Density Gradients and their Determinants: Evidence from India

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Abstract

Although India contains a large number of Urban Agglomerations (UAs), their suburbanization has drawn little attention of the literature. I calculate population, household and employment density gradients for India's UAs, using the two-point method. I *estimate* gradients for one major Indian city and document its spatial evolution. At the aggregate level, I find that the size of UA and lagged value of the population gradient explain population suburbanization. I find evidence from the employment suburbanization equation that it is the jobs that follow people, and not vice-versa, consistent with what has been found in the literature. I conclude with policy insights.

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Introduction and Motivation

The suburbanization of metropolitan areas in countries such as the United States and Canada has drawn a lot of attention of the researchers (Mills and Price, 1984; Mills, 1992; Margo, 1992; Mieszkowski and Mills, 1993; Small and Song, 1994). For developing countries, and a large country like India that contains a large number of urban agglomerations (UAs), suburbanization has drawn very little attention, primarily due to lack of detailed spatial data thus far. In this study, I focus on this sparsely studied issue.

Besides, better land use and infrastructure planning in a metropolitan area also requires understanding the current spatial structure, how the spatial structure is changing, and why it is changing. In India, there are numerous indications that the demand for suburban land use is increasing rapidly, but the underlying factors are poorly understood. For instance, data from India's decennial censuses indicate that over the period 1981-91, there was a small, but certain 3 percent increase in the average proportion of population that was living in the suburbs of cities. But the study of suburbanization in Indian cities has been severely hampered by poor data thus far. This paper sheds light on what is happening by studying the pattern of density gradients for population, households, and employment for 1981 and 1991 (the most recent years for which data are available) across Indian cities, and makes an attempt to explain India's suburbanization.

Objectives

In this study, I examine the following:

1. While the number of UAs in India grew from 275 to 375 over 1991-2001, what is the extent of population, household and employment suburbanization that has taken place?[1] I study population, employment and household suburbanization in India's UAs, as observed in 1991, using the two-point method. While the two-point method has been widely applied to calculate gradients for cities in several countries, in this study, I calculate population density gradients for all Indian UAs for which the data are available, using 1981 and 1991 census data, the most recent available.[2] Further, I calculate household and employment density gradients (including those for employment sub-sectors) for Indian UAs for 1991.[3] India, being a large country, shows variations in suburbanization across regions as well. I supplement the aggregate analysis of suburbanization by documenting the spatial evolution of one major Indian city by *estimating* its population density gradient in 1991 and again in 2001.

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[1] An UA, according to the Census of India (1981), is one with the following characteristics, and reports data separately for the core city (roughly the equivalent of CBD in American metro areas) and outside of the core city:

a. A city or town with continuous outgrowth(s) the outgrowth being outside the statutory limits but located within the boundaries of the adjoining village or villages; or
b. Two or more adjoining towns with their outgrowth(s); or
c. A city with one or more adjoining towns with their outgrowths all of which form a continuous spread.

[2] For 2001, the Census of India has not yet released land area data for all UAs. Based on my discussions with them, it could take them time ranging from a few months to a year, to release this data.

[3] Corresponding data for calculating household and employment density and employment sub-sector gradients for 1981 were not available.

2. What explains population, household and employment suburbanization in India's UAs?

The answers to these questions are quite important. The extent of suburbanization, and their determinants have implications for governmental policies relating to unemployment rate, universal literacy programs, provision of public services and their impacts. Better understanding of policy impacts enables better formulation and planning of optimal city growth.

Overview of Paper

The rest of this paper is organized as follows. The next section provides a review of relevant past literature on the subject. The literature review section is followed by a general overview of urbanization in India. Given its importance, a section on land use controls in India's cities follows the section on urbanization. Following this, a section briefly sets the terminology and measurement of suburbanization to be used in the rest of the paper. Then the relevant theoretical framework follows. This is followed by a section on the methodology, model and data sources for work in the paper. Then the data are described, followed by the results from explaining India's suburbanization, following which policy insights are discussed. Concluding remarks end the paper.

Review of Literature

Literature dealing with suburbanization in large and developed countries such as the United States and Canada is vast. (McDonald, 1989) provides a survey of the literature on density functions. A more recent literature review on studies of density functions and gradients is in (Anas, Arnott and Small, 1998) and (Glaeser and Kahn, 2001). (Cutsinger et al., 2004) operationalize seven distinct conceptual dimensions of sprawl (that includes density) for fifty large U.S. metropolitan areas using a variety of indices. Suburbanization studies relating to Canadian urban areas are in (Bunting, Filion and Priston, 2002) and (Walks, 2004).

Broadly, one stream of literature on traditional urban models relies on a market-based theory (which Mieszkowski and Mills, 1993 call as natural evolution theory) of the evolution of urban spatial structure, in the absence of land use controls. This market-based approach takes into account the impact of rising incomes, transportation technology, and population, on the density gradient. Standard urban economic theory shows that increases in income and population have the effect of increasing suburbanization. The literature dealing with a market-based theory of suburbanization shows that income growth in a metropolitan area leads to decreases in the gradient (Margo, 1992; Thurston and Yezer, 1994). The theory suggests that as new housing is built at the periphery of cities, high income groups who prefer larger amounts of housing settle there. Another factor that supports the market theory is that over time, increases in real income make expensive modes of transportation like the automobile more affordable. Second, larger metropolitan areas are more suburbanized than smaller ones (Mills and Price, 1984; Mieszkowski and Mills, 1993). Suburbanization is known to occur in large metro areas because of retail services and lower land costs in the suburbs. As the metro area becomes larger, households prefer to move to the suburbs to make use of retail services and consume greater amounts of housing than what would be available in the CBD.

A second class of explanations of suburbanization in the literature stem from the Tiebout model that relates suburbanization to central city problems such as high taxes, poor educational attainment, racial tensions, and poor quality of public services. This literature relies on "flight from blight" and argues that central city problems are the cause of the increasing suburbanization observed in the United States. (Mills and Price, 1984) made an attempt to look at the "flight from blight" hypothesis. Their empirical finding was that the set of measures representing central city problems – crime, educational attainment and taxes–adds nothing to our understanding of population and employment suburbanization. As (Mieszkowski and Mills, 1993) point out, even if the effect of "flight from blight" is relatively small, it could have considerable effect on the margin because the measurement of gradients is on an exponential scale rather than a linear one. Thus it is an important factor affecting suburbanization and is a key factor to whether it is considered a manageable phenomenon or a problem.

(Jordan, Ross and Usowski, 1998) measure and analyze differences in rates of suburbanization during the 1980s among U.S. metropolitan areas, which fit a monocentric urban model. (Glaeser and Kahn, 2001) study the decentralization of employment in American cities. They find that employment is highly decentralized in American cities, as may be seen in their finding that less than 16 percent of total employment was located within a 3-mile radius of the city center. They also find evidence that decentralization is more common in manufacturing employment than they are in services.

(Sridhar and Sridhar, 2003) study the impact of telecommuting, made possible by technology, on suburbanization, using data for U.S. metropolitan areas. They use the population and household density gradients as measures of suburbanization. For telecommuting indicators, they use data from Survey of Income Program and Participation (SIPP). They find support for the market-based model of suburbanization. They find that large cities (those with large populations) are likely to be more suburbanized than their smaller counterparts, when controlled for the influence of central city fiscal and socio-demographic characteristics. Further, they find that telecommuting contributes to centralization, not suburbanization, of metro areas, and conclude that technology could be a complement, not a substitute for face-to-face interaction, consistent with (Gasper and Glaeser, 1998).

(Mills and Tan, 1980) compare density functions for developed and developing countries. They find that the negative exponential density function is a good description of data from vastly different countries. They note that while suburbanization is a continuously occurring phenomenon in the developed as well as developing countries, central city densities are extremely high in large urban areas of developing countries when compared to those in the developed countries. They find average density gradients for (12) Indian cities to be 0.65 for 1960 (summarized in their Table 19), quite high when compared to that for cities in Brazil (0.17, for 1960) Japan (0.46 for 1965), and 0.34 (for Mexico), and 0.20 for USA (for 1960). Only the Korean average density gradient (for 12 cities) was higher than (being 0.70 for 1960) for India. Quite rightly as they point out, any modest income increases in the developing countries certainly induce people to move out. And, there is an intense conflict between suburban development and rural land uses. They point out that more research should be done on the determinants of land use patterns in developing and developed countries.

Due to data constraints, however, empirical studies of suburbanization in the context of developing countries, that too a large country like India that has a large number of UAs, is sparse. Only one study by the Census of India (Jain, 1993) studies the emerging trend in the suburbanization of India over 1971-81. That study does not analyze suburbanization as much as it analyzes changes in the composition of Standard Urban Areas. It also does not perform any more systematic analyses than calculating trends.

I concur with the literature and assume that the market-based model and fiscal-social problem approaches are both important in explaining suburbanization in the Indian context. Before we delve into a discussion of suburbanization, I provide a general overview of urbanization trends in India and discuss land use regulations in India's cities since they are quite important in determining cities' spatial growth.

Urbanization in India

While a large part of India's population continues to live in rural areas, the extent of urbanization in India increased slightly over 1991-2001, from 26 to 28 percent.[4] In 1991, India's urban population was 218 million, which steadily grew to 285 million in 2001, and is predicted to reach about 550 million by 2021. (Siddiqui, 2004) points out that, agglomerations covering several jurisdictions are likely to emerge as a distinct feature of India's urbanization.

(Mathur and Mookerjee, 2006) point out that India has been urbanizing at an average annual growth rate of 3.1 to 3.2 per cent which, although comparable with the growth rate observed for the less developed countries, is in fact, 1.1 percentage points lower compared with the average for Southeast Asia. One reason is that the level of urbanization, which was projected to cross the 30 per cent threshold, measured only 27.78 per cent in 2001. However, given India's population size, the absolute numbers and physical pattern of urban growth are important, as Table 2 on the size distribution of India's cities shows.

Table 2 describes the size distribution of cities in various class sizes since the beginning of the century. At the beginning of the twentieth century, there was only one city with million plus polulation, namely Calcutta, with a population of 1.5 million.[5] Bombay joined this league in 1911. In 1991, four metropolitan areas (Mumbai, Chennai, Kolkata and Delhi) were the only mega cities (with population

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[4] The Census of India defines settlements having the following characteristics as urban areas:
(a) a population of five thousand or more;
(b) a minimum density of 1000 people per square mile; and
(c) at least seventy five percent of work force outside agriculture.

This definition has remained the same during 1981-2001. The reader may hence be sure that the small *increase* in the extent of urbanization is no artifact of definition. However, the above definition of an urban area itself is conservative according to some. Cohen (2004) argues that India's definition of an urban area is restrictive enough to miss population growth occurring in urban areas just outside of the official city boundary. He suggests that if India were to adopt a different definition of an urban area, it would be transformed from being largely rural to being predominantly urban.

[5] These, being called as 'million-plus' cities, are at the apex of the urban hierarchy in India. Below the million-plus cities, the Census of India's definition for various class sizes of cities is as defined in the notes to Table 2.

greater than five million), but by 2001, the number of mega cities had increased to six (with Bangalore and Hyderabad joining the league). This trend continued steadily. In 1991, there were 23 cities with a population of over one million (which accounted for 33 percent of the urban population), over 300 cities with a population ranging between 100,000 and a million, and over 4,000 towns (see Table 2). In 2001, the number of cities with million-plus population grew to 35 (housing 38 percent of the total urban population), with 14 of these 35 growing at higher than average rate during 1991-2001 (Lahiri-Dutt and Samanta, 2001). In 2001, the number of cities in the population size category of 100,000 to one million (class I cities) grew to 464 from only over 300 in 1991.

We should note that there is quite a lot of disparity in the way in which these million-plus cities are spatially distributed across the Indian states. Uttar Pradesh and Maharashtra together contained the largest number (5) whereas there are many states without a single million-plus city. Note, however, that unlike most developing countries where a single city commands a disproportionately large proportion of population and economic activities, India's urban system is spatially dispersed, and is not characterized by primacy, as (Mathur and Mookerjee, 2006) highlight. In fact, urban primacy may have weakened. For instance, Mumbai's population weight in the country's total urban population declined from 5.79 in 1991 to 5.74 in 2001, and that of Kolkata also declined from 5.06 to 4.63 during the same period.

<INSERT TABLE 2>

Can we say something about a typical spatial pattern of the distribution of households by income in Indian cities? The spatial pattern of the distribution of households of various income groups within cities varies greatly across countries. In Paris, for instance, as (Brueckner *et al.*, 1999) point out, there is a stronger tendency for richer households to live centrally, while poor households often live in the suburbs. Two reasons explain this observation. In Brueckner *et al.*'s model, high-income households value a centrally located amenity. Further, historic preservation and height restrictions prevent dense low-income housing from being developed in the center, while public housing projects have been located in the suburbs. This is in contrast to most North American cities, where the richer households live in the suburbs and the central city is usually confined to the poorer households.

There is no data on income by city in India (let alone intra-city income) that would permit us to say something definitely about a typical spatial pattern by income in Indian cities. Casual observation suggests that in all metropolitan areas of the country, the relatively richer households settle in the periphery, whereas the central city continues to be dominated by lower income households, much like in North American cities.[6] One reason for this is that the poorer households rely on the bus system, which continues to be the dominant mode of transportation in Indian cities, and remains largely central city-oriented.[7] Note here that the poor are workers with lower skills (those that work in restaurants, small traders

[6] Mumbai, where the rich live in the central city, similar to what is observed in Paris, is an exception rather than the rule in Indian cities.

[7] In the CBD of North American cities, few people live. However, in India, the central business district is a broader term where people do live and do business. Mathur and Mookerjee (2006) point out how residential areas in the central districts and sub-central parts of cities such as Delhi, Bangalore and Hyderabad are now being transformed into

(retailers in mom and pop shops), transporters (drivers) and so on). Since higher income households can afford the automobile, they are prepared to trade-off access for more land and housing by staying away from the center. The later observation I make that employment suburbanization has occurred, refers primarily to high skill jobs (call centers, business process outsourcing activity, software industry jobs, and so forth).

It is easy to conceive of cities that have multiple employment centers. However, as long as employment density in the center is greater than it is in the suburbs, the monocentric urban model continues to be valid. Also, following the literature (Small and Song 1994), I use 'monocentric' to mean any distribution which is approximately circular and symmetric around a single center, not in the more restricted meaning of all employment being in the CBD. (McMillen, 2004) provides evidence to show that the central city still dominates urban spatial patterns, and the basic insights of the model apply to more complex polycentric cities. He points out that much of the apparent decline in the explanatory power of the monocentric city model is actually a misunderstanding of the empirical evidence. In fact, (Chakravorty, 2000) points out that in developing countries, city functions are rarely comparable to developed nation city functions, since the public sector in developing countries is much more active in urban land markets (refer to the discussion below regarding land use controls in India's cities). Further, he argues the CBD is more important as the locus of employment, rent gradients are more unilinear and steep, moving away from the CBD. All these factors lead to distinct monocentric cities in the developing world as opposed to the clearly established polycentric cities of the west. For India's cities, this is a reasonable assumption to make; metro areas like Bombay are predominantly monocentric. While this assumption is testable, a limitation is that the data are not rich enough to measure subcentering directly.

Land use controls and regulation in India's cities

A fundamental question to ask is whether India's urban areas are likely to evolve following the competitive model applicable in the US, or whether India's institutional framework could lead to a different evolution since there are stronger land use controls. Land use controls such as the Urban Land (Ceiling and Regulation) Act, 1976 continue to exist in India. This law was originally used to build an adequate stock of urban land for 'public interest' purposes such as road widening, development of open spaces and other 'public' facilities. While this law was repealed with effect from January 11, 1999, the law continues to be in force in a handful of states (Maharashtra and Bihar). This law stipulates that individuals or firms cannot hold property above a certain size (varies across metro areas). If they do, they have to sell the extra land to the government for what is considered quite low price by market standards.

Further, rent control in Indian cities, while being socialist in its original ethos to protect tenants from exploitative property owners, has now thwarted the effective development of the land market by limiting property owners' incentives to maintain and renovate property. In several cases, rent control has

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commercial spaces. For instance, they cite the fact that during 1994-2001, Bangalore added nearly 92,000 sq. meters of work space and 200,000 sq. meters of living space in its central district.

frozen the property tax revenue in cities where property taxes continue to be determined on the basis of stream of rental income accruing from the property.

Another draconian control in place in India's cities refers to extremely low maximum floor area ratio (FAR) (which happens to be a maximum of 1.33 in downtown Mumbai[8]) in the center of cities. Without higher FAR, real estate projects are usually not financially feasible. Because of low FARs, few buildings get renovated and the city is left with a lot of redundant space. The results are higher rents per square foot and lower consumption of floor space, resulting in greater than optimal expansion of the city. Higher FARs are often permitted in the suburbs, as in the case of Bangalore (where a maximum of 2.25 is allowed in some areas, according to its current master plan). In fact, (Bertaud and Brueckner, 2003) compute that in Bangalore, consumer loss from floor size index (FSI) restrictions (same as FAR) (due to excess commutes, higher rents and so forth) represented 3-6 percent of household consumption! Further, the fact that in Mumbai, transfer of development rights can be used only in suburban areas but not in the city contributes much more to density pattern and suburban expansions than market forces.

Having noted the importance of land use regulations, it is extremely difficult, if not impossible, to disentangle the impact of such land use regulations from consumer demand, in the database I work with in this study. The severity of regulation usually varies in inverse proportion with city size (the low FAR in Mumbai would be an exception). Next, it is likely that with the reform program and the opening up of foreign direct investment in construction, real estate in India could be freed of these controls. Once this happens, Indian UAs are likely to evolve as in the competitive model of the US. One example is: although land use controls exist in India's cities, free rural-urban migration is causing migrants to locate at the periphery of cities. Though not immediately, these migrants are annexed into the city limits gradually, increasing the city's geographical boundary and its burden of providing public services. There are however, natural limits to city growth (defined by optimum city size, given from general equilibrium models of city growth). Such limits to growth could be reached much faster in Indian cities due to rent control, and restrictions on the supply of housing.

Everything said and done, it is very difficult to determine to what extent land use controls are accommodating and to what extent they are restrictive. But, if land use controls are restrictive, it is reasonable to assume that there will be considerable political pressure (from developers) to have them changed. Thus, even when they are present, one expects land use controls to be adjusted in response to market forces, allowing the competitive model of individual migration decisions to determine city growth. In fact, some Indian cities are specifically adopting a laissez faire approach to city growth. This lends support to the idea of using a competitive model of city growth in the suburbanization regressions in this paper.

Another caveat to be noted is that unlike in the USA, Urban Agglomerations (UAs) in India have a loose description, and the Directorates of Censuses in the various states enjoy a high degree of discretion in designating an area as a UA. There are several instances where 'outgrowths,' shown as parts of UAs, have political and speculative overtones. This is a caveat to be noted so that the phenomenon of UAs is not mistaken as a purely demographic-cum-economic occurrence.

Finally, one should note that the selections of UA boundaries are notoriously idiosyncratic. For instance, if one were to superimpose a satellite image on the UA boundaries in a metropolitan area, one can see clear urban concentrations which are not part of the UA, while some parts of the UA would be undetectable as being urbanized.

Further, in Indian UAs, the process of mergers of suburbs with cities has just begun for better and integrated metropolitan governance. For instance, suburbs such as Delhi cantonment and Mahipalpur were not part of the 'city' in 1981, but were merged with the Delhi Municipal Corporation (DMC) (now called Municipal Corporation of Delhi (MCD)) in 1991. Delhi's example demonstrates that suburbanization in India's context is not defined relative to a historically determined central city.[9] The central city keeps growing as do the outlying areas. Because of this, the measure of suburbanization that is chosen in this paper is also free of any historically based scale effect.

Measurement and terminology of suburbanization

Readers should make a note about terminology used in this paper regarding suburbanization. Broadly speaking, suburbanization is the process where the percentage of population living in the suburbs rises. When I use the term in this general sense, I refer to it as suburbanization. In the literature, the density gradient is used as a standard measure of population or employment suburbanization. The gradient shows how population (employment) density (number of persons (employed) per square mile or kilometre) changes with distance from the CBD. Thus in a more narrow sense, b-suburbanization is the process that occurs when the absolute value of the gradient falls. When I use the term in its narrow sense defined in this way, I refer to it as b-suburbanization.

There are several criteria that are needed for an appropriate measure of suburbanization (Mills, 1992). I use the gradient b as a measure of suburbanization because it has several advantages. The first is that the gradient approach is relatively simple. As (Mieszkowski and Mills, 1993) point out, the exponential density function is a reduced form equation of a simple and robust model of metropolitan spatial organization (see also Brueckner, 1987).

There are two ways of measuring the gradient. We can either *estimate* it, or *calculate* it. Population (household or employment) density (per square mile or kilometre) for census tracts (wards) and distances of the tracts (wards) from the city center are data required to *estimate* density gradients. Specifically, the gradient is the coefficient in a regression of density (for census tracts or wards) on distance from the city center, as in the negative exponential equation:

$$D(r) = D_0 e^{-br} \qquad (1)$$

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[8] This means that only 1.33 square meters of floor area (including those on multiple storeys) can be built per square meter of lot area.

[9] If suburbanization is defined relative to an historically determined central city, and if the urban area grows, it is inevitable that suburbanization would increase. However, that is not a problem here.

where D (r) is the relevant density r miles (kilometres) from the center, e is the base of the natural logarithm, b (the gradient) and D_0 are constants estimated from the data, if the data are available at such a disaggregated level (usually census-tract or ward level).

As should be clear, estimation of gradients is a very data intensive process requiring population, household or employment density and land area (some suggest the use of residential or other relevant land area) data at a very disaggregate level (usually census tract, block or ward). Because of the data intensity required by the *estimation* of gradients, (Mills, 1972) demonstrated through the two-point method, that from data on just two points in the city, central city and metro area, we can *calculate* rather than estimate it. Thus in using the two-point method, I measure density gradients by comparing the densities of the central city and that of the urbanized area. I measure the central city by the municipal corporation limits of the primary town(s) in an UA and the urbanized area by the boundary of the UA, both as defined by the local statute.

(Bertaud and Malpezzi, 2003) study the spatial distribution of population in 48 cities of the world, of which they include 3 cities from India for which they estimate the gradients, based on data they obtained from their visits to the planning departments in these cities. In India's Census, data on *population* are readily available at the census tract level. However, detailed data on *land area* at the ward level, are not available in a centralized fashion, requiring one to go to each of the 375 UAs to obtain the land area data, by census ward. Further, the areas of many census wards within UA boundaries include lakes, rivers, hills and swamps. So one should note that, density calculated by dividing the census population by the (larger) area of the ward, as given by the census, will give a very low density, thus making the density gradient appear much steeper than it really is. However I am unable to make adjustments to these gross densities in the two-point method, due to lack of data on usable land that is net of lakes, rivers, hills and swamps.

Accurate land use maps to measure the built up area of each ward for the several UAs included in the study, are difficult to obtain from Google earth, making it a near-impossible proposition to estimate density gradients for all of India's UAs in one attempt. However, when the 2001 data and maps become available for the UAs, this is a potential area of future research. Further, even when population and household data are available at the *ward* level, data are certainly not available on *usable* land at the ward level, which makes the computation of population and household densities at a ward level, problematic. Therefore from this viewpoint also, computation of the population, household and employment gradients using the two point method is appropriate. Only for one major Indian city, Bangalore, (with 2001 population of 9.5 million in its municipal corporation limits), I am able to obtain *population* (not employment) and land area data at the *ward level* for two successive time periods (1991 and 2001). I *estimate* the population density gradients for this city for two successive time periods.

Employment data at the ward level are even more difficult. Employment data are not collected at the ward level in any Indian city including Bangalore. There are hundreds of such census wards in each city. Therefore I estimate the employment density gradient for all cities (including for Bangalore) using the two-point method. With these caveats having been stated, I am able to supplement my aggregate analysis of

India's suburbanization with a historical documentation of the spatial evolution of *population suburbanization* in Bangalore, a city with five million-plus population.

Theory

As (Brueckner, 1987) points out, standard models of population distribution provide the theoretical rationale for the exponential population density function. From the theoretical exponential density function in equation (1), we may derive the ratio of L_C to L as given below:[10]

$$\frac{L_c}{L} = \frac{1-e^{-bR_c} - bR_c e^{-bR_c}}{1-e^{-bR} - bR\, e^{-bR}} \qquad (2)$$

In equation (2), L_C and R_C respectively refer to population (households or employment) and land area in the central city of UAs. L and R respectively refer to population, (households or employment) and land area, of UAs. Given data on L_C, R_C, L, R, H_C (households in central city) H (households in UA), E_C (employment in central city), and E (employment in UA), I calculate population, household and employment gradient b in (2) for all Indian Urban Agglomerations (UAs). It should be readily clear then that the two-point method measures density gradients by comparing the densities of the central city and that of the urban agglomeration.

I use the two-point method noting its caveats. The two-point method is of course inferior to the regression procedure that uses many observations to estimate the gradient (as I do here for Bangalore). Further, neither does it provide a confidence interval for the value nor an estimate of the fit of the density equation, as the estimation technique does.

This is not to deny the several strengths of the two-point estimates. First, the two-point estimates constrain the integrated gradients to predict population (households) and employment correctly, as (Macauley, 1985) points out. In fact, population density gradients estimated by OLS usually do not add (integrate) up to total population over the appropriate geographic area. (White, 1977) performs a Monte Carlo experiment and concludes that the two-point estimates are a fairly good approximation of least

[10]Equation (1) is $D(r) = D_0e^{-br}$. Since $2\pi r$ is the circumference of a circle, expressions for L_C and L (H_C, H, E_C and E) are derived, as shown below, enabling computation of population, household and employment density gradients with L_C, L, H_C, H, E_C, and E respectively.

$$L_C = \int_0^{R_C} 2prD(r)dr$$

Substituting for D(r) from (1), we get

$$L_C = \int_0^{R_C} 2prD_0e^{-br}dr$$

Integrating the above yields

$$L_C = \frac{2pD_0}{b^2}[1 - e^{-bR_c} - bR_c e^{-bR_c}]$$

Similarly for L,

$$L = \int_0^{R} 2prD(r)dr = \int_0^{R} 2prD_0e^{-br}dr = \frac{2pD_0}{b^2}[1 - e^{-bR} - bR\, e^{-bR}]$$

squares estimates. No wonder, ever since Mills proposed the method, several studies have used it (for instance, Mills and Ohta, 1976, Macauley, 1985, McDonald, 1997).

While I estimate equation (1) for Bangalore, I derive the ratio of central city population (households and employment) to that in the total UA for all Indian UAs, using the two-point method. Using this equation (2) that is fairly standard in the literature (that does not have a closed form solution), I calculate population, household, and employment density gradients for all of India's UAs. Further, using these gradients, I estimate and explain population, household and employment suburbanization for India's UAs for 1991. At the time this paper was revised in 2006, the Census of India had not yet released the land area data for all UAs for 2001.

Methodology, Model and Data Sources

I obtained data on land area, population, households, and employment, along with other socio-demographic characteristics for the various constituents (primary town(s), adjoining town(s), and outgrowth(s)) of all UAs in the country for 1981 and 1991 respectively from the 1981 and 1991 Census of India Primary Census Abstract (PCA) tables. The details of these sources are in the data appendix at the end of this paper.

I then aggregated the data for various components of UAs separately for the central city (the primary town(s)) and the entire UA. In order to arrive at R_C and R (land areas of central city and UA respectively), I assumed that UAs are circular.[11] This assumption is quite reasonable as India's UAs have what are called as ring roads and outer ring roads, similar to the outer loop in the U.S. metropolitan areas, reinforcing the circular nature of these agglomerations.[12]

I supplement the aggregate gradient analysis with a detailed documentation of spatial evolution in one major Indian city. I do this by estimating several population density gradients for Bangalore for 1991 and 2001, using population data at the ward level.

Estimation of Density Gradient for Bangalore

I *estimated* population density gradients for Bangalore, for which land area and population data were available at the ward level for 1991 and 2001. I obtained ward-level population and land area data for Bangalore (for 1991 and 2001) from the Bangalore City Corporation's (*Bangalore Mahanagara Palike (BMP)*, as it is called) planning department. The digital (2001) map of Bangalore was obtained from the state of Karnataka's census directorate in Bangalore, to enable calculation of distances from the wards to the city center. Then I estimated the population density of ward i as being dependent on distance of ward i from a central point in the city (as shown by equation (1)).[13] Equation (3) shows equation (1) in linear form.

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[11] The area of a circle is ΠR^2, R (radius of circle) can be solved for.
[12] Many cities in the US are now undergoing 'strip development' in which urban areas expand only certain highways, rather than a more traditional symmetrical radial growth; this could change their existing shape. Very little research has been done regarding city shapes in India.
[13] With a digital map of Bangalore, I calculated distances from the city center to the center of every ward. After I did this, I checked and confirmed that the physical distances thus calculated are indeed about right.

$$\ln D(r) = \ln D_0 - br \qquad (3)$$

I estimated equation (3) at the level of Bangalore's wards, making various assumptions regarding the city center. The density function was estimated by OLS by taking the natural log of population density at every r (D(r)), and regressing this on the distance (r) of every ward from the city center, yielded the density gradient b, as shown in equation (3).

I was thus able to supplement the aggregate level density gradient analysis with a historical analysis of spatial evolution in one Indian city for which data on land area and population for two successive time periods were available at the level of census wards.

Calculation of Density Gradient for all UAs Using the Two-Point Method

Based on the aggregate data for all UAs, I calculated eight points for all UAs -- R_C and R,[14] L_C and L (population of central city and UA respectively) for 1981 and 1991, H_C and H (households in central city and UA respectively), and E_C and E (employment in central city and UA respectively), for 1991.[15] Using equation (2) (that requires an iterative method), I calculated population density gradients for 1981 and 1991, based on R_C and R, L_C and L for 1981 and 1991; household density gradients for all UAs, based on R_C and R, H_C and H for 1991 (data on households for central city and UA not available for 1981). Further, based on R_C and R, E_C and E for 1991, I calculated employment density gradients for total employment and for several sub-sectors including mining and construction, manufacturing, trade and commerce, communications, and other services, all for 1991 for the Indian UAs[16] for which the gradient was calculable.[17]

Given the caveats of the two-point method, I first calculated the gradients using a simple heuristic procedure, and then recalculated them using the Newton-Raphson iterative technique. The gradients calculated were robust to both the methods, except for some differences in the fourth decimal place. So I found the gradient estimates were robust with respect to the observations used.

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[14] I called all the state census offices to get land area data for UAs where they were not available. Further, even where they were available, I verified the land area data from the individual states. State governments in India get land area data from their local governmental units, compile and pass them to the Census of India office in New Delhi that disseminates it.

[15] The available data enable me to calculate only the population gradient for 1981 and 1991. Data on households and employment or employment by sub-sector were not available separately for central city and rest of central city for the UAs in 1981. For 1991 these data are available and all gradients -- population, household and employment -- are calculated.

[16] There were 221 UAs in the country in 1981, but their number had grown to 375 in 1991. Note the following caveats, however:

a. A large number of UAs in the north Indian state of Punjab for 1991 had to be left out due to the lack of disaggregated land area data, bringing the 1991 UA sample to about 340.
b. There were a large number of UAs in 1981 that were no longer enjoying the UA status in 1991, since they were de-classified. And, obviously enough, a large number of new UAs had developed by 1991. Thus there were only about 80 UAs for which both 1981 and 1991 data were available, for which gradients could be calculated and compared. This also explains why the sample for all regressions that include the lagged value of the population gradient is small.

[17] The gradients were calculated using Visual Basic.

Estimation of Determinants of Density Gradients

In the next step, at the aggregate level, I performed regressions of the population, household, total employment and the various employment sub-sector gradients I calculated for all Indian UAs as explained in the previous section, by ordinary least squares. I estimated these density gradients as in the standard literature. The following models were used:

$$b_{ij}* = f_i(y_j) + \xi_{ij} \quad (4)$$

As in previous literature, $b_{ij}*$ is the equilibrium value of the gradient b for i (population, household or employment) and UA j. It is assumed that the actual gradient (observed) eventually adjusts to the equilibrium value of the gradient, b* with a lag. y_j is the vector of explanatory variables. As always, ξ_{ij} is the random error term.

The empirical versions of the estimated population (and household) and employment density gradient functions respectively are:

$$b_{Pj} = \alpha_0 + \alpha_{PPOP} POP_j + \alpha_{PY} Y_j + \alpha_{PJS} JS_j + \alpha_{PN} N_j + \alpha_{PUN} UN_j + \alpha_{PSCST} SCST_j + \alpha_{PLIT} LIT_j + \alpha_{PLAG} PLAG_j + u_j \quad (5); \text{ and}$$

$$b_{Ej} = \beta_0 + \beta_{EPOP} POP_j + \beta_{EN} N_j + \alpha_{EW} W_j + \beta_{ELF} LF_j + \beta_{ESCST} SCST_j + \beta_{ELIT} LIT_j + \beta_{EPLAG} PLAG_j + \beta_{EPS} PS_j + e_j \quad (6)$$

where

b_{Pj} and b_{Ej} = Population (or household) and employment density gradients in UA j;

POP_j = Population of UA j (scaled and divided by 10,000);

Y_j = Annual household income in UA j;

W_j = Wage cost (workers' emoluments as proportion of value of output) in the state in which UA j is located;

JS_j = Proportion jobs suburbanized in UA j;

N_j = Number of local governments in UA j in 1981;

LF_j = Labor force as proportion of population in UA j;

UN_j = Ratio of unemployment rate in the central city to that in the suburbs in UA j;

$SCST_j$ = Ratio of scheduled castes and/or scheduled tribes[18] (SC/ST) as proportion of total population in central city to that in suburbs, in UA j;

LIT_j = Ratio of literacy rate, which is computed with the number of literates as a proportion of population above 6 years of age, in central city to that in suburbs, in UA j;

$PLAG_j$ = Lagged value of population gradient (for 1981);

PS_j = Proportion population suburbanized in UA j.

A data appendix at the end lists the various sources of data for all the above variables and explains how each of them is computed.

[18] Scheduled castes (SC) and scheduled tribes (ST) in India have been traditionally socially repressed, so it is possible to believe that their presence would deter the location of 'higher-caste' population and households in a given area.

As in the standard literature, the population variable is included in the population, household and employment suburbanization equations to test for the effect of market-based factors on suburbanization. It is well-known that larger metropolitan areas are more suburbanized than smaller ones (Mills and Price, 1984; Mieszkowski and Mills, 1993). As the metro area becomes larger, households prefer to move to the suburbs to make use of various retail services and consume greater amounts of housing than what would be available in the central city.

I included annual household income in the population and household suburbanization equations to test for a market-based evolution of suburbanization. That is, to study if richer UAs are any more suburbanized than poorer ones, since their households can afford the automobile that makes living farther away from the CBD more plausible. Data on annual household income are from the National Council of Applied Economic Research (NCAER). These data are such that within every state, the estimated distribution of households by income groups, are provided for all town groups classified by population.[19]

As explained earlier, a second class of explanations of suburbanization in the literature stem from the Tiebout model that relates suburbanization to central city problems. This literature relies on "flight from blight" and argues that central city problems are the cause of the increasing suburbanization observed in the United States. The ratio variables in the population and employment density gradient equations – ratio of SC/ST in the central city to that in suburbs, ratio of literacy rate in central city to that in suburbs, and finally, ratio of unemployment rate -- are meant to test the flight from central city blight hypothesis.[20]

The number of local governments in the UA is indicative of competition prevalent in the provision of public services. This variable (N_j) has been included to test for the Tiebout effect on the suburbanization of population, households and firms. (Jordan, Ross and Usowski, 1992) include this in their model of suburbanization. Note that the current number of local governments in the UA could be endogenous.

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[19] The town groups are: Over 500,000 population; 200,000-500,000 population; 100,000-200,000 population; 50,000-100,000 population; 20,000-50,000 population; and <20,000 population. The annual incomes for 1996-97 are in 1998-99 prices. The income groups used by NCAER are – upto INR 35,000; 35,001-70,000; 70,001-105,000; 105,001-140,000; Above 140,000. I take the mid-point of income for each of these categories, and calculate a weighted average of household income, where the weights are the estimated number of households in every income category. UAs' income vary depending on their population and their state of location. So all UAs above 500,000 population within any given state would have the same average annual household income. This works well in most cases, not well in some others. But this is the only resort since income data at the city level are not available in any other data source.

[20] Another possible candidate for indicating relative attractiveness of the central city is the property tax rate by UA (at this point, data on central city and UA ratios for property tax rate are not available). The property tax is the only one levied at the local level in India, apart from the octroi on businesses where they exist. Octroi is levied on business activity, being a tax on the entry of goods into a municipal area for consumption or sale. A number of states in the country have recently abolished octroi on businesses, as its cost of collection is high. Further, it is distortionary, distorts prices of goods and gives rise to a number of discretionary practices that become breeding ground for corruption.

The ratio of the property tax revenue to the taxable value of property would give us a measure of property tax rate. While data on property tax revenue are available (though not in centralized manner for all cities), data on the assessed value of taxable property is unavailable even for Delhi, let alone in a centralized fashion for all 375 UAs in the country. Most cities in India continue to follow the archaic annual rateable value (ARV) method of property valuation which is quite subjective, when compared to the unit area method, which is more objective and makes property valuation and assessment depend on characteristics of the property. Delhi has taken steps to move towards unit area method very recently. This means that the property tax base is subjective and is best not shared with public.

Because of these reasons, the tax base of cities in India is much less buoyant than it is in countries such as the United States and tax rates are less likely to be a factor influencing suburbanization. However, the level of public

Because of this, the number of local governments in the UA in 1981 was used as a measure of competition in public services. Note that while the 1991 number of governments is endogenous, the number of local governments in 1981 is exogenous to the model.

The 1991 proportion of jobs suburbanized in the UA (employment data were not available for UAs for any year other than 1991) is included as a regressor in the population gradient equation to test whether 'people follow jobs,' as this is a question that remains unresolved in the literature (see Partridge and Rickman, 2003, for recent evidence). While the extent of employment suburbanization is crucial for households, population suburbanization is important for firms, since it indicates the availability of skills.[21] I include in the employment gradient equation, the proportion of population suburbanized (lagged, from 1981), to test whether jobs follow people.

The reason for including the lagged value of the population gradient in both equations, as (Mills and Price, 1984) point out is to test whether the actual value of b adjusts to its equilibrium value with a lag.

The proportion of population in the labor force speaks for the work ethic of the population. The central cities of many UAs in India (for instance, Jamshedpur is built around Tata Iron and Steel) are built around specific industries or firms. Labor force as a proportion of population in these UAs would be high. If this proportion were spatially concentrated (very likely, since such towns have large campus style developments), there would be some impact on employment suburbanization. This implies that the employment history of a city could be important, and hence needs to be accounted for when studying employment suburbanization.

Indian statistical authorities do employ standard measures of population and households; however, there are no standard measures of the "labor force." But data are available on how many were working full-time, how many were working part-time, but would have liked a full-time job (these are defined as marginal workers), and how many were non-workers (housewives, students, retired, and so forth). In these surveys, main workers are defined as those who had worked for the major part of the year preceding the enumeration.[22] Marginal workers are defined as those who worked for sometime in the year preceding the enumeration but did not work for a major part of the year.[23] If an individual had not worked at all during the last year he or she is treated as a non-worker by the Census. Non-workers include (i) those attending to household duties at home; (ii) students; (iii) dependents; (iv) retired persons or renters; (v) beggars; (vi) inmates of institutions; and (vii) other non-workers. Informal employment is covered by the census of

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services could be a factor influencing suburbanization, and the number of local governments in the UA is taken to be an indicator of the extent of competition in local public service delivery.

[21] In the Indian context, this is important since BPO, call centres and other IT-enabled services depend quite heavily on the quality of manpower available. I am unable, however, to perform causality tests between jobs suburbanized and population suburbanized because of lack of data on jobs suburbanized for any period other than 1991. Recall that the Granger causality test (or other variants of the test) requires the use of lagged values of the variables in determining causality.

[22] These workers are those who were engaged in any economically productive activity for 183 days or six months or more during the year.

[23] These workers include those who worked for less than 183 days or six months during the year.

India, since the data are based on micro responses to surveys. Informal employment is captured in household responses to the full-time or part-time work question.[24]

To be consistent with Census' definition of non-workers, here, all non-workers in the categories (i)-(vii) above have been treated as those outside of the labor force. For purposes of this work, the ratio of population in the labor force is calculated as the total number of full-time workers plus workers looking for work (marginal workers), as a proportion of population for every UA.

Since marginal workers are treated in the Census as those that were willing, but have not found full-time work, the unemployment rate here is computed as the ratio of these marginal workers to those in the labor force (main plus marginal workers). This rate is computed separately for the central city and other parts of the UA, and the ratio is taken of the central city to suburban unemployment rate.

As should be clear, the population (household) and employment gradient equations (5) and (6) are both econometrically identified. Note that there are certain characteristics that each determines population and employment suburbanization. While household income along with other characteristics, determines population suburbanization, wage costs are the appropriate analogous regressor that explain suburbanization of employment. The local unemployment rate determines population suburbanization (if we were to assume information availability for residents), but not so for employment suburbanization. Further, for various reasons discussed earlier, the size of the labor force is an important factor affecting suburbanization of employment, but not that of population. Finally, the proportion of jobs suburbanized is a potential determinant of the extent of population suburbanization, whereas it is the extent of population suburbanization that would be important for firms in their locational decisions.

Findings from Data

When we study the proportion of population that is suburbanized in 1991 (21.33 percent) and 1981 (20.67 percent) (Table 3), there is a small, but certain increase in the percentage of suburbanization.

<INSERT TABLE 3>

On average, slightly higher proportion (22.02 percent) of households and employment (21.76 percent) is suburbanized than is population (21.33 percent). We expect households to be more suburbanized than population because they consume greater amounts of land and housing. Employment is more suburbanized than population. In India, as a whole, service sector employment accounts for 20 percent of total employment. In the context of urban India, however, most employment (33.5%) is in production-related work (report compiled by the Economic Times (2005) from the National Sample Survey Organization (NSSO)). Production and manufacturing jobs (i.e., relatively more skilled) tend to be more suburbanized (confirmed by Table 8) because of their nature. Further, in a large number of the UAs (140 of the 340), population density in the CBD is one-five times higher than in their suburbs. All these factors combined together explain why overall, (skilled) employment is more suburbanized than population.

[24] This question is, "Did you work any time at all last year (including unpaid work on farm or in family enterprise)?"

Table 4 summarizes suburbanization for the four metropolitan areas, as of 1991. This table shows that the population, households or jobs suburban for the metro areas is much higher than they are for all UAs, consistent with what we expect. When we look at the trend of population suburban over 1981-91 (Table 5) for the metro areas, Madras (Chennai) is more suburbanized in 1991 than in 1981. Delhi has remained more or less the same over this decade whereas Calcutta actually had less of its population suburban by 1991.[25] Greater Mumbai was not an UA in 1981, so comparable data were not computable.

Table 6 summarizes b-suburbanization--population, household and employment density gradients for India's UAs, and for the metro areas. A large number of UAs in the north Indian state of Punjab for 1991 had to be left out due to the lack of disaggregated land area data, bringing the 1991 UA sample to 340. Out of the 340 UAs, gradients were calculable for roughly 150 of them, due to the nature of land area data. Whenever the central city and UA land area data were not very different, the gradient for these UAs could not be calculated as the iterations for the function indicated by equation (2) did not converge, even when the maximum number of iterations was exceeded. Recall that the two-point method relies on comparing the central city density with that in the suburbs. UAs for which the gradient could not be calculated, had to be left out.

<INSERT TABLE 4>

<INSERT TABLE 5>

<INSERT TABLE 6>

Although not apparent from the proportion suburban (Table 3), when we examine b-suburbanization--the density gradients, on average, India's UAs have certainly suburbanized over the decade as may be seen in the declining value of the population density gradient (Table 6). This is consistent with what is observed in cities in other countries, where density gradients have been declining in general (Mills and Tan, 1980). Further, the density gradients for Indian UAs are larger compared to those for developed countries. For instance, the average population density gradient reported by (Jordan, Ross and Usowski, 1998) for 77 US metropolitan areas for 1990 is 0.16, whereas the population density gradients for Indian UAs (Table 6) are much higher (average is 0.47 for 1991). As (Papageorgiou and Pines, 1989) point out, we expect higher central densities and larger density gradients in countries of higher overall population densities because of the rising opportunity cost of land.

(Mills and Tan, 1980) summarize gradients for 12 Indian cities for various years over 1881-1961. Their gradients are not directly comparable with those calculated in this study, as the methods are different. (Mills and Tan, 1980) summarize gradients for Indian cities from (Brush, 1968) who *estimated* the gradients using the negative exponential density function. Here the density gradients are *calculated* for all UAs (assuming the negative exponential density function), *except in the case of Bangalore where they are also estimated.*

As one would expect, the metropolitan areas are more b-suburbanized (have lower absolute value of the gradient) in 1991 than when all the UAs are taken into account (Table 6). Table 6 also reports the

[25]The merging of some suburbs with the central city in Kolkata UA may explain the outcome there.

descriptive statistics of density gradients for the same set of UAs in 1981 and 1991. This is the comparison I place more confidence in, rather than in that for all UAs over 1981-91. This comparison of the average density gradients for the fixed set of UAs during 1981-91 shows that b-suburbanization has indeed taken place in India's UAs. Moreover, the percentage change (decline) in the absolute value of the density gradient for the same set of UAs is greater, as is shown in Table 6. The most centralized UA in 1981 also had suburbanized (as may be seen in the lowering of the maximum value of the density gradient from 0.99 in 1981 to 0.98 in 1991).

Further, on average, population b-suburbanization over 1981-91 in the metro areas has been at a much greater pace than in all the UAs, again consistent with our expectation (Table 6).[26] Household and employment density gradients are not very different from each other for the UAs and the metros (Table 6). This is consistent with what is observed in Tables 3-5. In general, when we take only 1991, and examine population, household and employment density gradients, households are the most b-suburbanized as we would expect, as presumably they would be in need of more land and housing.

Gradients by Region, Employment Sub-sector and Categories of UAs

India being a large country, shows variations in b-suburbanization across regions as well. Table 7 summarizes the population, household and employment gradients by region. Table 7 shows that the northern region's population is more b-suburbanized than the eastern, southern or western counterparts in 1991, although UAs in the southern region were much more b-suburbanized than those in all the other regions in 1981. Household and (total) employment in UAs situated in the northern and southern regions are much more b-suburbanized than their counterparts in the eastern and western regions that continue to be more centralized. In general, employment and population in UAs in the southern region are more b-suburbanized compared to the eastern or western regions of the country, something that has got to do with their GDP growth as much as suburban growth. All states in the southern region have higher per capita GDP compared with their eastern and some northern counterparts.

<INSERT TABLE 7>

Table 8 summarizes employment gradients for various employment sub-sectors. In general, gradients were calculable for a larger number of UAs in the case of manufacturing, but for much less number of UAs in the other sectors. This is partly because of the concentration of employment in manufacturing, and much smaller employment in other sectors, in most of the UAs. Table 8 shows that on average, mining and manufacturing employment are much more b-suburbanized compared to that in services (transport communications, trade and commerce, and other services), consistent with what (Glaeser and Kahn, 2001) find in American metro areas. The finding is intuitive for cities in India as much as for those in other countries because mines and manufacturing jobs are most likely located much away

[26]Household and employment density gradients or the proportion of households and employment suburban could not be calculated for 1981 as analogous data were not available. For 2001, the Census of India had not released land area data for all UAs, when this paper was revised.

from the CBD than the other jobs. The most centralized sector in terms of employment is trade and commerce services, easy to imagine since these are mostly office (white or blue-collar) jobs.

<INSERT TABLE 8>

With a view to distinguish between Urban Agglomerations (UAs) with varying combinations of population and employment densities at the center and periphery, I examined gradients for the following categories of UAs:

a. UAs which have high densities at the core (meaning central city) and low at the periphery (suburbs), say, with central city density 5-10 times or >10 times greater than that for the suburbs;
b. UAs with medium or low densities at the core and comparable densities or higher densities at the periphery. This could be measured with central city density lower than, or merely 1-5 times more than that for suburbs.

Such distinction between different kinds of UAs helps us to better appreciate the gradients that are obtained, instead of treating gradients of all UAs as being homogenous. Table 9 summarizes population, employment, household and various sub-sector gradients for UAs classified by the ratio of population density in the CBD when compared to that in suburbs. Table 10 summarizes the various gradients for UAs classified by the analogous employment density ratios as in (a) and (b) above.

When we examine the population gradient, the gradient progressively keeps getting bigger whenever the central city population density is higher compared to that in the suburbs (Table 10).

For instance, on average, the population gradient is only 0.44 for UAs with population density in central city 1-5 times greater than that in the suburbs (Table 9), but it is 0.81 for UAs that have population density in their central city greater than 10 times than that in their suburbs. This is consistent with what we expect, since the higher the central city population density relative to suburban density, the more centralized would UAs be. Further, employment in UAs with population density in central city lower than that in the suburbs, are also suburbanized. As example, on average, the employment gradient in UAs with population density in central city lower than that in suburbs is only 0.05 (very b-suburbanized) compared with an average of 0.78 in UAs where population density in central city is several times higher than that in suburbs. This is true in the case of all employment sub-sector density gradients, with the exception of mining.

Conversely, Table 10 confirms that UAs, whose central city employment density is lower than that in the suburbs, are more suburbanized even in terms of their population, all of which imply that population and employment suburbanization go hand in hand. Employment in the various sub-sectors is more b-suburbanized where total employment is b-suburbanized and vice-versa.

<INSERT TABLES 9-10>

Summarizing, the particular findings that are noteworthy are that population suburbanization has continually occurred in India’s UAs in both narrow and broad senses of the term. However, households are much more suburbanized than population since they are in need of more land and housing. Metropolitan areas of the country are much more suburbanized than the rest of the country. Population, households and employment in UAs of the northern and southern regions are much more b-suburbanized than their counterparts in the eastern and western regions that continue to be more centralized. Mining and manufacturing employment are much more b-suburbanized compared to services (transport communications, trade and commerce, and other services), consistent with what (Glaeser and Kahn, 2001) find in American metro areas. UAs, whose central city employment density is lower than that in the suburbs, are suburbanized even in terms of their population, all findings empirically consistent with past literature and which make sense intuitively.

Estimation of Population Density Gradients for Bangalore

As discussed earlier, the population density gradients for Bangalore were estimated as in equation (1).[27] The density function was estimated by OLS by taking the natural log of population density as shown in equation (3). Table 11 presents population density gradient estimates for 1991 and 2001, first assuming that the city center is in ward 77, *Sampangiramanagar,* (where the state legislature and secretariat, the *vidhana soudha* is located). Table 11 also presents other estimates, assuming other plausible areas as city centers, based on the findings. These gradient estimates for Bangalore show that the population distribution is quite steep, with the density gradient being (positive) 0.10 in 1991, becoming both negative and declining in absolute value, to -0.05 in 2001.[28]

A couple of observations have to be made here.

First, with the conventional city center, the estimated density gradient is positive in 1991, and negative in 2001. This shows that in 1991, population density was increasing as one moved away from the conventional city center. By 2001, this trend had reversed, with population density declining as one moved away from ward 77.

Second, during 1991-2001, population b-suburbanization has indeed occurred in Bangalore, as may be observed in the declining absolute value of the estimated gradient.[29] This makes sense because, with the conventional city center, while there were a couple of peaks (ward numbers 20 (*Sadashivanagar)* and 32 (*Kempapura Agrahara*)) in terms of population density in 1991, they collapsed to a single peak in 2001 (ward number 32). In fact, the density of the highest peak in 1991 declined from 124,034 persons per square kilometer by 44 percent to only 69,172 per square kilometer in 2001.

Based on these findings, I re-estimated the density gradient functions for 1991 and 2001 by making ward 20 and ward 32 respectively as the new centers of the city, and by recalculating the distances

[27] Bangalore had 87 wards in 1991, which increased to 100 by 2001. I had data on land area only for the 2001 wards. There were only 57 wards that were common during 1991 and 2001, so I assumed that the area of these 57 wards remained the same during 1991-2001. For this reason, I could use only 57 observations in the 1991 regressions, but all the 97 wards for which all data were available for the 2001 regressions, to estimate the gradient. Regressions for the same subset of wards for which all data were available in 1991 and 2001 are available, but not reported.

[28] These *estimated* gradients cannot be compared with the *calculated* one for Bangalore because the calculated gradients are for the Bangalore UA (which is a larger area) whereas the estimated gradient is only for the city of Bangalore (its municipal corporation limits).

[29] I also re-estimated the regression (for the same subset of wards in 1991 and 2001) by taking logs on both sides, and found the density increasing by 79 percent in 1991, but increasing less rapidly by 36 percent per square kilometer in 2001.

of all wards from these new city centers. When I do this, I find that the gradient becomes negative, and falling from the respective city centers to the edge. Over 1991-2001, the absolute value of the gradient falls from 0.06 to 0.05. All these results are summarized in Table 11.

These results motivate the question as to which is the real center of the city. If we were to adopt the reasoning of Alperovich (1982), the real center is that which, statistically, produces the highest R^2, as (Small and Song, 1994) also point out. If we were to use this criterion as the benchmark, then the real center of Bangalore is ward 32, which produces the highest R^2 (see Table 11). This ward is primarily a residentially zoned area, with mixed residential uses having mostly low-income housing, some commercial activity, small scale industry, and artisan activity.[30]

<INSERT TABLE 11>

Explaining India's Suburbanization

The results from the estimation of population, household and employment (total and for certain sub-sectors) suburbanization for all Indian UAs are presented in Tables 12-14. The equations are estimated by ordinary least squares.

The size of the UA (indicated by population) and the lagged value of the population gradient significantly affect population suburbanization (Table 12). Specifically, larger UAs are more suburbanized than smaller ones, as is clear from the negative sign on the variable. As metro areas grow bigger, people move farther out to make use of more land. The lagged value of the population gradient adds significantly to the model's explanatory power, consistent with what (Mills and Price, 1984) and much of the literature finds (see for instance, McMillen, 2004). The lagged population gradient is positive and significant, implying that UAs are likely to continue their historical b-suburbanization trends. As (McMillen, 2004) points out, this shows that inertia is a critical determinant of gradients. Further, it confirms that Indian cities' spatial structure cannot be separated from their political-economic history, as (Chakravorty, 2000) points out in the case of Calcutta. The history of Indian cities has been influenced strongly by global and local events.

<INSERT TABLE 12>

In the household suburbanization equation, in fact, the lagged value of population gradient continues to be significant. This implies that the gradual convergence towards the equilibrium value of the gradient is indeed significant. By and large, it is also because of the lagged population gradient that the sample size is a little smaller than otherwise. Overall, the explanatory power of the model is slightly better for the household b-suburbanization than it is for population b-suburbanization.

To examine the impact of automobiles on suburbanization, I estimated the population and household suburbanization equations with the number of motor vehicles per 1,000 population (which was

[30] In fact, going by the draft of Bangalore's master plan 2015 (the revised Comprehensive Development Plan (CDP)), the city will grow in circles over the next ten years. The plan classifies the city's areas into five major zones, all concentric belts, based on the current and planned land-use pattern. These include the city's old urban areas, urban re-development areas, residential areas, industrial areas, with the green areas being the outermost belt.

available only for 21 of the UAs) included as a regressor along with other independent variables shown in equation (5).[31] Even in this specification of the model, it was the lagged population gradient that was significant in explaining population as well as household suburbanization. In addition to this, another finding of interest was that when controlled for the motor vehicles per 1,000 population, the literacy rate ratio had a negative impact on the gradient. This implies that when ownership of the automobile is controlled for, population and households locate in the suburbs even when the literacy rate there is low relative to the central city! Another big difference is that when the motor vehicles per 1000 population are added to the equations, the explanatory power of the population suburbanization model increases to 0.83 and 0.80 for household suburbanization (both adjusted R-squared). Part of this is attributable to the fact that these estimations make use of only 15 observations and the model provides a good fit for the small sample. Apart from this, there could be little in the motor vehicles variable itself that explained suburbanization, since it was not significant.

When I estimated employment b-suburbanization (full sample), it was the lagged value of the population gradient, the proportion of population suburbanized, and the number of local governments that explained a substantial part of employment suburbanization in India's UAs (Table 13). The coefficients for the size of the UA, and the percentage population suburbanized variables had the right signs. This shows that jobs follow people, but not the other way (the percentage of jobs suburbanized does not have a significant impact on population or household b-suburbanization, Table 12), with the caveats noted earlier. This is consistent with the findings of (Mills and Price, 1984) for American cities.

The (1981) number of local governments had a positive impact, which indicated that greater governmental fragmentation in fact causes greater employment centralization, not suburbanization. This implies that the number of governmental jurisdictions in the UAs might be more than that which promotes competition in the provision of public services. Alternatively, this implies that in an UA with a large number of local governments (likely to be metropolitan area), only the one in the central city (usually the local government of the primary town) is most efficient in provision of public services and hence employment tends to be concentrated there. This model explains 36 percent of employment suburbanization.

<INSERT TABLE 13>

When I estimated manufacturing employment density gradients (full sample), some interesting new results emerged. Table 13 shows that the size of UA, literacy rate of central city relative to that in suburbs, and lagged value of the population gradient are significant in explaining manufacturing b-suburbanization. The finding regarding the impact of literacy rate means that a higher ratio in the central city relative to that in the suburbs implies less suburbanization of manufacturing employment. Further, larger UAs and those whose population has been historically suburbanizing, also have more suburbanized manufacturing employment. These findings are consistent with our expectations.

[31] These estimations were based on only 15 observations.

Finally, I estimate b-suburbanization of communications jobs and trade & commerce service jobs (Table 14). When we take the former, the literacy rate ratio and the lagged values of the population gradient are significant in explaining suburbanization of communication jobs. As with manufacturing jobs, if the literacy rate in the central city is high relative to that in suburbs, these jobs are centralized, if not, they are suburbanized. This reinforces the importance of a variety of skills for communications jobs as well, of which literacy rate is a measure. The more suburbanized the UA's population has been in the past, the more suburbanized are transport/communication jobs.

<INSERT TABLE 14>

Finally, the suburbanization of trade and commerce jobs follows a similar pattern as with manufacturing jobs. That is, larger UAs have more suburbanized trade and commerce employment. Further, the higher the wage costs in an UA, the more suburbanized are trade and commerce jobs. Other results are as expected. The higher the literacy rate in the central city relative to that in the suburbs, the more centralized trade/commerce jobs are and vice-versa. The statistically significant lagged value of the population gradient shows that UAs whose population has traditionally suburbanized, also have suburbanized trade and commerce jobs, yet another finding that reinforces the importance of the supply of labor for trade and commerce jobs.

Discussion and policy insights

When we take all results together, we find that population and household suburbanization has been continually occurring in India's UAs. Further, larger UAs are in general more suburbanized. Population gradients converge gradually to their equilibrium value, as rightly pointed out by (Mills and Price, 1984). This is evident in the robustness of the lagged population gradient in the population and household gradient equations. This is quite plausible to believe in the context of cities in India, a country that was colonized for a long time. Coastal cities such as Kolkata were promoted as trade centres by the British East India Company to facilitate trade. In fact, (Chakravorty, 2000) presents evidence with respect to Kolkata, as to how its basic structure created in the 18th century, still dominates the spatial pattern of work and home in this city.

One primary finding with respect to India's urban areas in the international literature (Mills and Tan, 1980, Bertaud and Malpezzi, 2003) on density gradients is that the negative exponential density gradient implied by the standard urban model fits the data quite well.[32] This research supports the finding that the negative exponential density function summarized by equation (1) fits the Indian data well. Second, I find that density gradients flatten with city population, and with historically flat density gradients, as the standard urban model predicts, and is consistent with the international literature on density gradients (see Mills and Price, 1984; Bertaud and Malpezzi, 2003). Third, while the international literature (Bertaud and Malpezzi, 2003) finds that cities with extremely repressive urban regulations, as in South Africa, Korea,

[32] Note that there is not yet a systematic body of *Indian literature on Indian density gradients* that has emerged.

and Russia, have flatter (sometimes inverted) population density gradients, I have been unable to test for this, due to the lack of detailed land use regulation information.

Further, jobs follow people as may be seen in the employment gradient equations. This is consistent with what is found by (Mills and Price, 1984) with respect to American cities. Various jobs in India closely follow people for the skills they have to offer of which literacy rate is an indicator. The statistical significance of the lagged value of the population gradient in the various employment suburbanization equations shows that it is the pre-existing population in the suburbs that matters for employment suburbanization. In fact, (Sridhar, 2006) finds it is not demand for labor, but its supply, represented by population, that is the constraint in reducing unemployment rate of growth centers in India.

Trade/commerce jobs are sensitive to wage costs as well. This indicates that ‘right to work’ laws may have to take precedence over minimum wage laws. Suburbanization of jobs is sensitive to competition in the provision of public services for which the number of local governments in the previous decade is used as a measure, but not in the expected way. The employment density gradient flattens with smaller number of local governments. This is in contrast to what (Jordan, Ross and Usowski, 1998) find with respect to the impact of this variable on the rate of change in population suburbanization in the United States during 1980-90.

In India’s context, these results are quite important. This is because a number of business process outsourcing (BPO) firms are looking to make use of labor force with 'employable' skills. Thus local governmental policies to attract population flows with certain skills may be more successful than other specific policies or incentives to attract these firms to a certain area. This result is quite important in the light of competition among India’s states for various kinds of firms (see Sridhar, 2005). This implies that states and local governments are better off focusing on improving skills of their population with universal literacy and vocational training programs. For instance, call centre firms look only for training in English speaking, and whether employees have a neutral English speaking accent. Recently, BPO firms in India classified various cities in India based on how much training of labor force is needed in every city category. See Table 15, which has been reproduced from India’s leading business newspaper, *The Economic Times* (October 5, 2004), for purposes of illustrating how important skills are in this booming industry in India. This is just an example of the specific skills communications firms require.

<INSERT TABLE 15>

If companies are making their judgments regarding talent pool availability, is the research relevant? The research here shows that over and above BPO and call centre firms, traditional firms such as transport, communications, manufacturing, trade and commerce firms are also sensitive to availability of workforce with specific skills. This is probably nothing new as well. The research and the database developed in this paper can be a useful warehouse of information for all these firms regarding where the population has suburbanized, and where they have not. Further, states and urban local governments in UAs where literacy rates are lower compared to others, can gear up to improve their public services so that they are able to attract and retain skilled labor force.

Concluding Remarks

This study has examined population, household and employment suburbanization in India's UAs, a topic that has received comparatively less attention in the literature. The findings of interest are that population, household and employment suburbanization has certainly taken place in India's UAs. Persons and households have suburbanized as urban agglomerations have naturally evolved, consistent with historical trends. Employment suburbanizes in response to availability of labor force with specific skills one measure of which is the literacy rate. In addition, trade/commerce jobs are sensitive to wage costs. However, the limits of spatial database availability should be remembered. For instance, in measuring land area, I am unable to measure the actual built area in the 340 UAs that are studied. Further, UA boundaries are idiosyncratically determined, and there are many land use controls that do affect Indian cities' spatial growth, which I have not been able to control for, due to the lack of centralized data. Further, the findings here cast little light on whether the observed suburbanization of jobs is associated with dispersion of subcentering of employment.

The logical question to ask is: does increasing suburbanization of urban agglomerations imply that individual UAs can suburbanize forever? As (Mills and Tan, 1980) note, there is an intense conflict between suburban development and rural land uses in the context of developing countries. It is likely that suburbanization in the Indian context implies conversion of a large number of rural areas into urban areas. If this is true, suburbanization means that the rural hinter-lands of the country would benefit from urbanization, public services and overall growth.

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Table 1: Office and Residential Rentals and Capital Values in Selected Metro Areas

Metro Area	CBD Rental* (Sqft/ Month)	Suburb Rental (Sqft/ Month)	CBD Capital Value (Per Sqft)	Suburban Capital Value (Per Sqft)
Office Rentals and Capital Values in Selected Metro Areas				
NCR	$0.46	$0.84	$187.43	$83.61
Mumbai	$2.11	$1.77	$251.03	$148.33
Bangalore	$0.96	$0.59	$91.28	$61.62
Average	**$1.18**	**$1.07**	**$176.58**	**$97.85**
Residential Rentals and Capital Values in Selected Metro Areas				
NCR	$3,137.84	$684.62	$193.98	$63.90
Mumbai	$2,110.91	$1,65 4.50	$251.03	$188.27
Bangalore	$1,597.44	$1,198.08	$68.46	$50.21
Average	**$2,282.06**	**$1,179.07**	**$171.15**	**$100.79**

Source: Compiled from Economic Times Realty Bites, December 28, 2003.

*The CBD office rentals are per square foot/month and residential rentals are per month.

Table 2: Size Distribution of India's Cities: 1901-2001

	Class I	Class II	Class III	Class IV	Class V	All cities*
1901	25	44	144	427	771	1,917
1911	26	38	158	388	750	1,909
1921	29	49	172	395	773	2,047
1931	31	59	218	479	849	2,219
1941	49	88	273	554	979	2,424
1951	76	111	374	675	1,195	3,060
1961	107	139	518	820	848	2,700
1971	151	219	652	988	820	3,126
1981[Ψ]	226	325	883	1,247	920	3,949
1991	322	421	1,164	1,451	1,260	4,909
2001	464	528	1,435	1,620	1,081	5,161

Sources: Census of India 1981, Series 1, Part II-A, General Population Tables A-4, Statement I, Census of India 1991 Town Directory and Census of India 2001 Population Data for Towns.

* Note that all cities include cities in class sizes I-VI, columns 2-5 report only class sizes 1-V. The Census of India's definition for various class sizes of cities is as follows:
Class I: Population >100,000
Class II: Population of 50,000-99,999
Class III: Population of 20,000-49,999
Class IV: Population of 10,000-19,999
Class V: Population of 5,000-9,999
Class VI: Population <5,000.

[Ψ] In 1981, there was no census held in Assam due to disturbed conditions there. So while during 1901-71, and 1991-2001, the number of cities reported include those in Assam, in 1981, they exclude Assam. If the reader is interested in comparing the figures on various class size cities for the time period considered without Assam, they are available from the author upon request.

Table 3: Suburbanization of Population, Households and Jobs in India, 1981 and 1991

	% 81 pop suburban	% 91 Pop suburban	% HH suburban	% Emp Suburban
Average	0.2067	0.2133	0.2202	0.2176
Maximum	0.9252	0.9231	0.9356	0.9285
Minimum	0.0018	0.0005	0.0012	0.0012
Std.Dev	0.2008	0.2014	0.2041	0.2011
Observations	233	374	374	374

Sources: Census of India 1981, and 1991 *Primary Census Abstract Tables* and Author's computations.

Table 4: Population, Household and Employment Suburbanization in India's (4) Metropolitan Areas, 1991

Variable	Mean	Std.Dev.	Minimum	Maximum
% Population suburban	0.3031	0.2122	0.1082	0.6008
% Households suburban	0.3087	0.2112	0.1069	0.6023
% Jobs suburban	0.2899	0.2011	0.0993	0.5681

Sources: Census of India 1991 *Primary Census Abstract Tables* and Author's computations.

Table 5: Population Suburbanization in India's Metropolitan Areas during 1981-91

	% Pop suburban, 1981	% Pop suburban, 1991
Delhi	0.10	0.11
Kolkata	0.64	0.60
Mumbai	NA*	0.21
Chennai	0.24	0.29

*Not available. Mumbai was not a UA in 1981, so separate central city and suburban data are not applicable.
Source: Census of India 1981 and 1991 *Primary Census Abstract Tables* and Author's computations.

Table 6: Summary of Population, Household and Employment Density Gradients

	Population density gradients						HH density gradient	Employment density gradient
	1981	**1991 (Same subset as in 1981)**	**% Change (Same subset of UAs) 1981-91**	**1981 (All UAs)**	**1991 (All UAs)**	**% Change (all UAs) 1981-91**	**1991**	**1991**
Average, all	0.4783	0.4303	-10.04%	0.4933	0.4669	-5.35%	0.4533	0.4621
Maximum	0.9910	0.9780	-1.31%	0.9910	0.9983	0.74%	0.9879	0.9871
Minimum	0.0117	0.0262	123.93%	0.0102	0.0072	-29.41%	0.0049	0.0194
Std.Dev	0.2414	0.2397	-0.70%	0.2649	0.2697	1.79%	0.2624	0.2601
Observations	80	80	80	94	154	77	161	160
Average, metros*	0.2467	0.1963	-20.43%	NA	NA	-20.44%	0.2306	0.2578
Max, metros	0.3475	0.2995	-13.81%	NA	NA	-13.81%	0.2933	0.3473
Min, metros	0.1870	0.1244	-33.48%	NA	NA	-33.48%	0.1693	0.1818
Std.dev, metros	0.0878	0.0745	-15.15%	NA	NA	-15.08%	0.0629	0.0794

* The 1981 and 1991 data are for the four metropolitan areas of the country.

Source: Census of India 1981 and 1991 *Primary Census Abstract Tables* and Author's computations.

Table 7: Population, Household and Employment Density Gradients by Region

Region	**Population density gradients**		**HH density gradient**	**Employment density gradient**
	1981	**1991**	**1991**	**1991**
Average, Southern region*	0.4569	0.4583	0.4121	0.4266
Average, Eastern region**	0.5225	0.4587	0.4834	0.4833
Average, Northern region***	0.5075	0.4140	0.4036	0.4239
Average, Western region****	0.5008	0.5493	0.5361	0.5004

*Karnataka, Kerala, Andhra Pradesh, Tamilnadu, Pondicherry

**Orissa, West Bengal, Bihar, Manipur, Meghalaya, Assam

***Delhi, Haryana, Uttar Pradesh, Chandigarh, Madhya Pradesh, Himachal Pradesh

****Maharashtra, Goa, Rajasthan, Gujarat

Source: Census of India 1981 and 1991 *Primary Census Abstract Tables* and Author's computations.

Table 8: Density Gradients for Employment Sub-sectors

	Mean	Std.Dev.	Minimum	Maximum	Observations
Mining & quarrying	0.4568	0.2593	0.0020	0.9708	81
Manufacturing (household and non-household industry) and Construction	0.4590	0.2839	0.0191	0.9971	151
Transport, Storage and Communications	0.4965	0.2621	0.0109	0.9777	126
Trade and commerce services	0.5080	0.2587	0.0403	0.9996	111
Other services	0.4613	0.2652	0.0024	0.9337	136

Source: Census of India 1991 *Primary Census Abstract Tables* and Author's computations.

Table 9: Density Gradients for UAs by Category of CBD Population Density Vis-à-vis Suburban Density

	Gradients for UAs with CBD Population density:			
	Less than that in suburbs	1-5 times more than that in suburbs	5-10 times more than that in suburbs	>10 times than that in suburbs
	Mean (Std.Dev.)	**Mean (Std.dev)**	**Mean (Std.dev)**	**Mean (Std.dev)**
Population gradient	NA (NA)	0.44 (0.26)	0.64 (0.25)	0.81 (0.09)
Household gradient	0.02 (0.02)	0.44 (0.25)	0.60 (0.24)	0.80 (0.07)
Employment gradient	0.05 (0.03)	0.44 (0.25)	0.64 (0.22)	0.78 (0.07)
Mining gradient	0.39 (0.27)	0.46 (0.24)	0.43 (0.35)	0.56 (0.25)
Manufacturing gradient	0.32 (0.28)	0.43 (0.27)	0.64 (0.26)	0.76 (0.18)
Communications gradient	0.28 (0.16)	0.48 (0.26)	0.61 (0.23)	0.80 (0.08)
Trade & Commerce gradient	0.44 (0.28)	0.50 (0.26)	0.54 (0.19)	0.89 (0.08)
Other services gradient	0.38 (0.20)	0.44 (0.26)	0.58 (0.29)	0.85 (0.05)
Population gradient, 1981	0.36 (0.36)	0.48 (0.25)	0.70 (0.24)	0.56 (0.04)

Source: Census of India 1981 and 1991 *Primary Census Abstract Tables* and Author's computations.

Table 10: Density Gradients for UAs by Category of CBD Employment Density Vis-à-vis Suburban Density

	Gradients for UAs with CBD employment density			
	Less than that in suburbs	1-5 times more than that in suburbs	5-10 times more than that in suburbs	>10 times than that in suburbs
	Mean (Std.Dev.)	**Mean (Std.dev)**	**Mean (Std.dev)**	**Mean (Std.dev)**
Population gradient	0.10 (0.13)	0.45 (0.26)	0.65 (0.26)	0.79 (0.09)
Household gradient	0.19 (0.36)	0.44 (0.25)	0.62 (0.26)	0.78 (0.07)
Employment gradient	NA (NA)	0.44 (0.26)	0.63 (0.25)	0.77 (0.08)
Mining gradient	0.30 (0.25)	0.47 (0.24)	0.48 (0.34)	0.51 (0.27)
Manufacturing gradient	0.31 (0.26)	0.45 (0.28)	0.61 (0.26)	0.81 (0.15)
Communications gradient	0.27 (0.15)	0.48 (0.26)	0.63 (0.23)	0.83 (0.06)
Trade & Commerce gradient	0.42 (0.27)	0.50 (0.26)	0.54 (0.19)	0.89 (0.08)
Other services gradient	0.39 (0.20)	0.43 (0.26)	0.68 (0.22)	0.85 (0.05)
Population gradient, 1981	0.37 (0.35)	0.49 (0.26)	0.69 (0.26)	0.56 (0.04)

Source: Census of India 1981 and 1991 *Primary Census Abstract Tables* and Author's computations.

Table 11: Estimates of Population Density Functions for Bangalore, 1991 and 2001

Dependent Variable: Natural logarithm of population density, 1991			
	Coeff.	**Std.Err.**	**t-ratio**
Intercept	9.17***	0.28	33.21
Gradient (with conventional city center), 1991	0.10***	0.03	3.49
R^2	0.18		
Dependent Variable: Natural logarithm of population density, 2001			
	Coeff.	**Std.Err.**	**t-ratio**
Intercept	10.75***	0.18	59.92
Gradient (with conventional city center), 2001	-0.05***	0.01	3.64
R^2	0.12		
Dependent Variable: Natural logarithm of population density, 1991			
	Coeff.	**Std.Err.**	**t-ratio**
Intercept	10.77***	0.20	54.68
Gradient (with (ward 20) new city center)	-0.06***	0.02	-3.94
R^2	0.22		
Dependent Variable: Natural logarithm of population density, 2001			
	Coeff.	**Std.Err.**	**t-ratio**
Intercept	10.79***	0.11	97.82
Gradient (with (ward 32) new city center)	-0.05***	0.01	-6.83
R^2	0.33		

Number of observations=57 (wards) for 1991 regressions and 97 for 2001 regressions

Source: Data from *Bangalore Mahanagara Palike's* Town Planning Department and Author's analyses.

Table 12: Estimation of Population and Household Density Gradients, 1991

	Population suburbanization		**Household suburbanization**	
Variable	**Coefficient (Standard Error)**	**Mean for relevant sample**	**Coefficient (Standard Error)**	**Mean for relevant sample**
Constant	0.2769 (0.2267)		0.1831 (0.2054)	
Population/10,000	-0.0006 (0.0003)*	80.99	-0.0005 (0.0003)	80.99
Income (in Indian Rupees)	0.0000 (0.00)	63,290.62	0.00 (0.00)	63,290.62
Lagged population gradient	0.5280 (0.0979)***	0.47	0.5252 (0.0886)***	0.47
Proportion jobs suburbanized	-0.1836 (0.1104)	0.29	-0.1087 (0.1000)	0.29
Ratio of unemployment rate in central city to that in suburb	0.0070 (0.0082)	1.51	0.0065 (0.0074)	1.51
Ratio of proportion SC/ST population in the central city to that in suburb	-0.0550 (0.0701)	0.80	-0.0559 (0.0635)	0.80
Number of governments in UA, 1981	0.0058 (0.0039)	6.33	0.0042 (0.0035)	6.33
Literacy rate ratio (central city to suburb)	0.0122 (0.0914)	1.05	0.0098 (0.0828)	1.05
Mean, dependent variable		**0.42**		**0.39**
Adjusted R^2	**0.38**			**0.40**
Number of observations	**76**			**76**
F	**6.67**			**7.12**

* Significant at 10 percent level of significance.
***Significant at 1 percent level of significance.

Source: Census of India 1981 and 1991 *Primary Census Abstract Tables* and Author's analyses.

Table 13: Estimation of Employment and Manufacturing Density Gradients

	Employment suburbanization		Manufacturing Suburbanization	
Variable	**Coefficient (Standard Error)**	**Mean for relevant sample**	**Coefficient (Standard Error)**	**Mean for relevant sample**
Constant	0.2985 (0.1877)		0.3522 (0.2567)	
Population/10,000	-0.0007 (0.0003)**	82.20	-0.0007 (0.0003)**	95.34
Wage costs in state (Emoluments as % of output)	2.7710 (1.6786)	0.06	-2.1702 (2.0257)	0.06
Number of governments in UA, 1981	0.0062 (0.0036)*	6.45	0.0063 (0.0039)	7.06
Ratio of proportion SC/ST population in the central city to that in suburb	-0.0451 (0.0662)	0.80	-0.0061 (0.0957)	0.75
Literacy rate ratio (central city to suburb)	-0.0086 (0.0868)	1.05	0.1875 (0.0979)*	1.06
Lagged population gradient (1981)	0.4192 (0.1005)***	0.48	0.4302 (0.1165)***	0.47
Proportion population in labor force	-0.3189 (0.5313)	0.30	-0.4849 (0.7671)	0.29
Proportion population suburbanized	-0.3112 (0.1248)**	0.30	-0.1741 (0.1443)	0.28
Mean of dependent variable		**0.41**		**0.42**
Adjusted R^2	**0.36**		**0.32**	
Number of observations	**74**		**63**	
F	**6.08**		**4.58**	

* Significant at 10 percent level of significance.
** Significant at 5 percent level of significance
***Significant at 1 percent level of significance.

Source: Census of India 1981 and 1991 *Primary Census Abstract Tables* and Author's analyses.

Table 14: Estimation of Density Gradients, Employment Sub-sectors

	Transport and Communication suburbanization		**Trade and Commerce Suburbanization**	
Variable	**Coefficient (Standard Error)**	**Mean for relevant sample**	**Coefficient (Standard Error)**	**Mean for relevant sample**
Constant	-0.0307 (0.2586)		0.2338 (0.2477)	
Population/10,000	-0.0005 (0.0004)	95.99	-0.0006 (0.0003)*	110.40
Wage costs in state (Emoluments as % of output)	-0.7533 (2.5208)	0.05	-4.9141 (2.3821)**	0.06
Number of governments in UA, 1981	0.0037 (0.0043)	7.17	0.0055 (0.0040)	7.74
Ratio of proportion SC/ST population in the central city to that in suburb	0.0163 (0.0965)	0.80	0.0257 (0.0889)	0.80
Literacy rate ratio (central city to suburb)	0.1847 (0.1086)*	1.05	0.2021 (0.0975)*	1.06
Lagged population gradient (1981)	0.4252 (0.1313)***	0.46	0.4492 (0.1363)***	0.41
Proportion population in labor force	0.6797 (0.7619)	0.30	0.5837 (0.7144)	0.29
Proportion population suburbanized	-0.0217 (0.1671)	0.28	-0.0582 (0.1575)	0.31
Mean of dependent variable		**0.50**		**0.51**
Adjusted R^2	**0.26**		**0.37**	
Number of observations	**60**		**51**	
F	**3.58**		**4.62**	

* Significant at 10 percent level of significance.
** Significant at 5 percent level of significance
***Significant at 1 percent level of significance.

Source: Census of India 1981 and 1991 *Primary Census Abstract Tables* and Author's analyses.

Table 15: Search for Talent: Classification of Towns for Locational Decisions

Type	A City	B City	C City
Locations	Delhi, Mumbai, Bangalore, Chennai, Gurgaon, Faridabad, Noida, Pune, Thane Satellites: Hyderabad, Kolkata, Ahmedabad, Baroda, Trichy, Kochi	Chandigarh, Jaipur, Kota, Goa, Nagpur	Meerut, Jodhpur, Bhopal, Patna, Nasik, Guwahati, Vizag, Pondicherry, Coimbatore, Gwalior
Talent pool availability	High	Medium	---
Costs	High	Medium-low	Low
Attrition	Very high (45%-50%)	Less than 15%	Less than 10%
English accent	Very little training required	Training required	High training required

Source: The Economic Times (http://www.economictimes.com), October 5, 2004.

Data Appendix

For purposes of estimating the population density gradients for Bangalore, I obtained ward-level data on population for 1991 and 2001, and land area for the wards for 2001 (ward-level land area for 1991 was not available) from the *Bangalore Mahanagara Palike (BMP)'s town* planning department. I calculated distances from wards to the city centers, using the digital 2001 ward-level map of Bangalore supplied by the Directorate of Census Operations, Karnataka, based in Bangalore.

For purposes of the aggregate gradient analysis, and for computing population, household, and employment density gradients for all the Indian UAs, data on population, households and employment for various constituents of all UAs (for 1991 and 1981) and their land area was obtained from the Census of India (http://www.censusindia.net/), Primary Census Abstract (PCA). Only 2001 census data are on the web (here too, while 2001 UA population data has been released, 2001 UAs' land area are not yet available). 1991 PCA data were available on a CD from the Census of India. For 1981 data, I relied on hard copy of the publication (since it was not on the web, or on CD), Census of India 1981 Series I, Part II-A (ii), "General Population Tables A-4: Towns and Urban Agglomerations Classified by Population in 1981 with Variation Since 1901."

The 1981 publication contains data only on UA population and land area for their constituents. In addition, the exogenous instrument, number of local governments in UAs in 1981, was obtained by counting the number of local governments in every UA, from the Census of India 1981 publication described above.

The 1991 census PCA contains data on the population, land area, households, number of literate persons, SC/ST population, marginal workers, main workers, workers by category, and non-workers, relevant data by gender, for all constituents of UAs (primary town(s), other town(s) and outgrowths, if any). The proportion jobs suburbanized for all UAs was computed based on the employment (main workers, see text for description of these workers) in the UA not in central city. Jobs are measured by the existence of full-time workers, these data for various constituents of UAs were obtained from the 1991 Census of India PCA. As described elsewhere in the text, the central city is defined as the municipal corporation limits of the primary towns(s) in the UA. The data necessary for computing labor force proportion, and the unemployment rate, were obtained for UAs from the Census of India 1991, from the PCA, which provides data on all constituents of UAs, and was computed in a manner described in the text (p.16-17). The proportion population suburbanized for all UAs was computed based on population in the UA not in the central city.

Data on annual household income for million-plus cities (not UAs) was obtained from the National Council of Applied Economic Research (NCAER, 2002) publication *India Market Demographics Report 2002*. These data are such that within every state, the estimated distribution of households by income groups, are provided for all town groups classified by population. See footnote 19 for more information regarding how this variable was computed. For wage costs, I used data on the total emoluments as a proportion of the total value of output for Indian states, published in the *Annual Survey of Industries*, for 2001-02, by India’s Central Statistical Organization, of the Ministry of Statistics and Programme Implementation, Government of India, http://mospi.gov.in/mospi_asi.htm, Table 4.