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Agglomeration Economies and Productivity in Indian Industry

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The benefits to Indian manufacturing firms of locating in dense urban areas do not appear to offset the associated costs. Improving the quality and availability of transport infrastructure linking smaller urban areas to the rest of the interregional network would improve manufacturing plants' access to markets and would give standardized manufacturing activities a chance to move out of large, costly urban centers to lower cost secondary centers.

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Summary findings

"New" economic geography theory and the development of innovative methods of analysis have renewed interest in the location and spatial concentration of economic activities. Lall, Shalizi, and Deichmann examine the extent to which agglomeration economies contribute to economic productivity. They distinguish three sources of agglomeration economies:

- At the firm level, from improved access to market centers.
- At the industry level, from enhanced intra-industry linkages.
- At the regional level, from inter-industry urbanization economies.

The input demand framework they use in analysis permits the production function to be estimated jointly with a set of cost shares and makes allowances for nonconstant returns to scale and for agglomeration economies to be factor-augmenting. They use firm-level data for standardized manufacturing in India, together with spatially detailed physio-geographic information that considers the availability and quality of transport networks linking urban centers—thereby accounting for heterogeneity in the density of transport networks between different parts of the country.

The sources and magnitudes of agglomeration vary considerably between industrial sectors. Their results indicate that access to markets through improvements in interregional infrastructure is an important determinant of firm-level productivity, whereas the benefits of locating in dense urban areas do not appear to offset the associated costs.

Improving the quality and availability of transport infrastructure linking smaller urban areas to the rest of the interregional network would improve market access for manufacturing plants. It would also give standardized manufacturing activities a chance to move out of large, costly urban centers to lower cost secondary centers.

This paper—a product of Infrastructure and Environment, Development Research Group—is part of a larger effort in the group to understand the role of economic geography and urbanization in the development process. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Roula Yazigi, room MC2-622, telephone 202-473-7176, fax 202-522-3230, email address ryazigi@worldbank.org. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The authors may be contacted at slall@worldbank.org, zshalizi@worldbank.org, or udeichmann@worldbank.org. August 2001. (34 pages)

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1. BACKGROUND AND MOTIVATION

There has been considerable interest over the last decade in examining the location and geographic concentration of economic activity. In most cases, the antecedents of the underlying analytic and empirical work can be traced to the early work in regional science and location theory (Weber, 1909; Lösch, 1940; Hotelling, 1929; Greenhut and Grenhut, 1975). As noted in Krugman (1991), difficulties in modeling increasing returns to scale was one of the main reasons for the marginalization of geographical factors in mainstream economic analysis. The recent body of research examining the economics of agglomeration has been made possible by progress in mathematical modeling and by an improved understanding of three factors which influence the spatial concentration of population and economic activity: (1) technological or non pecuniary externalities (Fujita, 1989), (2) increasing returns to scale (Dixit and Stiglitz, 1977; Krugman, 1991; Abdel-Rahman and Fujita, 1990; Fujita, et al., 1999), and (3) imperfect / spatial competition (Dixit and Stiglitz, 1977; Fujita et al., 1999).

Increasing returns to scale are essential for explaining the spatial concentration of economic activities. This 'folk theorem' of geographical economics (Fujita and Thisse, 1996) implies that under non-increasing returns and uniform distribution of resources, each individual would only produce for his consumption and each location would be the base of an autarkic economy where goods are produced on an arbitrarily small scale. However, if average production costs decline as scale of production increases at either the firm, industry, or regional level, then it will be beneficial to concentrate production in particular locations[1]. At the firm level for example, if a plant is located in a region with

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* Corresponding Author: Somik Lall, MC 2540, Development Research Group, The World Bank, Washington DC, 20433. Email: slall1@worldbank.org; Fax: 202 522 3230. The findings, interpretations, and conclusions are entirely those of the authors, and do not necessarily represent the views of the World Bank, its executive directors, or the countries they represent. We are grateful to the Central Statistical Organization (CSO), Government of India, for making the firm level data available for this study. We would like to thank Kenneth Chomitz, Ed Feser, Vernon Henderson, Mead Over, Timothy Thomas and participants of the World Bank seminar on sub-national regional economics for helpful comments and suggestions.

[1] In exceptional circumstances, clustering of activities can occur in the absence of increasing returns. For example, when resource-based industries locate near ore-heads, or retail stores co-locate to attract price and quality shoppers.

good access to markets, the entrepreneur has an incentive to increase production to meet increasing demand. The increasing scale of production enables a restructuring of the production process through the use of increased specialized labor and investment in cost reducing technologies.

Beyond the firm level, agglomeration economies can also be driven by industry and regional factors. For example, a firm that is located in close proximity to other firms in the same industry can take advantage of so-called localization economies. These intra-industry benefits include access to specialized know-how (i.e., knowledge diffusion), the presence of buyer-supplier networks, and opportunities for efficient subcontracting. Employees with industry-specific skills will be attracted to such clusters giving firms access to a larger specialized labor pool. Another case of agglomeration economies external to the firm relates to benefits that accrue from being located in close proximity to firms in other industries -- so called urbanization economies. These inter-industry benefits include easier access to complementary services (publishing, advertising, banking), availability of a large labor pool with multiple specialization, inter-industry information transfers, and the availability of less costly general infrastructure.

The origins of these ideas can be traced back at least to the works of Marshall (1890), who stated that the geographical concentration of economic activities can result in a snowball effect, where new entrants tend to agglomerate to benefit from higher diversity and specialization in production processes. Workers would also benefit from being in an agglomeration as they can expect higher wages and have access to a larger choice set of employers. There is a rich body of literature on the benefits to firms from co-locating in close proximity to other firms in the same industry (Henderson, 1974 and 1988; Carlino, 1978; Selting et al.,1994).

Localization and urbanization economies can be considered as centripetal forces leading to concentration of economic activities. Acting in the opposite direction are a number of centrifugal forces. These include increased costs resulting from higher wages driven by competition among firms for skilled labor, higher rents due to increased demand for housing and commercial land, and various negative externalities such as congestion. These costs offset some or all of the benefits of being located in an agglomeration.

Theoretical and empirical work on urban economics and economic geography (see review by Henderson et al., 2001) suggests that the net benefits of industry concentration and location in dense urban areas are disproportionately accrued by technology intensive and innovative sectors. This is because the benefits of knowledge sharing (ideas) and access to producer services (e.g., venture capital) are considerably higher in these sectors than in low-end manufacturing that employs standardized production processes. As a result, these innovative sectors can afford the high wages and rents in dense urban locations and industry clusters. In this framework low-end industry producing standardized products can be expected to move to smaller urban centers with lower costs.[2]

Paradoxically however, we find a considerable range of standardized industrial activity in most large developing country cities. One explanation for this is the lack of inter regional transport infrastructure linking small centers to large urban areas, thereby reducing the opportunities for efficient location decisions and de-concentration of large urban areas. In a recent empirical study, Henderson (2000) documents the linkages between improvements in inter regional infrastructure and decline in urban concentration. We explore this important issue in more detail below.

In this paper, we examine the nature and scale of agglomeration economies using firm level manufacturing data for India.[3] Indian industry exhibits a highly skewed distribution of activity across administratively defined spatial units as illustrated, for instance, by the Gini coefficient of the distribution of sector-specific employment shares across districts (Table 1). The district is the third tier of administrative jurisdiction in India -- equivalent to counties in the US and China, and municipios in Brazil. To avoid distortions in the Gini coefficients from scale heterogeneity between districts, we normalized employment in each sector by total industry employment in each district. The Gini coefficient takes on values between zero and one with zero being interpreted as no inequality or, in this case, an equal number of employees in each district. A value of zero for a sector implies that the activity in the sector is not disproportionately represented in any district. For the sample of Indian industry sectors, the Gini coefficients range from 0.55 and 0.75. This means that industries tend to concentrate in a relatively small number of districts, which raises the question of the nature of the benefits that leads to an individual firm's location decisions. More specifically, we examine the following questions in this paper:

1. Does the magnitude and source of agglomeration economies vary between industrial sectors?
2. Does improved market accessibility enhance plant level output?
3. Does a firm benefit from co-locating near other firms in the same industry?
4. Does a firm benefit from being located in dense urban areas?

Our empirical application is based on plant or "factory" level data for 1994-95, which is collected by the Central Statistical Office of India in the Annual Survey of Industries (ASI). These plant level data are supplemented by district and urban demographic and amenities data from the 1991 Census of India and detailed,

[2] This reasoning is consistent with product-cycle theory (see Vernon 1966), where the development stage of an industry (innovative, mature, or standardized) guides the location choice of firms in that sector. At any point in time, the spatial economy can be divided into regions with innovation based activities and those specializing in the production of standardized commodities. Over its product cycle, a industry sector is likely to incubate in locations where new product innovation takes place (such as dense urban areas), and then diffuse to other locations when its range of products gets standardized (such as secondary locations).

[3] While agglomeration can come about for different reasons (such as production based or consumption based), we are only looking at production based agglomerations.

geographically referenced information on the availability and quality of transport infrastructure linking urban areas (CMIE, 1998; ML Infomap, 1998). Available information allows us to identify each plant at the district level spatially and at the four digit SIC level sectorally. This is one of the first studies to use a combination of plant level and disaggregate physio-geographic data to examine the contribution of agglomeration economies to plant level productivity.

This paper is organized in six sections. Following this introduction, the analytic framework is presented in Section 2 and the methodology used to test for the sources and magnitude of agglomeration economies is laid out in Section 3. The analytic framework and methodology for empirical analysis is suitable for examining agglomeration economies in innovative as well as in standardized products industries. Data availability, however, limits our analysis to the more established, standardized products part of Indian industry. We discuss the choice of variables in Section 4. Results from the analysis are presented and discussed in Section 5. Section 6, concludes with some final observations and directions for future research.

2. ANALYTIC FRAMEWORK

In the 'new economic geography' literature Krugman (1991) and Fujita et al. (1999) analytically model increasing returns, which are primarily driven by externalities (both technological and pecuniary). In models of technological externalities, inter firm information spillovers provide the incentives for agglomeration of economic activity. Information is treated as a public good—i.e., non-rival in consumption. The diffusion of information thus produces benefits for each firm. Assuming that each firm produces different information, the benefits of interaction increase with the number of firms. As these interactions are informal, the extent of information exchange decreases with increasing distance. This provides incentives for the entrepreneur to locate the firm in close proximity to other firms, leading to agglomeration.[4]

Models from Fujita and Thisse (1996) and Fujita (1989) assume the existence of a continuum of firms that are symmetric in the pattern of spillovers in a given location X. However, they can be differentiated by their products and stock of information. Thus, each firm benefits from information spillovers from other firms. Let $a(x, y)$ be the benefit for a firm at x obtained from a firm at y. If $f(y)$ denotes the density of firms at each location $y \in X$ then,

$$A(x) \equiv \int_X a(x,y) f(y) dy \qquad (1)$$

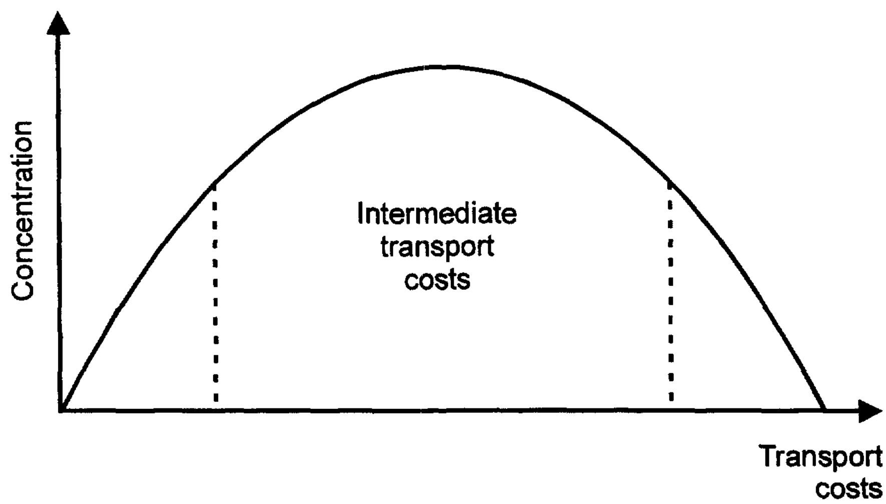
[4] However, concentration of firms in a single area increases average commuting times for workers, as well as wage rates and rents in surrounding areas. This will deter further agglomeration of firms in the same location (Fujita and Thisse, 1996). The equilibrium is established when the centripetal forces of increasing returns from interaction balance the centrifugal forces of congestion, and increases in wages and rents (Krugman, 1991 and 1998).

In equation (1), A(x) represents the aggregate benefit accrued to a firm at x from the information available in location X. Assuming that production utilizes land (S_f) and labor (L_f) with rents of R(x) and W(x) respectively at x, a firm located at $x \in X$ would maximize profits subject to:

$$\Pi(x) = A(x) - R(x)S_f - W(x)L_f \qquad (2)$$

In addition to the benefits from information spillovers, transport costs are important in determining the location choice of firms. If transport costs are very high, then activity is dispersed. In the extreme case, under autarky, every location must have its own industry to meet final demand. On the other hand, if transport costs are negligible, firms may be randomly distributed as proximity to markets or suppliers will not matter. Agglomeration would occur at intermediate transport costs when the spatial mobility of labor is low (Fujita and Thisse, 1996). We therefore expect a bell shaped (inverted U shaped) relationship between the extent of spatial concentration and transport costs (Figure 1).

Figure 1: Transport costs and concentration of economic activity



Thus, transport costs figure prominently in a firm's location decision. Equation (2) can be modified as:

$$\Pi(x) = A(x) - R(x)S_f - W(x)L_f - TC(x) \qquad (3)$$

to include transport cost (TC) for the firm at location x. With a decline in transport costs, firms have an incentive to concentrate production in a few locations to reduce fixed costs. Transport costs can be reduced by locating in areas with good access to input and output markets. Thus, access to markets is a strong driver of agglomeration. In fact, analytical models of monopolistic competition generally show that activities with increasing returns at the plant level are pulled *disproportionately* towards locations with good market access -- locations where transport costs are low enough that it is relatively cheap to supply markets due to availability of quality transport networks (Henderson et al., 2001).

The analytic framework in this section highlights the importance of information spillovers gained from co-locating near firms involved in similar activities and the benefits from locating in regions with good access to markets. We develop the empirical approach to test these hypotheses in the following section.

3. EMPIRICAL APPROACH

In this section we present the methodology to test the benefits of agglomeration economies. Based on the framework in the analytic section, we distinguish three sources of agglomeration economies -- (1) at the firm level -- *from improved access to market centers*, (2) at the industry level -- *intra industry localization economies*, and (3) at the regional level -- *inter-industry urbanization economies*. This relationship can be represented as:

$$Y_i = g(A_i)\hat{X}(K_i) \qquad (4)$$

where Y_i is output for firm *i*, g($\mathbf{A}_i$) represents external influences on production from agglomeration economies, and $\hat{X}$ ($\mathbf{K}_i$) is the firm's production technology for a vector of inputs **K**. This is a commonly used form to examine the contribution of external factors in a production function framework (Moomaw, 1983; Nakamura, 1985; Henderson, 1988). We disaggregate equation (4) to distinguish between various sources of agglomeration economies --

$$g(A_i) = f(S, L, U) + \varepsilon_i \qquad (5)$$

where $\boldsymbol{S}$ measures scale economies from improved market access, $\boldsymbol{L}$ measures localization economies, and $\boldsymbol{U}$ measures urbanization economies.

We use a production function framework in the empirical analysis. In general, the choice of estimating a cost or production function is based on assumptions related to the exogeneity of key model variables, particularly output. In a production function, output is endogenous and input quantities exogenous; in comparison, within the dual cost function, input prices and the level of output are exogenous. Berndt (1990) suggests that when output levels and input prices can be assumed exogenous (the latter is more likely to be the case when disaggregated, i.e. micro, data are available), it is preferable to use a cost function with input prices as regressors, rather than a production function with input quantities as right-hand side variables. The profit maximizing firm however, regards output as endogenous, adjusting production as input prices change. Therefore using a production function approach, even with micro unit data appears to be appropriate (Feser, 2000).[5]

We use a transcendental (translog) logarithmic production function in the empirical analysis. This specification provides considerable flexibility and imposes the fewest technical assumptions compared to other forms such as the Cobb Douglas or the CES (Christensen et al., 1973). Applying this functional form, we use the following production function:

$$\begin{aligned}\ln Y = \alpha_0 + \sum_i \alpha_i \ln X_i + \sum_m \xi_m A_m + 1/2 \sum_i \sum_j \beta_{ij} \ln X_i \ln X_j + \\ \sum_i \sum_m \gamma_{im} \ln X_i \ln A_m + 1/2 \sum_m \sum_n \delta_{mn} \ln A_m \ln A_n + \sum_i \eta_i \ln C_i\end{aligned} \qquad (6)$$

where Y is the firm's output, $\boldsymbol{X}$ is a vector of firm factor inputs and A consists of measures of various sources of agglomeration economies. The subscripts i and j refer to firm level production factors, and m and n refer to the different sources of agglomeration benefits.[6] The term $\boldsymbol{C}$ and the vector of coefficients η, represent control variables, which reflect economic structure (e.g., labor market), social structure (ethnicity and educational attainment), as well as regional development outcomes (per capita income at the state level).

Most firm level studies using the trans-log function use duality theory to estimate the cost function or a set of associated factor-share or input demand functions (Chung, 1994; Feser, 2000). The joint estimation of the share equations with the production function improves efficiency and reduces multicollineariy. In competitive markets with constant returns to scale (CRTS) and where price equals marginal cost, the factor demands equal the cost shares. Estimation procedures which jointly estimate cost shares with CRTS however are often criticized on the grounds that returns to scale should be estimated, rather than assumed a priori (Chan and Mountain, 1983; Kim, 1992; Feser, 2000 and 2001).

Kim (1992) provides an innovative approach for deriving cost share equations directly from the input demand using the first order conditions of profit maximization. The framework does not place restrictions on returns to scale and allows homotheticity to be a testable proposition. In Kim's (1992) approach, for a production function Y= f($\boldsymbol{X}$), the firm maximizes profits where $\boldsymbol{P}$ is the price of output and $\boldsymbol{W}$ is a vector of input prices. From standard first order conditions and assumptions of competitive markets, the following input demand functions are obtained, and written in cost share form:

[5] While in principle, it is desirable to examine estimates using both frameworks to check for potential biases, this is often impossible given data constraints. Like most studies using plant-level data, our study of agglomeration economies is precluded from examination of the dual cost function because of the absence of detailed data on input prices (rental rates on capital, real wage rates, etc.).

[6] The translog production function in (8) is nonhomothetic and imposes no restrictions on production technology.

$$S_i = \frac{\partial \ln Y / \partial \ln X_i}{\sum_i \partial \ln Y / \partial \ln X_i} = \frac{W_i X_i}{C} \qquad (7)$$

where C is the total cost (***WX***) and S_i is the cost share of the i^{th} input[7]. The cost shares sum to unity. Differentiating (7) according to (6) provides the cost share equations:

$$S_i = \frac{\alpha_i + \sum_j \beta_{ij} \ln X_j + \sum_m \gamma_{im} \ln A_m}{\sum_i \alpha_i + \sum_i \sum_j \beta_{ij} \ln X_j + \sum_i \sum_m \gamma_{im} \ln A_m} \qquad (8)$$

The translog parameters can be efficiently determined by jointly estimating (6) and (8). Under constant returns to scale, $\sum_i \partial Y / \partial X = 1$, thereby giving the following equation for the cost shares:

$$S_i = \alpha_i + \sum_j \beta_{ij} \ln X_j + \sum_m \gamma_{im} \ln A_m \qquad (9)$$

which is the form widely used in empirical studies of production technologies. In most studies however, (8) is not derived using the inverse demand function, but from the marginal product function assuming competitive markets and CRTS. In our empirical analysis, (6) and (8) are jointly estimated (*without imposing CRTS*) to get efficient estimators for the production parameters.

We use geographic information linking the plant to spatially disaggregate administrative units to develop indicators of market access. These indicators allow us to test if the availability of quality infrastructure and access to markets influence firm productivity. In principle, such an indicator would be a function of distance to market centers and population density of these centers, scaled by the per capita purchasing power of the centers.

The benefits of intra-industry concentration or localization can be examined with detailed plant level information on buyer - supplier linkages which are localized in geographic space. The benefits of information exchange and knowledge diffusion can be evaluated with information, for example, on the extent to which employees change jobs in the same area and interact informally to exchange tacit knowledge. Benefits of urbanization can be evaluated by information on productive services, infrastructure such

[7] The cost share for each input is calculated with the following information: Capital costs are the costs of rental expenditures and interest payments for buildings and machinery; labor costs are total compensation to employees, which include wages and salaries, as well as supplementary benefits in kind and cash; energy costs are the sum of fuel and electricity expenditures; material inputs are defined as the total delivered value of all items of raw materials, components, chemicals, packing materials and stores which enter into the production process.

as transport and telecommunications, and urban amenities such as entertainment and education facilities.

In practice however, it is often not possible to get the necessary information to adequately test the mechanisms through which agglomeration economies influence productivity. Even when plant level data are available through surveys, confidentiality clauses often preclude plants to be identified over time, thereby limiting the scope of longitudinal analysis. Longitudinal analyses are important as they allow us to test if linkages developed in one period (such as knowledge transfers and improved market access) lead to productivity gains in subsequent periods. Further, it is often only possible to identify plants at a fairly high level of spatial aggregation which mask the effects of some types of agglomeration economies. There is considerable evidence showing that clustering in some industries can occur in a very small geographic area (e.g., within1-2 miles) and the use of county equivalent spatial units for examination may not adequately capture the underlying processes (Wallsten, forthcoming).

In the absence of 'perfect' information, we develop several proxy measures to examine the benefits of agglomeration economies. These measures are described in Section 4. The choice of some proxies has been motivated by their use in previous studies examining industry concentration and agglomeration economies. It is however difficult to compare estimates from different studies due to heterogeneity in methods and data sources.

Previous studies, while providing important insights, have two limitations. First, the use of city and industry rather than plant level data introduces aggregation problems in the analysis, thereby biasing the returns to scale parameters upward (Selting et al., 1994). Further, the use of industry data invokes assumptions of homogeneity in production and factor mix, both of which are tenuous when the industry is defined broadly (2 or 3 digit SIC) and when there are large variations in intra-industry firm size. For example, Selting et al. (1994) shows that firm level heterogeneity in the composition of capital introduces aggregation problems when industries are used as the unit of observation. Aggregation implies that two distinct forms of capital with similar values have the same productivity effects.

The second limitation is that agglomeration economies are often modeled as being Hicks-neutral, a constraint which should be tested empirically and not imposed a priori. Hicks-neutrality assumes constant marginal rates of substitution among factor inputs. This assumption is quite limiting as agglomeration economies are likely to disproportionately augment specific factor inputs compared to others. For example, in addition to providing a larger market for final products, improved access to market centers can disproportionately reduce the costs of intermediate goods necessary for production. Duffy (1987) and Calem and Carlino (1991), among others, used a modified approach that models agglomeration economies as being factor augmenting.

In our empirical application, we use disaggregate plant level data which is better suited for examining agglomeration economies than aggregate city or industry data. We also do not impose prior restrictions of Hicks neutrality in the effects of agglomeration economies. Our methodology is based on solving the firm's profit maximizing problem.

Data Sources

We use plant level data from the Annual Survey of Industries (ASI), conducted by the Central Statistical Office of the Government of India.[8] The "factory" or plant is the unit of observation in the survey and data are based on returns provided by factories.[9] Data on various firm level production properties such as output, sales, value added, labor cost, employees, capital, materials and energy are used in the analysis (see Table 2 for details). Data quality has been examined by cross referencing with standard growth accounting principles as well as by reviewing comments from other researchers who have used these data. Observations with incomplete or inconsistent information were dropped from the analysis. The geographic attributes allow us to identify each firm at the district level.[10]

These plant level data are supplemented by district and metropolitan area level demographic and amenities data from the 1991 Census of India and detailed information on the availability and quality of transport infrastructure linking urban areas. The plant level data have been combined with district level indicators such as concentration of industry in the district, urban population density, and potential access to urban markets.

The analysis is carried out for eleven industry sectors, grouping plants by their two-digit National Industry Classification (NIC) codes: 22 (beverages and tobacco), 23 (cotton textiles), 28 (paper, paper products, printing, publishing), 29 (leather, fur, and leather substitutes), 30 (basic chemicals and chemical products), 32 (non-metallic minerals), 33 (basic metals and alloys), 35 (machinery and equipment), 36 (electrical, electronics, and computer products), 37 (motor vehicles), and 39 (repair of capital goods). Data limitations preclude the analysis of other industry sectors. It is important to note that India's best-known "industrial" export -- software (which embodies high levels of human capital), is not included in the data for NIC 36. The software export industry is currently worth in excess of some $5 billion per year and is growing at a very rapid rate (Lall and Rodrigo, 2000).

[8] The ASI covers factories registered under sections 2m(i) and 2m(ii) of the Factories Act 1948, employing 10 or more workers and using power, and those employing 20 or more workers but not using power on any day of the preceding 12 months.

[9] Goldar (1997) notes that factories are classified into industries according to their principal products. In some cases this causes reclassification of factories from one class to another in successive surveys, making inter-temporal comparisons difficult.

[10] While the ASI data structure allows the identification of the firm at the block level, and the firm addresses are reported in the survey, these data were not made available due to confidentiality concerns.

4. VARIABLES REPRESENTING AGGLOMERATION ECONOMIES

Scale Economies from improved market access:

Transport infrastructure has an inherent role in improving inter regional connectivity and access to markets. Availability of reliable infrastructure reduces unit cost of production by lowering transport costs of inputs and outputs, generates consumer surplus by reducing cost of consumption thereby improving the general quality of life, and attracts private investment. Firms with good access to market centers are thus likely to be more productive than firms in relatively remote areas. Further, better infrastructure in high accessibility areas encourages interaction and knowledge spillovers between firms, as well as between firms and research centers, government and regulatory institutions, etc. The gains from improved market access can, however, be offset by costs of enhanced competition if local firms are not efficient. Improvements in transport connectivity is likely to increase inter regional trade, thereby increasing the likelihood of crowding out inefficient local producers. We use two measures to test the net effects of market access on plant level output -- (a) market accessibility (MA) , and (b) distance from trans-shipment hubs (DHUB). Table 3 lists all measures of agglomeration economies included in the analysis.

Market Accessibility (MA): In principle, improved access to consumer markets (including inter industry buyers and suppliers) will increase the demand for a firm's products, thereby providing the incentive to increase scale and invest in cost reducing technologies. Access to markets is determined by the distance from and the size and density of market centers in the vicinity of the plant. However, effective access to urban markets also depends on the willingness and ability to pay for transport costs and the purchasing power in the market area. Thus,

$$S = f(\textit{distance to market area, population density in market area, purchasing power}) + C_k + \varepsilon_k \qquad (10)$$

where S is scale economies due to access to markets, and C represents other variables limiting the catchment area of the market. A major constraint in testing this formulation is the lack of data on purchasing power at the district level. We therefore use a modified indicator of market access which is discussed below.

The classic gravity model which is commonly used in the analysis of trade between regions and countries that the interaction between two places is proportional to the size of the two places as measured by population, employment or some other index of social or economic activity, and inversely proportional to some measure of separation such as distance. Following Hansen (1959):

$$I_i^c = \sum_j \frac{S_j}{d_{ij}^b} \qquad (11)$$

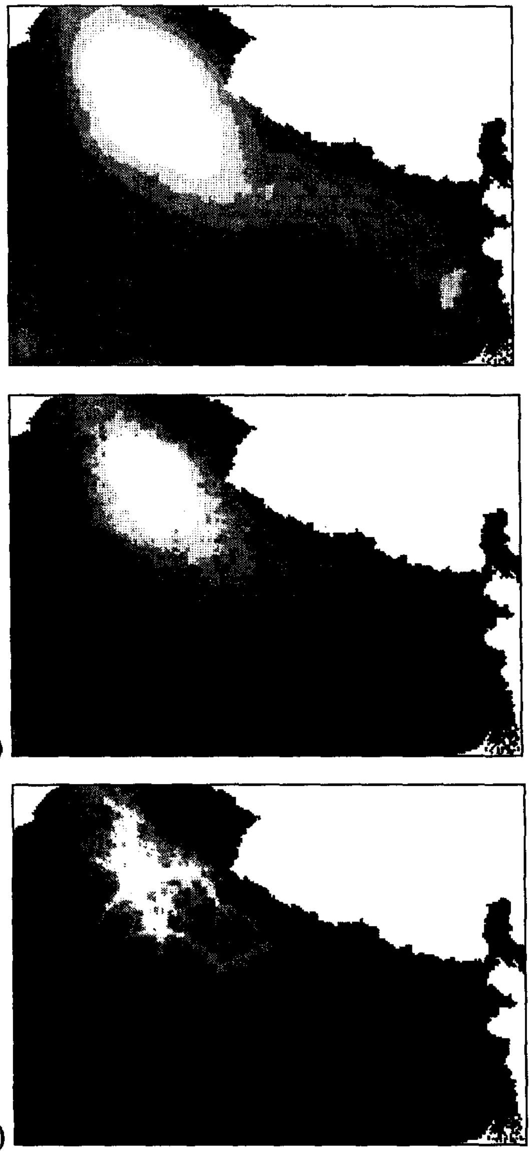
where I_i^c is the 'classical' accessibility indicator estimated for location i, S_j is a size indicator at destination j (for example, population, purchasing power or employment), d_{ij} is a measure of distance (or more generally, *friction*) between origin i and destination j, and b describes how increasing distance reduces the expected level of interaction. Empirical research suggests that simple inverse distance weighting describes a more rapid decline of interaction with increasing distance than is often observed in the real world (Weibull, 1976). The most commonly used modified form is a negative exponential model such as

$$I_i^{ne} = \sum_j S_j \cdot e^{\left(-d_{ij}^h / 2a^2\right)} \tag{12}$$

where I_i^{ne} is the potential accessibility indicator for location i based on the negative exponential distance decay function, most other parameters are defined as before, and the parameter a is the distance to the point of inflection of the negative exponential function. There are several options for developing accessibility indicators depending on the choice of distance variables used in the computation. These include: (a) indicators based on Euclidean distance; (b) indicators incorporating topography; (c) indicators incorporating the availability of transport networks; (d) indicators incorporating the quality of transport networks. In studies related to agglomeration economies and economic geography (e.g., Hanson, 1998), the distance measure of choice is usually the straight-line distance, which has the advantage of computational simplicity. However, this assumption of a Christaller-like isotropic plane is clearly unrealistic, particularly in countries where topography and sparse transport networks of uneven quality greatly modify the effort required to move between different parts of the country.

A better alternative is to use network distance as the basis of the inverse weighting parameter and to incorporate information on the quality of different transportation links. Feasible travel speed and thus travel times will vary depending on each type of network link. A place located near a national highway will be more accessible than one on a rural, secondary road. The choice of the friction parameter of the access measure will therefore strongly influence the shape of the catchment area for a given point—i.e., the area that can be reached within a given travel time. This, in turn, determines the size of potential market demand as measured by the population within the catchment area. Figure 2 shows the accessibility surface for the Northern Indian Gangetic plain using three measures of market access – (1) based on Euclidean distance, (2) network distance, and (3) network travel time. It is clear that indicators based on (1) and (2) overestimate potential market area, and the variation in infrastructure quality between regions leads to a more realistic representation of the structure of market areas. Thus, incorporating the quality of the transport network is important in assessing the potential market integration.

Figure 2: Variations in catchment areas with different measures of market accessibility (dark areas represent lower accessibility)



(1)

(2)

(3)

We computed an accessibility index, which describes market access using digital maps of the Indian road network and the location and population of urban centers (ML Infomap 1998). The urban centers database includes latitude and longitude coordinates and 1991 population for 3,752 cities with a total population of about 217 million. This represents more than one quarter of India's total 1991 population of 846 million. Measures of personal income or consumption may better represent approximate market attractiveness, and employment levels may be a better indicator of the local labor pool. However, in the absence of detailed local data on these parameters, total urban population represents a reasonable proxy for potential market access.

The digital transport network data set includes an estimated 400,000 km of roads[11]. Each road segment is categorized into four classes according to road quality: national highways (about 30,000 km or 7.7 percent of total roads), state highways (90,000 / 22.5 percent), metal roads (120,000 / 29.8 percent), and other roads (160,000 / 39.9 percent). The complete digital network used for the accessibility index thus consists of a set of urban centers represented as nodes connected by lines that correspond to roads of different quality. Rather than distance, the weighting parameter used in the accessibility computation is an estimate of travel time. This makes it possible to incorporate road quality information by assigning different travel speed estimates to different types of roads. Based on information available in the Indian Infrastructure Handbook (CMIE, 1998) varying travel speeds ranging from 25 to 50 km/hour were used, depending on the type of road. The computer routine used for the accessibility computation uses the familiar Dijkstra algorithm to compute the network travel time to urban centers for each of more than 100,000 points distributed across India. As the exact geographic location of each firm is not publicly available, we summarized the accessibility for each district by averaging the individual values for all points that fall into the district. The negative exponential function in Equation (12) is chosen as the most suitable functional form for the decay of interaction with increasing travel time.

Distance from Transshipment hubs (DHUB): We calculated distances (travel times) to transshipment hubs to see if these had external effects over and beyond the effects of market accessibility. In general, trade flows through hubs are disproportionately higher than through nodes (points) along a simple linear network. As a result, proximity to hubs will provide firms with a larger choice of transport providers and intermediate input suppliers than in market centers along a linear network. Further, transshipment nodes (such as ports) have historically had an important role in the evolution of urban centers. In fact, through path dependency such urban centers continue to be prosperous (and efficient) even after the initial advantage of the hub access becomes irrelevant (Fujita and Mori, 1996). In the analysis, we use travel time to seaports as a measure of distance from hubs. Data limitations preclude us from expanding the choice of indicators to include surface transport and airport hubs. We computed travel times between each district headquarter and the closest hub using the same road network as in the market accessibility measure.

Localization Economies (LOC):

At the industry level, scale economies accrue to firms due to the size of the industry in a particular location. These economies are external to the firm but internal to the industry. In the presence of perfect competition, firms are assumed to exhibit constant returns to scale in production. The co-location of firms in the same industry

[11] The total road length is determined using a geographic information system. Due to generalization at large cartographic scales, this represents a low estimate of the total length of all roads in the data set. Furthermore, the digital roads data are unlikely to include all roads in the country. According to Indian government figures, the total length of surfaced roads was about 1 million kilometers in 1991, of which 34,000 km are national highways and 128,000 km state highways (CMIE 1998). However, we assume that the data set contains all major links between urban centers and that the results are unlikely to be affected by omitted minor roads.

generates externalities that enhance the productivity of all firms in that industry. These benefits include sharing of sector specific skilled labor, sharing of tacit and codified knowledge, intra-industry linkages, and opportunities for efficient subcontracting. Further, disproportionately high concentration of firms within the same industry increases possibilities for collective action to lobby regulators or bid prices of intermediate products. These location-based externalities imply that firms are likely to benefit from locating near large concentrations of other firms in their own industry. In addition to supply side linkages discussed above, localization economies are also realized on the demand side. These include reduction of information asymmetries for consumers as well as attracting price and quality comparison shoppers.[12] These so-called 'thick-market externalities' benefit all firms in an industry located in close geographic proximity and can occur in relative isolation from other industries. There is considerable empirical literature supporting the positive effects of localization economies (Henderson 1988, and Ciccone and Hall, 1995). In a recent study of Korean industry, Henderson et al. (1999) estimate scale economies using city level industry data for 1983, 1989, and 1991-93, and find localization economies of about 6 percent to 8 percent. This implies that a 1 percent increase in local own industry employment results in a .06-.08 percent increase in plant output.

The benefits of own industry concentration can, however, be offset by costs such as increased competition between firms for labor and land causing wages and rents to rise, as well as increased transport costs due to congestion effects. Firms in industry sectors which predominantly use standardized technologies and low skilled workers for production may not benefit enough from intra-industry externalities to offset costs from increased own industry concentration.

There are several ways of measuring localization economies. These include own industry employment in the region, own industry establishments in the region, or an index of concentration which reflects disproportionately high concentration of the industry in the region in comparison to the nation. We use one such index of concentration in the analysis -- the <u>location quotient</u> (LQ). The LQ is measured as:

$$LQ_{KR} = \frac{\sum E_{K,R} / \sum E_R}{\sum E_K / \sum E} \qquad (13)$$

where E represents employment, subscripts K and R represent industry and region respectively (Isard, 1956; Hoover, 1975). A LQ greater than 1 implies that the industry is more concentrated in the region than in the nation.

In principle, we expect that increases in the scale of an industry in a given area relative to the nation should be accompanied by positive localization economies through increases in interaction between firms in the same industry. Due to associated costs

[12] The location of several automobile dealerships and restaurants on the same street in most urban areas are examples of this phenomenon.

however, the net effect of industry concentration on plant output needs to be empirically assessed.

Urbanization Economies:

Scale economies from urbanization emanate from the overall size (not only in terms of the number of firms but also in terms of population, income, output or wealth) and diversity of the urban agglomeration. To a firm, benefits from urbanization include access to specialized financial and professional services, inter-industry information transfers, and availability of general infrastructure such as telecommunications and transportation hubs. There is considerable empirical work which supports the positive effect of urbanization economies on productivity. In one of the earliest studies examining urbanization economies Sveikauskas (1975) using manufacturing data for the U.S. at the 2 digit SIC level found that a doubling of city size increased labor productivity by 6 percent. Using Japanese data, Tabuchi (1986) found that a doubling of population density increases labor productivity by 4.3 percent.

Size is usually correlated with diversity as larger urban areas can support a wider range of activities. Small cities are specialized in a few manufacturing activities, or are either administrative centers (such as regional capitals or university towns in some countries), or agricultural market centers providing services for farmers. In comparison, larger cities are more diverse supporting a variety of manufacturing activities that require buyers and suppliers to be in close spatial proximity(I-O linkages). Further, larger cities are centers of innovative technologies and usually tend to offer business or productive services.

While there are numerous benefits to firms from being located close to large urban centers (as mentioned above), these economies can be offset by costs such as increases in land rents and wage rates, as well as commuting times for workers. In fact, most manufacturing activities cannot afford the cost of wages and rents in large metropolitan areas (Henderson et al, 2001). In a recent empirical study, using a cross section sample of 80 cities worldwide, Henderson (2000) finds elasticities of 0.25 for both housing prices and commuting times with respect to metro area population.

While there are both benefits and costs of being located close to large urban areas, the net effect of urbanization on firm productivity (or general economic productivity) is an empirical question.

Urban Population Density (URBDENS): In general, urban concentration is an important contributor to economic efficiency as the spatial concentration of economic activity can lead to the conservation of economic and social infrastructure (Hansen, 1990). In the analysis, we use urban population density as an indicator of concentration, which is measured as the ratio of urban population to the urban area of the district. While many empirical studies have used urban size to examine urbanization economies, we use density as it reflects spatial concentration, which is a better indicator of potential interactions than pure size alone. In addition, by decomposing agglomeration benefits into those deriving from urbanization and those from market access (which is a function of urban scale / size) we can distinguish the relative effects of urban concentration and market size.

Control Variables:

At the regional level (both the district and the state), we include control variables in the analysis. In principle it would be useful to include natural resource endowments, ethnicity, and minority status as they are particularly important in explaining the historical location and concentration of industry. For example, the Indian leather industry is located in close proximity to sources of raw materials (cattle). Due to ethno-cultural reasons it is also dominated by particular religious/ethnic groups such as the Muslims and the Chinese. Consequently the industry is spatially concentrated in regions such as Agra and Calcutta, where these groups are prominently represented. Unfortunately the data available from the 1991 Census do not have information on ethnicity and minority status. Instead we proxy these variables by the share of marginalized population.

In addition to these variables, regional quality of life and general levels of economic development have a bearing on plant level productivity. District level literacy and infant mortality rates are used to represent educational attainment and health outcomes (quality of life indicators), and district workforce participation and state per capita domestic product are used to represent regional economic characteristics.

5. Agglomeration Economies in Indian Industry

The empirical analysis is conducted by jointly estimating equations (6) and (8) as a system, using an iterative seemingly unrelated regression (ITSUR) procedure. The underlying system is nonlinear, and is primarily derived from the structure of the input demands, as represented in equation (8). The ITSUR procedure estimates the parameters of the system, accounting for heteroscedasticity, and contemporaneous correlation in the errors across equations. As the cost shares sum to unity, $n-1$ share equations are estimated (where n is the number of production factors). The ITSUR estimates are asymptotically equivalent to maximum likelihood estimates and are invariant to the omitted share equation (Greene, 1993). All estimations were carried out with the MODEL procedure of the SAS system.

As we are estimating a nonlinear system, we cannot use standard analytic procedures to derive standard errors. Therefore, we use a bootstrap approach to determine the standard errors of the parameter estimates. Bootstrapping is a method for resampling the original data to create replicate datasets from which the variation in the parameter estimates can be evaluated without making strong prior analytic assumptions (Davison and Hinkley, 1997). The procedure used in this study utilizes a nonparametric sampling approach *with replacement* to replicate datasets. Starting with the standard model $y_i = \boldsymbol{X}_i\beta + \varepsilon_i$, we re-sampled the data with replacement from the original $(y, \mathbf{X})$ sample in "pairs", computed statistics of interest, and repeated the procedure a large number of times. The procedure is robust to heteroscedasticity and one does not have to assume that the errors are i.i.d (Johnston and Dinardo, 1997).[13]

We estimated parameter values for each re-sampled dataset, and then computed the means and standard errors from the estimates. Returns to scale parameters for each dataset were computed by summing the marginal products of factors of production (capital, labor, energy, and materials) with respect to output. Similarly, the effects of agglomeration economies were computed by summing the marginal products of the "externalities" variables with respect to output. The final means (estimates) and standard errors were computed by pooling the estimates from all bootstrapped datasets.

We also conducted specification tests for examining if the benefits of agglomeration economies are Hicks neutral or factor augmenting. If they are Hicks neutral, then in equation 6, $\sum_i \gamma_{im} = 0$. The F - statistic is used to test whether the restrictions of Hicks neutrality for the agglomeration terms are valid. The F-statistic for testing a linear hypothesis is:

$$F = \frac{(Rb-q)'[R(X'X)^{-1}R']^{-1}(Rb-q)/J}{e'e/(n-k)}$$

where the null hypothesis is that $R\beta = q$. Thus, (Rb-q) is the deviation from satisfying the null hypothesis (*b* is the least squares estimator). F is the ratio of two chi-squared distributions each divided by its degrees of freedom -- F is distributed as **F** [J, *(n-k)*]. The above representation can be further simplified as

$$F = \frac{(Rb-q)'[s^2R(X'X)^{-1}R']^{-1}(Rb-q)}{J}$$

The critical values for F [J, n-k] can be looked up in standard statistical tables, where *J* is the number of restrictions, *n* the number of observations, and *k* the number of estimated parameters in the unrestricted model.

The F-test rejects the hypothesis that the agglomeration terms are Hicks neutral $(\sum_i \gamma_{im} = 0)$ at the 5 percent significance level for seven of the nine sectors. In two sectors—beverages and tobacco (SIC 22) and repair of capital goods (SIC 39)—we could not reject Hicks neutrality of the agglomeration terms. We re-estimated the restricted model (interaction terms being zero) for these two sectors. The results of the F – tests are

[13] We also re-estimated the specification without bootstrapping using the standard PROC MODEL in SAS and found the standard errors to be smaller by about a magnitude of 10 in some cases. If we had used these estimates, we were likely to erroneously reject the null hypothesis of agglomeration economies being zero.

available from the authors, and detailed parameter estimates for each sector are presented in Appendix 1.

Summary results of the estimated production parameters are reported in Table 4. We could only solve the model for 9 of the 11 sectors. Data problems (lack of convergence of the model) precluded us from reporting results for SIC 30 (chemicals and chemical products) and SIC 37 (transport equipment). Estimated returns to scale parameters range between 0.77 and 1.02. As the returns to scale are calculated by summing the marginal products of production factors, they do not include the direct contribution of the agglomeration variables. However, the interaction of the agglomeration variables with production factors is included in the returns to scale estimates ($\sum\sum\gamma_{im}\ln X_i \ln A_m$ term from equation 8). The returns to scale show that firms in Indian industry are operating either at constant return or decreasing returns to scale. The estimates of decreasing returns observed for 5 of the 9 industries suggest low levels of production efficiency. Lall and Rodrigo (2000) recently observed similar patterns of inefficiency for four Indian industry sectors that exhibit average technical efficiency of about 50% of the domestic best practice frontier.

The returns to production factors reported in Table 4 also indicate that Indian industry is under-developed in comparison to industrialized countries. In general, this can be inferred from the low returns to either labor or capital. In general, industry evolution is accompanied by an increasing share of capital or labor in value added / output due to improved technology embodied in capital and labor (human capital) which improve efficiency and productivity. The share of labor ranges between 0.05 and 0.26, considerably less than results of around 0.7 for industrialized nations (Englander and Gurney, 1994).

Do agglomeration economies matter? Yes they do. Estimates reported in Table 5, however, suggest that there is considerable heterogeneity in the sources and magnitudes of agglomeration economies between industry sectors. For example, market accessibility (MA) has the strongest effect for the leather products industry. The coefficient of 0.66 implies that a 10 percent change in MA would lead plants to increase output by 6.6 percent or that a doubling of MA would increase plant output by 66 percent with no additional plant level production inputs. This means that there are benefits to increasing access to markets by improving the availability and quality of transport networks linking urban areas. This would increase demand for a firm's products and provide the entrepreneur with incentive to increase scale of production. Similarly, positive and significant effects of 0.09 for MA are found for SIC 36 -- electronics and computer equipment.[14]

[14] The MA indicator used in the analysis takes into account the quality of the infrastructure network linking urban areas. We used this measure as it is a better indicator of ground conditions than measures using straight-line indices, which tend to over-estimate market potential. Although the MA indicator is not measured on a scale that allows easy interpretation of policy simulation results, one could use geographic information systems techniques to estimate the productivity effects of newly constructed roads or future road improvements on firms within a specific region.

However, the net effects of improving MA are not always positive. While improved market access potentially increases demand for a firm's products and enables investment in cost saving technologies, it also opens avenues for competition with other domestic firms as well as with products made internationally. In the absence of good inter-regional connectivity, inefficient firms can be in business as they are quasi-monopolies in small market areas. With improved transport connectivity, firms from outside the region can also sell their products in the local market. These effects are similar to reducing tariff barriers. This enhances competition and can reduce the demand for domestic products. For SICs 32 (Non metallic mineral products) and 35 (machinery and equipment), the coefficients for MA are -0.08 and -0.10 respectively. For SIC 35 this would mean that the net effect of doubling MA would reduce plant level output by 10 percent.

In addition to MA, we used travel time to transshipment hubs (DHUBS) as a measure of scale economies from improved market access. Our prior expectation was that increases in travel time to transshipment hubs would have a negative effect on output as firms would incur higher costs and reduced profitability. The coefficients for DHUB are negative for six of the nine sectors and statistically significant for 4 sectors. The strongest effects are for cotton textiles and leather products where the coefficient of -0.23 means that a 10 percent increase in travel time to the nearest port would reduce plant output by 2.3 percent. Similarly, reductions in travel time by improving transport links would increase plant level output.

The net effects of localization economies (measured by the location quotient -- LOC) vary considerably between sectors. While they are positive for three sectors, supporting our priors of positive intra-industry externalities, they are negative for one, and statistically insignificant for the other five sectors. For computers and electronics equipment (SIC 36), the coefficient of 0.05 for LOC means that a doubling of own industry concentration in the region relative to the nation would increase plant output by 5 percent. Similarly, the coefficient of -0.04 on LOC for non-metallic mineral products (SIC 32) means that doubling of own industry concentration in the region (district) would decrease plant output by 4 percent.

There are some limitations with this approach of measuring localization economies. The available data only permit us to identify each firm at the level of the district. Given the large size of many Indian districts (the mean district population in 1991 was about 1.8 million and the mean area approximately 7000 sq. km), this may still be too coarse to capture localization effects. The location quotient represents the potential for exchanges in the form of knowledge transfers and labor pooling, which tend to be quite localized in small spatial extents. If the precise location of each firm had been available, we would have used a finer geographic extent to measure externality benefits of own industry concentration.

In general, we find that urban density has a negative effect on plant level output. The coefficient on urban density (URBDENS) is negative for 6 of the 9 sectors. However, the coefficients are significant in two sectors – Beverages and Tobacco (SIC

22) and Cotton Textiles (SIC 23). The coefficient of –0.20 for beverages and tobacco means that a 10 percent increase in a district's urban population density would reduce plant level output by 2 percent. Similarly, for cotton textiles, the coefficient of – 0.14 for URBDENS means that a doubling of urban population density would reduce plant level output by 14 percent. Even though the negative coefficients for the other 4 sectors are not significant, the results point to a trend that the economies of urban concentration arising from factors such as access to specialized financial and professional services, and inter-industry information transfers do not offset the high costs of locating in dense urban areas. These results are not unexpected as Indian industry in general is inefficient and uses standardized processes and product designs without much innovation. As a result, firms in these industries cannot afford the relatively high wages and rents in dense urban areas, and prefer to locate in smaller / secondary centers.

While it is difficult to make generalizations about the effects (both sources and magnitudes) of agglomeration economies due to considerable heterogeneity between industry sectors, some common patterns do emerge from the analysis. Firms in the sample tend to benefit from internal scale economies driven by market accessibility. Estimates for our two indicators—market access and proximity to transshipment hubs—indicate that improved market access is likely to provides incentives for increasing scale of production. It also allows firms to invest in cost reducing technologies. It is difficult to make generalizations about the effects of localization economies, though the net gains from intra-industry transfers are not likely to be very high in the generally inefficient Indian industry. Even between sectors, the benefits of localization are higher in the machine tools (SIC 35) and electronics (SIC 36) sectors, which are have relatively higher levels of technology embodied in production processes.

The benefits of urban concentration do not offset associated costs. The estimated parameters suggest that there are either no benefits or in fact costs of increasing urban concentration. Higher wages, rents, and congestion in dense urban areas counteract benefits such as inter industry transfers and access to productive services.

We use the leather products industry as an example to put these results in perspective. The leather products industry is at the low end of the technology-skill spectrum and has a large presence in most developing countries due to its roots in pre-industrial society. The industry is highly clustered in India – it is located in only 50 out of more the 500 Indian districts with a Gini coefficient of 0.74, which is the highest distribution inequality among all industry sectors. In some dominant clusters such as Agra, the industry is 66 times as concentrated (represented) in the district as it is in the nation. This dominant cluster is located on a high quality transport corridor with access to a large market area. An important factor influencing the spatial distribution of the leather products industry is that its firms are not predominantly located in major metropolitan areas but are in locations with good access to markets. This is one reason why we see a high response of output to market access (elasticity of 65 percent) in the leather products sector.

The leather products industry is also the fourth largest foreign exchange earner in India, accounting for around 5 percent of the world market for leather products (Lall and Rodrigo, 2000). Thus, proximity to transhipment hubs such as ports is very important for productivity—the empirical evidence of the negative coefficient on travel time to hubs supports this hypothesis. India's comparative advantage in leather products derives from its large bovine population and abundance of low-skilled, inexpensive labor. Technology and innovation embodied in the production process is low, and proximity to sources of raw materials is important. Consequently, there is little scope for significant net benefits arising from intra-industry knowledge transfers or access to diverse productive services -- conjectures that are supported by the lack of significance for variables representing localization or urbanization economies in the empirical analysis.

6. Conclusions

In this paper, we examine the effects of agglomeration economies on plant level productivity. We disaggregate the sources of agglomeration economies to distinguish between economies of scale (1) at the firm/ plant level from increases in market access, (2) at the industry level from localization economies, and (3) at the regional level from urbanization economies across industries. We use a production function framework in the empirical analysis and make allowances for non-constant returns to scale, and for agglomeration economies to be factor augmenting.

Several innovations are made in this paper. This is one of the first studies to use a combination of plant level and disaggregate physio-geographic data to examine the contribution of agglomeration economies to economic productivity. Our indicators of market accessibility take into account the availability as well as quality of transport networks linking urban centers. This allows us to account for heterogeneity in network density between different parts of the country. This is important because traditional measures using physical distance (assuming equal connectivity) tend to bias the estimates of potential market accessibility. Further, as we are more interested in the geography of networks rather than physical geography per se, our measures of market access and proximity to transshipment hubs can be influenced by policy instruments. For example, the benefits of coastal location can be enhanced by development of efficient sea-ports, and the costs of being landlocked can be reduced by investments in transport networks linking the hinterland to regions with access to ports.

We find considerable variation in the sources and effects of agglomeration economies between sectors. For most sectors we find the effects of agglomeration economies to be factor augmenting. In particular, our results indicate that access to markets is an important determinant of firm level productivity. In contrast, benefits of locating in dense urban areas does not appear to offset associated costs. As market size can be maximized by either locating in large urban areas or on high access transport corridors, firms employing standardized production processes (as in Indian industry) would tend to offset costs of high density (high wages and rents) by moving to secondary centers.

If the net benefits of locating in dense urban areas are marginal, then why do we still see high levels of industrial activity in big cities? There are at least two reasons for this. The first one is the large inequality in the spatial distribution of transport infrastructure linking urban areas. With the exception of high density links connecting large urban areas and the centers en route, connectivity of other urban areas is sparse. As a consequence, it is difficult for firms to move to lower cost secondary urban centers and maintain linkages with inter-industry and final buyers and suppliers. From this perspective, a possible option for improving efficiency in industry location would be to improve the availability and quality of inter regional transport infrastructure linking smaller urban areas to the rest of the network. In the absence of such infrastructure, firms will concentrate in a few large centers bearing costs of high wages and rents. In conjunction with Henderson (2000), de-concentration is possible by improving inter urban transport connectivity. The second reason for limited mobility of firms out of large urban areas is regulatory: firm owners cannot close facilities and sell land or assets without authorization from the state governments -- which is difficult at best due to the close linkages between strong labor unions and the government machinery. Further research on the productivity effects of inter-regional transport improvements with concomitant regulatory reform to permit firm re-location will be useful for developing policy instruments.

While investments in inter regional infrastructure and regulatory reform are necessary conditions for enhancing productivity, they are definitely not sufficient. Recent work by Lall and Rodrigo (2000) on Indian industry (using the same data) points to the existence of significant plant level technical inefficiencies, which range from 50 - 60 percent of the domestic best practice standards. Productivity gains from scale economies will be limited if the internal efficiency of firms does not improve.

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Table 1: Spatial distribution of Indian industry

Sector	Name	Number of Districts	Number of plants	Gini Coefficient
SIC 22	Manufacture of Beverages, Tobacco, and related products	164	2051	0.681
SIC 23	Manufacture of Cotton Textiles	159	2480	0.545
SIC 28	Manufacture of Paper products, and Priniting and Publishing	149	2434	0.631
SIC 29	Manufacture of Leather Products	50	899	0.741
SIC 30	Manufacture of Chemicals and Chemical Products	182	3527	0.559
SIC 32	Manufacture of Non Metallic Mineral Products	253	3816	0.675
SIC 33	Basic Metals and Alloys Industries	167	2657	0.649
SIC 35	Manufacture of Machinery and Equipment	140	3093	0.550
SIC 36	Manufacture of Electronics and Computers Equipment	128	2455	0.650
SIC 37	Manufacture of Transport Equipment	97	1917	0.629
SIC 39	Repair of Capital Goods	142	1352	0.637

Table 2: Firm Level Variables used in the study

Variable	Description
Output	Factory value of products and by-products manufactured during the accounting year -- includes the receipt for non-industrial services rendered to others, the receipt for work done for others on materials supplied by them, value of electricity sold and net balance of goods sold in the same condition as purchased.
Capital	Our measure of capital is the sum of the book values of capital assets and capitalized rentals. It includes the total original (undepreciated) value of installed plant and machinery at the end of the accounting year for each firm.
Capital Costs	Capital costs are composed of rental expenditures and interest payments for buildings and machinery as reported in the Annual Survey of Industries.
Labor	Total manday employees, which is the sum of the number of persons of specified categories attending in each shift over all the shifts worked on all days (working and non-working), is used to represent labor input. This measure is selected over the commonly used variable – number of employees -- to capture variations in hours of work.
Labor Cost	Total labor costs are total compensation to employees, which include wages and salaries, as well as supplementary benefits in kind and cash.
Energy	Energy costs are defined as the sum of fuel and electricity expenditures, and defined as the total purchase value of all items of fuels, lubricants, electricity, water etc. consumed by the factory during the accounting year including gasoline and other fuels for vehicles except those that directly enter into products as materials consumed.
Materials	Material input for each firm is defined as the total **delivered** value of all items of raw materials, components, chemicals, packing materials and stores which actually entered into the production process of the factory during the accounting year. This also includes the cost of all materials used in the production of fixed assets including construction work for factory's own use.
Age	Age is calculated as the number of years the factory has been in operation.
Manager Quality (MQ)	To test if managerial quality, as represented by educational attainment and experience, is positively associated with productivity gains, we construct a variable to proxy for this characteristic. We take the earnings per supervisory staff as an indicator representing quality of managerial staff.

Table 3: Variables representing agglomeration economies

Factor	Variable	Notation
1. Scale economies from increased market access	Transportation network and population weighted access	MA
	Access to transshipment hubs	DHUB
2. Industry Concentration	Localization economies (LQ in own industry)	LOC
3. Urban Utilities and Services	Urban density	URBDENS

Table 4: Production Parameters for Indian Industry

Sector	*Name*	**Returns to Scale**		S_k		S_l		S_e		S_m	
		Estimate	*Standard Error*	*Estimate*	*Standard Error*	*Estimate*	*Standard Error*	*Estimate*	*Standard Error*	*Estimate*	*Standard Error*
SIC 22	Manufacture of Beverages, Tobacco, and related products	0.871	0.029	0.110	0.010	0.047	0.005	0.468	0.022	0.247	0.015
SIC 23	Manufacture of Cotton Textiles	0.874	0.010	0.087	0.002	0.105	0.003	0.500	0.008	0.183	0.005
SIC 28	Manufacture of Paper products, and Priniting and Publishing	1.023	0.005	0.110	0.003	0.244	0.005	0.077	0.002	0.592	0.007
SIC 29	Manufacture of Leather Products	0.952	0.025	0.115	0.007	0.062	0.003	0.552	0.021	0.223	0.009
SIC 32	Manufacture of Non Metallic Mineral Products	1.009	0.007	0.113	0.002	0.262	0.005	0.381	0.005	0.254	0.004
SIC 33	Basic Metals and Alloys Industries	0.915	0.017	0.074	0.003	0.139	0.005	0.610	0.009	0.092	0.004
SIC 35	Manufacture of Machinery and Equipment	1.002	0.011	0.096	0.002	0.053	0.001	0.639	0.008	0.213	0.005
SIC 36	Manufacture of Electronics and Computers Equipment	0.984	0.029	0.100	0.004	0.040	0.002	0.666	0.022	0.178	0.005
SIC 39	Repair of Capital Goods	0.772	0.026	0.039	0.003	0.053	0.004	0.239	0.011	0.441	0.015

Table 5: Sources of Agglomeration Economies

Sector	*Name*	MA		DHUB		LOC		URBDENS	
		Estimate	*Standard Error*	*Estimate*	*Standard Error*	*Estimate*	*Standard Error*	*Estimate*	*Standard Error*
SIC 22	Manufacture of Beverages, Tobacco, and related products	0.039	0.118	**-0.102**	**0.048**	-0.021	0.038	**-0.204**	**0.076**
SIC 23	Manufacture of Cotton Textiles	0.049	0.054	**-0.228**	**0.080**	**0.082**	**0.039**	**-0.142**	**0.040**
SIC 28	Manufacture of Paper products, and Priniting and Publishing	-0.034	0.021	0.005	0.009	-0.007	0.007	-0.004	0.017
SIC 29	Manufacture of Leather Products	**0.658**	**0.222**	**-0.228**	**0.050**	-0.039	0.048	-0.117	0.161
SIC 32	Manufacture of Non Metallic Mineral Products	**-0.079**	**0.026**	**-0.063**	**0.013**	**-0.039**	**0.010**	0.054	0.028
SIC 33	Basic Metals and Alloys Industries	0.027	0.036	-0.005	0.017	0.000	0.015	-0.024	0.028
SIC 35	Manufacture of Machinery and Equipment	**-0.103**	**0.041**	0.019	0.025	**0.082**	**0.017**	-0.021	0.026
SIC 36	Manufacture of Electronics and Computers Equipment	**0.090**	**0.045**	-0.024	0.020	**0.052**	**0.026**	0.048	0.057
SIC 39	Repair of Capital Goods	0.017	0.095	0.002	0.032	-0.017	0.032	0.059	0.055

Note: Coefficients in bold are statistically significant at 5% level.

Appendix 1

(following equation (6), all production variables are in logs;
sector fixed effects and control variables not reported)

Parameter estimates and asymptotic standard errors

	SIC 22: Beverages and Tobacco			SIC 23: Cotton Textiles		
Parameter	Estimate	s.e.	t-stat	Estimate	s.e.	t-stat
α_0	7.811	8.824	0.885	19.286	6.691	2.882
α_k	0.317	0.059	5.351	0.169	0.032	5.311
α_l	0.048	0.021	2.340	0.321	0.046	6.926
α_m	0.580	0.130	4.478	0.354	0.098	3.596
α_e	-0.039	0.161	-0.240	0.059	0.113	0.519
ξ_{MA}	-0.521	1.562	-0.333	-3.397	0.946	-3.591
ξ_{DPORT}	-0.102	0.047	-2.178	-0.228	0.080	3.306
ξ_{LOC}	-0.349	0.647	-0.540	-0.124	0.475	-0.261
$\xi_{URBDENS}$	-0.396	1.245	-0.318	0.409	0.735	0.556
β_{kk}	0.015	0.002	7.057	0.037	0.002	14.892
β_{kl}	0.002	0.001	2.136	-0.007	0.002	-3.800
β_{ke}	-0.022	0.003	-7.156	-0.014	0.002	-6.912
β_{km}	0.000	0.002	-0.079	-0.021	0.002	-14.031
β_{ll}	0.005	0.003	1.796	0.018	0.006	2.960
β_{le}	-0.017	0.002	-8.821	0.032	0.005	6.359
β_{lm}	0.013	0.002	6.482	-0.042	0.003	-14.077
β_{ee}	-0.077	0.009	-8.663	-0.103	0.008	-13.745
β_{em}	0.067	0.005	14.368	0.101	0.005	20.057
β_{mm}	-0.069	0.005	-13.188	-0.070	0.006	-12.304
γ_{kMA}				-0.007	0.002	-3.310
γ_{lMA}				-0.001	0.003	-0.408
γ_{eMA}				0.025	0.008	3.218
γ_{mMA}				-0.009	0.008	-1.190
γ_{kLOC}				-0.002	0.001	-1.239
γ_{lLOC}				-0.007	0.002	-4.282
γ_{eLOC}				-0.001	0.004	-0.311
γ_{mLOC}				-0.006	0.005	-1.210
$\gamma_{kURBDENS}$				0.003	0.003	0.988
$\gamma_{lURBDENS}$				-0.009	0.003	-2.610
$\gamma_{eURBDENS}$				-0.009	0.009	-0.959
$\delta_{mURBDENS}$				0.045	0.010	4.362
$\delta_{MA\ MA}$	0.186	0.207	0.896	0.193	0.083	2.324
$\delta_{MA\ LOC}$	0.028	0.054	0.514	0.102	0.043	2.361
$\delta_{MA\ URBDENS}$	-0.136	0.135	-1.006	0.171	0.079	2.158
$\delta_{LOC\ LOC}$	-0.033	0.019	-1.758	0.095	0.024	3.978
$\delta_{LOC\ URBDENS}$	-0.007	0.040	-0.183	-0.086	0.034	-2.546
$\delta_{URBDENS.URBDENS}$	0.090	0.126	0.716	-0.329	0.103	-3.206

Parameter estimates and asymptotic standard errors

	SIC 28: Paper products, printing and publishing			SIC 29: Leather Products		
Parameter	Estimate	s.e.	t-stat	Estimate	s.e.	t-stat
α_0	7.132	4.454	1.601	68.767	21.681	3.172
α_k	0.159	0.042	3.779	0.226	0.088	2.575
α_l	0.767	0.079	9.773	0.253	0.049	5.104
α_m	0.143	0.061	2.351	0.205	0.179	1.146
α_e	0.110	0.031	3.492	-0.096	0.251	-0.380
ξ_{MA}	-0.904	0.715	-1.264	-7.393	3.486	-2.121
ξ_{DPORT}	0.005	0.009	0.545	-0.228	0.052	-4.384
ξ_{LOC}	-0.008	0.003	-2.870	0.904	0.908	0.995
$\xi_{URBDENS}$	-0.113	0.340	-0.333	-6.632	2.128	-3.117
β_{kk}	0.044	0.002	17.463	0.051	0.005	9.309
β_{kl}	-0.012	0.002	-5.254	-0.003	0.002	-1.758
β_{ke}	-0.007	0.001	-6.591	-0.037	0.005	-7.177
β_{km}	-0.030	0.002	-17.069	-0.026	0.002	-11.136
β_{ll}	0.162	0.007	22.216	0.000	0.005	-0.094
β_{le}	-0.024	0.002	-13.552	0.027	0.004	6.670
β_{lm}	-0.101	0.002	-47.619	-0.025	0.002	-11.938
β_{ee}	0.069	0.002	38.988	-0.061	0.010	-5.891
β_{em}	-0.038	0.002	-24.505	0.102	0.004	23.987
β_{mm}	0.148	0.002	65.296	-0.071	0.004	-19.567
γ_{kMA}	0.002	0.003	0.655	0.014	0.009	1.555
γ_{lMA}	-0.011	0.005	-2.036	-0.008	0.005	-1.568
γ_{eMA}	-0.002	0.002	-0.832	0.007	0.025	0.258
γ_{mMA}	0.013	0.006	2.077	0.049	0.020	2.504
γ_{kLOC}	0.041	0.162	0.251	0.002	0.002	0.792
γ_{lLOC}	-0.001	0.002	-0.620	0.002	0.001	2.498
γ_{eLOC}	-0.002	0.004	-0.682	-0.003	0.006	-0.516
γ_{mLOC}	0.004	0.001	2.805	-0.011	0.004	-2.416
$\gamma_{kURBDENS}$	-0.007	0.003	-2.173	-0.014	0.005	-2.800
$\gamma_{lURBDENS}$	0.005	0.005	0.971	-0.003	0.003	-1.040
$\gamma_{eURBDENS}$	0.002	0.003	0.769	0.011	0.018	0.640
$\delta_{mURBDENS}$	-0.004	0.001	-4.111	-0.007	0.006	-1.099
$\delta_{MA\ MA}$	0.050	0.060	0.838	0.133	0.336	0.397
$\delta_{MA\ LOC}$	0.013	0.015	0.853	-0.026	0.067	-0.382
$\delta_{MA\ URBDENS}$	0.034	0.035	0.983	0.671	0.278	2.413
$\delta_{LOC\ LOC}$	-0.003	0.012	-0.241	0.002	0.022	0.073
$\delta_{LOC\ URBDENS}$	-0.007	0.012	-0.577	-0.064	0.088	-0.726
$\delta_{URBDENS.URBDENS}$	-0.017	0.030	-0.569	0.018	0.303	0.059

Parameter estimates and asymptotic standard errors

	SIC 32: Non metallic products			SIC 33: Basic metals and alloys		
Parameter	Estimate	s.e.	t-stat	Estimate	s.e.	t-stat
α_0	-2.526	3.524	-0.717	13.864	5.427	2.555
α_k	0.099	0.031	3.201	0.117	0.038	3.074
α_l	0.026	0.047	0.555	-0.010	0.061	-0.159
α_m	1.039	0.093	11.139	0.405	0.058	7.032
α_e	0.290	0.050	5.822	-0.274	0.185	-1.481
ξ_{MA}	0.860	0.564	1.525	-1.043	0.772	-1.352
ξ_{DPORT}	-0.063	0.014	-4.654	-0.005	0.017	-0.273
ξ_{LOC}	0.587	0.145	4.042	0.610	0.273	2.229
$\xi_{URBDENS}$	-0.364	0.368	-0.989	-0.075	0.556	-0.134
β_{kk}	0.044	0.002	26.636	0.025	0.002	14.511
β_{kl}	-0.012	0.002	-6.425	-0.006	0.001	-4.109
β_{ke}	-0.008	0.001	-6.651	-0.019	0.003	-5.993
β_{km}	-0.028	0.001	-19.016	-0.001	0.002	-0.229
β_{ll}	0.072	0.008	9.174	-0.047	0.005	-9.413
β_{le}	0.064	0.005	12.362	0.040	0.006	6.533
β_{lm}	-0.100	0.003	-35.720	0.011	0.007	1.561
β_{ee}	-0.135	0.003	-46.225	0.036	0.013	2.780
β_{em}	0.097	0.003	31.316	0.004	0.008	0.475
β_{mm}	-0.024	0.004	-5.658	-0.021	0.005	-3.934
γ_{kMA}	0.004	0.002	1.739	-0.008	0.002	-3.569
γ_{lMA}	0.021	0.004	4.899	-0.001	0.004	-0.259
γ_{eMA}	0.009	0.005	1.848	0.019	0.013	1.475
γ_{mMA}	-0.042	0.009	-4.833	0.002	0.003	0.647
γ_{kLOC}	0.000	0.001	-0.222	0.000	0.002	-0.225
γ_{lLOC}	0.002	0.002	1.097	-0.003	0.003	-1.004
γ_{eLOC}	-0.002	0.002	-1.019	-0.017	0.008	-2.213
γ_{mLOC}	-0.007	0.003	-2.103	0.000	0.002	-0.129
$\gamma_{kURBDENS}$	-0.004	0.003	-1.326	-0.001	0.002	-0.360
$\gamma_{lURBDENS}$	0.009	0.004	2.313	-0.007	0.004	-1.880
$\gamma_{eURBDENS}$	-0.004	0.004	-0.908	0.003	0.011	0.286
$\delta_{mURBDENS}$	-0.003	0.002	-1.389	-0.017	0.005	-3.659
$\delta_{MA\ MA}$	-0.001	0.047	-0.030	-0.008	0.056	-0.135
$\delta_{MA\ LOC}$	0.000	0.014	-0.024	-0.042	0.022	-1.935
$\delta_{MA\ URBDENS}$	-0.088	0.035	-2.500	0.116	0.058	2.001
$\delta_{LOC\ LOC}$	-0.037	0.010	-3.830	-0.019	0.017	-1.143
$\delta_{LOC\ URBDENS}$	-0.060	0.015	-4.042	0.009	0.019	0.459
$\delta_{URBDENS.URBDENS}$	-0.042	0.011	-3.870	-0.092	0.049	-1.874

Parameter estimates and asymptotic standard errors

	SIC 35: Machinery and Equipment			SIC 36: Electronics and Computers		
Parameter	Estimate	s.e.	t-stat	Estimate	s.e.	t-stat
α_0	-5.621	4.588	-1.225	15.066	5.537	2.721
α_k	0.129	0.039	3.272	0.107	0.040	2.701
α_l	0.128	0.014	8.859	0.122	0.016	7.431
α_m	0.875	0.091	9.647	0.804	0.093	8.678
α_e	0.031	0.144	0.216	0.474	0.132	3.583
ξ_{MA}	1.002	0.684	1.465	-1.697	0.663	-2.559
ξ_{DPORT}	0.019	0.025	0.753	-0.024	0.027	-0.903
ξ_{LOC}	0.364	0.336	1.083	-0.645	0.234	-2.762
$\xi_{URBDENS}$	0.709	0.536	1.323	-1.881	0.767	-2.451
β_{kk}	0.040	0.002	18.509	0.043	0.006	6.923
β_{kl}	-0.003	0.001	-3.126	0.001	0.001	1.130
β_{ke}	-0.016	0.002	-6.925	-0.031	0.005	-5.898
β_{km}	-0.024	0.002	-11.177	-0.021	0.004	-5.225
β_{ll}	0.002	0.003	0.653	0.007	0.003	2.218
β_{le}	0.032	0.002	13.820	0.023	0.003	7.067
β_{lm}	-0.032	0.003	-11.865	-0.031	0.003	-9.701
β_{ee}	-0.145	0.012	-12.409	-0.125	0.013	-9.815
β_{em}	0.130	0.010	12.672	0.122	0.008	16.273
β_{mm}	-0.087	0.009	-10.158	-0.092	0.007	-13.902
γ_{kMA}	-0.006	0.003	-1.658	0.000	0.004	0.113
γ_{lMA}	0.001	0.001	0.603	0.003	0.001	3.058
γ_{eMA}	0.024	0.012	1.986	0.007	0.013	0.516
γ_{mMA}	-0.022	0.008	-2.964	-0.009	0.008	-1.205
γ_{kLOC}	0.005	0.002	2.224	0.000	0.002	-0.024
γ_{lLOC}	-0.001	0.001	-1.253	0.000	0.001	0.165
γ_{eLOC}	0.006	0.011	0.518	-0.002	0.007	-0.207
γ_{mLOC}	0.020	0.004	4.714	0.017	0.004	3.929
$\gamma_{kURBDENS}$	0.004	0.003	1.438	0.008	0.003	2.291
$\gamma_{lURBDENS}$	0.001	0.001	1.186	0.000	0.001	-0.116
$\gamma_{eURBDENS}$	0.015	0.010	1.450	-0.001	0.014	-0.061
$\delta_{mURBDENS}$	-0.013	0.005	-2.755	-0.003	0.005	-0.702
$\delta_{MA\ MA}$	-0.081	0.069	-1.181	0.050	0.062	0.805
$\delta_{MA\ LOC}$	-0.066	0.028	-2.336	0.051	0.025	1.998
$\delta_{MA\ URBDENS}$	-0.020	0.067	-0.294	0.155	0.057	2.720
$\delta_{LOC\ LOC}$	-0.016	0.014	-1.171	0.007	0.027	0.272
$\delta_{LOC\ URBDENS}$	-0.007	0.035	-0.185	-0.007	0.035	-0.202
$\delta_{URBDENS.URBDENS}$	-0.069	0.063	-1.098	0.043	0.086	0.498

Parameter estimates and asymptotic standard errors

SIC 39: Repair of Capital Goods			
Parameter	Estimate	s.e.	t-stat
α_0	23.565	6.695	3.520
α_k	0.045	0.050	0.900
α_l	0.141	0.051	2.760
α_m	0.272	0.236	1.155
α_e	-0.044	0.305	-0.144
ξ_{MA}	-1.234	0.891	-1.384
ξ_{DPORT}	0.002	0.032	0.063
ξ_{LOC}	0.293	0.433	0.678
$\xi_{URBDENS}$	-2.945	1.051	-2.803
β_{kk}	0.013	0.002	6.587
β_{kl}	-0.006	0.001	-4.394
β_{ke}	-0.011	0.003	-4.322
β_{km}	-0.008	0.001	-5.969
β_{ll}	-0.049	0.008	-5.918
β_{le}	0.049	0.006	8.066
β_{lm}	-0.004	0.002	-1.928
β_{ee}	-0.085	0.015	-5.471
β_{em}	0.052	0.008	6.711
β_{mm}	-0.020	0.014	-1.487
γ_{kMA}			
γ_{lMA}			
γ_{eMA}			
γ_{mMA}			
γ_{kLOC}			
γ_{lLOC}			
γ_{eLOC}			
γ_{mLOC}			
$\gamma_{kURBDENS}$			
$\gamma_{lURBDENS}$			
$\gamma_{eURBDENS}$			
$\delta_{mURBDENS}$			
$\delta_{MA.MA}$	-0.162	0.125	-1.294
$\delta_{MA\ LOC}$	-0.055	0.047	-1.157
$\delta_{MA\ URBDENS}$	0.295	0.111	2.659
$\delta_{LOC\ LOC}$	-0.069	0.022	-3.180
$\delta_{LOC\ URBDENS}$	0.010	0.035	0.281
$\delta_{URBDENS.URBDENS}$	0.022	0.102	0.214

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