}}$$

Where the numerator is a measure of the number of firms F in industry i in city j with respect to the employment e in that urban industry, and the denominator is the number of firms on the national level in industry i with respect to the total employment in that industry on the national level. A value of COMP above unity should be interpreted as a high degree of local competition, as the number of firms per employee is above the national average for that industry[24]. According to MAR, urban industry growth should be a decreasing function of COMP, while the relationship according to Jacobs should be positive.

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[21] Note that this measure essentially measures *nondiversity*, as diversity decreases as the employment share of the five largest urban industries increases.

[22] The index utilized is a *Shannon index*, sometimes referred to as a *Shannon-Wiener* or *Shannon-Weaver index*.

[23] In the aggregated sample the range of E thus becomes 0-0.95.

[24] Another interpretation is that the firms in city j is smaller than the national average for industry i.

Control Variables

To control for factors influencing urban industry growth other than the three main regressors, aggregate employment growth, initial employment, and regional wage differentials are included in the specification.

The principal determinant of employment growth in an industry is shifts in the aggregate demand for that industry´s output. Thus, to control for shifts in aggregate demand, the log of aggregate employment growth between 1896-1910 in each urban industry is included in the specification, which is calculated as:

$$AEG_i = log\left[\frac{e_{i,1910}}{e_{i,1896}}\right]$$

Where AEG is aggregate employment growth and e is employment, in industry i. Controlling for the aggregate employment growth ought to be especially important, since the time period at hand was characterized by broad industrial growth. The expected coefficient sign for this variable is positive; a coefficient above one indicates that employment in the sampled cities grew faster than that same industry in the country, when aggregate demand increased.

Ideally, the wage in each urban industry should be included in the specification. Since no such data is readily available for the manufacturing industry, the ratio of the initial wage level (W) in each region with respect to the national average wage is included in the specification, to control for wage differentials between cities. In line with neoclassical assumptions, it is fair to assume that firms have a preference for low-wage areas, while workers migrate to high-wage areas. Employment growth in an industry should thus, ceteris paribus, correlate with the wage level. Since data is only readily available for the agricultural sector, at the county-level, a variable that measures a county's agricultural wage level with respect to the average national wage is constructed, to control for wage differentials. De Groot et al. (2007, p.20) conclude that the inclusion of initial wages has had a limited effect on the variation in observed outcomes in the empirical literature. Although the W variable should be viewed as a weak proxy for differences in industrial wages, it is included in the specification as a second-best control variable for regional wage differentials in the manufacturing industry.

Further, to control for initial employment levels (IE), initial employment in thousands, in each urban industry is included in the specification. Ideally, employment growth should be regressed on variables capturing agglomeration externalities from 1896 and onwards. In effect, IE controls for past agglomeration externalities that have shaped the current distribution of employment. It is assumed that industries with high initial employment will have lower successive employment growth.

4.2 Specification of the Econometric Model

Drawing upon the discussion of the variables above, the log-linearized ordinary least squares models are thus specified as follows:

$$EG_{i,j,,1896-1910} = \alpha + \beta_1 LQ_{i,j,1896} + \beta_2 COMP_{i,j,1896} + \beta_3 E_{j,1896} + \beta_4 AEG_{i,1896-1910} + \beta_5 IE_{i,j,1896} + \beta_6 W_{j1896} + \varepsilon_i \quad (9)$$

$$EG_{i,j,,1896-1910} = \alpha + \beta_1 LQ_{i,j,1896} + \beta_2 COMP_{i,j,1896} + \beta_3 DIV_{i,j,1896} + \beta_4 AEG_{i,1896-1910} + \beta_5 IE_{i,j,1896} \quad (10)$$
$$+\beta_6 W_{j1896} + \varepsilon_i$$

Where (9) is estimated for the aggregated sample and (10) is estimated for the disaggregated sample.

4.3 Results, Aggregated Sample

In estimating equation (9), the log of employment growth in for instance the manufacture of textiles-industry in Stockholm, between 1896-1910, is regressed on the degree of specialization and competition in that industry and the diversity in Stockholm, in 1896; while controlling for the log of employment growth in manufacturing of textiles outside Stockholm, initial regional wage differentials, and initial employment in the urban industry. In one estimation, industry-specific effects will be controlled for through the inclusion of dummies for each industry. The cross-sectional data from all 499 aggregated urban industries are pooled in the estimations. Briefly, the results support Jacobs theory that diversity and competition encourages employment growth in urban industries, while they reject the conclusions of MAR.

Table 6 summarizes the descriptive statistics for the dependent variable and all regressors. The aggregated urban industries included in the sample were relatively specialized in 1896, as given by the mean of the LQ (2.7), although the degree of specialization was relatively dispersed. The maximum value (79.6) is a probable outlier as it represents the electricity, gas, and water services-industry in Sater. As the aggregated employment in this industry only constituted 0.1 percent of the total employment in the manufacturing sector in 1896, the values of the LQ are blown up as the denominator approaches zero. Cities were relatively diversified, both completely specialized (such as Umea) and almost perfectly diverse cities (such as Linkoping) are included in the sample. Aggregated urban industries were generally more competitive than the national average, which could be interpreted as if urban areas in general were more competitive than the countryside.

Table 6 General Descriptive Statistics (Aggregated Sample)

	EG	LQ	E	COMP	AEG	IE	W
Mean	0.21	2.71	0.55	2.91	0.22	0.17	0.97
Standard Deviation	0.41	5.92	0.18	3.73	0.15	0.59	0.21
Minimum	-1.05	0.01	0.00	0.02	0.11	0.001	0.64
Maximum	2.26	79.56	0.86	41.84	0.93	8.31	1.92
N	499	499	99	499	9	499	23

Note: Variables are defined in section 4.1.

In Table 7 the results of the estimations of the aggregated sample are presented. The estimation of equation (1) suggests that employment growth decreases as the degree of specialization increases. The result is highly significant; raising the employment share of an urban industry relative the national average with one standard deviation (5,92) decreases the cumulative employment growth over fourteen years in an urban industry with roughly 6 percent. Specialized urban industries thus grew slower, contrary to the predictions of MAR. In estimation (2) diversity is positively, and significantly, associated with higher employment growth in urban industries, thus lending support to Jacobs's notion that diversity induces growth. Though, the qualitative effect is rather small; raising the measure of diversity with one standard deviation (0,18) increases the cumulative employment growth over fourteen years with 3,4 percent. With regard to competition, it is associated with significantly higher employment growth in both (3) and (4); increasing the degree of local competition with one standard deviation (3,73) increases employment growth roughly 11 percent, consistent with Jacobs's theories, but contrary to MAR. All coefficient estimates remain statistically significant when estimated in the same equation in (4), which suggests that the specification is rather robust.

Table 7 *Employment Growth in Aggregated Urban Industries, 1896-1910*

Dependent Variable	Employment Growth (Log[Employment in aggregated urban industry 1910/Employment in aggregated urban industry 1896])				
	(1)	(2)	(3)	(4)	(5)
Constant	0.335***	0.245**	0.210**	0.088	…
	(0.088)	(0.107)	(0.088)	(0.106)	
Specialization	-0.011***	…	…	-0.007**	-0.008**
(LQ)	(0.003)			(0.003)	(0.003)
Diversity	…	0.186*	…	0.180*	0.188*
(E)		(0.101)		(0.096)	(0.099)
Competition	…	…	0.031***	0.030***	0.029***
(COMP)			(0.005)	(0.005)	(0.005)
National Employment	0.311**	0.132	0.223*	0.349***	…
Growth in the Industry	(0.131)	(0.118)	(0.115)	(0.127)	
(AEG)					
Initial Employment in	-0.043	-0.054*	-0.014	-0.017	-0.031
the Urban Industry	(0.031)	(0.031)	(0.030)	(0.030)	(0.031)
(IE)					
Regional Wage	-0.160*	-0.159*	-0.137*	-0.120	-0.116
Differentials	(0.086)	(0.086)	(0.083)	(0.083)	(0.082)
(W)					
Aggregate Industry Dummies					
Metal, Engineering, and	…	…	…	…	0.234**
Mining Industries					(0.112)
Quarrying and	…	…	…	…	0.086
Manufacturing					(0.119)
of Stone, Clay, and Glass					
Products					
Wood Industries	…	…	…	…	0.175
					(0.113)
Manufacture of Pulp,	…	…	…	…	0.106
Paper,					(0.114)
Paper Products &					
Printing					
and Allied Industries					
Food Manufacturing	…	…	…	…	0.166
Industries					(0.108)
Manufacture of Textiles	…	…	…	…	0.185
					(0.122)
Leather, Hair, and	…	…	…	…	0.093
Rubber Industries					(0.113)
Manufacture of	…	…	…	…	0.128
Chemicals					(0.130)
and Chemical Products					
Electricity, Gas, and	…	…	…	…	0.537***
Water Services					(0.152)
F statistic	4.284***	2.735**	12.200***	9.931***	16.489***
Adjusted R²	0.026	0.014	0.083	0.097	0.302
N	499	499	499	499	499

Note: ***, **, * means significant at the 1-, 5-, and 10 % level respectively; standard errors of coefficient estimates in parenthesis.

In estimation (5) aggregated industry dummies are included in the equation. The constant is thus allowed to vary across industries, capturing industry-specific average effects. As aggregate employment growth is industry-invariant it cannot be estimated. All main regressors have the same signs, stable coefficient estimates, and are still highly significant. Two industries have highly positive and significant effects: the metal, engineering, and mining industries and the electricity, gas, and water services. While the latter probably should be seen as a statistical artifact since the industry was highly underrepresented in the sample in 1896, the former is a real growth industry. It is noted that

estimation (1) to (4) could be driven by omitted variable bias since the inclusion of industry dummies raises the adjusted determination coefficient from 10 percent to 30 percent.

All control variables have the expected signs. Regarding the aggregate employment growth, a one percent increase in the cumulative employment growth in the aggregate industry outside the city were associated with an increase of growth in the urban industry with roughly 0.3 percent over fourteen years, in estimation (4). Intuitively, employment growth slowed as the wage level in the region compared to the national average rose. Increasing the ratio between the regions wage level with regard to the national average with one standard deviation (0.21) decreases cumulative employment growth with roughly 3 percent; the effect is significant in two of the four estimations. High initial employment in an urban industry is expected to decrease successive employment growth. This is corroborated by estimation (1) to (5). Although the effect is non-significant, raising the initial employment in an urban industry with one thousand workers decreases cumulative growth over fourteen years with roughly 3 percent in that industry, as given by (5).

Taken together, there is no evidence for positive MAR externalities, while there is ample support for Jacobs's position – both regarding competition and diversity. Specialization decreases, while diversity and competition increases urban industrial growth. A major caveat to keep in mind when interpreting these results are the low values of the adjusted determination coefficient, ranging from 1-30 percent, implying that other factors had considerable effects on employment growth during the time period.

4.4 Results, Disaggregated Sample

In estimating equation (10)[25], the log of employment growth in for example the cotton spinning mills-industry in Gothenburg, between 1896-1910, is regressed on the degree of specialization, and competition in that industry, and the diversity outside the industry, in 1896; while controlling for the employment growth in that industry throughout the country, initial wage differentials, and initial employment in the urban industry. All sixty disaggregated urban industries are pooled in the estimations. Briefly, the results reject the conclusions of MAR – that specialization encourages growth – while being mixed on Jacobs; strictly interpreted, diversity decreases, while competition increases growth.

In Table 8, the general descriptive statistics of the dependent variable and all regressors included in the estimations are presented. The industries included in the disaggregated sample are highly specialized, as given by the mean of the LQ (4.8). Since the sample only includes the six largest industries in each respective city, this is an expected outcome. Recall that if MAR externalities are an important source of long run growth, they should be evident in these industries. Diversity *outside* the urban industry is quite low; the average share of employment in the five largest industries, outside the urban industry, was 40 percent. The average level of competition is below unity in the sample. Large industries in large cities were not very competitive. It is also worth noting, that although the sample only includes the six largest industries in the ten largest cities, both very small and very large industries are included in the sample, which is given by the range of initial employment.

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[25] $EG_{ci,1896-1910} = \alpha + \beta_1 LQ_{ci,1896} + \beta_2 COMP_{ci,1896} + \beta_3 DIV_{ci,1896} + \beta_4 AEG_{i,1896-1910} + \beta_5 IE_{ci,1896} + \beta_6 W_{C,1896} + \varepsilon_i$

Table 8 General Descriptive Statistics (Disaggregated Sample)

	EG	LQ	DIV	COMP	AEG	IE	W
Mean	0.05	4.83	2.50	0.91	0.11	0.58	0.96
Standard Deviation	0.36	5.94	2.10	0.85	0.29	0.75	0.15
Minimum	-1.84	0.20	1.12	0.05	-1.66	0.01	0.80
Maximum	0.75	30.14	16.90	4.98	0.75	3.82	1.23
N	60	60	60	60	26	60	9

Note: Variables are defined in section 4.1.

In Table 9 the results of the estimations of the disaggregated sample are presented. In estimation (1) and (4) there is no support for the MAR prediction that specialization encourages employment growth. The coefficient estimates of specialization are non-significant and marginally negative. Specialization had no growth-enhancing effect. Contrary to the results in the estimations regarding the aggregated industries, the effect of diversity on employment growth is negative in the disaggregated sample. The coefficient estimate is highly significant in both (2) and (4); raising the inverted share of employment in the five largest industries outside the urban industry with one standard deviation (2.10) *decreases* cumulative employment growth over fourteen years with 17 percent. Urban industries, on a low level of aggregation, thus seem to benefit from proximity to other dissimilar *dominant* industries. While these results might seem counterintuitive bearing in mind the results from the aggregated estimations, there are two plausible interpretations. First, knowledge spillovers may have been important between aggregated industries (for example, the engineering and textile industry), but less so between disaggregated industries. Second, the fact that an industry seems to benefit from proximity to dissimilar large industries might in fact be interpreted as a diversity effect. In this case industries would benefit from proximity to dissimilar *dominant* industries, even though this would imply that the city as a whole became more specialized. Regarding competition, it is significantly associated with an increase of employment growth in urban industries, when all control variables are included in estimation (4), but not in estimation (3). Raising the number of firms per worker relative the national average with one standard deviation (0.85) increases cumulative employment growth over fourteen years with roughly 6 percent.

Including the control variables and estimating all variables in (4) yield the expected results. When a disaggregated urban industry grew in the whole country, it also grew in the cities included in the sample. It is interesting to note that employment in the cities included in the sample grew slower than the aggregate employment growth in the aggregate industry, since the estimated coefficient is below unity. Increasing the rate of aggregate employment growth in the country with 1 percent is associated with an increase of employment growth in the urban industry with roughly 0.3 percent. The probable explanation is that this was a period of rapid city formation and expansion, and that employment growth thus was relatively dispersed (see Enflo et al., 2010, p.21). As expected, a higher regional wage level relative the national average is associated with slower employment growth. Similar to the results of the aggregated sample, the level of initial employment in an urban industry had only marginal effects on successive employment growth.

In estimation (5) city dummies are included to control for city-specific average effects. As the regional wages are city-invariant they cannot be estimated in the same equation. Three cities (Boras, Jonkoping, Malmo) had significant effects. All these cities experienced high employment growth in the manufacturing industry between 1896-1910 (see Table 5). The inclusion of city dummies does not radically change the results in estimation (4). The negative effects of diversity increase in (5), while competition goes from highly significant to non-significant. Although (5) includes ten

Table 9 Employment Growth in Disaggregated Urban Industries, 1896-1910

Dependent Variable	Employment Growth (Log[Employment in disaggregated urban industry 1910/Employment in disaggregated urban industry 1896])				
	(1)	(2)	(3)	(4)	(5)
Constant	0.485** (0.240)	0.618*** (0.226)	0.359 (0.255)	0.469** (0.233)	…
Specialization (LQ)	-0.010 (0.006)	…	…	-0.004 (0.006)	-0.007 (0.006)
Diversity (DIV)	…	-0.079*** (0.023)	…	-0.079*** (0.023)	-0.091*** (0.030)
Competition (COMP)	…	…	0.069 (0.044)	0.075*** (0.041)	0.060 (0.041)
National Employment Growth in the Industry (AEG)	0.811*** (0.122)	0.379** (0.169)	0.770*** (0.124)	0.339* (0.171)	0.238 (0.187)
Initial Employment in the Urban Industry (IE)	-0,054 (0.048)	-0.060 (0.044)	-0.048 (0.049)	-0.030 (0.045)	0.009 (0.057)
Regional Wage Differentials (W)	-0.0471* (0.244)	-0.396* (0.228)	-0.452* (0.246)	-0.305 (0.227)	…
City Dummies					
Boras	…	…	…	…	0.416*** (0.126)
Eskilstuna	…	…	…	…	0.301 (0.129)
Gavle	…	…	…	…	0.111 (0.118)
Gothenburg	…	…	…	…	0.110 (0.127)
Halmstad	…	…	…	…	0.217 (0.172)
Helsingborg	…	…	…	…	0.190 (0.159)
Jonkoping	…	…	…	…	0.425*** (0.144)
Malmo	…	…	…	…	0.225* (0.131)
Norrkoping	…	…	…	…	-0.020 (0.120)
Stockholm	…	…	…	…	0.247 (0.149)
F statistic	12.986***	17.239***	12.914***	12.790***	7.144***
Adjusted R²	0.448	0.524	0.447	0.545	0.590
N	60	60	60	60	60

Note: ***, **, * means significant at the 1-, 5-, and 10 % level respectively; standard errors of coefficient estimates in parenthesis.

dummies, the adjusted determinant coefficient only increases from 55 to 59 percent, implying that the explanatory power of city-specific average effects is rather limited.

To summarize, there is no evidence of MAR externalities, while the support for Jacobs depends on the interpretation of the results. Industries that were overrepresented in a city did not grow faster, rejecting the theories of MAR. Interpreting the results regarding diversity is harder. Clearly, industries benefit from proximity to other large *different* industries; or put differently, when the share of employment in the largest firms outside an urban industry increases, so does the employment growth in that urban industry. This is not strictly compatible with the position of Jacobs, and could

be evidence of an urbanization effect, rather than a localization effect, i.e. it could be evidence of demand spillovers between industries. Regarding competition the results are unequivocally on Jacobs side; a higher degree of local competition is associated with higher successive employment growth in urban industries.

5 Conclusions

The *Second Industrial Revolution* is generally characterized by increasing dependence on applied scientific knowledge and complex engineering skills in industrial production (see Schön 2000; Landes 2003). Implicit in the nature of this so-called revolution is that knowledge, and knowledge spillovers ought to be an important feature of industrial development in the late 19th century. The diffusion of innovations and knowledge between nations, regions, cities, and industries should then - in line with endogenous growth theory - have significant effects on long run growth. If one takes this view - and accepts the indirect evidence provided in this thesis – then these knowledge spillovers, or externalities, would seem to have been most prevalent in diverse cities, and competitive industries. Knowledge and innovations arising in one industry benefited proximate *different* industries. On a low level of industrial aggregation, an important aspect of diversity seems to have been the proximity of dissimilar *dominant* industries, even though this would imply that the city as a whole became more specialized. Diversity was associated with higher long run growth. This seems to be a sensible conclusion, in line with much of the more descriptive literature, as many of the expansive industries such as the mechanical workshops and the electrical engineering industry operated in the borderland of other industries, providing an environment in which cross-fertilization of ideas ought to have been particularly important. Further, as industries became increasingly dependent on broad scientific advances, diversity indeed should be expected to have growth-enhancing effects. Or put differently: an industry does not mechanize itself. Competition seems to have induced firms to innovate, and to adapt to innovations in other firms. Both these notions support the conclusions of Jacobs (1969). The theories of Marshall (1890), Arrow (1962), and Romer (1986) predict that specialized industries should grow faster because of intra-industrial knowledge externalities. No such effect is found; rather, specialization seems to have *decreased* long run growth in urban industries. Anecdotal evidence is provided from the Swedish growth industries of the *First Industrial Revolution,* where geographically concentrated industries such as sawing mills, and iron and steel works gradually lost ground in the 1880s, leading to relative regional decline. While diversity presumably facilitates adjustment to changing economic conditions it also render new growth paths possible. A diverse city has the capacity to perpetually renew itself.

These conclusions highlight an interesting paradox: If specialization did not encourage employment growth, then why was it, and still is, such a prevalent characteristic of the distribution of economic activity - why were the textile industry concentrated in Norrkoping and Boras, and the iron and steel industries in Eskilstuna? There are a number of factors, other than knowledge spillovers, that can explain the localization of industries. Natural resources, or advantageous locations with regard to transport costs can very well determine the location of an industry; these factors can account for localization, but not for long run growth[26]. In general, the results do not favor these types of explanations of specialization, if they are not assumed to have provided all potential growth effects *before* 1896[27]. This does not mean that the results reject the role of localization externalities in determining the pattern of geographical specialization; they reject the notion that specialization induces long run growth.

Some authors have stressed the possibility that the influence of externalities differ along an industry or product's life cycle (Duranton and Puga 2000; Neffke et al. 2011). The general view is that specialization should be most important at the inception, in young industries, while diversity would become increasingly more important along the life cycle. Although the results lends some support

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[26] Ellison and Glaeser (1999) conclude that in the U.S., geographical advantages *does not* sufficiently explain the high degrees of concentration observed in industries. Externalities ought to explain *some* of that concentration.
[27] Since the disaggregated sample consists of presumably mature industries, one could make the case that location matters most in young industries, and that the construction of the sample is biased against these industries.

to this view, if the dynamics of the time period are taken into consideration as it was a period characterized by renewal, the results in this thesis cannot ultimately reject or verify this view.

Finally, a possible explanation is that urbanization externalities are a part of the story. Cities provide industries with larger markets and higher local demand, generating demand spillovers between industries. But they also give rise to negative externalities, such as higher land rents and wages, and congestion. The results cannot reject any type of urbanization externality. In fact, the finding that urban industries, on a low level of aggregation, benefited from proximity to other dominant industries could be interpreted as indirect evidence of the notion that demand spillovers between industries encourages industrial growth. As Sweden was relatively rural in the late 19th century, the urban industrial growth effects of urbanization could arguably be considerable.

If one disregards the fact that the evidence of externalities is indirect, the methodological approach in this thesis raises mainly three possible objections. First, the results could be biased by the time period at hand. In 1907, Sweden experienced a severe financial crisis which where followed by increasing unrest on the Swedish labor market. Employers' attempts to restrain, or decrease, wage growth were met with local strikes in 1907 and 1908. In 1909, following a general lockout from the employers organization, around 300 000 workers were called on strike. While the conflict abated during the year, local conflicts went on well into 1910 (see Schön 2000, p.267ff). The effects of these strikes on the distribution and level of employment (growth) are not regarded when creating the dataset utilized in this thesis. Biases could thus be introduced, as the effects on industries presumably were highly uneven. Second, a conceivable objection could regard the definition of the regional unit of analysis. Cities are not isolated points in space. In this thesis, by construction of the dataset, only spillovers *within* cities have been considered; but cities interact with their surroundings. Spillovers between cities, and regions, ought to be important, which leads to the suspicion that the results in part might be driven by spatial autocorrelation. One way to correct for this would be to construct functional regions, or control for an area of influence constructing distance-decay functions, where spillovers are allowed over larger geographical units. Third, since it is assumed that the production function only includes one production factor (labor), the level and growth of capital is not controlled for. Thus, the results cannot reject any type of theory that predicts that industries will grow faster where capital is cheap and/or plentiful. To reject a neoclassical explanation of the growth pattern, these factors would have to be controlled for.

While the approach in this thesis has obvious limitations and drawbacks, the results should serve as a useful first approximation of the relationship between dynamic agglomeration externalities and growth in urban industries, in the context of industrialization. Nonetheless, further research is desirable to draw better-founded conclusions. The author would suggest three, mainly technical or methodological, directions: First, estimating a panel data-model would facilitate controlling for time, industry, and city fixed-effects; while also controlling for different lag-lengths between the dependent variable and the regressors. Second, drawing upon data from a longer time period than fourteen years, one could also examine if the influence of externalities were more prevalent during certain periods; in addition, the relationship could more convincingly be regarded as a valid long run relationship. Third, as discussed above, constructing functional regions would capture spillovers *between* cities and regions; which ought to be a more realistic model of the relationship between externalities and growth.

6 References

Arrow, K. J. (1962). The Economic Implications of Learning by Doing. *The Review of Economic Studies Ltd. , 29* (3), 155-173.

Bairoch, P. (1988). *Cities and Economic Development: From the Dawn of History to the Present.* Chicago: The University of Chicago Press.

Braunerhjelm, P., & Borgman, B. (2006). *Agglomeration, Diversity and Regional Growth.* The Royal Institue of Technology, Department of Transport and Economics. Stockholm: CESIS Electronic Working Paper Series.

Braunerhjelm, P., & Borgman, B. (2004). *Geographical Concentration, Entrepreneurship and Regional Growth: Evidence From Regional Data in Sweden, 1975-99.*

Braunerhjelm, P., & Borgman, B. (2004). Regional tillväxt, geografisk koncentration och entreprenörskap. *Ekonomisk Debatt , 32* (8), 34-46.

Ciccone, A., & Hall, R. E. (1996). Productivity and the Density of Economic Activity. *The American Economic Review , 86* (1), 54-70.

Crafts, N., & Mulatu, A. (2006). How Did the Location of Industry Respond to Falling Transport Costs in Britain Before World War I? *The Journal of Economic History* (66), 575-607.

de Groot, H. L., Poot, J., & Smit, M. J. (2007). *Agglomeration, Innovation and Regional Development.* Amsterdam: Tinbergen Institute.

de Vor, F., & de Groot, H. L. (2008). *Agglomeration Externalities and Localized Employment Growth.* Tinbergen Institute Discussion Paper. Amsterdam: Tinbergen Institute.

Duranton, G., & Puga, D. (1999). *Diversity and Specialisation in Cities: Why, where and when does it matter?* London: CEPR Discussion Paper 2256.

Duranton, G., & Puga, D. (2004). *Micro-foundations of urban agglomeration economies.* In J.Thisse and J.V. Henderson (eds) Handbook of Regional and Urban Economics, vol.4.

Duranton, G., & Puga, D. (2000). *Nursery Cities: Urban diversity, process innovation, and the life-cycle of products.* London: CEPR.

Ellison, G., & Glaeser, E. L. (1997). Geographic Concentration in U.S. Manufacturing Industries: A Dartboard Approach. *Journal of Political Economy* , 889-927.

Ellison, G., & Glaeser, E. L. (1999). The Geographic Concentration of Industry: Does Natural Advantage Explain Agglomeration? *The American Economic Review , 89* (2), 311-316.

Enflo, K., Henning, M., & Schön, L. (2010). *Swedish regional GDP 1855-2000 Estimations and general trends in the Swedish regional system.* Department of Economic History, Lund University. Madrid: Universidad Carlos III de Madrid.

Enflo, K., Kander, A., & Schön, L. (2008). Electrification and energy productivity. *CIRCLE Working Papers* (16).

Fujita, M., & Thisse, J.-F. (2002). *Economics of Agglomeration: Cities, Industrial Location, and Regional Growth.* Cambridge: Cambridge University Press.

Glaeser, E. L., Kallal, H. D., Scheinkman, J. A., & Schleifer, A. (1992). Growth in Cities. *Journal of Political Economy , 100* (6), 1126-1152.

Henderson, J. V. (1997). Externalities and industrial development. *Journal of Urban Economics , 42* (3), 449-470.

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

Jacobs, J. (1984). *Cities and the Wealth of Nations: Principles of Economic Life.* New York: Vintage.

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

Jörberg, L. (1972). *A History of Prices in Sweden 1732-1914 Part II.* Lund: Gleerup.

Keilbach, M. (1998). *Marshallian Externalities and the Dynamics of Agglomeration and Regional Growth.* Mannheim: Centre for European Economic Research.

Kim, S. (2006). Divison of labor and the rise of cities: evidence from US industrialization, 1850-1880. *Journal of Economic Geography , 6*, 469-491.

Kim, S. (1995). Expansion of Markets and the Geographic Distribution of Economic Activities: The Trends in U. S. Regional Manufacturing Structure, 1860-1987. *The Quarterly Journal of Economics , 110* (4), 881-908.

Krugman, P. (1991). Increasing Returns and Economic Geography. *Journal of Political Economy , 99*, 483-99.

Landes, D. (2003). *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present* (2nd Edition ed.). Cambridge: Cambridge University Press.

Lucas, R. E. (1988). On the Mechanics of Economic Development. *Journal of Monetary Economics , 22*, 3-42.

Lund University Macroeconomic and Demographic Database. (n.d.). Retrieved 05 09, 2011, from http://www.ehl.lu.se/database/LU-MADD/

Marshall, A. (1890). *Principles of Economics.* New York: MacMillan.

Neffke, F., Henning, M., Boschma, R., Lundquist, K.-J., & Olander, L.-O. (2011). The Dynamics of Agglomeration Externalities along the Life Cycle of Industries. *Regional Studies , 45* (1), 49-65.

Porter, M. E. (1998, Nov-Dec). Clusters and the New Economics of Competition. *Harvard Business Review* , 77-90.

Porter, M. E. (1990). *The Competitive Advantage of Nations.* New York: Free Press.

Romer, P. (1990). Endogenous Technological Change. *Journal of Political Economy , 98* (5), 71-101.

Romer, P. M. (1986). Increasing Returns and Long-Run Growth. *The Journal of Political Economy , 94* (5), 1002-1037.

Rosenberg, N., & Trajtenberg, M. (2004). A General Purpose Technology at Work: The Corliss Steam Engine in the Late-Nineteenth-Century United States. *Journal of Economic History , 64* (1), 61-99.

Rosenthal, S. S., & Strange, W. C. (2002). *Evidence on the Nature and Sources of Agglomeration Economies.* Syracuse: Preliminary Draft.

Rosés, J. R. (2003). Why Isn't the Whole of Spain Industrialized? New Economic Geography and Early Industrialization, 1797-1910. *Journal of Economic History* (63), 995-1022.

SCB. *Bidrag till den Officiella Statistiken: Fabriker och manufakturer 1896, 1910.* Statistics Sweden.

SCB. *Tätorter 1960-2005 Article Number: MI38SM0703.* 2005: Statistics Sweden.

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

Schön, L. (2000). Electricity, technological change and productivity in Swedish industry, 1890-1990. *European Review of Economic History , 4*, 175-194.

Schön, L. (2000). *En modern svensk ekonomisk historia - Tillväxt och omvandling under två sekel.* Stockholm: SNS.

Schön, L. (2009). *Technological Waves and Economic Growth - Sweden in an International Perspective 1850-2005.* Department of Economic History, Lund University. Lund: CIRCLE (Centre for Innovation, Research and Competence in the Learning Economy).

von Thünen, J. H. (1826). *The Isolated State.* Hamburg: Perthes.